# Financial indicators for next-generation EPCs v2

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# DELIVERABLE 2.9

## Financial indicators for next-generation EPCs v2

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## Version History

| v | Author | Date | Brief Description |
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| 1.1 | Mija Sušnik (DMO) | 13.06.2023 | Review of the first version of the deliverable |
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| 1.4 | Mija Sušnik (DMO) | 03.08.2023 | CS4 calculation inputs |
| 1.5 | Adrian Cano Cabanero (SGS) | 07.08.2023 | Input on the platform |
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| 1.7 | Mija Sušnik (DMO) | 18.08.2023 | Final draft for internal review |
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# Executive Summary

This deliverable is an updated version of D2.4 and is an outcome of Task 2.4 Analysis of Cost and Economic Indicators for EPCs. The goal was to deliver financial indicators for the next generation of EPCs. The aim of the developed set of indicators in the project is to increase user awareness by providing additional information and enhancing the user-friendliness of EPCs.

In the present version of the deliverable, the overview of the state-of-the-art which was performed through a literature review remained the same. The methodology which was based on that was slightly updated while the purpose remained the same - to provide users with a real-time image of the monetized performance of the building by comparing the design phase with the operational phase and including the future values. Such comparison allows users to allocate the performance of their building. Financial indicators do not impact the energy class of the building but present additional information for the user.

The demonstration of the financial KPIs was done on two case studies (CS), namely the CS1 and CS2. The updated version of the deliverable also includes the theoretical background for building stock comparison and the addition of indicators that describe the negative effect of rapidly changing energy prices on tenants.

The outcome of this task, presented in this document, is the guideline for extracting required data concerning the financial indicators and providing instructions for the calculation.

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## List of Acronyms and Abbreviations

| Term | Description |
|---|---|
| AC | Annual Cost |
| AEV | Annual Equivalent Value |
| AIRR | Adjusted Internal Rate of Return |
| BIM | Building Information Modelling |
| BPM | Building Performance Module |
| DB | Database |
| EBC | Energy in Buildings and Communities |
| EPB | Energy Performance of Buildings |
| EPC | Energy Performance Certificate |
| EUR | Euro |
| HVAC | Heating, Ventilation, Air Conditioning |
| IEA | International Energy Agency |
| IFC | Industry Foundation Classes |
| IRR | Internal Rate of Return |
| ISO | International Standardisation Organisation |
| KPI | Key Performance Indicator |
| LCA | Life Cycle Assessment |
| LCC | Life Cycle Cost / Life Cycle Costing |
| LCCA | Life Cycle Cost Assessment |
| MS | Member States |
| NPV | Net Present Value |
| NS | Net Savings |
| NUTS | Nomenclature of Territorial Units for Statistics |
| nZEB | Nearly Zero-Energy Building |
| OpEx | Operating Expenses |
| ROI | Return on Investment |
| SIR | Savings-to-Investment Ratio |

| | |
|---|---|
| **VRV** | **Variable Refrigerant Volume** |
| **WLC** | **Whole-life cycle cost** |

# 1 Introduction

D^2EPC aspires to deliver the next generation of dynamic EPCs for the operational and static assessment of buildings' energy performance through a set of cutting-edge digital design and monitoring tools and services. D^2EPC relies upon and adjusts accordingly to the Smart- Readiness level of the buildings and the corresponding data collection infrastructure and management systems. It subsequently builds upon actual data and the "Digital Twin" concept to calculate energy, environmental, financial, and human comfort indicators and result in the final EPC classification of the building in question.

## 1.1 Scope and objectives of the deliverable

This document is defined within task 2.4 "Analysis of cost and economic indicators for EPCs". The goal of T2.4 is to establish simplified financial indicators which will enhance the user-friendliness of the building energy performance certificate. This document presents the overall activities conducted within T2.4 and provides a set of financial indicators, developed based on the literature review of well-established standards and schemes. The financial Key Performance Indicators (KPIs) enable the interpretation of the individual elements of buildings' energy performance into monetary normalised values and employment of EPCs for the financial assessment of building upgrade measures.

This document represents the second version and is thus an upgrade based on the received feedback and the development of the project.

## 1.2 Structure of the deliverable

The structure of this version of the document is the same as in the previous version, following the steps and progress throughout the work done under T2.4. It starts with the literature review in Chapter 2, which provides an overview of the existing methods, standards, schemes, and calculations of financial indicators. This part has not been modified in the second version of the deliverable. In Chapter 3 the methodology of the financial KPIs for D^2EPC is presented with the definition, the integration into D^2EPC and the calculation itself. Here some updates were done compared to the first version, with the major addition of the section on building stock, where connection to WebGIS is presented. Newly added Chapter 4 includes an overview of the D^2EPC platform, more precisely, the part where Cost & Economic indicators are calculated. The major update of this deliverable is the demonstration chapter, where the calculation is performed on two case studies. Chapter 6 is also an addition to this version of the document and it talks about the existing indicators that describe the effect of fluctuating prices on the users. Finally, in Chapter 7, the overall work is concluded with a short discussion and summary of the results.

## 1.3 Relation to Other Tasks and Deliverables

Being a part of the work package 2 "Development of the Operational Framework for dEPC Schemes", task 2.4 and this document have a strong relation to T2.5 "D^2EPC Information Model". T2.4, together with other tasks in this WP provide valuable input for the development of the information model which integrate all the newly developed KPIs in a uniform way and thus enriches the current standards/protocols for issuing the EPCs.

Additionally, the outcomes of this task will contribute to T5.1, where methodology will be delivered elaborating all parameters and aspects of the D^2EPC scheme. A technical manual addressed to EPC assessors will include the theoretical background, the methodology and the calculation steps of the D^2EPC scheme.

# 2 Literature review

The first step towards the definition of financial indicators was an extensive literature review of existing standards, regulations, schemes etc. The study included:

- IEA EBC Annex 56: Cost-Effective Energy & $CO_2$ Emissions Optimization in Building Renovation
- ISO 15686-5: Buildings and constructed assets – Service life planning – Part 5: Life-cycle costing
- EN 15643-4: Sustainability of construction works – Assessment of buildings
- EN 16627:2015: Sustainability of construction works – Assessment of economic performance of buildings – Calculation methods
- D1.3: Aspects of Next Generation EPC's definition
- Level(s) scheme

Each document is further described in the following sections, highlighting the aspects, relevant to the definition of the financial indicators in the scope of the D^2EPC project.

## 2.1 IEA EBC Annex 56

The International Energy Agency (IEA) was established within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme. Their aim is to increase energy security through energy research, development, and demonstration in the fields of technologies for energy efficiency and renewable energy sources. The IEA coordinates research and development in a number of areas related to energy. The mission of the Energy in Buildings and Communities (EBC) Programme is to develop and facilitate the integration of technologies and processes for energy efficiency and conservation into healthy, low-emission, and sustainable buildings and communities, through innovation and research. The projects are established as Annexes, where Annex 56 is related to "Cost-Effective Energy & $CO_2$ Emissions Optimization in Building Renovation" [1].

The document presents a set of recommendations providing guidance for professionals and homeowners for the cost-effective optimization of the building renovation process. It also provides a framework to understand the relationship between cost-effective building renovation, energy savings and the use of renewable energy sources, remarking on the added value achieved by the interventions. The proposed methodology is focused on the promotion of nearly-zero energy or nearly-zero emission levels in the renovation of the existing building stock. The report clearly supports the development of a long-term life cycle cost assessment in order to determine how far it is favourable to go in the improvement of the building. It is identified that the aspect that still has the most influence in the decision-making process of the homeowners is the initial costs since reaching energy performance near the zero-energy level presents very high initial costs. However, it can be proved that these investments can be economically attractive in the long term, and present additional benefits that improve the building quality and users' well-being [1].

## 2.2 ISO 15686-5

ISO 15686-5:2017 *Buildings and constructed assets – Service life planning – Part 5: Life-cycle costing* is an international standard that provides requirements and guidelines for performing Life-cycle cost analysis of buildings and constructed assets [2].

Life-cycle costing (LCC) is a methodology for the economic evaluation of a cost of an asset over a period of analysis. Such analysis is used for decision-making and evaluation processes through a comparison between alternatives and evaluation of different investment scenarios or through estimation of future costs for budgetary purposes and evaluation of the acceptability of an investment. It can be used for new assets or major refurbishments and for planning the future use of existing assets. Costs that should be included in the LCC are construction, operation, maintenance, and end-of-life costs. The typical scope of costs for each category is shown in **Figure 1**. Due to the uncertainty of the future, the cost should be expressed in real values and not in the value in the future (nominal cost). The design life of the constructed asset and the time profile of when the cost occurs or reoccurs should be determined as well. Cost values can be derived from a direct estimation of known costs, historical data analysis of typical applications (e.g., bills of quantities), models based on expected performance, or best guesses of future trends in technology, market, and application [2].

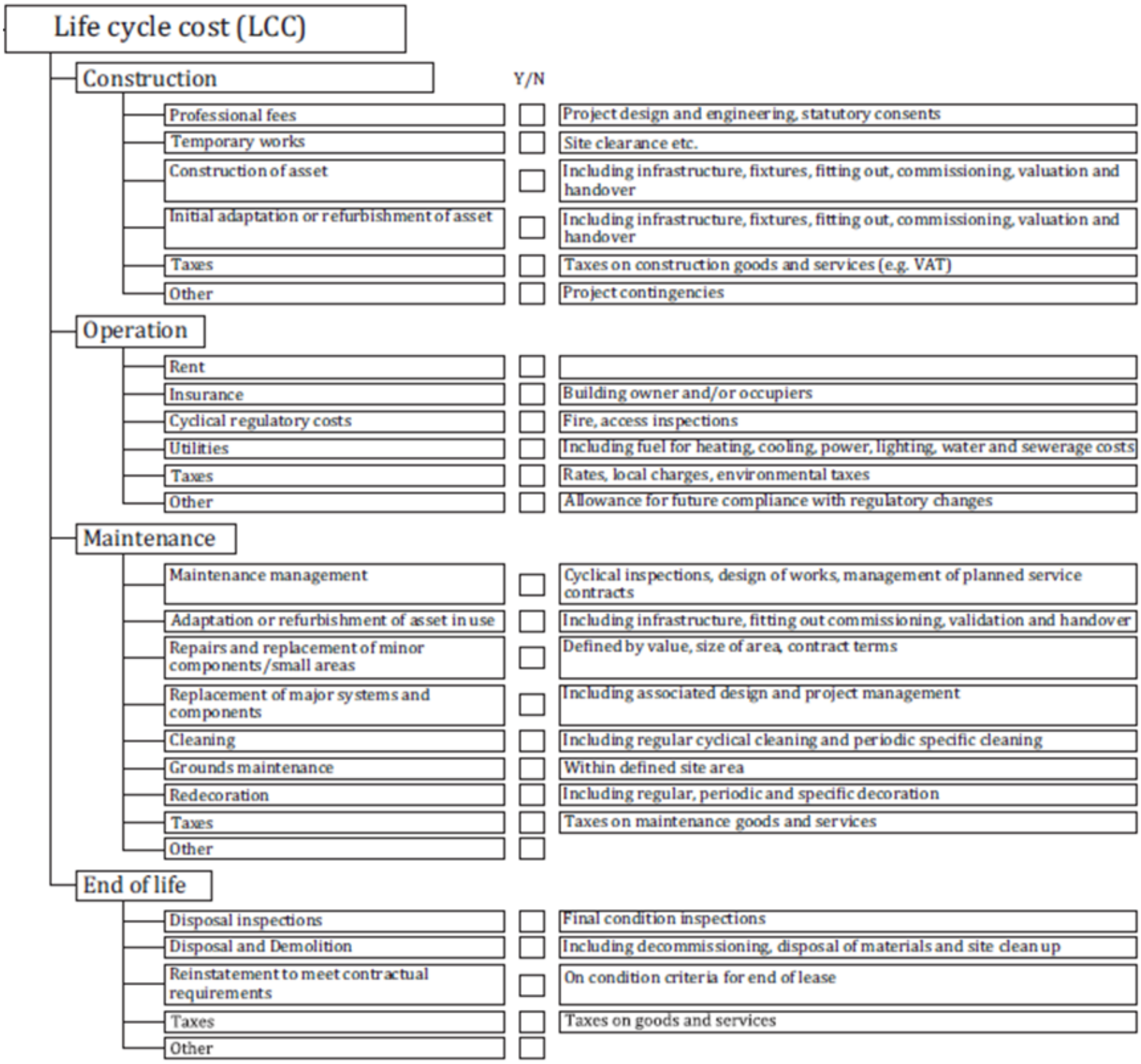



**Figure 1 Typical scope of LCC costs [2]**

LCC analysis can be performed during different stages of the life cycle of the construction asset, namely in the project investment and planning phase, the design and construction phase, the occupation phase or the disposal phase. Based on the level of available information, the LCC analysis can be performed at a coarse level, using benchmarking figures or at a detailed level, using specific estimates or predictions. The benchmark analysis can be based on the functional unit or total area of the asset, while detailed analysis shall be based on the proposed design detailing and a quantum of individual elements. The LCC calculation requires some assumptions about the future, such as discount rates, the period of analysis and information about the service life or maintenance, repair and replacement cycles or costs. The range of uncertainty and risks regarding the LCC analysis can be assessed using the Monte Carlo method or the sensitivity analysis [2].

To compare different alternatives over a defined period of time, the present value should be used, which represents the present monetary sum that should be allocated for future expenditures on an asset. It is calculated by discounting future cash flows to the base date. Two types of costs should be distinguished in the calculation process:

- Real cost: cost expressed as a value at the base date, including estimated changes in price due to forecast changes in efficiency and technology, but excluding general price inflation or deflation.
- Nominal cost: expected price that will be paid when a cost is due to be paid, including estimated changes in price due to, for example, forecast change in efficiency, inflation or deflation and technology.

The net present value (NPV) is a single figure that can be used to compare different alternatives for informed decision-making [2].

$$NPV = \sum(Cn \times q) = \sum_{n=1}^{p} \frac{Cn}{(1+d)^n} \quad (1)$$

Where

- Cn is the cost in year n
- q is the discount factor
- d is the expected real discount rate per annum
- n is the number of years between the base date and the occurrence of the cost
- p is the period of analysis

Other measures that can be used to compare alternatives and evaluate different investment scenarios in life-cycle costing are:

- Payback period – the time it takes to cover investment costs. It is calculated as the number of years elapsed between the initial investment, its subsequent operating costs, and the time at which cumulative savings offset the investment.
- Net Savings (NS) – the value of operating-related savings minus the value of additional investment costs. When assessing the viability of alternatives, the new savings is the difference between the LCC of the two alternatives.
- Savings-to-investment ratio (SIR) – the ratio of savings and cost, a dimensionless measure.
- (Adjusted) internal rate of return (IRR or AIRR) – the compound rate of interest that, when used to discount the cost and benefits over the period of analysis, makes costs equal to benefits when cash flows are reinvested at a specified interest rate.
- Annual cost (AC) or annual equivalent value (AEV) – a uniform annual amount equivalent to the project net costs, taking into account the time value of money throughout the period of analysis.
- Return on Investment (ROI) – the ratio between net income and investment [2].

Some of the mentioned measures are graphically presented in **Figure 2**.

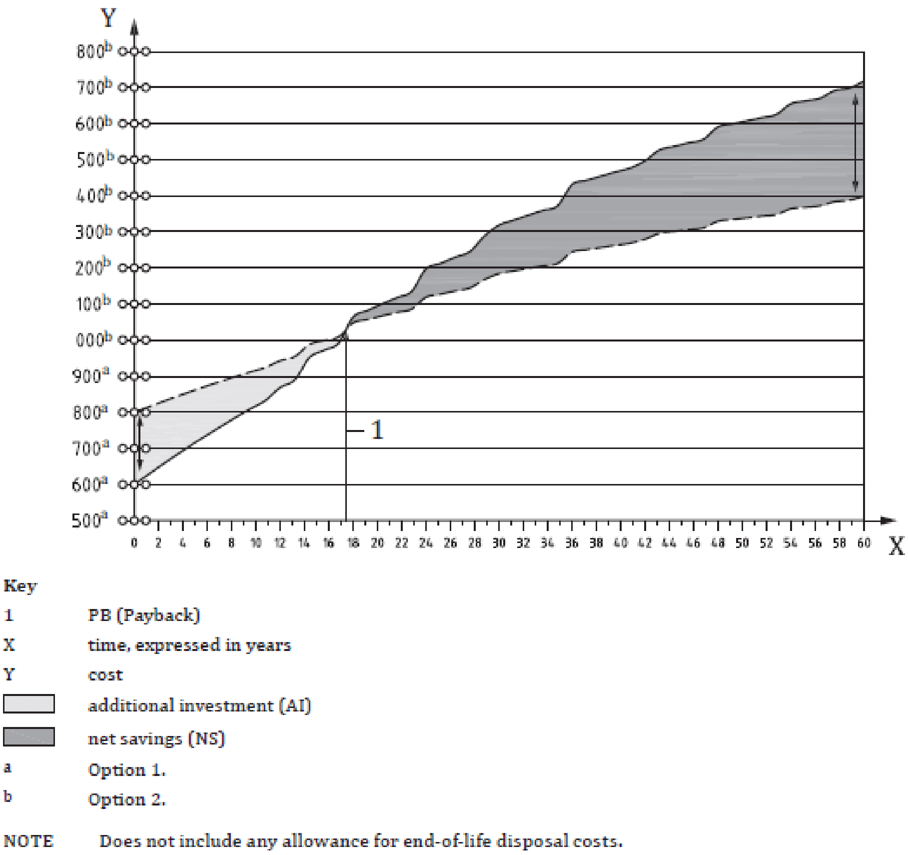



**Figure 2 Measures of comparison [2]**

## 2.3 EN 15643

To assure quality, safety, and sustainability, construction projects all over the world rely on industry-driven standards and guidelines [3]. The European Standard *Sustainability of construction works – Assessment of buildings* (EN 15643:2021) was developed by CEN/TC 350 "Sustainability of construction works", which was established to promote more sustainable construction techniques [4]. It was published in 2021 based on 5 previous framework standards.

This standard is part of a set of documents developed under the Mandate M/350, issued by the European Commission, to assess the sustainability of buildings based on three pillars: environmental, social and economic.

EN 15643 constitutes the framework for the sustainability assessment of buildings, illustrated in the "framework level" in **Figure 3**. This standard provides principles and requirements for sustainability assessment of built assets, including definitions and the relation between the different levels.

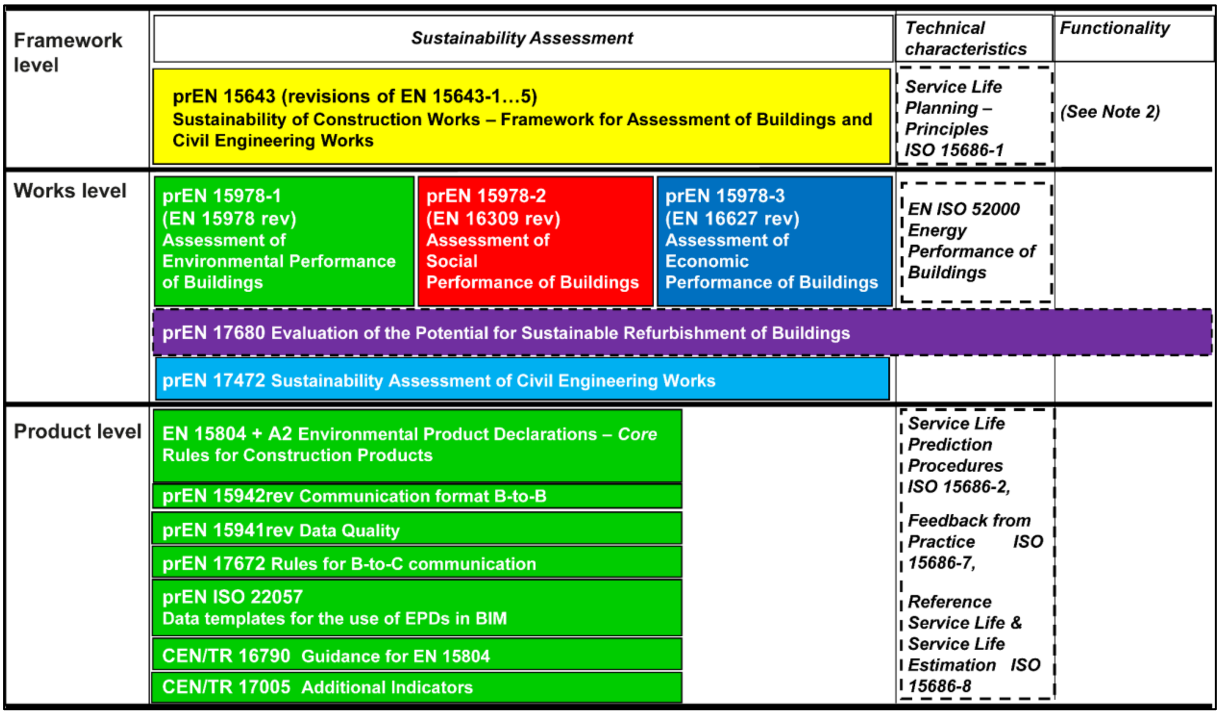



**Figure 3 The work program of CEN/TC 350 [4]**

The objective of the CEN/TC 350 set of standards is the assessment at the level of the works (i.e., the building or civil engineering work). They are used to assess the impacts and aspects of the building and its site or the civil engineering works in its area of influence, as well as enable the client, user, and designer to make decisions and choices that will help to address the need for sustainability of buildings or civil engineering works.

The results of a sustainability assessment of the building provide values for the different types of indicators and information on the scenarios and building cycle stages included in the assessment. Assessment at the building level means that the descriptive model of the building with the major technical and functional requirements has been defined in the client's brief or the regulations. Assessments can be undertaken for the whole building, parts of the building, which can be used separately or elements of the building.

The third level is the product level, mainly the Environmental Product Declarations according to EN 15804.

The European Standard EN 15643:2021 provides a system for the sustainability assessment by quantifying impacts and aspects of the economic performance of buildings using quantitative and qualitative indicators. It was released in 2021 and provides specific principles and requirements for the assessment of the economic performance of buildings taking into account the technical characteristics and functionality of a building. A building's economic performance addresses the life cycle costs, external costs, and benefits, as well as the impacts on economic value and the long-term value stability of the asset. To ensure transparency and a consistent flow of information, the indicators avoid double counting of the same economic area of concern and the results of individual indicators from the product level to the construction works level to be possible to aggregate.

## 2.4 EN 16627:2015

The European Standard *Sustainability of construction works – Assessment of economic performance of buildings – Calculation methods* (EN 16627:2015) applies as a complement of the European Standard EN 15643-4:2012 (superseded by EN 15643:2021) and provides calculation rules for assessing the economic performance of new and existing buildings as one part of an assessment of the sustainability of a building. The two approaches to calculating economic performance described in this European Standard are concerning the LCC and the Life Cycle Economic Balance. The LCC consists of the economic performance expressed in cost terms over the life cycle, taking account of negative costs related to energy exports and from reuse and recycling parts of the building during its life cycle and at the end of life. Calculation of this indicator is mandatory for compliance with the standard. The Life Cycle Economic Balance consists of LCC and incomes over the life cycle and at the end of life. The calculation of economic indicators uses a building model and its life cycle with the associated time and financial cost. The stages illustrated in **Figure 4** should be followed in order to carry out and complete the calculations necessary for the assessment of the economic performance of buildings. This helps ensure that the essential information is gathered and processed in accordance with the requirements of this European Standard.

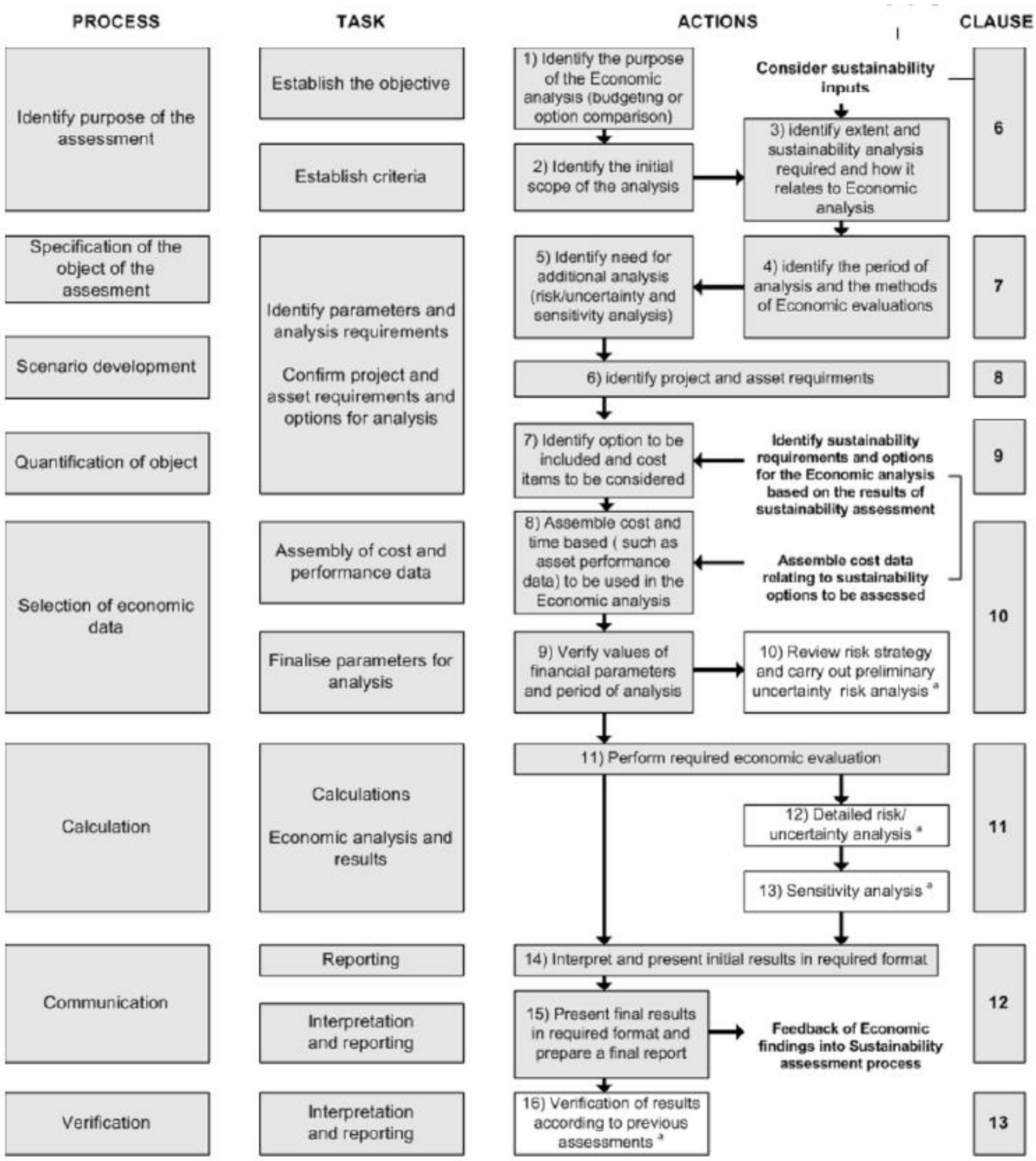



**Figure 4 Flowchart of the process for the calculation of the economic performance [5]**

*White boxes are optional

**The clauses numbered in the right column explain in more detail each stage specified in the central column

## 2.5 D1.3 Aspects of Next Generation EPC's definition

EU targets of the next-generation energy performance certificates are to evaluate buildings in a holistic and cost-effective methodology considering building envelope performances, system performances and smart readiness. It is expected that the assessment methods will consider output measures of performance (actual measured data) making use of an available and increasing number of building energy-related data from sensors, smart meters, and connected devices. The next-generation EPCs should improve the effectiveness of certificates within a framework that aids compliance checking and the effectiveness of financial support [10]. The next-generation EPCs developed under the project platform aim to transform within time current EPCs into dynamic, user-friendly, reliable, cost-effective and sustainability-informative tools for different stakeholder groups: building users, occupants, owners, building managers, engineers, designers, etc. The dynamic EPCs will monitor the actual performance of the building and, at the same time, introduce intelligent financial schemes associated with output-based assessment.

D^2EPC project proposes additional indicators that display the environmental performance of buildings for their introduction in the next-generation EPCs jointly with LCC analysis to implement energy efficiency measures. To develop the environmental indicators, LCA methodologies and tools will be introduced to the dynamic EPC scheme for the efficient energy design of buildings and enable the parameterization of its embodied energy and primary energy demand to be included in dynamic EPCs. According to the applicable criteria, LCA helps recognize opportunities to enhance the environmental performance of the product or service under review and informs decision-makers to select the most efficient environmental instruments. The integration of LCC indicators into the EPC allows the use of EPCs for the financial evaluation of energy upgrading measures for buildings.

Based on the well-established principle of life-cycle costing, a set of financial indicators could be developed to allow the individual elements of a building's energy efficiency to be interpreted into standardized numerical values. The availability of such indicators may enable EPCs to be used for the financial evaluation of energy-saving measures for buildings. Furthermore, it may allow the use of information generated by EPCs through energy audit processes, bridging the gap between EPBD's energy-related requirements and between energy efficiency. These should develop several strategic scenarios and encourage substantiated decision-making based on several indicators, such as financial indicators, energy indicators, building element condition, renovation time, and level of comfort, as described above.

According to the policy implication rationale, the D^2EPC project proposes to deliver a framework of concepts addressing the required upgrade of standards to integrate the dynamic certification concept into existing standards. The project will lead to the transition from the EPC to a systemic instrument that recognizes the entire life cycle of a building as a structure and encourages best practices in the field of resource performance, which is a core policy concern for the European Union, based on the findings of the D^2EPC. In this regard, it is anticipated that the next EPC generation, as proposed by the D^2EPC project, will provide guidance and decision-making on issues connected to natural resource sustainability.

## 2.6 Level(s) scheme

Level(s) is the most recent European way to assess and report on the sustainability performance of buildings across their entire life cycle. The Level(s) framework and its indicators, which are based on existing standards, provide a shared identity for sustainable development that can be applied to construction projects and portfolios, as well as serve as a foundation for other proposals, regulations, strategies, and actions, such as life cycle thinking and circularity. Level(s) provides the fewest number of indicators, such as "Cost, value and risk indicator", with the greatest potential for long-term sustainability. It tracks performance over the course of a development project's many phases to offer a complete view of the project's lifespan. Each indicator in the Level(s) framework is designed to link the impact of a given particular structure with European sustainability targets, such as (i) the industry, innovation and infrastructure development goal which aims to build resilient infrastructure, promote sustainable industrialization and foster innovation, or (ii) the partnerships for the goals which target to strengthen the means of implementation and revitalize the global partnership for sustainable development by broken down into five categories: finance, technology, capacity building, trade and systemic issues.

The "Cost, value, and risk indicator" [7] is intended to track and quantify the beneficial impact of increased sustainability performance on a property's financial valuation and/or risk rating. It does so by assessing at a basic level, whether the valuation or risk-rating technique employed has taken into consideration three key areas of possible influence:

- Increased revenues from more stable investments: This may be accomplished by making assets more appealing within local markets, reducing vacancy rates, and allowing properties to be adaptable to future market situations.
- Reduced operational overheads: This may be accomplished through lowering operational expenditures (OpEx) for energy and water utilities, as well as anticipated maintenance, repair, and replacement costs.
- Reduced future risk: This may be accomplished by predicting future exposure to the consequences of climate change, which could occur as a result of extreme weather occurrences pushing parts of a structure and its interior conditions beyond their limits of tolerances, potentially leading to:
    - rise in operational costs,
    - circumstances that are unhealthy,
    - as a result of changing client and regulatory performance expectations, stranded assets
    - loss of income and higher insurance costs as a result

The indicator applies to all building life cycle stages; however, the major focus is on the impact on costs and hazards incurred during the usage stage. The three primary areas of the possible effect on value and risk evaluation are addressed in the use of the indicator. Although reporting on whether or not a possible impact was considered in an evaluation is a binary yes or no, supporting data should be given. This method currently only provides instructions for Level 1; nevertheless, it has the potential to be extended to a similar qualitative reporting of the influence of value through to Levels 2 and 3 as well (**Table 1**).

**Table 1 Corresponding activities used to assess and address the potential influence**

| Level | Activities related to the use of indicator 6.2 |
|---|---|
| 1. Conceptual design (following design principles) | ▪ Early-stage identification of potential design influences on the appraisal of value and risk |
| 2. Detailed design and construction | Detailed design decisions<br>▪ Support to the detailed appraisal and value engineering of design decisions<br>▪ The development of more informed scenarios for the performance of the property in the market<br>Financial approvals and due diligence<br>▪ Support to demonstrate how performance aspects have been taken into account in the value engineering of the project<br>▪ Support to demonstrate the tangible steps taken to address possible future risks to performance and value<br>Cost control on site |

| | |
|---|---|
| | ▪ Support to more clearly distinguish sustainability specifications that are important from a value and risk perspective |
| 3. As-built and in-use performance | ▪ Greater ongoing awareness of design features that are intended to protect the future value and minimise risks<br>▪ Management and monitoring of ongoing maintenance and replacement cycles, including the link to operational expenditure<br>▪ Management of costs and overheads that may be influenced by the improved management of risks. |

Furthermore, the Level(s) framework aims to promote life cycle thinking. It guides users from an initial focus on individual aspects of building performance towards a more holistic perspective, with the aim of the wider European use of Life Cycle Assessment (LCA) and Life Cycle Cost Assessment (LCCA) methods [8]. According to the European Commission, Life Cycle Costing is a technique that "enables comparative cost assessments to be made over a specified period of time, taking into account all relevant economic factors, both in terms of initial capital costs and future operational and asset replacement cost". It is particularly relevant to achieving improved environmental performance because higher initial capital costs may be required to achieve lower life cycle running costs. The indicator shall be calculated for the elemental costs of a building and measures all building element costs incurred at each life cycle stage of a project for the reference study period and if defined by the client, the intended service life. The life cycle stages reflect those used as the basis for the reference standards EN 16627 and ISO 15686-5. These costs will be strongly influenced by the decisions and calculated performance of the following indicators in the Level(s) framework:

- Use stage primary energy use
- Bill of quantities, materials, and lifespans
- Efficient use of water resources.

Any relevant assumptions that are required for the LCC can be based on the Commission Delegated Regulation No. 244:2012 [9]. In accordance with Article 5 of, and Annexes I and III to, Directive 2010/31/EU of the European Parliament and the Council, this Regulation establishes the conditions on the energy performance of buildings and a comparative methodology framework to be used by Member States (MS) for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements. The methodology framework specifies rules for comparing energy efficiency measures, measures incorporating renewable energy sources and packages and variants of such measures, based on the primary energy performance and the cost attributed to their implementation. It also lays down how to apply these rules to selected reference buildings with the aim of identifying cost-optimal levels of minimum energy performance requirements.

When calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements, MSs shall apply the comparative methodology framework laid down in Annex I to this Regulation. The framework prescribes the calculation of cost-optimal levels for both macroeconomic and financial viewpoints but leaves it up to the MSs to determine which of these calculations is to become the national benchmark against which national minimum energy performance requirements will be assessed. For the purpose of the calculations, MSs shall take as a starting year for the calculation the year in which the calculation is being performed, use the calculation period, as well as the cost categories in Annex I to this Regulation, and use for carbon costing as a minimum lower bound the projected ETS carbon prices as given in Annex II.

Additionally, MSs shall complement the comparative methodology framework by determining for the purpose of the calculations the estimated economic life cycle of a building and/or building element, the discount rate, the costs for energy carriers, products, systems, maintenance cost, operational costs and labour costs, the primary energy factors, as well as the energy price developments to be assumed for all energy carriers taking into account the information in Annex II to this Regulation. Through this comparative methodology framework, MSs shall undertake an analysis to determine the sensitivity of the calculation outcomes to changes in the applied parameters, covering at least the impact of different energy price developments and the discount rates for the macroeconomic and financial calculations, ideally, also other parameters which are expected to have a significant impact on the outcome of the calculations, such as price developments for other than energy. Finally yet importantly, MSs shall endeavour to calculate and adopt cost-optimal levels of minimum energy performance requirements in relation to those building categories where so far, no specific minimum energy performance requirements exist.

# 3 Methodology

The main objective of WP2 is to define new indicators that will be implemented in the Next Generation EPCs and thus increase users' awareness of energy efficiency and enhance the user-friendliness of the building certificate. Task 2.4 focuses on developing cost and economic indicators, enabling the interpretation of the individual elements of a building's energy performance into normalized monetary values.

Some of the starting points for the KPI development are presented below:

- The purpose of the D^2EPC KPI is to provide users with a real-time image of the monetized performance of the building
- The relevance of the financial indicators in the D^2EPC project is the comparison between:
    - the asset values (as-designed)
    - the operational values, to monitor the performance of the building (as-operated)
    - the prediction model
    - the building stock (benchmarking with similar buildings)
- The comparison between different scenarios will allow users to allocate the performance of their building. The focus of the comparison is user behaviours and his awareness of energy use rather than the improvement of the building's systems and envelope.
- Financial indicators will not affect the energy class of the building, they will be presented as additional information for the user.
- In the scope of this task, the user is a professional (an EPC assessor), who is anticipated to implement the principles of D^2EPC in building certification.
- The outcome of this task is the guideline for extracting required data (from IFC) concerning the financial indicators and providing instructions for the calculation.

## 3.1 Definition of financial KPIs

The financial indicators aim to increase user awareness about the energy efficiency of buildings. The approach is to monetize the energy consumption, which means that the energy consumption is translated to EUR. Tenants will be able to see how much money they are spending on energy and compare it with different scenarios (asset values, operational values, prediction values…). Such indicators are expected to enable the financial assessment of the building and thus provide additional information to the user. This could encourage them to adapt their behaviour in order to improve the energy efficiency of the building.

The development of financial indicators is based on the well-established concept of whole life cycle costing (LCC). The LCC methodology is a decision-making tool that helps assess different options over a certain period of time. The indicators, developed in D^2EPC are not intended for the long-term planning or comparison of alternatives; nevertheless, the LCC concept is used as a base, as it defines a typical scope of costs throughout the construction, operation, maintenance, and end-of-life phase. Therefore, the approach is to evaluate the relevant costs and present them to the user as additional information in next-generation dynamic EPCs.

The idea of how to define the financial indicators is based on the comparison of the current state (as-operated) with different scenarios, for example, the as-designed state, the as-operated state at a different (past) time, the predicted model, and the building stock, as illustrated in **Figure 5**. The energy consumption of different scenarios is going to be monetized and compared to each other.

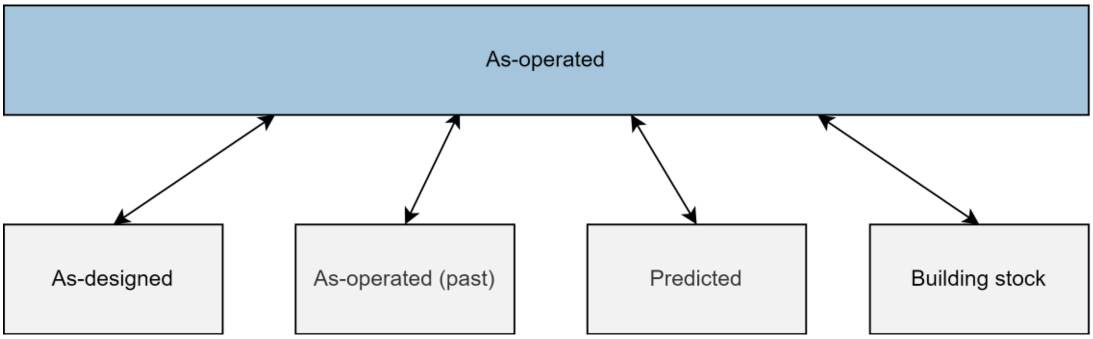



**Figure 5 The comparison of scenarios**

Besides the comparison between the monetized energy consumptions, the financial indicator will also include the expected cost for the replacement and maintenance of the building's systems and envelope. In this way, the user will be informed about the approximate expenses in the near future, which will allow him to better plan his expenditures.

## 3.2 Integration into D^2EPC

One of the goals of the D^2EPC project is to integrate a novel set of indicators that cover different aspects. The demonstrated task focuses on the development of financial indicators. In order to integrate the KPIs into D^2EPC, certain requirements need to be satisfied regarding data collection.

As defined in the D1.9 "D^2EPC Framework Architecture and Specifications v3", the Calculation Engine in the Service/Processing Layer is one of the fundamental components in the D^2EPC Architecture, responsible for all the calculations to assess asset and operational performance. Besides, the sub-component Building Performance Module (BPM) will calculate all the D^2EPC KPIs and the data input will be based on BIM literacy, as introduced by the complete Digital Twin.

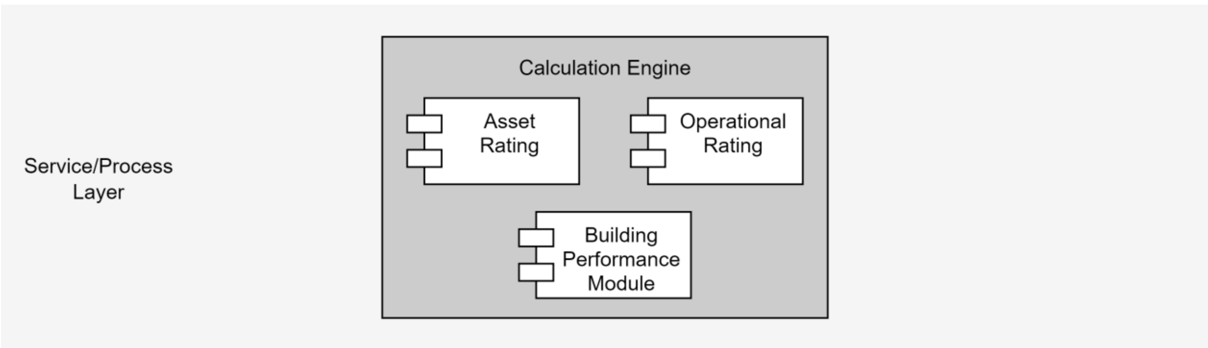



**Figure 6 Service/Process Layer**

The outcomes from the Asset Rating Module and the Operational Rating Module and contribution from the user, where applicable are the required inputs for the Building Performance Module to calculate the financial KPIs, as presented in **Figure 7**.

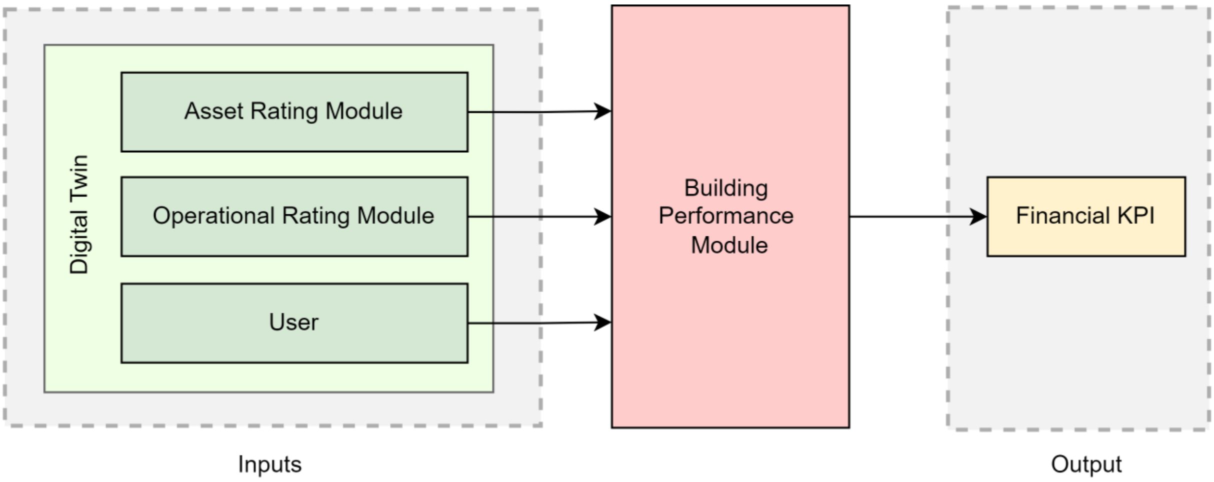



**Figure 7 Process overview**

## 3.3 Calculation of the financial indicators

This section illustrates the idea and the process for the calculation of the financial indicator and explains the steps required for it. First, it describes the necessary input data, followed by the explanation of the calculation itself, including the values based on the designed data, operated data and predicted values. For future exploitation, the building stock comparison is briefly outlined. Next, the calculation of the expected costs is summarized and finally, the data which is required from the IFC model is presented.

To better understand the theoretical idea presented in this section, the next chapter demonstrates a real-case example and performs the calculation with actual numbers as a proof of concept.

### 3.3.1 Inputs

The aim of the financial indicators is to monetize the energy performance of the building. Looking at ISO 15686-5:2017, the generic cost classification that may be used for comparative analysis, i.e., the operational utility costs are described as costs of fuel for heating, cooling, power, lighting, water, and sewerage costs (see **Figure 1**). Since water and sewage costs are not related to energy use, the focus is on costs linked to thermal and electrical energy consumption, i.e., the cost of heating, cooling, ventilation, lighting, and power (appliances).

The as-designed energy consumption of the building can be extracted from the Asset Rating Module outputs, which focuses on asset rating methodology. The as-operated energy consumption of the building can be retrieved from the Operational Rating Module, where the operational rating EPC is calculated. The expected value from the Asset Rating Module is the design-based energy consumption in kWh/m$^2$ per month (delivered energy), whereas the expected values from the Operational Rating Module are measurement-based monthly energy consumption values of the building in kWh/m$^2$.

Crucial information for this KPI calculation is the price of the energy carriers. Even though the aim is to provide universal KPIs, there is no uniform price that can be used, which would be valid for all member states. It was therefore decided that the price information will be provided by the user. This way, the results can be more accurate and provide better information to the user.

Since the calculation is performed for the past year (the latest value is the last completed month) and the prices of energy carriers in the past months are thus known, it was decided to slightly update the input steps for the calculation of the financial KPI. The update from the previous version is that now the user can provide and edit the price per energy carrier per month, which allows for a more accurate representation of price fluctuations throughout the year. In the previous version of the calculation, the user provided an average price for the whole year.

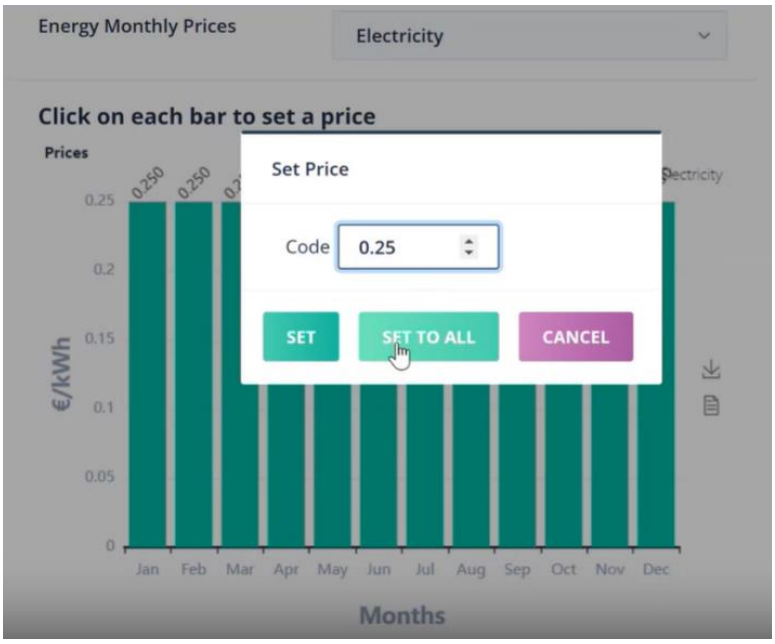



**Figure 8 Changing monthly prices per energy carrier**

Different countries define their electrical tariffs in different ways. In some cases, there are multiple tariffs, while in others, there is only one. To overcome this discrepancy, it was decided to perform the calculation with an average value of all the tariffs entered without tax.

The user is also expected to define which energy carrier is used for different energy consumption, for example, which energy carrier is used for heating, cooling, ventilation, lighting, and appliances, if such information is not already available in the Digital Twin model. This part should be made flexible and adapted to each specific case based on the available measurements. One possible distribution of energy use can be heating, cooling, ventilation, lighting, and appliances. However, in some cases, the measurements are taken for the HVAC only, thus combining the heating, ventilation, and air conditioning in one item. Similarly, the lighting and appliances can be joined together in one item. Once this information is collected, it can be connected to the price that the user has previously provided. The user can choose between different kinds of energy carriers, such as electricity, natural gas, district heating, etc.

In order to evaluate future values, the prediction model requires information regarding the inflation rate and the discount rate. The average expected rates for the next 10 years are provided by the user as they differ from country to country, but it also allows the user to compare different possible scenarios by using different rates.

Lastly, the financial indicator aims to list all the expected future costs related to the maintenance and replacement of the building's systems. The systems' information will be retrieved from the BIM model of the building and through the inputs from the user. More precisely, the required information is:

- The installation date (year) of the Heating, Ventilation and Air Conditioning (HVAC) systems installed,
- The price of the HVAC systems,
- The life span of HVAC systems,
- The maintenance schedule (e.g., maintenance required every two years),
- The maintenance price.

The extraction of data from the IFC file is performed through an IFC parser, developed in T2.5 and T3.3. The table with the requirements of a BIM file has been prepared which shows the relation between the expected indicator's inputs and their relation with the IFC entity and reference to the IFC4 schema. The attributes' metadata is described in the last four columns. If such data is not available in the BIM file, the user would be required to provide this information through some other form, e.g., through the user interface of the platform.

**Table 2 Required data from IFC**

| Indicator Name | Indicator Description | Unit | Static/ Dynamic | Category | Relation with IFC entity | Reference to IFC schema contents | Entity attribute metadata | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Attribute name | Attribute value | | |
| | | | | | | | | Datatype | Format | Unit |
| HVAC system | HVAC system of the building / apartment | N/A | Static | Financial indicators | IfcSystem | 5.4.3.53 | InstalledIn | integers | 0000 | / |
| | | | | | | | Price | real number | 00,00 | EUR |
| | | | | | | | LifeSpan | integers | 00 | years |
| | | | | | | | MaintenanceOccurance | integers | 00 | years |
| | | | | | | | MaintennaceCost | real number | 00,00 | EUR |
| Area | Building / apartment area | $m^2$ | Static | Financial indicators | IfcSpace | 5.4.3.45 | Area | real number | 00,00 | $m^2$ |

Based on that, the expected costs for maintenance and replacements per year will be calculated and presented to the user which will allow better planning of their expenditure.

## 3.3.2 Calculation

### 3.3.2.1 As-designed and as-operated model

Based on the acquired inputs, the calculation follows the simple formula of multiplying the energy consumption by the energy price. The as-designed asset values follow the Energy Performance of Buildings (EPB) standards with the main core of the EN ISO 52000 family of standards and divide the consumption into heating, cooling, domestic hot water (DHW) and lighting. On the other hand, the as-operated energy consumption values depend on the measurements that take place in the building, for example, heating and cooling can be combined due to having only one system present for both, while there might be additional values such as energy consumption of appliances.

The outcomes of the as-operated scenario therefore include:

- Cost in EUR per month per energy use
- Cost in EUR per month per energy carrier
- Total cost in EUR per month
- Total cost in EUR per year
- Total cost in EUR per square meter

The separation of costs per energy use and energy carrier can be beneficial for the user, as it indicates where improvements can be made in case the building is performing poorly.

The outcomes of the as-designed scenario include:

- Cost in EUR per month per energy use
- Cost in EUR per month per energy carrier
- Total cost in EUR per month
- Total cost in EUR per year
- Total cost in EUR per square meter

Due to the above-mentioned differences in what values are available in the asset and operational rating, the comparison between both scenarios shows the total cost in EUR per month and year, providing additional information, and thus increasing user awareness regarding energy consumption. The comparison can clearly indicate whether the performance of the building is better or worse than the design values. The as-operated yearly cost in EUR is a true reflection of the monetarized energy use in the building, although it does not match the bills that the residents receive because the additional costs and taxes are, in this case, omitted.

### 3.3.2.2 Prediction model

The prediction model tries to evaluate the future costs, based on the inflation rate and discount factor provided by the user. The basis for the calculation is the monetized annual energy consumption from the measurements, to which the inflation rate and discount factor are applied. The prediction looks into the next 10 years, and it includes:

- the real cost, which is adjusted for inflation, meaning that it can be compared as if the prices have not changed on average
- the nominal cost, which has not been adjusted to inflation and therefore reflects the effect of inflation
- the Net Present Value (NPV), which represents the future price in today's value, is determined by the discount rate

The calculation follows the formula, presented below:

- $inflation = (1 + r)^n$
- $nominal\ cost = real\ cost \cdot inflation$

- $discount = (1 + d)^n$
- $NPV = nominal\ cost\ /\ discount$

Where *r* is the inflation rate, *d* is the discount rate and *n* is the number of years between the base date and the occurrence of the cost.

The comparison between the real value, nominal value and NPV is an approximation and aims to illustrate to the user the impact of time on the value of money they will be paying for the energy use in their building.

Furthermore, the AI-driven Performance Forecast component of the D^2EPC platform is responsible for forecasting building operating conditions and their impact on the building's energy efficiency/performance, and can thus improve future cost estimation. The component predicts energy consumption for the month ahead using available weather data. This can help the user with short-term planning on their expenses, compared to the prediction model, which can be useful for long-term estimations.

#### 3.3.2.3 Building stock

The future exploitation of the D^2EPC platform which would increase user awareness even more is presenting the monetized energy use on an expanded, larger scale, i.e., the comparison with the building stock. For that reason, an analysis was performed on how financial indicators could be presented using GIS and geoinformatics. Moreover, the WebGIS tool of the D^2EPC platform can be used for visualizing and analysing spatial data related to building energy consumption and thus producing added value information such as energy consumption patterns and financial indicators.

As a sub-component of the representation layer of the D^2EPC platform, the WebGIS tool is an application that functions as an endpoint between end users and the D^2EPC system, providing data in a form to be shown in a D^2EPC portal. The application is also designed to operate independently from the D^2EPC Web platform while also being able to connect to the main repository and the respective geospatial database (DB) for updating its contents. The D^2EPC WebGIS application incorporates the open-source Relational Database Management System (RDBMS) PostgreSQL for storing and handling the building-related generated data. Moreover, it employs Postgres and PostGIS extensions for handling geospatial data. Additionally, towards optimizing the dissemination and map creation for the data contained in PostgreSQL we explored the usage of the Geoserver web server.

Based on the flexible dockerised design and implementation of the GIS framework it can be easily expanded to enable extra functionalities and data display based on the information stored per building (e.g., calculated economic indicators). For anonymisation and privacy protection purposes, the economic indicators statistics can be automatically calculated per NUTS region.

More specifically, the WebGIS DB utilizes four main tables, each one corresponding to the four NUTS regions provided by Eurostat, chosen to host the updated economic indicators statistics via the comparison mode functionality of the WebGIS. The columns of the table contain the main features of NUTS (ID, country & level code, NUTS name and NUTS name Latin etc.), the geometry attributes (polygon geometry and centroid), the total number of EPCs issued per grade (A-F) and region and the economic indicators per building operating and designed cost:

- Cost per month per energy use
- Total cost per sqm

The EPC statistics are produced by accessing the (approximate) location and economic indicator from D^2EPC Repository's DB and using the PostGIS function ST_Contain to allocate the selected statistical information of a building/dwelling to the corresponding NUTS region. The WebGIS backend automatically updates the PostgreSQL database in case of insertion, deletion, or update of an EPC asset rating.

To better present the mentioned functionality, the following use cases for visualizing and comparing economic indicators per region via the D^2EPC WebGIS application were defined:

UC1: The user selects two European NUTS regions and compares the generated statistics of the Buildings' designed energy cost

- Per month and energy use (UC1.A) (Figure 9)
- Total cost per sqm (UC1.B) (Figure 10)

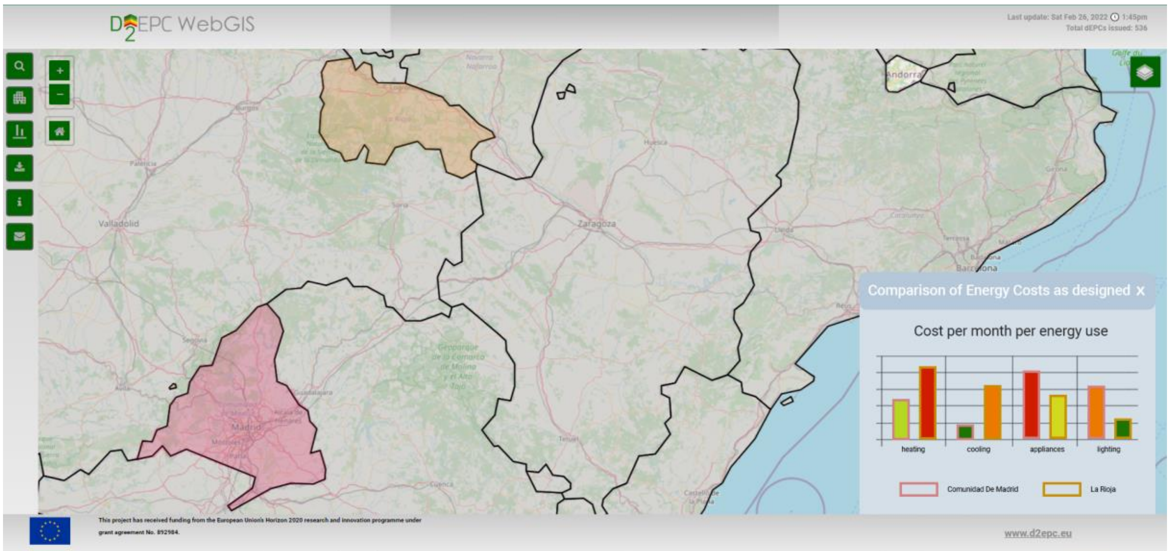



Figure 9 Comparison mode for economic indicators of the use case (UC1.A)

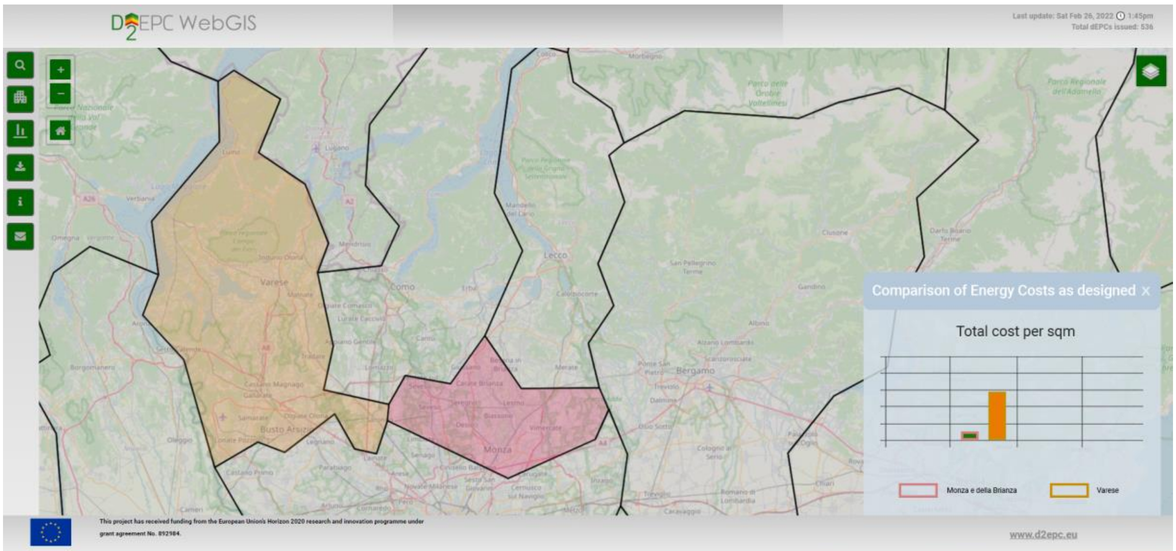



Figure 10 Comparison mode for economic indicators of the use case (UC1.B)

UC2: The user selects two European NUTS regions and compares the generated statistics of the Buildings' operational energy cost

- Per month and energy use (UC2.A) (Figure 11)
- Total cost per sqm (UC2.B) (Figure 12)

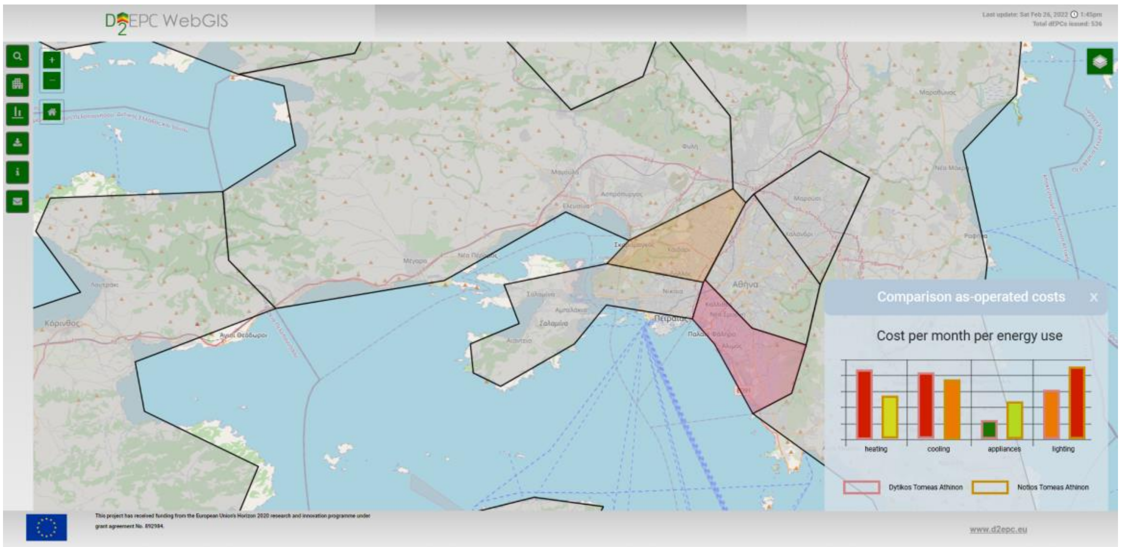



**Figure 11 Comparison mode for economic indicators of the use case (UC2.A)**

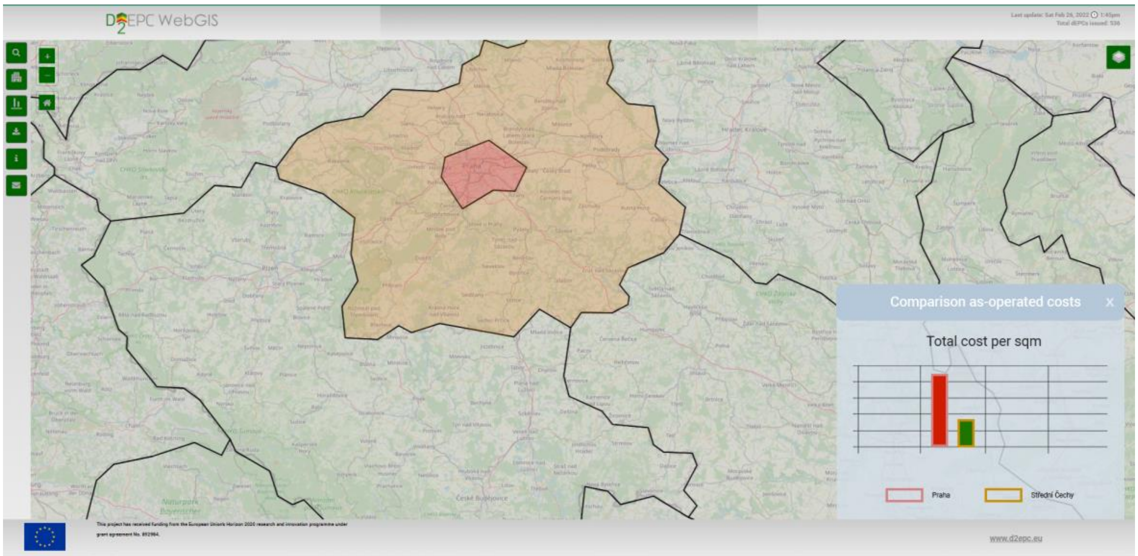



**Figure 12 Comparison mode for economic indicators of the use case (UC2.B)**

### 3.3.2.4 Expected costs for building systems

Expected yearly costs for building systems are calculated based on the inputs from the BIM model and inputs from the user, by simply summing up the expected costs for the maintenance and replacement of the systems in the next few years.

At this point, it was also considered to include the expected costs for the building's envelope (façade and windows). However, the idea was dropped after taking into consideration different systems that are present in the MS in this regard. For example, in some countries to perform maintenance work on the façade, all building's residents need to agree on it, while in other countries residents are already paying monthly contributions to the fund which is later used for the maintenance works on the building's envelope.

### 3.3.3 D^2EPC Financial indicators

The table below shows an overview of the D^2EPC financial indicators, developed in the task.

**Table 3 D^2EPC Financial indicators**

| Indicator name | Indicator description | Units |
|---|---|---|
| As-operated costs | The "as-operated cost" indicator presents the following costs to the user:<br>- Cost per month per energy use<br>- Cost per month per energy carrier<br>- Total cost per month<br>- Total cost per year<br>- Total cost per square meter | EUR |
| As-designed costs | The "as-designed cost" indicator presents the following costs to the user:<br>- Cost per month per energy use<br>- Cost per month per energy carrier<br>- Total cost per month<br>- Total cost per year<br>- Total cost per square meter | EUR |
| Total cost comparison<br>(graphically presented) | The "total cost comparison" indicator is comparing the as-designed and as-operated costs, namely the total costs per month and total costs for the whole year.<br>- Total cost comparison per month<br>- Total cost comparison per year | EUR |
| Predicted costs | The "predicted costs" indicator presents the real cost, the nominal cost, and the Net Present Value for the next 10 years | EUR |
| Expected costs for building systems | The "expected costs for building systems" are an estimation of the costs that the user can expect for the replacement and maintenance of building systems | EUR |

# 4 D^2EPC platform

In this subsection, the Cost & Economic module of the D^2EPC Platform is described. Previous needed steps, such as logging in, uploading a valid BIM (.ifc) file, running the asset and operational rating module, etc. are here not explained, as they are in detailed presented within D5.6 D^2EPC Manual v2.

The Cost & Economic module can be found by accessing the Building Performance Module of the Platform and then clicking on "Cost & Economic", as shown in Figure 13.

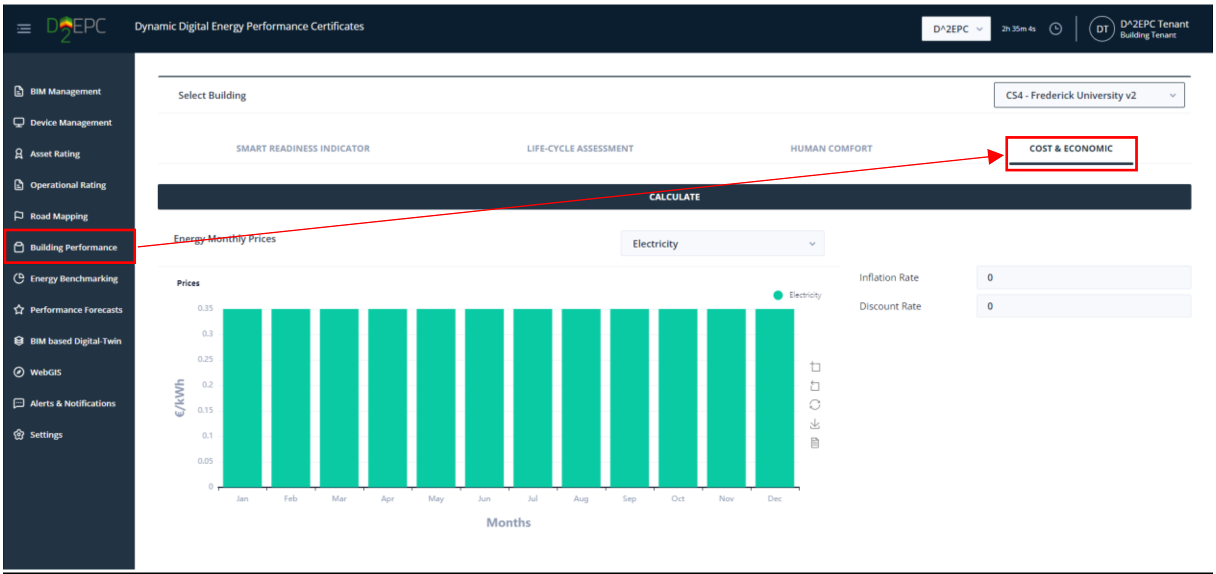



Figure 13 Reaching Cost & Economic indicator in the D^2EPC platform

First, as seen in Figure 14, there is a drop-down list (A), in which the user can choose different energy carriers (electricity, natural gas, fossil fuels, etc.). For the selected option, there is a bar chart (B) that represents the monthly energy price, which in this case is 0.35 €/kWh for electricity. On the right-hand side, there are two boxes (C) where the user can insert the inflation rate and the discount rate.

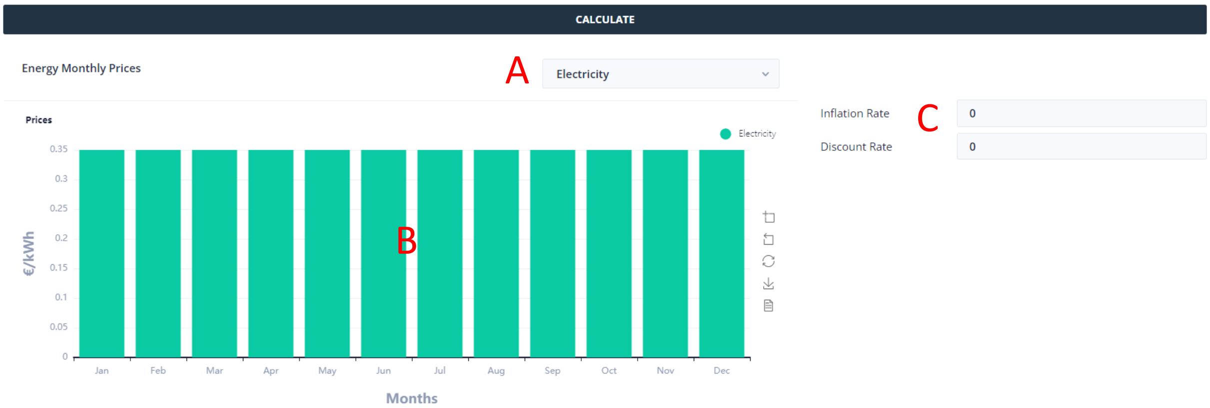



Figure 14 Energy prices, inflation, and discount rate

Once checked that the prices and the rates are correct, the calculations can be run by pressing the "CALCULATE" button. When the calculation has finished, the following results are presented:


**Figure 15 Results for cost & economic indicators**

Three different graphs are presented as a result. The top ones show the results for the as-designed building and the as-operated building. The user can choose between four different options on these graphs, namely the monthly cost per energy carrier (electricity, natural gas…), the monthly cost per use (cooling, heating, lighting…), the monthly total cost and the monthly total cost per square meter.

Lastly, the third graph shows the as-predicted values for the building, representing the real energy cost (green), the nominal cost (blue), and the net present value of the costs (purple).

# 5 Demonstration on case studies

One of the main outcomes of this document is to provide guidelines for the integration of the KPI into the D^2EPC scope. This chapter combines all the efforts and work that has been performed within T2.4 by considering the real-life example. Using data from the Frederic University demonstration case (FRC building) allows us to better understand the calculation process of the financial indicator, how it can increase user awareness and what is its benefit for the EPCs.

## 5.1 Case Study 4: Mixed-use building in Nicosia

The building in Cyprus (FRC building) is located in the area of Palouriotissa, Nicosia, Y. Frederickou Str. (Longitude and Latitude 33°22’46.70 “E, 35°10’46.20 "N), Frederick University's new wing building is a three-story 2100 $m^2$ building, its volume is approximately 7,100m3 (including the basement floor/parking area), and it was built in 2007. The understudy building does not border with any other building. The building consists of a basement (an area of 450 $m^2$), a ground floor (an area of 545 $m^2$), and two floors (an area of 545 $m^2$ on each floor). University's cafeteria is on the ground floor; on the first floor, there are three seminar halls of 220 students’ capacity, and offices are found on the second floor. The building can host up to 390 people. The total height of the building is 15,60 m from the basement floor to the terrace. The individual heights of the floors are 4,10 m for the typical floors and the ground floor. The services that are provided within the building include heating, cooling, ventilation, lighting, and electrical appliances.


**Figure 16 FRC building**

The building introduced in this case study is a multi-use building with quite a diverse set of spaces, systems, and assets. The entire new wing building covered is divided into three separate zones monitored in detail. The entire building is also covered in terms of energy monitoring, providing a complete data flow that fully depicts the building’s status.

**Figure 17 IFC model of a FRC building**

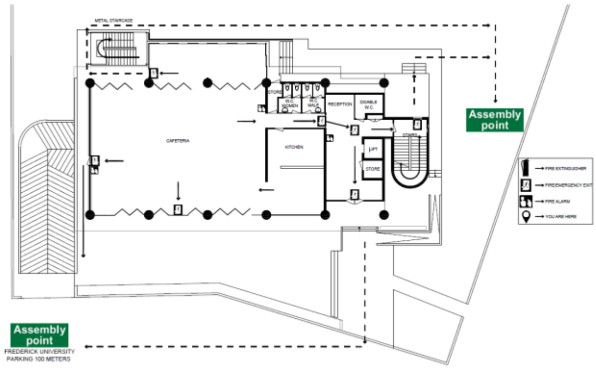



**Figure 18 Floor plan - Ground floor**

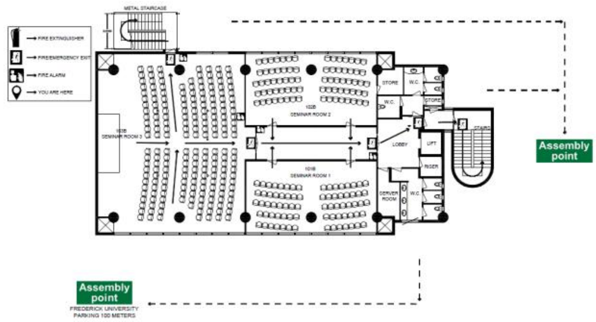



**Figure 19 Floor plan - 1st floor**

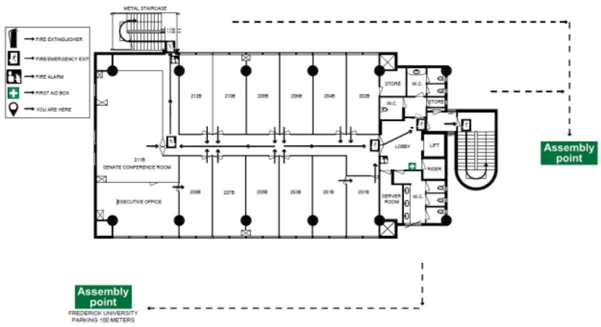



**Figure 20 Floor plan - 2nd floor**

## 5.1.1 Measured data

In the FRC building, there are 30 input meter data loggers and 45 input meter core data loggers for measuring the energy performance of the building, while three-zone monitoring and remote sensors are responsible for measuring the carbon dioxide, temperature, and relative humidity. The measurements started in the middle of June 2021 and will continue throughout the project. The measurement data is divided in a way, as seen in **Table 4**.

On the ground floor, there are two measurements available, one for the canteen and one for the elevator. The canteen values include all the appliances and lighting in this area. On the first floor, the measurements are divided into the lights and sockets, where lights are further divided into three different lecture rooms and utility areas (WC, server room, store, etc.). The lights and sockets are summed up under item Usage. The same division can be found on the second floor and measurements on the roof are related to the energy, used for the VRVs air conditioning system. Three of them are on the ground floor and two are on the second floor. The VRVs on the first floor are also installed but the measurement results will be provided in the later project phase.

**Table 4 Measurement data for FRC building**

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

| | | |
|---|---|---|
| | | - 2nd Floor Sockets |
| Roof | Usage | - Power EVRV-G3\|<br>- Power EVRV-G2\|<br>- Power EVRV-G1\|<br>- Power VRV-2F2\|<br>- Power VRV-2F1\| |

By the installed equipment there are extracted measurements for the total power consumption of the pilot building, as well as HVAC data on the ground, first and second floor. First and second floor have the same division concerning the power consumption documentation, as well as the measurements on the roof are related to the energy, used for the VRVs air conditioning system. During the previous period, the addition of the sensors presented in **Table 5** took place.

**Table 5 Monitoring equipment characteristics**

| Name | Accuracy | Qty | Picture |
|---|---|---|---|
| Hobo EG4115 Core Data Logger | 0.5% revenue-grade accuracy compliance | 3 |  |
| Hobo EG4130Pro Data Logger | 0.5% revenue-grade accuracy compliance | 1 | |
| Hobo T-EG-0630-0100 | Up to +/-1% | 21 |  |
| Hobo T-EG-0940- 0100 | Up to +/-1% | 3 | |
| Hobo T-EG-0940- 0200 | Up to +/-1% | 3 | |
| Hobo T-EG-0390-0050 | Up to +/-1% | 30 | |
| AM107-868M Milesight AM107 (LoRaWAN®) | Temperature sensing: -40°C - 85°C, ± 1°C accuracy<br>Humidity sensing: 0% – 100% RH, ± 3% accuracy<br>$CO_2$ sensing: 400 – 5000 ppm, ±30 ppm or ±3 % | 7 |  |

In **Figure 21** and **Figure 22** the measurement values in kWh per floor for the total power consumption, as well as the total energy use of the FRC building are presented graphically for a whole year. The measurements are up to date on real time every one hour and can be extracted from the D^2EPC platform in a more detailed manner.

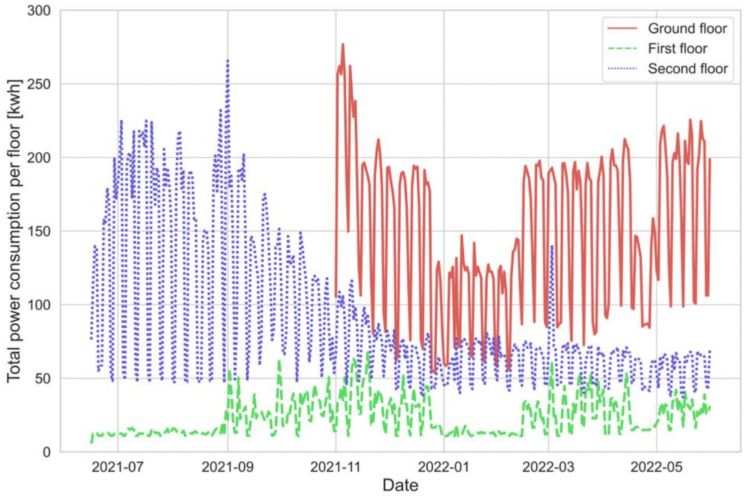


**Figure 21 Available measurements' data per floor for the total power consumption**

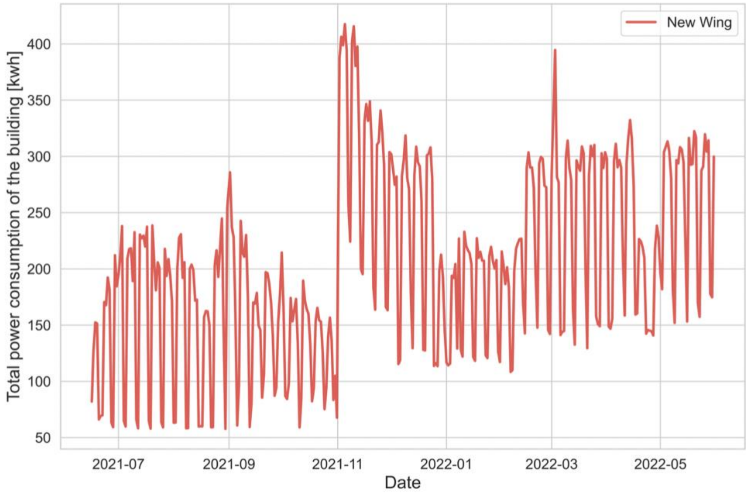



**Figure 22 Total energy use of the FRC building**

## 5.1.2 Example calculation for CS4

In the previous version of this deliverable, the calculation was performed using dummy values, due to a lack of available measured data at that time. However, the concept was proven, and the methodology was tested. During in the final month of the project, there have been enough available data to perform real-time calculation on a case study.

In this chapter, an example of the financial indicator calculation is presented, utilizing data from the FRC building that include measurements of the building's energy use for one year. An Excel file for this purpose was divided into four tabs, namely the User inputs, Data, Calculation and System. Each of them is further described below.

### 5.1.2.1 User inputs

In the first tab, three tables were prepared in order to gather the inputs from the user, that is:

- the price of the energy carriers that are present in the building,
- the definition of the energy carrier which is used for certain energy consumption (for heating, for cooling, for ventilation etc.) and
- predicted inflation and discount rate for the next 10 years.

**USER INPUTS**

**Define price**

| Energy carrier | | Price EUR/kWh | |
|---|---|---|---|
| Biomass | | | NA |
| District heating | | | NA |
| Electricity | Tariff 1 | 0,35 | 0,35 |
| | Tariff 2 | / | |
| | Tariff 3 | / | |
| Fossil fuels | | | NA |
| Geothermal | | | NA |
| Other | | | NA |
| Natural gas | | | NA |
| Solar | | | NA |
| Wind | | | NA |

**Define energy carrier**

| Energy use | Carrier |
|---|---|
| Heating | Electricity |
| Cooling | Electricity |
| Ventilation | Electricity |
| DHW | NA |
| Lighting | Electricity |
| Appliances | Electricity |

**Define prediction values**

| Predicition values | % |
|---|---|
| Inflation rate | 4,5% |
| Discount rate | 2,0% |

| | |
|---|---|
| Current year | 2023 |

User inputs | Data | Calculation | Systems

**Figure 23 User inputs tab**

### 5.1.2.2 Data

The Data tab includes all the required information about the energy use, i.e., the measured energy consumption, the designed values of the energy use and the area of the building for the BPM to complete the calculation for the case of financial indicators. The input data will be based on BIM literacy, as introduced also by the complete Digital Twin while the measured values are expected to come as an output of the Operational Rating Module and design values are expected to come as an output of the Asset Rating Module as described in D1.4.

In **Figure 24** the as-operated values are filled in for one year, from August 2022 to July 2023 and the table below is prepared to collect values for the upcoming year. By adding tables for each coming year, this tab functions as the database of the energy consumption of the building. The values that are needed for the calculation correspond to “Final Energy”, which refers to the energy consumed by the equipment that serves the use.

**DATA**

**As-operated**

**Values based on the measurements**

| | 2022-23 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | August | September | October | November | December | January | February | March | April | May | June | July |
| Heating | 0,0 | 0,0 | 0,0 | 830,1 | 590,9 | 1831,0 | 2320,0 | 657,6 | 0,0 | 0,0 | 0,0 | 0,0 |
| Cooling | 2222,8 | 5382,6 | 3451,1 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 461,2 | 966,5 | 1212,5 | 1644,7 |
| Lighting & Apliances | 3146,5 | 8625,6 | 9043,4 | 8672,8 | 7718,0 | 6793,5 | 5884,8 | 7484,7 | 6643,2 | 8752,4 | 8067,5 | 6247,2 |

| | 2023-24 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | August | September | October | November | December | January | February | March | April | May | June | July |
| Heating | | | | | | | | | | | | |
| Cooling | | | | | | | | | | | | |
| Lighting & Apliances | | | | | | | | | | | | |

**As-designed**

**Values based on the design - delivered energy**

| | August | September | October | November | December | January | February | March | April | May | June | July |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Heating | 0 | 0 | 0 | 305,46458 | 889,86946 | 1213,5711 | 936,07263 | 566,92432 | 44,67385 | 0 | 0 | 0 |
| Cooling | 6177,5 | 1693,21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 888,04 | 3976,78 | 6240,66 |
| DHW | | | | | | | | | | | | |
| Lighting | 1334,94 | 1291,88 | 1334,94 | 1291,88 | 1334,94 | 1334,94 | 1205,76 | 1334,94 | 1291,88 | 1334,94 | 1291,88 | 1334,94 |

**Area**

2147 m2

User inputs | Data | Calculation | Systems

Figure 24 Data tab

## 5.1.3 Calculation

The Calculation tab is the most extensive one as it consists of several parts: first, the costs are calculated for the as-operated values, then for as-designed values and lastly for the prediction values. On the right-hand side, the results are visually presented with graphs. This division is illustrated in **Figure 25** and each part is further explained in the following sub-sections.

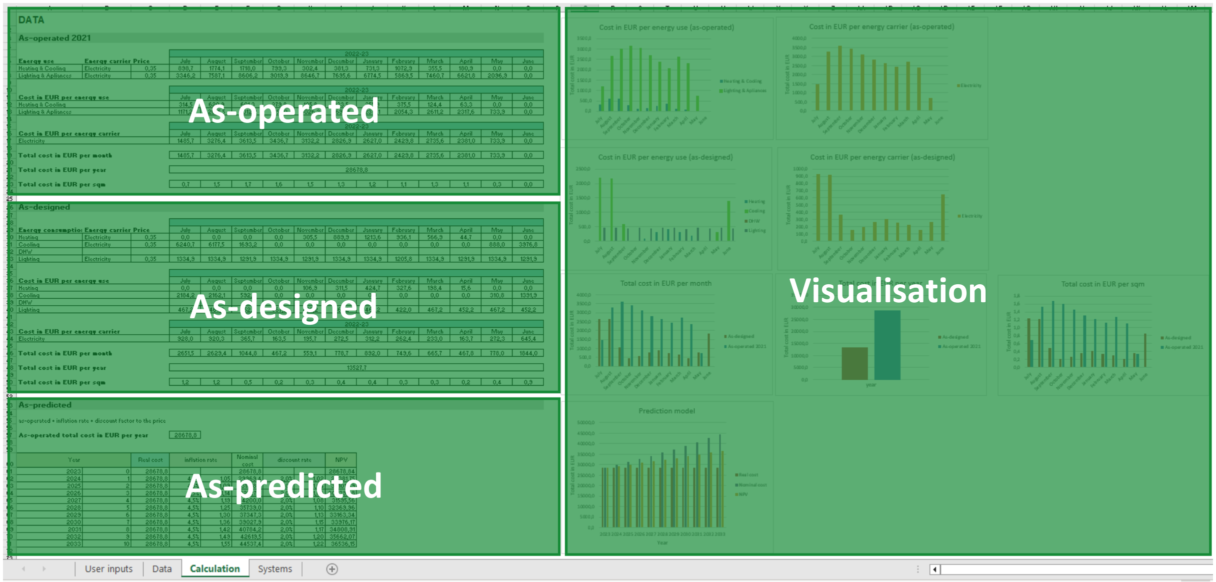



Figure 25 Calculation tab

### 5.1.3.1 As-operated

For every energy consumption, the energy carrier is assigned based on the inputs from the user. Prices are also taken from the user's inputs and by multiplying them with the energy consumption, the costs in EUR are calculated. Next, costs are presented separately for each energy use and each energy carrier. Finally, the total costs in EUR per month, per year and per square meter are calculated.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | **As-operated** | | | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | | | | |
| 5 | | | | 2022-23 | | | | | | | | | | | |
| 6 | **Energy use** | **Energy carrier** | **Price** | August | September | October | November | December | January | February | March | April | May | June | July |
| 7 | Heating | Electricity | 0,35 | 0,0 | 0,0 | 0,0 | 830,1 | 590,9 | 1831,0 | 2320,0 | 657,6 | 0,0 | 0,0 | 0,0 | 0,0 |
| 8 | Cooling | Electricity | 0,35 | 1304,9 | 5382,6 | 3451,1 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 461,2 | 966,5 | 1212,5 | 1644,7 |
| 9 | Lighting & Apliances | Electricity | 0,35 | 1960,6 | 8625,6 | 9043,4 | 8672,8 | 7718,0 | 6793,5 | 5884,8 | 7484,7 | 6643,2 | 8752,4 | 8067,5 | 6247,2 |
| 10 | | | | | | | | | | | | | | | |
| 11 | | | | 2022-23 | | | | | | | | | | | |
| 12 | **Cost in EUR per energy use** | | | August | September | October | November | December | January | February | March | April | May | June | July |
| 13 | Heating | | | 0,0 | 0,0 | 0,0 | 290,5 | 206,8 | 640,9 | 812,0 | 230,2 | 0,0 | 0,0 | 0,0 | 0,0 |
| 14 | Cooling | | | 456,7 | 1883,9 | 1207,9 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 161,4 | 338,3 | 424,4 | 575,6 |
| 15 | Lighting & Apliances | | | 686,2 | 3019,0 | 3165,2 | 3035,5 | 2701,3 | 2377,7 | 2059,7 | 2619,6 | 2325,1 | 3063,3 | 2823,6 | 2186,5 |
| 16 | | | | | | | | | | | | | | | |
| 17 | | | | 2022-23 | | | | | | | | | | | |
| 18 | **Cost in EUR per energy carrier** | | | August | September | October | November | December | January | February | March | April | May | June | July |
| 19 | Electricity | | | 1142,9 | 4902,9 | 4373,1 | 3326,0 | 2908,1 | 3018,6 | 2871,7 | 2849,8 | 2486,5 | 3401,6 | 3248,0 | 2762,2 |
| 20 | | | | | | | | | | | | | | | |
| 21 | **Total cost in EUR per month** | | | 1142,9 | 4902,9 | 4373,1 | 3326,0 | 2908,1 | 3018,6 | 2871,7 | 2849,8 | 2486,5 | 3401,6 | 3248,0 | 2762,2 |
| 22 | | | | | | | | | | | | | | | |
| 23 | **Total cost in EUR per year** | | | 37291,4 | | | | | | | | | | | |
| 24 | | | | | | | | | | | | | | | |
| 25 | **Total cost in EUR per sqm** | | | 0,5 | 2,3 | 2,0 | 1,5 | 1,4 | 1,4 | 1,3 | 1,3 | 1,2 | 1,6 | 1,5 | 1,3 |
| 26 | | | | | | | | | | | | | | | |

**Figure 26 Calculation tab - As-operated**

To better understand the results, the total costs in EUR per energy use and per energy carrier are graphically presented to the user as seen in **Figure 27**.

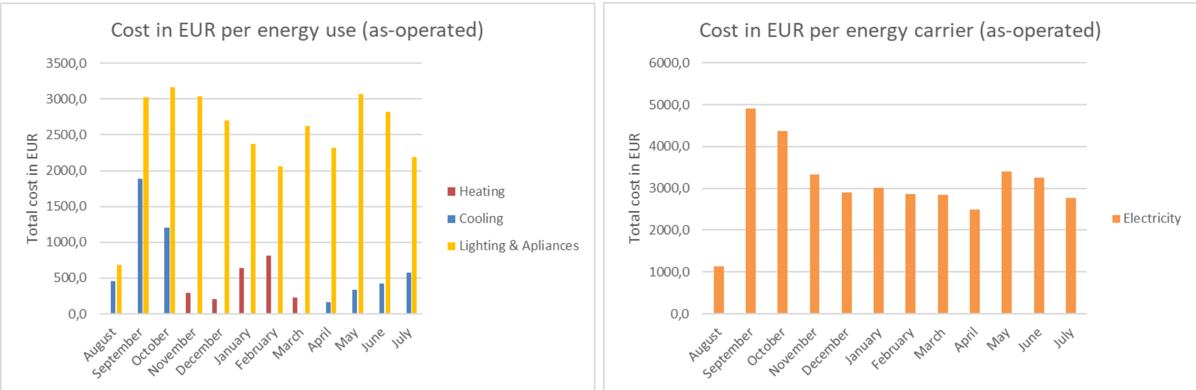



**Figure 27 As-operated total cost in EUR per energy use (left) and energy carrier (right)**

## 5.1.3.2 As-designed

Having the designed energy consumption available, the calculation follows the same approach as operated values, multiplying the consumption with the price, provided by the user. As outcomes, the costs per energy use and energy carrier are calculated, followed by the total cost in EUR per month, per year and square meter.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 28 | **As-designed** | | | | | | | | | | | | | | |
| 29 | | | | | | | | | | | | | | | |
| 30 | | | | | | | | | | | | | | | |
| 31 | **Energy consumption** | **Energy carrier** | **Price** | August | September | October | November | December | January | February | March | April | May | June | July |
| 32 | Heating | Electricity | 0,35 | 0,0 | 0,0 | 0,0 | 305,5 | 889,9 | 1213,6 | 936,1 | 566,9 | 44,7 | 0,0 | 0,0 | 0,0 |
| 33 | Cooling | Electricity | 0,35 | 6177,5 | 1693,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 888,0 | 3976,8 | 6240,7 |
| 34 | DHW | | | | | | | | | | | | | | |
| 35 | Lighting | Electricity | 0,35 | 1334,9 | 1291,9 | 1334,9 | 1291,9 | 1334,9 | 1334,9 | 1205,8 | 1334,9 | 1291,9 | 1334,9 | 1291,9 | 1334,9 |
| 36 | | | | | | | | | | | | | | | |
| 37 | | | | | | | | | | | | | | | |
| 38 | **Cost in EUR per energy use** | | | August | September | October | November | December | January | February | March | April | May | June | July |
| 39 | Heating | | | 0,0 | 0,0 | 0,0 | 106,9 | 311,5 | 424,7 | 327,6 | 198,4 | 15,6 | 0,0 | 0,0 | 0,0 |
| 40 | Cooling | | | 2162,1 | 592,6 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 310,8 | 1391,9 | 2184,2 |
| 41 | DHW | | | | | | | | | | | | | | |
| 42 | Lighting | | | 467,2 | 452,2 | 467,2 | 452,2 | 467,2 | 467,2 | 422,0 | 467,2 | 452,2 | 467,2 | 452,2 | 467,2 |
| 43 | | | | | | | | | | | | | | | |
| 44 | | | | 2022-23 | | | | | | | | | | | |
| 45 | **Cost in EUR per energy carrier** | | | August | September | October | November | December | January | February | March | April | May | June | July |
| 46 | Electricity | | | 2629,4 | 1044,8 | 467,2 | 559,1 | 778,7 | 892,0 | 749,6 | 665,7 | 467,8 | 778,0 | 1844,0 | 2651,5 |
| 47 | | | | | | | | | | | | | | | |
| 48 | **Total cost in EUR per month** | | | 2629,4 | 1044,8 | 467,2 | 559,1 | 778,7 | 892,0 | 749,6 | 665,7 | 467,8 | 778,0 | 1844,0 | 2651,5 |
| 49 | | | | | | | | | | | | | | | |
| 50 | **Total cost in EUR per year** | | | 13527,7 | | | | | | | | | | | |
| 51 | | | | | | | | | | | | | | | |
| 52 | **Total cost in EUR per sqm** | | | 1,2 | 0,5 | 0,2 | 0,3 | 0,4 | 0,4 | 0,3 | 0,3 | 0,2 | 0,4 | 0,9 | 1,2 |
| 53 | | | | | | | | | | | | | | | |

**Figure 28 Calculation tab - As-designed**

To better understand the results, the total costs in EUR per energy use and energy carrier are graphically presented to the user as seen in **Figure 27**.

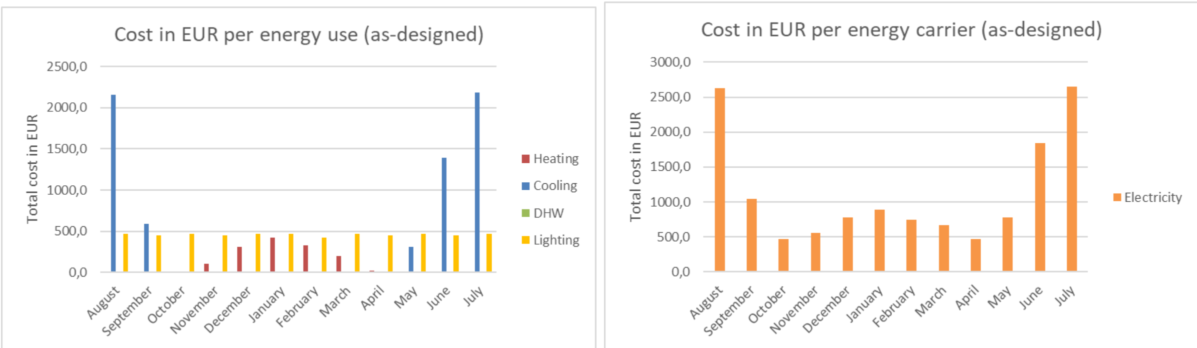
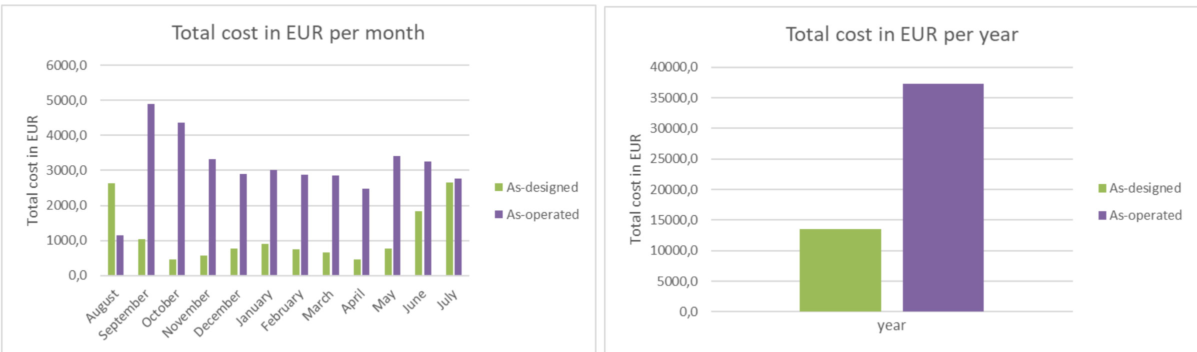



**Figure 29 As-designed total cost in EUR per energy use (left) and energy carrier (right)**

The above-mentioned prices, coming from as-operated and as-designed values can be visualised with graphs for better understanding and comparison. **Figure 30** compares costs based on the operated and design values on a monthly and yearly basis and per square meter.



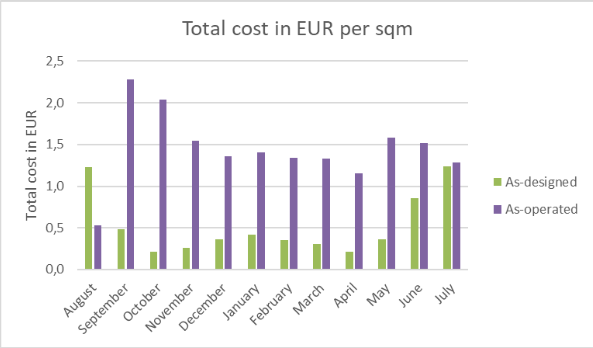



**Figure 30 Total cost in EUR per month (left, up), per year (right, up), per sqm (bottom)**

## 5.1.3.3 As-predicted

The basis (real cost) for the predicted values is the total cost in EUR per year coming from the as-operated consumption. The calculation depicts the horizon of the next ten years and uses the inflation rate and the discount rate provided by the user.

**As-predicted**

as-operated + inflation rate + discount factor to the price

**As-operated total cost in EUR per year** 38027,7

| Year | | Real cost | inflation rate | | Nominal cost | discount rate | | NPV |
|---|---|---|---|---|---|---|---|---|
| 2023 | 0 | 38027,7 | | | 38027,7 | | | 38027,71 |
| 2024 | 1 | 38027,7 | 4,5% | 1,05 | 39739,0 | 2,0% | 1,02 | 38959,76 |
| 2025 | 2 | 38027,7 | 4,5% | 1,09 | 41527,2 | 2,0% | 1,04 | 39914,66 |
| 2026 | 3 | 38027,7 | 4,5% | 1,14 | 43395,9 | 2,0% | 1,06 | 40892,96 |
| 2027 | 4 | 38027,7 | 4,5% | 1,19 | 45348,8 | 2,0% | 1,08 | 41895,24 |
| 2028 | 5 | 38027,7 | 4,5% | 1,25 | 47389,4 | 2,0% | 1,10 | 42922,08 |
| 2029 | 6 | 38027,7 | 4,5% | 1,30 | 49522,0 | 2,0% | 1,13 | 43974,09 |
| 2030 | 7 | 38027,7 | 4,5% | 1,36 | 51750,5 | 2,0% | 1,15 | 45051,89 |
| 2031 | 8 | 38027,7 | 4,5% | 1,42 | 54079,2 | 2,0% | 1,17 | 46156,10 |
| 2032 | 9 | 38027,7 | 4,5% | 1,49 | 56512,8 | 2,0% | 1,20 | 47287,38 |
| 2033 | 10 | 38027,7 | 4,5% | 1,55 | 59055,9 | 2,0% | 1,22 | 48446,38 |

**Figure 31 Calculation tab - As-predicted**

The results of the prediction model can be better understood if they are shown on the graph, as seen in **Figure 32.**

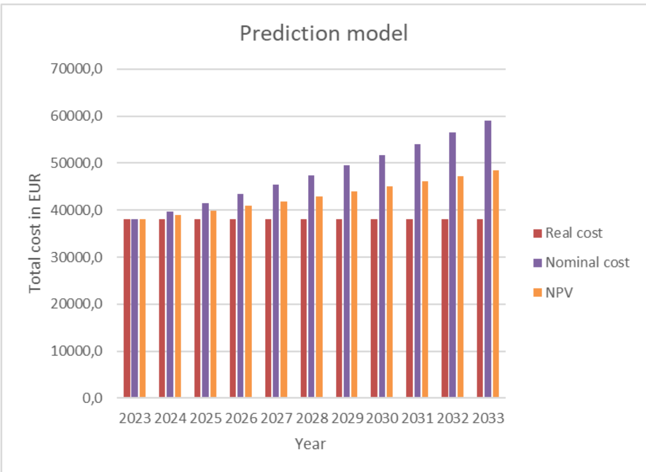


Figure 32 Prediction model

### 5.1.3.4 Building systems

Several inputs about building systems were collected to estimate the expected yearly costs. Based on that a timeline was established where all the expected costs for replacement and maintenance were summed up.

**SYSTEMS**

**Information from the IFC**

list of all the HVAC systems
when were they installed
what is their price
what is their life expectancy
how often should the maintenance be performed
what is the price for maintenance

| Systems | Installed in | Price | System life expectancy | Maintenance occurance | Maintenance cost | Replacement in | Maintenance in |
|---|---|---|---|---|---|---|---|
| HVAC | 2010 | 5000 | 15 | 2 | 600 | 2025 | 2024, 2026, 2026, 2028,... |

| | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Replacement | | | 5000 | | | | | | | | | |
| Maintenance | | 600 | | 600 | | 600 | | 600 | | 600 | | 600 |
| **Expected yearly costs** | **0** | **600** | **5000** | **600** | **0** | **600** | **0** | **600** | **0** | **600** | **0** | **600** |

Figure 33 Systems tab

## 5.1.4 Discussion on results

The above-calculated results can be obtained from the D^2EPC platform by inserting the price for energy carriers and defining the inflation and discount rates. The results from the platform are presented below. On the left-hand side, the designed values are shown and on the right-hand side, there are the operated values. Below the graphs, the user can choose which results to show:

- Monthly cost carrier
- Monthly cost use
- Total cost month
- Total cost month sqm


**Figure 34 Screenshots from the D^2EPC platform**

By comparing the designed and operated costs, a significant difference between the values identified which is explained from the fact that existing EPCs are based on the designed values that are not realistic. What tenants are paying every month for their energy consumption is closer to the operational costs, meaning that presenting such results to the tenants can be much more beneficial for them and allow them for a more accurately planning of their expenses.

## 5.2 Case Study 1: nZEB Smart House DIH

Smart House building is as 316 $m^2$ rapid prototyping demonstration infrastructure shaped like a real residential household, located in Thessaloniki. It is a duplex apartment, built between 2014 and 2016. Typically, the building has no actual residents, since it functions as an office during the usual office hours. However, except for the specific rooms that are officially used as offices (Control Rooms) the building has also common residential rooms such as a living room, bedrooms etc. It has luminance, temperature, humidity and $CO_2$ sensors, three energy meters and two multisensors.

The house consists of two floors. People can enter the building both by the ground floor and the first floor (by using an external winding staircase). The two stories are connected internally by a staircase, while there is also an elevator. The nZEB Smart House includes a total number of 14 rooms divided into two main categories according to their use. The control rooms on the ground floor along with the demo room on the first floor are included in the “office” category. The central space on the ground floor (living room, kitchen, bedroom) and the rest of the first’s floor area are included in the “residential” zone category. Lastly, the engine room on the first floor is considered an unoccupied space. The ground floor includes two office spaces on the east and west sides of the floorplan. Furthermore, the machinery room which is also located on the ground floor is considered a non-heated space. The first floor includes two office spaces on the west and south sides while the rest of the floorplan consists of two bedrooms, a bathroom and circulation spaces.

**Figure 35 nZEB Smart House DIH**

### 5.2.1 Measured data

Since the Smart House had already many IoT devices installed, there is plenty of existing data/measurements and information that can be used for testing the D^2EPC methodologies and calculation of the financial indicators. The installed IoT infrastructure in the building includes multisensors, motion sensors, contact sensors luminance sensors, temperature-humidity sensors, $CO_2$ sensors and energy meters. The latter is collecting information which is needed for the calculation of financial indicators.

Figure 36 BIM model of the nZEB Smart House DIH

## 5.2.2 Example calculation for CS1

For CS1 or any other case, the calculation process is the same as presented in the previous chapter. For that reason the results of CS1 are presented as a comparison of results from the Excel spreadsheet and the D^2EPC platform, to display and confirm that the platform works well and produces values following the procedure, defined within this task. A speciality of this CS is that it uses RES, meaning that energy is not just used but also produced. This can be visible from the graphs, where negative values show the production of the PV panels.

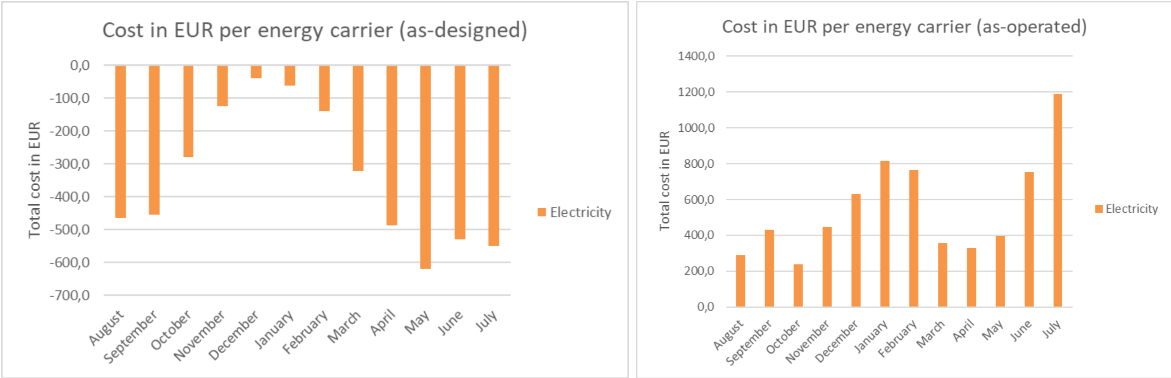



**Figure 37 Monthly cost per energy carrier in the platform (up) and the Excel (down)**


**Figure 38 Monthly cost per energy use in the platform (up) and the Excel (down)**

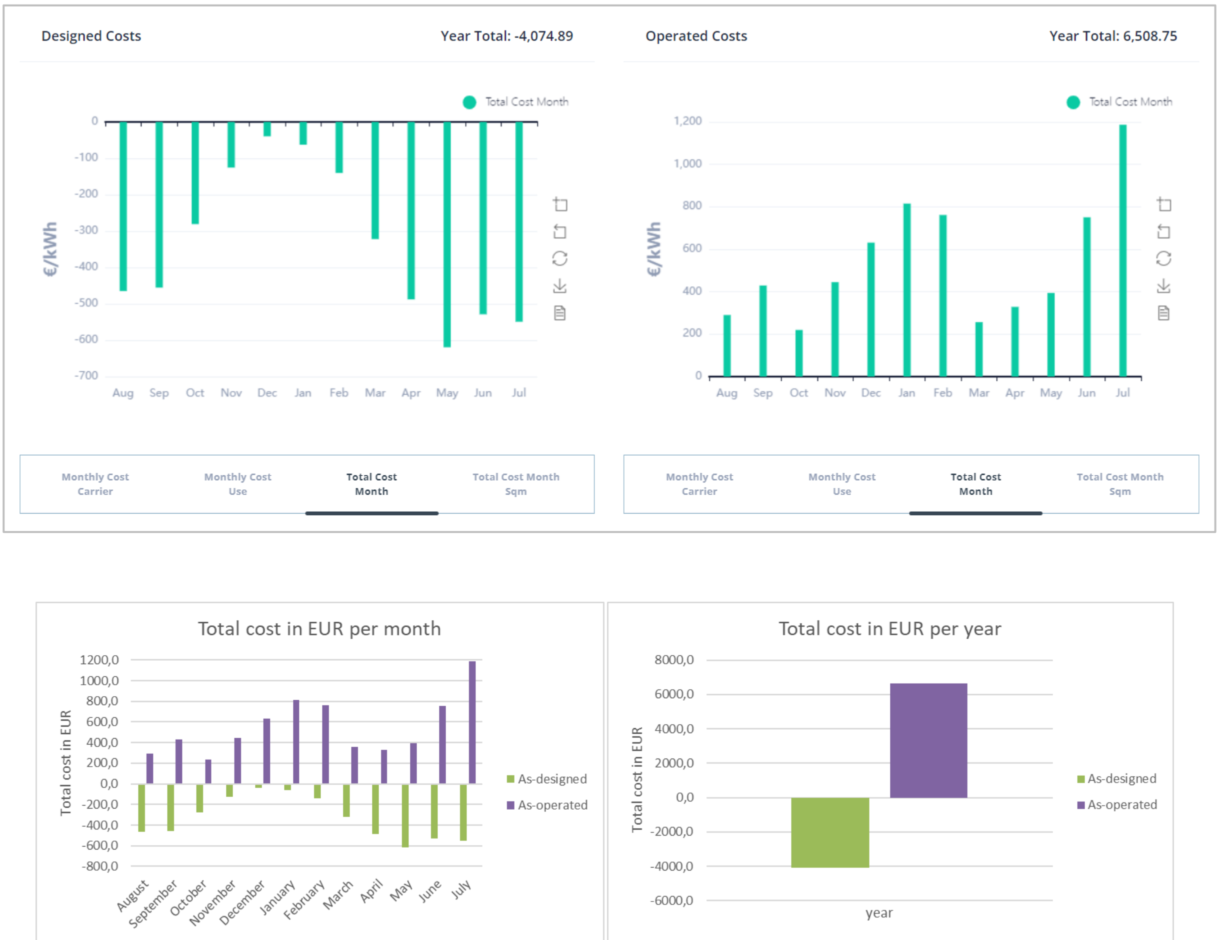



**Figure 39 Total monthly cost in the platform (up) and the Excel (down)**

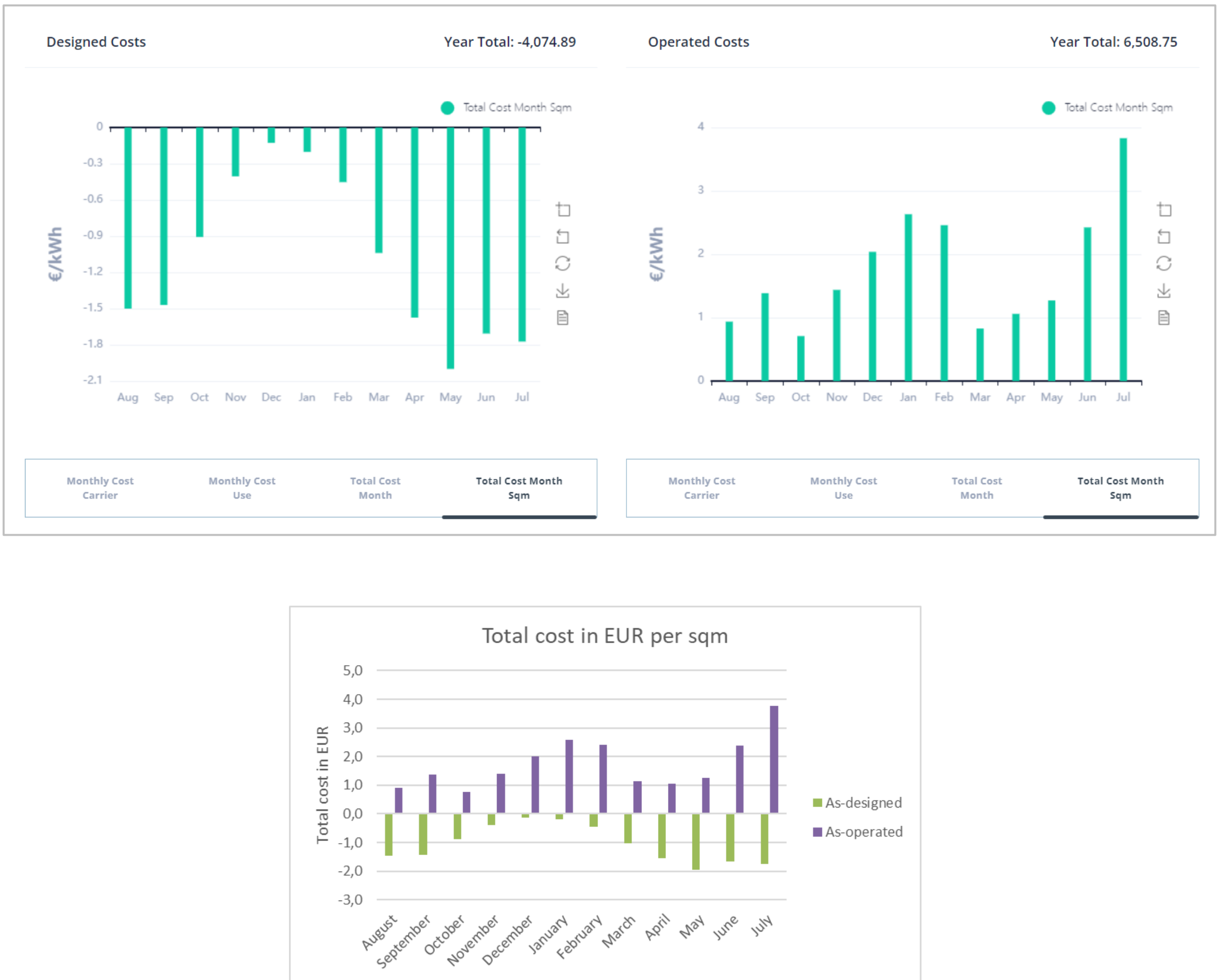



**Figure 40 Total cost per sqm in the platform (up) and the Excel (down)**

# 6 Additional indicators

The fluctuation of energy prices seen in the past period can affect tenants heavily. The additional information provided by the financial indicators can ease this slightly by allowing tenants to monitor their monthly expenses related to energy use, however, the situation can still hinder the well-being of the household.

A short literature review was performed to investigate whether any existing indicators describe the before-mentioned situation and the findings are presented below, listing a few indicators that describe the negative impact on the increased energy bills.

Several factors can be listed as a reason for increased energy prices in the past period: geopolitical situation, national energy mix, import diversification, network costs, environmental costs, severe weather conditions, and levels of excise and taxation… [11]. All these factors and the high energy price have an obvious social cost that European institutions intend to combat, to guarantee the protection of vulnerable energy users. As stipulated in EU Directive 2019/944:

*“Energy services are fundamental to safeguarding the well-being of the Union citizens. Adequate warmth, cooling and lighting, and energy to power appliances are essential services to guarantee a decent standard of living and citizens' health. Furthermore, access to those energy services enables Union citizens to fulfil their potential and enhances social inclusion. Energy-poor households are unable to afford those energy services due to a combination of low income, high expenditure on energy and poor energy efficiency of their homes.”* [12]

Energy poverty can be defined as the situation when the health and well-being of people are negatively impacted by energy bills. This situation occurs when energy costs represent a high percentage of family incomes. The energy poverty level can be determined through a series of indicators, which can be divided into four groups [13]:

- indicators comparing spending on energy with income.
- indicators based on self-assessment.
- indicators based on direct measurement.
- indirect indicators such as arrears on utility bills, number of disconnections, and housing quality.

European Commission stated in October 2021 [14] that the current situation could weigh on:

- Europe’s fairness and inclusiveness
- Exacerbate energy poverty
- Undermining confidence and support in the clean energy transition

The loss of family income means less investment in efficiency and more efficient supplies that could help save energy and improve their economic level. That’s why some policies influence the modification of consumer behaviour. As stated in a recent study:

“*Actions against energy poverty that use the behavioural mechanism seek to modify consumer behaviour by promoting debate on this problem, raising social awareness about good energy consumption habits and access to relevant information to support decision-making. In this way, the provision of adequate information allows consumers to increase their knowledge about their rights and duties, while offering them a greater possibility of making use of all available public and private support options to address the situation of energy poverty. The main types of behavioural action are offer comparators, energy audits, energy schools and support networks*.” [15]

# 7 Conclusions

The aim of the task was to investigate the possibilities of integrating financial KPIs into new-generation EPCs, which will raise user awareness and provide additional information and thus improve the existing EPCs.

The methodology which was drafted based on the literature review, existing knowledge and experience and discussions remained the same as in the previous version. The demonstration was in previous version performed using dummy values as the available information was not sufficient to properly test the method. In the updated version of the deliverable there was enough information to fully perform the calculation and the test was done for CS1 and CS4. The results were compared with the outcomes in the platform to confirm the process.

Two additions were added to the deliverable, namely the investigation on connecting the financial indicators to WebGIS to explore the results on a larger scale, and the addition of the literature review on existing indicators, which describe the effect that fluctuating prices have on tenants.

The financial KPIs, developed in this task allow the user to better understand their energy consumption since it will be translated into monetary values. Considering that tenants operate with money daily, such an interpretation of energy use can be clearer and more understandable for them compared to other units such as kWh or $m^3$.

With financial KPIs, the user can compare the monetary value of actual consumption with the monetary values of design consumption. Besides, the user can get an overview of predicted costs based on inflation and discount rate. Finally, the user can get an estimation of future costs, related to the building systems. This data will raise user awareness of energy consumption and help them plan future expenditures related to building systems.

Some current EPCs already include information about the monetary value of energy consumption, which is based on the design values. The estimation shows yearly values, the number of people it considers is an average and it does not include the energy use of household appliances. On the other hand, the financial KPIs within the D^2EPC project show the monetized values of energy consumption based on the monitored/operational use, meaning that the user will have an insight into monthly values. This will reflect the actual consumption, including the household appliances and with no need to estimate the number of people. Additionally, the D^2EPC version of the financial indicators provides information about predicted and estimated future values.

# 8 References

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