QUEST TECHNICAL MANUAL

Quality Management: De-Risking Green Investments in Building Projects

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Foreword: De-Risking Green Investments in Building Projects

When releasing the Renovation Wave strategy in October 2020, the European Commission confirmed its objective to make Europe's building stock climate-neutral by 2050. Today, buildings are responsible for 40% of the EU's energy consumption and 36% of the greenhouse gas emissions, which signifies the tremendous challenge that Europe is faced with.

Investments into sustainable building projects will need to be multiplied on a large scale and accelerated if the EU wants to accomplish carbon-neutrality in the coming decades. Unfortunately, many building projects show a significant gap between expected energy performance in the design phase and the real performance in operation. This performance gap puts investments at risk raising operational expenditures, decreasing the asset value and increasing CO_2-emissions.

Quality Management Services help to de-risk investments into green buildings. New digital services like Technical Monitoring, a well-defined commissioning process and green certification schemes can reduce the performance gap and help buildings to achieve their performance objectives. And what is best: They pay off very quickly!

QUEST can help you to integrate effective Quality Management Services into your investments. The **QUEST tool** helps you to estimate the cost and value-add of QMS for your projects giving you an early indication for project budgets. The **QUEST Data engine** complements the services with a data set for unified technical documentation of your investments.

I encourage you to use QUEST and apply Quality Management Services in your projects – for the good of your investments and the good of our endangered world.

Frank Hovorka
REHVA President,
2019 – 2022

Preface

Climate change presents a tremendous challenge to the real estate sector. Every building in Europe must undergo refurbishment and retrofitting by 2050 to achieve climate neutrality. The challenge is manifold. Innovative concepts and technologies must be applied, the speed of retrofitting must be more than doubled, and all these measures must be applied at the highest level of quality in terms of energy efficiency and emission reduction. While the technical solutions — ranging from insulation and airtightness to electronic pumps, LED lighting, and photovoltaics — are currently available, achieving these goals with the necessary speed and quality is a difficult task.

The QUEST Technical Manual (which is based on the results of the European QUEST project H2020 846739) helps owners, investors, and developers achieve a higher level of technical quality in their projects with Quality Management Services (QMS), while accelerating the implementation of these services. The manual provides two solutions to support the integration of QMS into building projects:

The QUEST Tool: An easy-to-use tool which calculates appropriate budgets for Quality Management Services in the early phases of a project to ensure the maximum value-add for the project.

The QUEST Data Engine: An open-source data set for Certifiable Post-Project Evaluations based on a unified data set that enables the continuous documentation and evaluation of measures taken and the impact of QMS. **Annex II** and **Annex III** define the processes for evaluation and explains their application for easy procurement.

The Technical Manual explains the underlying technical causes of quality deficits, explains the application of Quality Management Services, gives a short introduction to the application of the QUEST Tool and Data Engine, and provides templates for tender documents and procurements (see **Annex III**). Their application will help to remove risk from green investments and bring about success in the green transformation of European building stock.

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1. Introduction: Quality Management in Buildings

Given that 36% of European emissions are caused by buildings, addressing buildings is essential in fighting climate change. To reduce emissions, owners, developers, private companies, and public administrations need to invest heavily in the green transformation of the European building stock. A primary barrier to investment in buildings is the 'performance gap' [1], where the performance of buildings targeted in the design phase is not met by their operational performance. This gap is illustrated in Figure 1, which shows that over the lifespan of a building, multiple instances of renovation exist, and at each stage there is a risk of a deficit between the targeted performance and the real performance. This can lead to a significant gap between the ideal building performance and the reality in 2050.

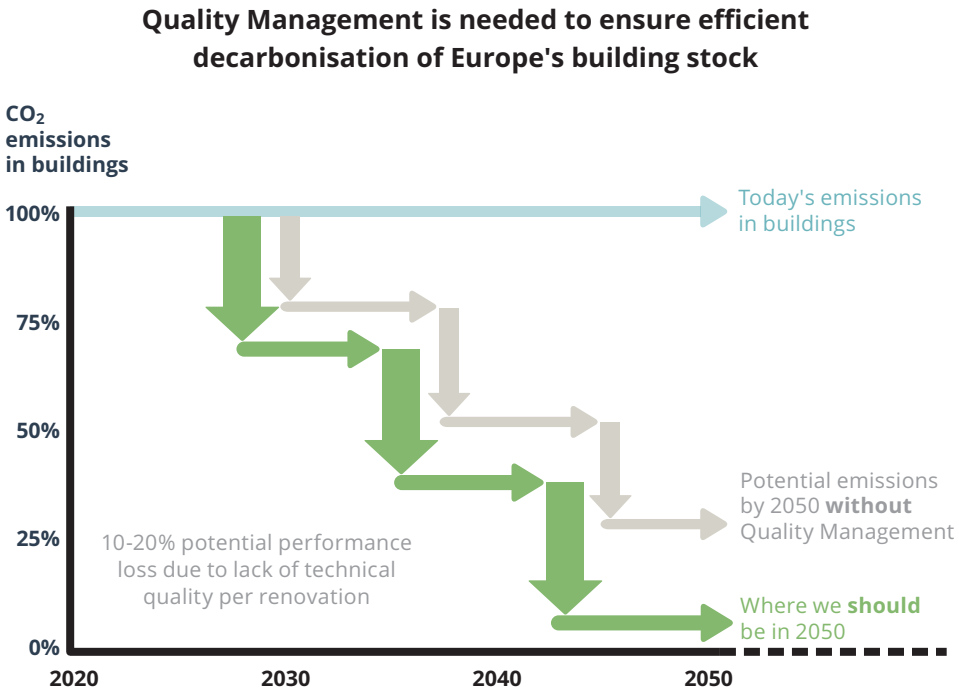

Figure 1. Pathways of Europe's building stock toward a green transformation in CO_2-emissions, with and without quality management in building projects.

When investments do not deliver on the desired outcomes, they lose their value, and in the worst cases, they become stranded assets. This has become even more prominent after the introduction of the EU Taxonomy by the European Commission, which classifies what economic activities can be considered truly sustainable. Investors who want to ensure that their building projects are truly green and in line with the sustainability requirements of the Taxonomy need to have procedures in place during the design phase to guarantee that their investments will deliver on their predefined targets. Quality Management Services support investors and owners by defining targets clearly and providing effective means of testing to ensure achievement in operation.

Colloquially, quality is often used as a synonym for 'good' or 'high' quality. In the fields of engineering and business, however, quality also refers to the degree to which a unit (e.g., a product) meets the requirements set for it. Quality management supports the fulfilment of these requirements. In addition to the definition of requirements, testing the degree of fulfilment (which consists of defining and applying the testing methodology) is a central component of the quality management process.

In recent years, the first well-defined Quality Management Services (QMS) have been established on this basis in the construction and real estate industries. These services utilize digitisation to varying degrees, making their application technically and economically feasible on larger scales, and mitigating technical risks to building performance.

Technical systems refer to technical building services such as heating and ventilation. Malfunction or failure of technical systems negatively impacts building performance, increases CO_2-emissions, and thus poses a 'technical risk' for real estate investments. Statistically evaluating technical risk on specific construction and real estate investments has been a consistent challenge to the real estate investment community.

The objective of the QUEST project is to support the integration of Quality Management Services in building projects and how they support to reduce risks involved in green building investments. What Quality Management Services are and what these services do are described in Chapter 2.

Chapter 3 presents an easy-to-use tool developed under the QUEST project that calculates the costs and the financial value-add of different QMS applications to specific building projects. Chapter 4 explain the QUEST Data Engine and its methodology to technical building experts. Through the Data Engine, QUEST aims to collect continuous building data and increase the empirical evidence of the impact of QMS on building performance. Chapter 5 includes contributions from guest authors from other projects, such as CRREM, and EEnvest. These contributions describe their datasets, methodologies, and how their approaches can support de-risking investments in building projects in ways that are complementary with QUEST.

2. Quality Management Services

Quality Management Services (QMS) aim to ensure that buildings meet the predefined sustainability requirements placed on them. How these requirements are defined is dependent on the owners or investors. Annex V provides a short description of how to determine building requirements. QUEST supports the integration of three separate Quality Management Services into building projects, each of which covers aspects of how to ensure buildings meet the requirements specified by owners and investors. In this chapter, we provide an overview of the process of each QMS, what it seeks to do, and how it can be implemented. The three Quality Management Services that are covered by QUEST, are the following:

- Technical Monitoring (TMon)
- Building Commissioning (Cx)
- Green Building Certification (GBC)

While TMon and Cx are services focused on minimizing the 'performance gap' between predicted and actual performance, Green Building Certification is a means of helping building investors and owners judge what requirements are 'green', for individual buildings. As illustrated in Figure 2, green certification is a QMS which *can* encompass both TMon and Cx, and Cx can encompass TMon.

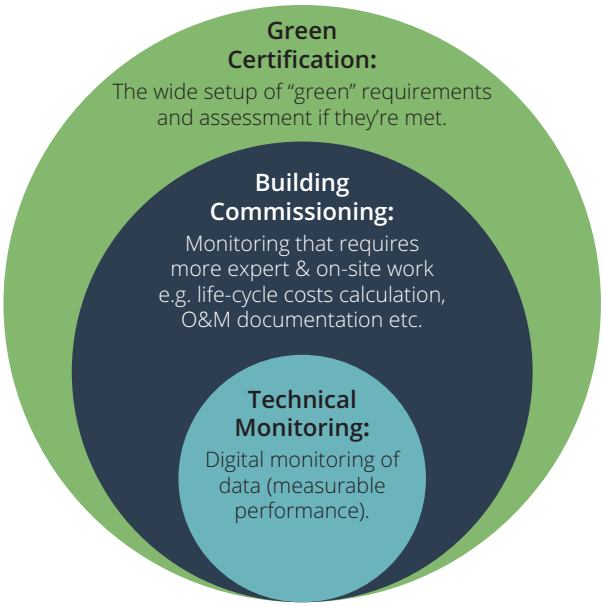

Figure 2. The scope of the three Quality Management Services supported by QUEST. Green Building Certification can encompass both Building Commissioning and Technical Monitoring, and Building Commissioning can encompass Technical Monitoring.

All three Quality Management Services begin with the establishment of requirements. These define "quality" for the investor or owner of the building project. Green Building Certification can facilitate compliance with the EU Taxonomy, if the Taxonomy criteria are incorporated into green requirements. All three services interact with the Taxonomy to different degrees.

2.1. Technical Monitoring (TMon)

TMon assesses whether a building's requirements are met through the evaluation of its digital performance data. The desired system parameters are specified and tested in commissioning and operation by a third-party service provider to compare target and operational performance. The operational data are usually logged by building automation systems and can be assessed remotely by the service provider. This simplifies the monitoring process and lowers the costs by comparison to other Commissioning or Green Building Certification processes, as there is no need for on-site visits.

As described in the REHVA Guidebook no. 29 (chapter 1.1.1), and as shown in Figure 3, TMon is carried out as a quality control loop. First, the measurable target values are defined by the investors or owners together with the third-party service provider (preferably during the design phase of the building project). An example of such a target value could be the maximum CO_2-concentration in a conference room.

After construction and during the commissioning process, the measured values are gathered from the building systems. This data can only be gathered if the building is technically equipped to provide it, e.g., with building automation and control systems. The retrieved data logs carry the values measured by the service provider, which can then be compared to the target values through established evaluation procedures.

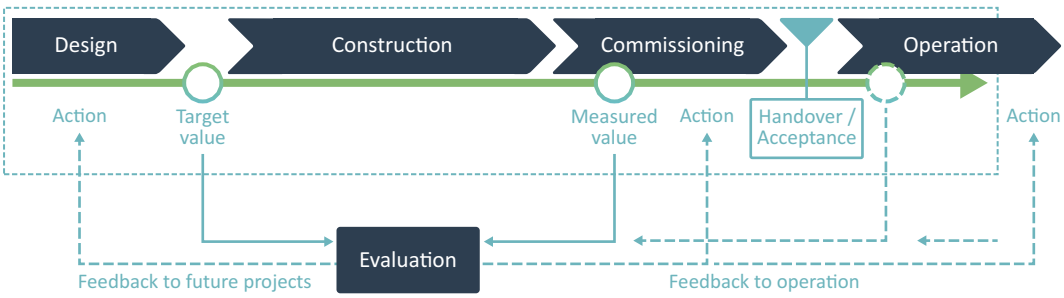

Figure 3. The quality control loop of technical monitoring. [2]

TMon can support you in achieving alignment with some of the EU Taxonomy requirements. These include the requirement for large commercial buildings using power for heating systems of more than 290 kW to be operated efficiently with monitoring and assessment of energy performance (see Table 1).

Table 1. How to set up Technical Monitoring (TMon) for a building project.

How to set up Technical Monitoring	
Phase of construction	**Actions to be carried out**
Pre-Design	○ Describe the process in relevant documents to ensure that the building is designed to be monitored. Set up datalogging for the relevant data. ○ Taxonomy requirements can be taken into consideration so that the monitoring is aligned with the Taxonomy.
Design	○ Specify testing procedures. ○ Set up target values, preferably no later than the design phase.
Construction	○ Retrieve logged data from the Building Automation and Control System after a period of trial operation. ○ Report TMon status to the engineers, contractors, and maintenance personnel in a timely manner to allow appropriate actions to be taken to ensure the performance of the building.
Operations	There are no mandatory activities in the operations phase, but recommended follow-up activities include the following: ○ Define or review target values. ○ Analyse data continuously or cyclically. ○ Report continuously or cyclically. ○ Conduct Taxonomy focused reporting on the efficiency of operations, including energy consumption, according to the EU Taxonomy Annex I, Mitigation, section 7.7, Acquisition and ownership of buildings, subsection 3.

2.2. Building Commissioning Process (Cx)

Building Commissioning (Cx) is a detailed and complex process that requires the skill, experience, and expertise of a third-party service provider who visits the site. The scope of Cx is broader and deeper than that of TMon, as it provides additional services to ensure that requirements are met. Cx verifies and documents that all commissioned systems and assemblies are planned, designed, installed, tested, operated, and maintained to meet the owners' requirements. [2]

Table 2. How to set up the Building Commissioning Process (Cx) for a building project.

How to set up the Building Commissioning Process	
Phase of construction	**Actions to be carried out**
Pre-Design	○ Describe the process in relevant documents to ensure that the building is designed to be commissioned and that the relevant parties are motivated to participate in the process. ○ Set up the target values of the owner's project requirements (OPR), preferably no later than the pre-design phase. Taxonomy targets should also be set at this stage.
Design	○ Assist the designers with the writing of the basis of design (BOD), a document that outlines solutions for each of the requirements in the OPR. ○ Conduct operation-focused design reviews.
Construction	○ Conduct functional performance tests. ○ Train of the O&M staff and ensure that the staff can document efficient operations according to the Taxonomy requirements. ○ Create O&M, documentation, and systems manuals. ○ Plan Cx activities in the operations phase, such as TMon in the form of 'monitoring-based commissioning activities' (MBCx) and/or Taxonomy-focused monitoring. ○ Report Cx status.

Operations	○ Report a one-year follow-up on performance.
	○ Conduct on-going Commissioning activities (OCx) that can include Monitoring-Based Commissioning activities (MBCx) and energy management. These could include:
	  ○ Define or review target values.
	  ○ Analyse data continuously or cyclically.
	  ○ Report continuously or cyclically.
	  ○ Conduct Taxonomy focused reporting on the efficiency of operations, including energy consumption, according to the EU Taxonomy Annex I, Mitigation, section 7.7, Acquisition and ownership of buildings, subsection 3.
	○ Review Cx report and/or entries in the issues log and demand action as appropriate.

The additional services can vary, but they can include checking the design documents, checking the operability (e.g., accessibility to air handling units for maintenance services), calculation or recalculation of life-cycle costs, O&M documentation, and supervision of building maintenance personnel training. In simple or small buildings, TMon will often be sufficient to ensure the performance of building systems, but for more complex constructions, both TMon and Cx are needed. Investors and owners who want to ensure their building projects are aligned with the requirements set under the EU Taxonomy should carry out both TMon and Cx and discuss setting the Taxonomy requirements as the basis for both services with the service provider(s).

2.3. Green Building Certification

Green Building Certification is the best-known Quality Management Service, and as mentioned in the introduction of this chapter, it can encompass both TMon and Cx. Certification programmes typically use quality assurance documentation from contractors to verify the level of 'green' achieved. If there is a need for real performance verification, green building certification programmes use TMon or Cx as tools to manage quality.

Table 3. How to set up the Green Building Certification (GBC), for a building project.

How to set up Green Building Certification	
Phase of construction	**Actions to be carried out**
Pre-Design	○ Establish targets for specific criteria, e.g., process, environment, social, technical, and surroundings criteria. ○ Determine to what extent TMon and/or Cx will be point-giving elements of the Green Building Certification.
Design	○ Conduct successive meetings with stakeholders to ensure the targets receive focussed attention. ○ Create detailed descriptions of the building, floor areas, indoor environment, technical systems, materials used, building organization, time schedule, etc. ○ Conduct a life-cycle cost analysis (LCC) and a life-cycle assessment (LCA). ○ Conduct a conformity check with the Green Building Council in charge.
Construction	○ Collect necessary documentation for activities related to the specific criteria targets. ○ Update LCA and LCC. ○ Take required measurements, such as TVOC measurements. ○ Set up required monitoring and operations procedures, such as Taxonomy reporting (not required for new construction and major renovations, as of January 2022). ○ Conduct a document check with the Green Building Council in charge and deliver final documentation to obtain the certificate. ○ Set up required on-going activities, e.g., to maintain Taxonomy compliance.

Operations	○ Report a one-year follow-up on performance.
	○ On-going Commissioning activities (OCx) that can include Monitoring-Based Commissioning activities (MBCx) and energy management. These could include:
	  ○ Define or review target values.
	  ○ Analyse data continuously or cyclically.
	  ○ Report continuously or cyclically.
	  ○ Conduct Taxonomy focused reporting on the efficiency of operations, including energy consumption, according to the EU Taxonomy Annex I, Mitigation, section 7.7, Acquisition and ownership of buildings, subsection 3.
	○ Review Cx report and/or entries in the issues log and demand action as appropriate.

Multiple organisations have set up rating systems to evaluate whether building projects meet their sustainability requirements. Most of these certification programmes have their origin in national criteria such as HQE (France), DGNB (Germany), LEED (US), and BREEAM (UK). However, all of these programmes have adopted a more international approach and are applied in multiple countries around the world. Both the requirements and the rating systems differ depending on the certification scheme, but most of them give a rating to a building, and the building is certified accordingly.

It is important to note here that at time of writing this Technical Manual, the Taxonomy requirements are still in development, and the certification programmes are not yet fully aligned with these requirements. Some of these programmes, such as **DGNB**, are actively seeking alignment, however, and will continue to be updated accordingly. By integrating this into their existing criteria, they could even provide a more extensive and deeper overview of the sustainability of a building, beyond just whether it complies with the Taxonomy requirements. If the objective of the investor/owner is only to ensure alignment with the Taxonomy, and no other sustainability rating is desired, then the combination of TMon and Cx might be more appropriate for a building project than pursuit of certification, although green certification can have a larger positive effect on the value of buildings, depending on the ambitions set for the certificate.

3. Applying the QUEST Tool to your Building Projects

The **QUEST Tool** calculates the potential costs and (financial) value-add of applying Quality Management Services (QMS) to building projects. It was designed for ease of use by investors and building owners who seek to assess the value-add of QMS to their building projects in the design phase. Users input answers to five questions which are used to calculate the different risk and cost factors of building projects. The first two questions are answered using pull-down menus. The remaining three questions require numeric responses. Example inputs are shown in Table 4. Based on the user inputs, QUEST algorithms will estimate investment costs and value-adds of different services.

3.1. QUEST Tool Input Questions

Table 4 shows the five questions that users must answer to obtain estimated value-adds of different Quality Management Services. The questions are meant to be easy for anyone to understand and can be answered by people who are not technical experts in building projects. This simplifies the integration of QMS into building projects by allowing investors and owners to obtain predictions of the potential value-add easily.

Question 1: What is the type of building?

Users select from among different building types, including residential, office, hotel, and retail. If they are unsure of the building type, they may indicate whether the building is of a low, medium, or high level of complexity. Help with assessing the specific risk profile for buildings, can be found in Annex VI.

The default value is office building and is used if the user makes no selection.

The value-add estimated by the Tool will increase as the building complexity increases.

Table 4. QUEST Tool input values.

Your building project	
DE-RISK INVESTMENTS IN CONSTRUCTION & SUSTAINABLE BUILDINGS	**INPUT VALUES**
What is the type of building?	Office
How do you rate the experience in the technical teams managing the project?	Medium confidence
What is the estimated project cost (per m²)? *Build/renovation / refurbishment / technical installation including design work*	1 000 € *€/m²*
What are the expected operating expenses per m² per year {OPEX/m²/year)? *Energy, operation & maintenance*	20 € *€/m²/year*
Define the time horizon that the rating should consider for your QM-investment (minimum 5 years, maximum 20 years) *This value is used to capitalise annual savings*	10 *years*

Question 2: How do you rate your confidence in the experience of the technical teams managing the project?

Users indicate whether they have a low, medium, or high level of confidence in the technical teams managing the project. In pilot testing of the QUEST Tool, we observed how difficult it is for financial stakeholders to evaluate the design and engineering, installation, and operational competence of technical personnel and services. The combination of questions 1 and 2 allows financial stakeholders to create a simple technical risk profile of the project.

The default value is medium confidence and is used if the user makes no selection.

The value-add predicted by the Tool increases as the confidence level decreases.

Question 3: What is the estimated project cost (per m²)?

Users input the budgeted work cost of the building/renovation/refurbishment/technical installation project. This cost includes design and engineering, installation, and handover work. It does not include land cost. Costs are indicated per square meter.

The default value is 1 000 €/m² and is used if the user makes no selection.

Project inefficiencies such as repeated work, waste, and delays result in the value-add estimated by the Tool increasing as project costs increase.

Question 4: What are the expected operating expenses per m² per year (OPEX/m²/year)?

Users input budgeted operating expenses per square meter per year. This should include energy, operation, and maintenance costs.

Expenses are indicated per square meter of floor area of the project. The default value is 20 €/m² and is used if the user makes no selection.

The value-add predicted by the Tool increases as the operating costs increase.

Question 5: Define the time horizon that the rating should consider for your QM investment.

Users input the number of years used in their return-on-investment calculations for the project. The QUEST algorithms use this value to capitalise annual value-add calculations.

As the Tool evaluates capital investment projects, the minimum period the user may input is 5 years, and the maximum period is 20 years. The default value is 10 years and is used if the user makes no selection. The value-add predicted by the Tool increases as the time increases.

3.2. QUEST Output

The output of the QUEST algorithm is presented in the QUEST Tool as a euro-per-square-meter value-add estimation for Quality Management Services (see Table 5).

Table 5. QUEST Tool output values.

De-risking solutions		Value-add (per m²) over investment lifetime of 10 years
CERTIFIED SERVICES	**Investment cost**	
Certified Technical Monitoring *(ex. COPILOT)*	1 €	13 €
Certified Building Commissioning *(ex. COPILOT)*	10 €	63 €
Certified Green Buildings *(ex. LEEO, BREEAM)*	20 €	20 €

The QUEST Tool performs value-add calculations for each QMS based on the savings generated. The output is adjusted dynamically as the input is modified. As an additional aid, the Tool provides an estimate of the costs of the different Quality Management Services for the project.

The output data are not an offer or a fixed prognosis but rather an indication of cost and value-add that can be expected based on empirical data. The output can be used to budget the QMS costs in the early project stages and to argue for the application of QMS based on the value-adds of different services.

The QUEST Tool is available to download for free on the QUEST website.

3.3. QUEST Tool Algorithm

QUEST evaluates how different Quality Management Services will impact the project based on user inputs. To ensure a standardised process and third-party neutrality, QUEST assesses value-adds for certified projects and services only, i.e., Certified Technical Monitoring, Certified Building Commissioning, and Certified Green Buildings.

Based on the research, experience, and pilot testing of QUEST, the QUEST Tool applies algorithms to the input data to predict value-adds per square meter (see Figure 4).

Figure 4. QUEST Tool algorithm.

4. The QUEST Data Engine: Documentation of QMS

Collection of data on relevant variables is essential for continuous documentation and evaluation of the impact of QMS on the technical, financial, and ESG performance of buildings. Therefore, the QUEST data engine is used to collect and evaluate data on new construction measures, retrofit measures of any kind, and the impact of QMS on these measures. The QUEST data engine is an open-source data set for post-project evaluations based on a unified data set that allows continuous documentation and evaluation of the impact of QMS.

The QUEST data engine allows the collection of building data from several property owners before and after the implementation of measures, at regular intervals (such as quarterly or yearly). Therefore, as time passes, the QUEST data engine creates a panel data set (also known as a longitudinal data set) that contains information about different buildings from many property owners across time. Such a panel data set will create value for the property owners, real estate debt and equity investors, and real estate consultancy companies.

4.1. The QUEST unified data set

The QUEST unified data set consists of four parts:

1. General Building Information (Section A)

This part contains general information on the building and is used in any documentation of buildings and measures.

2. Evaluation of Building Performance (Section B)

The second part gathers data on the building's performance and shows its status, a prognosis for new construction or refurbishment, and corresponding data for the performance achieved.

3. Evaluation of Measures (Section C)

Given that many investments in sustainability will be made in existing buildings and potentially cover only partial improvements, the third part of the data set collects data on individual measures of improvement in buildings, ranging from simple adjustments of operations to comprehensive refurbishments. The topics addressed in this part include general documentation, prognosis, and evaluation of improvements.

4. Evaluation of QMS (Section D)

The fourth part collects data on the Quality Management Services that have been applied and on the perceived effects of the services on the project and on building performance. Therefore, it consists of the QMS documentation and QMS impact evaluation. In addition, the data set includes two questionnaires that are applied as part of a comprehensive post-project evaluation because these ask about individual perceived effects of QMS rather than objective data.

Annex I, Annex II and Annex III of this Technical Manual describe the whole data set and its application to your projects. To receive unified and compliant documentation for a measure of buildings and portfolios, building owners can request documentation according to the QUEST Technical Manual.

4.2. QUEST Certifiable Processes

QUEST has developed certifiable processes for verifying the application of the Data Engine. These can be slotted into or applied in parallel with the rules of certification authorities such as LEED, BREEAM, DGNB, COPILOT, etc. QUEST proposes four post-project evaluation processes (see Annex II for flowcharts of all QUEST-certifiable processes):

1. Basic post-project evaluation
2. Advanced post-project evaluation
3. Certified technical monitoring and advanced post-project evaluation
4. Total Quality Management

Total Quality Management, for example, combines the advanced post-project evaluation of Certificate 2 with the Building Certification, and Technical Monitoring Certification. Users are free to select their preferred Building Certification.

Flow charts of all the certifiable processes are shown in Annex II. These processes should respect formal certification rules and the international ISO 17065 standard.

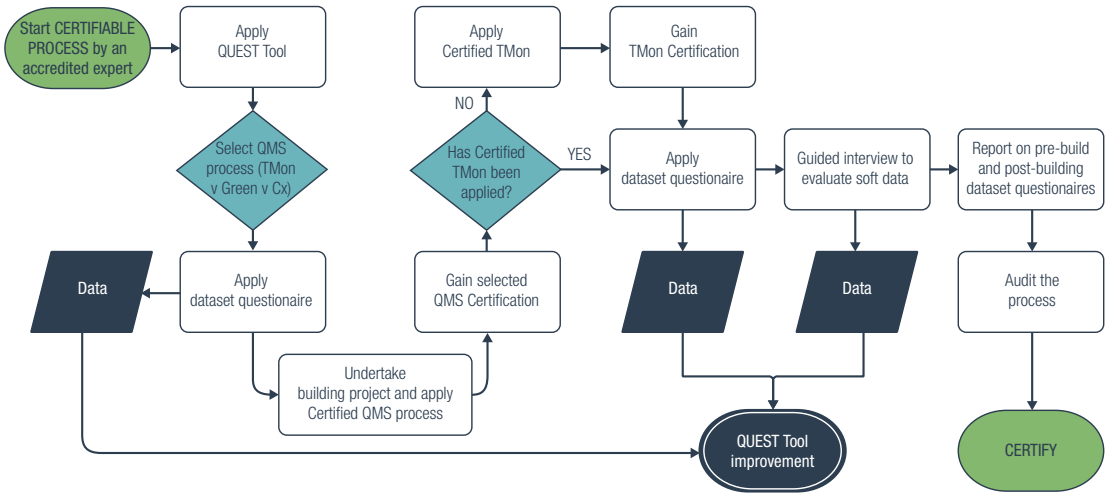

Figure 5. Diagram of Total Quality Management as a certifiable process.

5. Services Complementing QUEST

QUEST addresses pre-design and post-evaluation phases in the construction process for a better return on investments and guaranteed performance. The EEnvest and CRREM projects strongly complement our approach, as they focus on different aspects. EEnvest has created a platform to connect investors with building owners by ensuring a reliable sharing of building data between different actors. CRREM focuses on the impact of carbon performance of buildings on the financial value. Read more about both services in the following.

5.1. EEnvest

Giulia Paoletti & Cristian Pozza - EURAC Research

The EEnvest project (Risk Reduction for Building Energy Efficiency Investment) seeks to assist investors in evaluating the financial performance of investments related to energy efficiency renovation projects. The project develops a framework for de-risking energy efficiency renovation investment in commercial office buildings across the EU. It does this while maintaining a general and modular approach to foster replication of different asset types. Among the possible project outcomes, a web-based *search and match* platform can facilitate meetings between building owners and investors and can provide a report to investors (with financial Key Performance Indicators

(KPIs) of the energy efficiency project for which funding is sought). The platform relies on a blockchain-backed validation system which certifies the validity of the information reported to the investors.

The EEnvest evaluation methodology outputs performance indicators for multiple benefits and contributions to the Sustainable Development Goals which are valued for the energy efficiency renovation project.

The EEnvest methodology introduces an innovative approach to estimating risk which considers the complexity of renovation projects. Mapping and analysis of the main risks connected to a renovation enables the identification of various technical risks that exist during the renovation phases (design, construction, and operation).

Seven KPIs have been identified to describe the technical risks and financial performance of a renovation investment, two for evaluation of technical risks and five for financial performance.

Technical risk KPIs

The technical risks indicators that affect the financial indicators are:

1. Performance gap: the risk of incurring additional costs related to the deviation of actual energy performance from projected energy performance
2. Damage: the risk of incurring additional costs due to failure, malfunctioning, or breakages after the building renovation

A *technical risk database* was developed to collect data on the probability and impact of risks due to design errors (e.g., a thermal bridge where none should be), installation errors (e.g., installation of the wrong pumps, windows, etc.), or damage to or failure of components (e.g., malfunctioning thermostats) on the energy performance gap and damage. Then, the contribution of each risk is estimated in relation to the context of the energy efficiency project, such as building features and boundary conditions (like the climate of the building). The database also collects data on corrections introduced by mitigation measures which can be implemented in the project to reduce risk impact.

In the EEnvest methodology, the technical risks are then input into a financial model, and financial indicators are computed.

Financial KPIs

3. Payback time: the number of years required for an investment to recover its initial cost.
4. Maturity: the total duration of the project.
5. Internal rate of return (IRR): the discount rate that makes the net present value (NPV) of a specific project equal to zero.
6. Net present value (NPV): the value of all future cash flows (positive and negative) over the entire life of an investment, discounted to the present. Net present value on investment (NPV/INV) is the ratio between the net present value (NPV) and the investment (INV), which is a measure of the profitability of the project.
7. Debt service coverage ratio (DSCR) is an indicator of the project's ability to repay a debt. It is calculated as the ratio between the operative cash flows generated by the project and the cash flows for debt, lease, or other obligations (debt service, both for interests and principal payment) due in one year.

EEnvest search and match web platform

The EEnvest methodology is implemented in a web platform which calculates technical and financial risk KPIs for a given energy efficiency project and provides information on multiple benefits generated by the project.

EEnvest Platform profiles and inputs-outputs

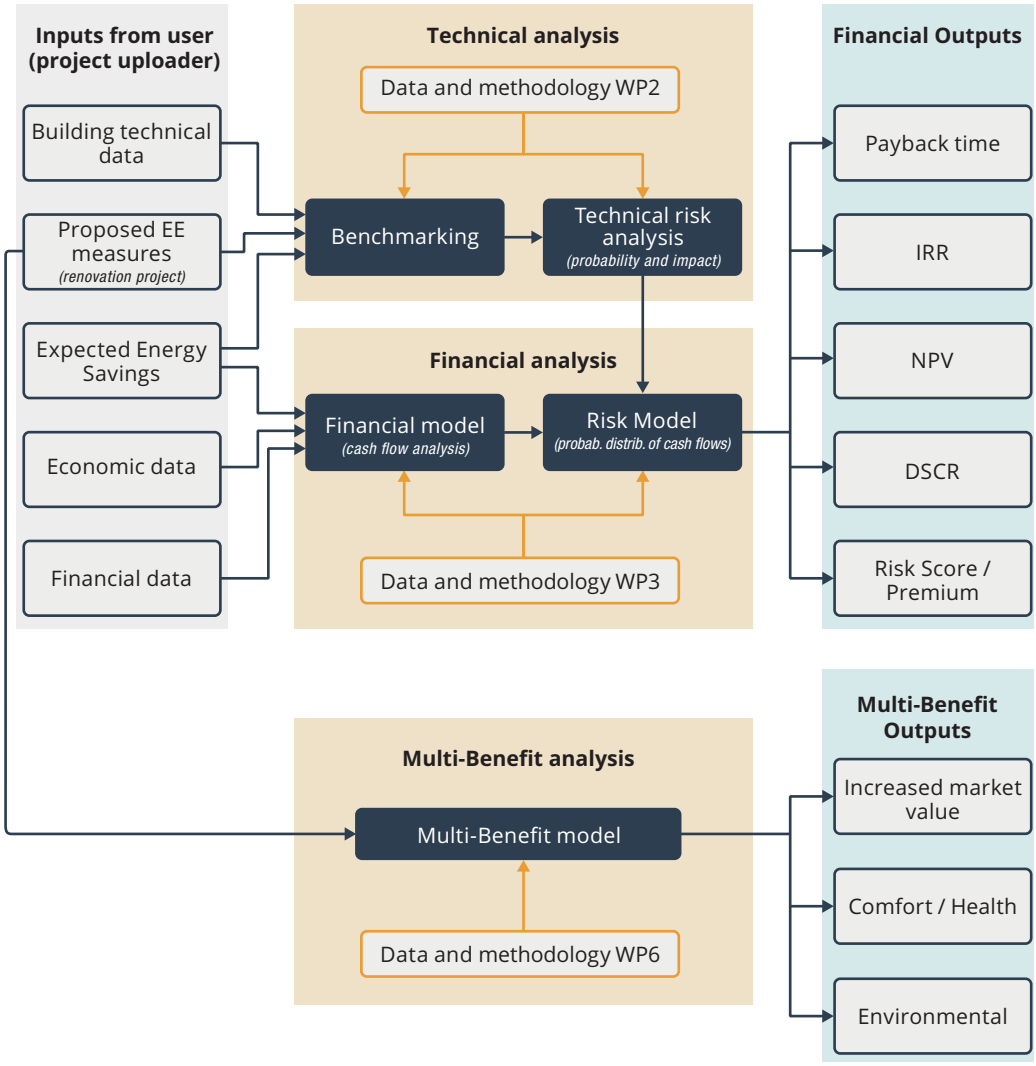

Figure 6. EEnvest calculation framework for evaluating the financial impacts of technical risks related to energy-efficient renovations of commercial buildings.
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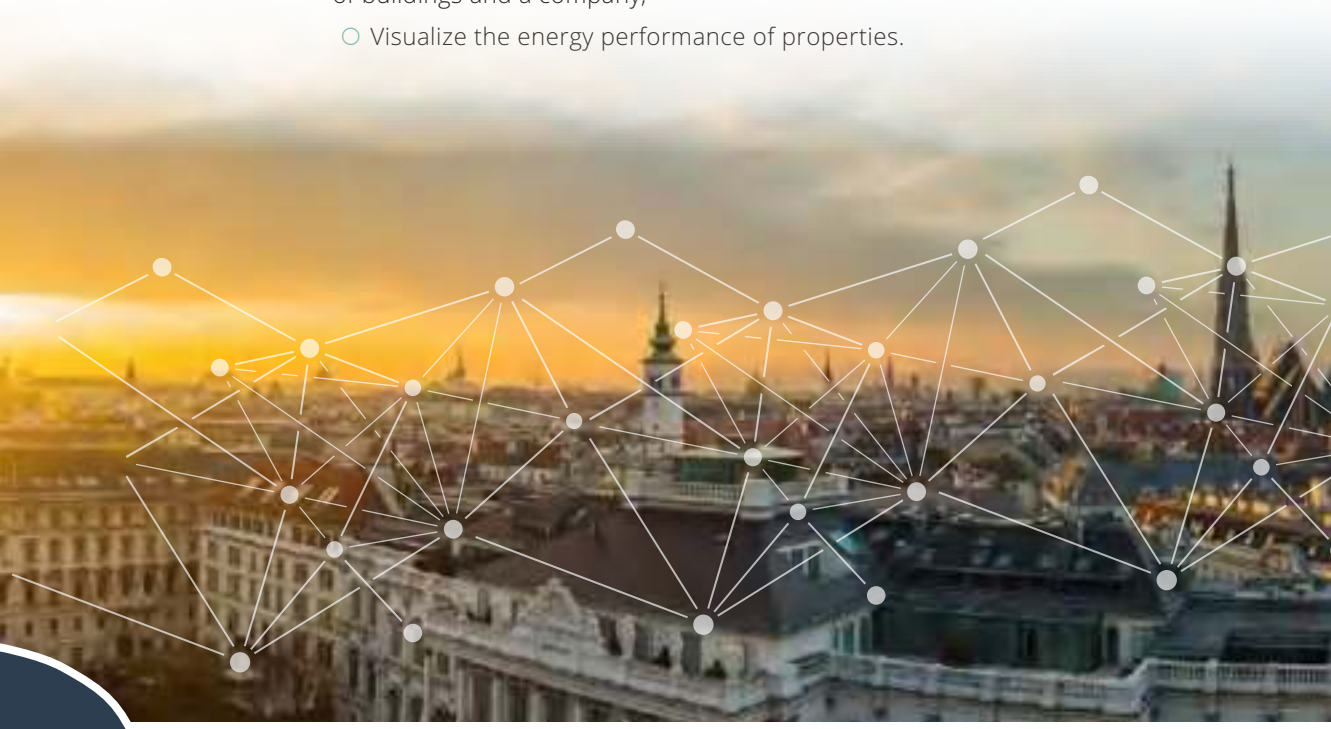
5.2. The Carbon Risk Real Estate Monitor (CRREM)

Julia Wein, Vanessa Huber - IIö, Institute for Real Estate Economics

The Carbon Risk Real Estate Monitor (CRREM) initiative aims to accelerate decarbonisation and climate change resilience of the global commercial and residential real estate sector by clearly communicating the financial risks associated with poor energy and carbon performance and quantifying the financial implications of climate change on building stock.

Key objectives of the CRREM tool are to:

- Identify and assess the risk of economic obsolescence of single properties,
- Enable investors to account for different future GHG emission reduction pathways (including 1.5°C and 2°C scenarios and NDC) and the possibility of integrating individual targets,
- Undertake aggregated analysis of portfolios,
- Benchmark properties and portfolios,
- Evaluate the progress of investors' carbon performance,
- Quantify risks based on cost estimations of necessary refurbishment measures to fulfil targets,
- Analyse the impact of retrofitting on the total carbon performance of buildings and a company,
- Visualize the energy performance of properties.



The Carbon Risk Real Estate Monitor (CRREM) initiative provides an elegant solution to the challenges of the commercial real estate sector in aligning with Paris targets and mitigating transition risk. CRREM delivers a science-based, methodically rigorous, industry supported, and framework-aligned way for the commercial and residential real estate sector to understand international contexts, set science-based targets, benchmark specific real assets, and analyse portfolio performance. Using the statistical framework of the Sectoral Decarbonisation Approach (SDA) (a downscaling methodology also used by the Science-Based Targets Initiative) CRREM has derived Paris-aligned decarbonisation pathways for commercial real estate assets that can be used to benchmark the current and future performance of commercial real estate assets against long-term international targets. The property and construction sector accounts for more than 30% of energy consumption and GHG emissions globally and therefore plays a crucial role in decarbonisation efforts stated in the NDCs (nationally determined contributions) which countries have submitted to the UNFCCC secretariat in accordance with the Paris agreement. The poor energy efficiency of the global real estate stock and low refurbishment rates are among the key obstacles to achieving the ambitious decarbonisation targets established in the Paris Climate Agreement.

Since all anthropogenic CO_2-emissions must reach almost zero around 2050, clear, reliable, scientific, and granular decarbonisation pathways

for the participating countries and all economic sectors – including real estate – are needed to provide clear guidance for market participants. The Carbon Risk Real Estate Monitor (CRREM) initiative has derived decarbonisation (GHG intensity) and energy reduction (energy intensity) pathways (i.e., trajectories from 2020 to 2050). The purpose of these pathways is to translate the goals of the Paris Agreement (to limit global warming to 2°C, with an ambition of limiting it to 1.5°C by the end of the century) into regional- and property-type-specific trajectories against which real estate assets and portfolios can benchmark themselves. Such century-long temperature targets have come to be associated with specific global carbon budgets and emissions pathways. Further funding from APG, PGGM, and NBIM has allowed CRREM to expand its pathways to cover most of the global real estate markets (not just that of the EU) and residential real estate. An extended version for North America and the Asia-Pacific region can also now be downloaded from the **CRREM homepage**.

After inputting specific information about assets into the **CRREM Tool**, real estate portfolio managers can analyse their real estate portfolios in several different ways. These range from alignment with Paris goals,

to identification of assets at risk of becoming stranded because of potential regionally-specific climate policies, to understanding of the costs of future energy consumption and carbon emissions, to the design of retrofit strategies to comply with future regulations. This benchmarking exercise allows asset managers, institutional investors, and other stakeholders to estimate when a particular asset might be stranded not only due to non-compliance with national carbon intensity and energy efficiency regulations, but also upon aggregation, the implications this has at the level of the portfolio.

CRREM is the leading global initiative and source for setting, managing, and reducing operating carbon emissions for the real estate industry.

A sustainable global real estate stock is a core necessity for long-term value creation for our industry and plays a crucial role in reducing GHG emissions. A future financial system committed to sustainable

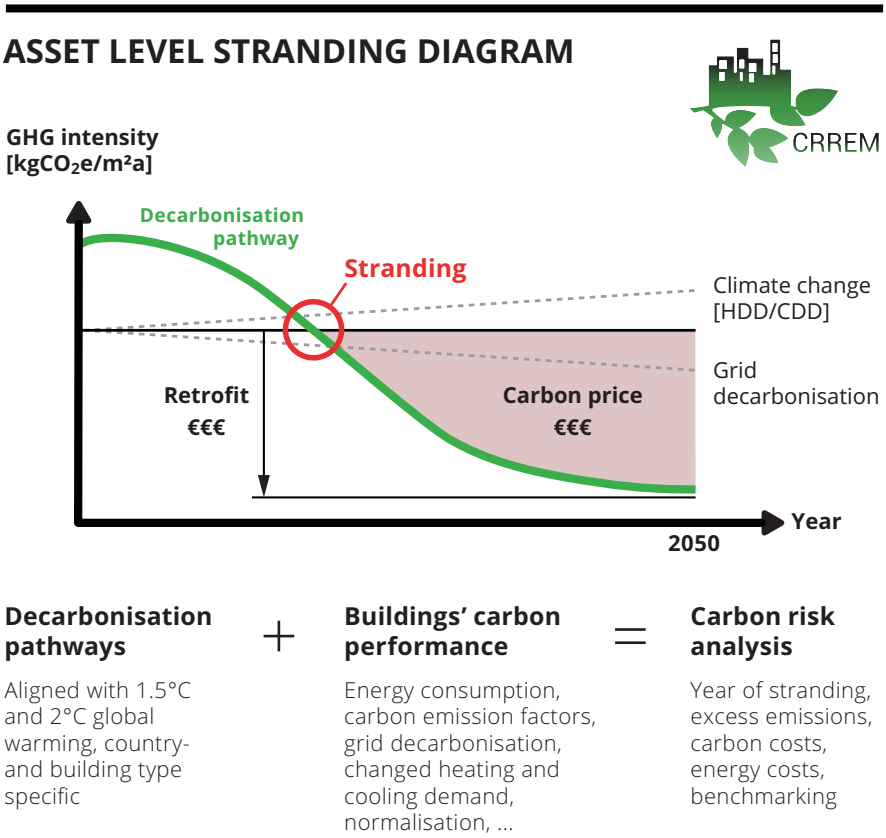


Figure 7. CRREM asset level stranding diagram.

Environmental, Social and Corporate Governance (ESG) will reward long-term, responsible real estate investment that benefits the environment and society. The CRREM initiative works to support this sustainable global financial system by encouraging the adoption of the Paris-aligned decarbonisation targets, collaborating on their implementation, fostering good governance and reporting standards, and encouraging integrity and accountability by avoiding green-washing. The initiatives' main objectives are the following:

- Increasing transparency regarding country- and use-type-specific decarbonisation requirements in accordance with the Paris accord and the latest scientific evidence applicable to real estate.
- Supporting real estate investors and asset managers in measuring and reducing their operational carbon footprints on the property and portfolio levels with software tools, new methods, and scientific reports.
- Supporting global harmony in decarbonisation initiatives within and between real estate sectors.
- Promoting awareness to transition risks within the real estate industry by means of various dissemination activities.

CRREM has received funding from the European Union's Horizon 2020 research and innovation programme and has grown into a global initiative. It has also received funding from the Laudes Foundation. With major global investors, industry bodies, and academics recommending the use of CRREM for the real estate sector (e.g., IIGCC, UNEP FI, ULI Greenprint, NZ AOA, and many more), CRREM is now the standard for the real estate market's net zero ambitions.

The heterogeneous group of users represents a wide variety of the most relevant stakeholders in the tool's audience. Major investors with more than 500 Bn. Euro AuM have already applied CRREM on a regular basis to avoid stranding risk, to address transition risk, and to comply with Paris-aligned decarbonisation efforts. The tool has already been used for more than 4,500 properties, representing more than 50 mil. m² of space globally (as of 01.12.2021). Updates and news about CRREM will be posted on its homepage and on LinkedIn.

Annex I: Applying QUEST to your Portfolios

The following three options are available for you to apply the QUEST documentation methodology with ease:

Option 1: You can use the Excel template provided on the **QUEST website** for data collection.

Option 2: You can use the following text for easy tendering:

'The project/measure has to be documented by the contractor following the provisions of the QUEST Technical Manual applying the unified data set defined in its Annex III.'

Option 3: Contact a QUEST partner to carry out a post-project evaluation of your project. The service can receive COPILOT certification according to Annex II.

Please check for QUEST partners in your country at **https://project-quest.eu/contacts**

'For the project/measure, a Certified Post Project Evaluation (CPPE), Certificate (1…4), has to be carried out by an accredited QUEST partner. The CPPE must be certified by COPILOT Building Certification following the provisions of the QUEST Technical Manual.'

Annex II: Certifiable Post-Project Evaluation (CPPE) Services

QUEST defines several Certifiable Post-Project Evaluation processes. For application and tendering, please see the QUEST website or contact COPILOT Building.

Certificate 1: Basic Post-Project Evaluation

The following is the most basic certifiable process provided by QUEST and is based on the application of QUEST questionnaires before and after a building project.

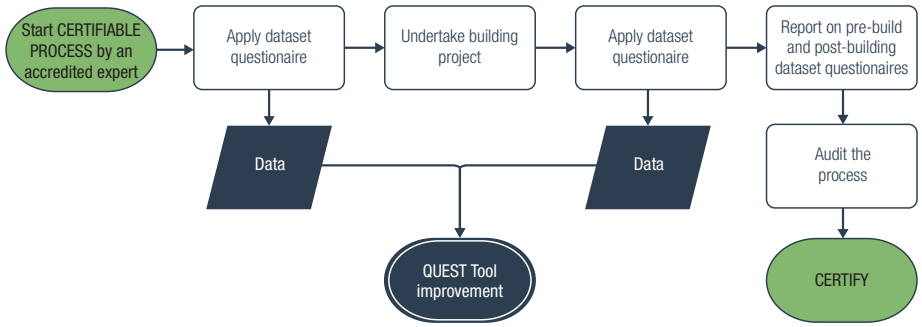


Figure 8. Flowchart of the 'Basic Post-Project Evaluation' certification process.

Certificate 2: Advanced Post-Project Evaluation

The following flowchart describes the Advanced Post-Project Evaluation process which integrates guided interviews into the basic evaluation of Certificate 1 to improve 'soft' data, such as perception of technical risks.

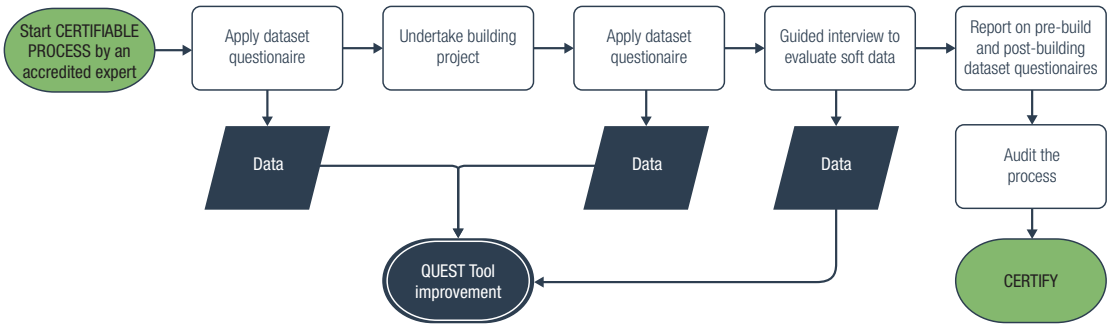


Figure 9. Flowchart of the "Advanced Post-Project Evaluation" certification process.

Certificate 3: Certified Technical Monitoring and Advanced Post-Project Evaluation

The following flowchart describes the Certified Technical Monitoring and Advanced Post-Project Evaluation which, in addition to the Certificate 2 requirements, requires Certified Technical Monitoring (TMon) of real operational performance of the building during normal occupation.

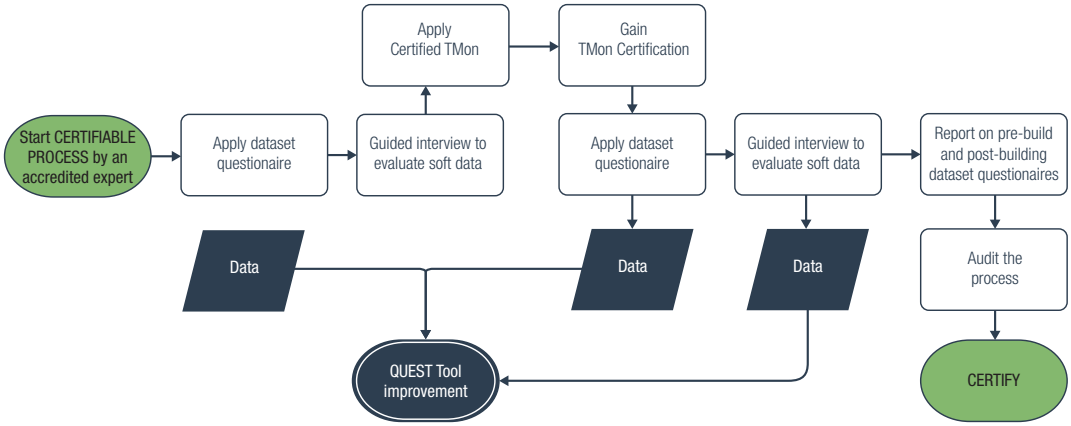


Figure 10. Flowchart of the "Certified Technical Monitoring and Advanced Post-Project Evaluation" certification process.

Certificate 4: Total Quality Management

This certification process combines the classic building certification with the Technical Monitoring Certification and the Advanced Post-Project Evaluation. Users are free to select their preferred building certification. This is reinforced, if appropriate, by a Technical Monitoring Certification of building performance in normal operation to maximise real-world impact. Projected performance is compared to actual performance.

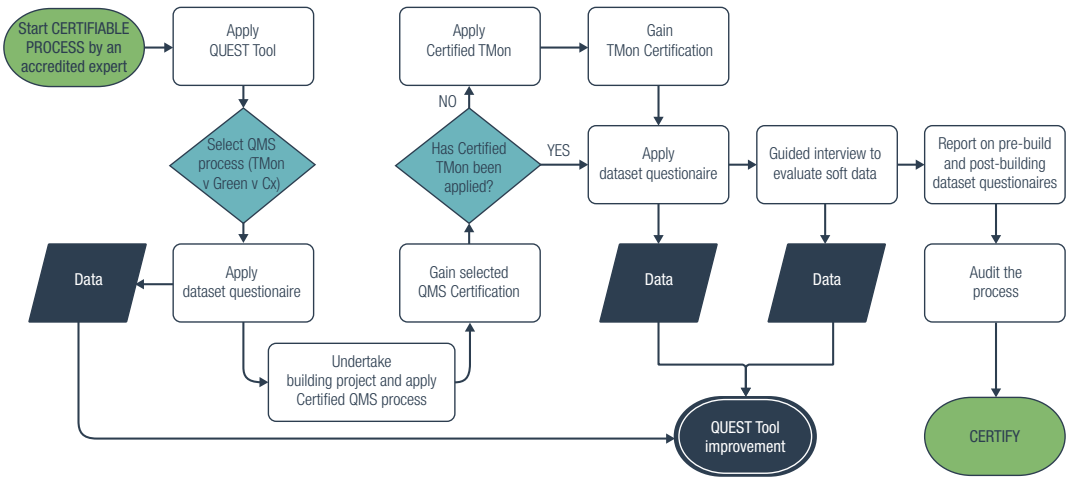


Figure 11. Flowchart of the "Total Quality Management" certification process.

Annex III: The QUEST Unified Data Set

The following tables show the QUEST unified data set. If individual content items cannot be provided, they must be marked as "not available" in the 'Comments' column.

Section A — Building Documentation

No.	Question	Unit	Choices	Answer	Comments
1	ID	-			
2	Project name	-			
3	Start of Design Phase	-			
4	Start of Construction Phase	-			
5	Start of Use Phase	-			
6	Project type	-			
7	Country	-			
8	Postal code	-			
9	City	-			
10	Street	-			
11	House number	-			
12	Year of initial construction	-			
13	Year of last deep retrofit	-			
14	Gross floor area	m²			
15	Net floor area	m²			
16	Number of storeys above ground	-			
17	Number of storeys below ground	-			
18	Main types of use	%	Office		
		%	Retail		
		%	Hotel		
		%	Residential		
		%	Other (please explain)		
19	Name of the owner	-			
20	Owner's contact details	-			
21	Owner type	-	Public		
		-	Institutional Investor		
		-	Corporate Investor		
		-	Other: free indication		
22	Renting Situation	-	Self-use		
		-	Single Tenant		
		-	Multi-Tenant		
23	Facilities Management company	-			

Section B1 — Whole Building Status

No.	Question	Unit	Choices	Answer	Comments
1	Year for which data is provided	-			
2	Build / renovation cost	€			
3	Performance cost comprise (several answers possible)	%	Percentage of total buidling space		
		%	Percentage of common space		
		%	Percentage of Tenant space		
4	Energy cost	€/a			
5	Operation & Maintenance Cost	€/a			
6	Rent	€/a			
7	Average rent level	€/(m²a)			
8	Occupancy	%			
9	Energy Consumption Electricity	€/a			
10	Energy Consumption Heat	€/a			
11	Energy Consumption Cooling	€/a			
12	CO_2-emissions Electricity	tco_2/a			
13	CO_2-emissions Heat	tco_2/a			
14	CO_2-emissions Cooling	tco_2/a			
15	Energy Cost Electricity	€/a			
16	Energy Cost Heat	€/a			
17	Energy Cost Cooling	€/a			
18	Operation & Maintenance Cost	€/a			
19	Has continuous quality management been applied to the entire building?	-	Yes, Technical Monitoring		
			Yes, Commissioning Management		
			Yes, Green Buidling Certification		
			Yes, other		
		-	No		
20	If there is a continious quality management services, what are the costs?	€/a			

Section B2 — Whole-Building Prognosis

No.	Question	Unit	Choices	Answer	Comments
1	Prognosis				
2	Build / renovation cost	€			
3	Energy cost	€/a			
4	Operation & Maintenance Cost	€/a			
5	Rent	€/a			
6	Average rent level	€/(m²a)			
7	Occupancy	%			
8	Energy Consumption Electricity	€/a			
9	Energy Consumption Heat	€/a			
10	Energy Consumption Cooling	€/a			
11	CO_2-emissions Electricity	tco_2/a			
12	CO_2-emissions Heat	tco_2/a			
13	CO_2-emissions Cooling	tco_2/a			
14	Energy Cost Electricity	€/a			
15	Energy Cost Heat	€/a			
16	Energy Cost Cooling	€/a			
17	Operation & Maintenance Cost	€/a			
18	Shall a continuous quality management service been applied to the entire building?	-	Yes, Technical Monitoring		
			Yes, Commissioning Management		
			Yes, Green Buidling Certification		
			Yes, other		
		-	No		
19	According to which methodology defined by IPMVP shall the measure be evaluted?	-	A: Partially Measured ECM Isolation		
		-	B: ECM Isolation		
			C: Whole Buidling Comparison		
		-	D: Whole Building Calibrated Simulation		
		-	Other		

Section B3 — Whole-Building Achievement

No.	Question	Unit	Choices	Answer	Comments
1	Year for which data is provided	-			
2	Build / renovation cost	€			
3	Energy cost	€/a			
4	Operation & Maintenance Cost	€/a			
5	Rent	€/a			
6	Average rent level	€/(m²a)			
7	Occupancy	%			
8	Energy Consumption Electricity	€/a			
9	Energy Consumption Heat	€/a			
10	Energy Consumption Cooling	€/a			
11	CO_2-emissions Electricity	tco_2/a			
12	CO_2-emissions Heat	tco_2/a			
13	CO_2-emissions Cooling	tco_2/a			
14	Energy Cost Electricity	€/a			
15	Energy Cost Heat	€/a			
16	Energy Cost Cooling	€/a			
17	Operation & Maintenance Cost	€/a			
18	Has a continuous quality management service been applied to the entire building?	-	Yes, Technical Monitoring		
			Yes, Commissioning Management		
			Yes, Green Buidling Certification		
			Yes, other		
		-	No		
19	If there was a continious quality management, what are the costs?	€/a			
20	According to which methodology defined by IPMVP has the measure been evaluted?	-	A: Partially Measured ECM Isolation		
		-	B: ECM Isolation		
			C: Whole Buidling Comparison		
		-	D: Whole Building Calibrated Simulation		
		-	Other		

Section C1 — Measure

No.	Question	Unit	Choices	Answer	Comments
1	Type of measure	-	New construction		
		-	Total refurbishment		
		-	Partial refurbishment		
		-	Modernisation		
		-	Renewal		
		-	Repair		
		-	Maintenance & Inspection		
		-	Operational management		
		-	Improved use		
		-	Other: free indication		
2	Reason for the measure	-	User complaints		
		-	Safety and security		
		-	Value retention / value enhancement		
			Excessive OPEX		
			Technical Issues		
		-	Other: free indication		
3	Main trade concerned (except for new construction and refurbishment)	-	Total building		
		-	Facade total		
		-	Facade opaque		
		-	Windows		
		-	Sun protection		
		-	TGA total		
		-	Heating		
		-	Cooling		
		-	Ventilation		
		-	Lighting		
		-	Sanitary		
		-	Building automation		
		-	PV installation		
		-	Equipment		
		-	Other: free indication		

Section C1 — Measure (continued)

No.	Question	Unit	Choices	Answer	Comments
4	Type of EU Taxnomoy measure	-	Construction of new buildings		
		-	Renovation of existing buildings		
		-	Installation, maintenance and repair of energy efficiency equipment		
		-	Installation, maintenance and repair of charging stations for electric vehicles in buildings (and parking spaces attached to buildings)		
		-	Installation, maintenance and repair of instruments and devices for measuring, regulation and controlling energy performance of buildings		
		-	Installation, maintenance and repair of renewable energy technologies		
5	Did you check the measure for Climate Change Adaption (CCA) according to the EU Taxonomy?	-	Yes		
			No		
6	Did you check for "Do no significant harm" (DNSH) requirements according to the EU Taxonomy?	-	Yes		
		-	No		
7	Has the measure been applied as part of an Energy Performance Contracting (EPC)?	-	Yes		
		-	No		

Section C2 — Measure Prognosis

No.	Question	Unit	Choices	Answer	Comments
1	Reference Value	m²	Total building: Gross floor area		
		m²	Facade total: total facade area		
		m²	Facade opaque: total opaque facade area		
		m²	Windows: surface area		
		m²	Sun protection: surface area		
		m²	TGA total: Gross floor area		
		kWp	Heating: installed heatung power		
		kWp	Cooling: installed cooling power		
		m³/h	Ventilation: total volume flow rate		
		m²	Lighting: affected floor area		
		m²	Sanitary: affected floor area		
		m²	Building automation: affected floor area		
		kWp	PV installation: electrical peak power		
		m²	Equipment: affected floor area		
			Other: free indication		
2	Costs of the measure	€	All costs associated with the measure; VAT excl.		
3	Total Savings	kWh/a			
4	Electricity Saving	kWh/a			
5	Savings Heat	kWh/a			
6	Savings Cold	kWh/a			
7	Total Savings CO_2	tco_2/a			
8	CO_2-savings Electricity	tco_2/a			
9	CO_2-savings Heat	tco_2/a			
10	CO_2-savings Cold	tco_2/a			
11	Total Cost Savings	€/a			
12	Electricity Cost Saving	€/a			
13	Savings Cost Heat	€/a			
14	Savings Cost Cold	€/a			
15	Date of Identification of the saving potential	-			
16	Planned Date of Decision of the implementation of the measure	-			
17	Planned Date of Implementation finish	-			
18	Comment (further descriptions of abnormalities)	-			-
19	Shall a quality management service be applied to the implementation of the measure?	-	Yes, Technical Monitoring		
			Yes, Commissioning Management		
			Yes, Green Buidling Certification		
			Yes, other		
		-	No		
20	According to which methodology defined by IPMVP shall the measure be evaluted?	-	A: Partially Measured ECM Isolation		
		-	B: ECM Isolation		
		-	C: Whole Buidling Comparison		
		-	D: Whole Building Calibrated Simulation		
		-	Other		

Section C3 — Measure Achievement

No.	Question	Unit	Choices	Answer	Comments
1	Reference Value	m²	Total building: Gross floor area		
		m²	Facade total: total facade area		
		m²	Facade opaque: total opaque facade area		
		m²	Windows: surface area		
		m²	Sun protection: surface area		
		m²	TGA total: Gross floor area		
		kWp	Heating: installed heatung power		
		kWp	Cooling: installed cooling power		
		m³/h	Ventilation: total volume flow rate		
		m²	Lighting: affected floor area		
		m²	Sanitary: affected floor area		
		m²	Building automation: affected floor area		
		kWp	PV installation: electrical peak power		
		m²	Equipment: affected floor area		
			Other: free indication		
2	Costs of the measure	€	All costs associated with the measure; VAT excl.		
3	Total Energy Savings	kWh/a			
4	Energy Savings Electricity	kWh/a			
5	Energy Savings Heat	kWh/a			
6	Energy Savings Cold	kWh/a			
7	Total Savings Emissions	tco_2/a			
8	Emissions Savings Electricity	tco_2/a			
9	Emissions Savings Heat	tco_2/a			
10	Emissions Saving Cold	tco_2/a			
11	Total Cost Savings	€/a			
12	Cost Savings Electricity	€/a			
13	Cost Savings Heat	€/a			
14	Cost Savings Cold	€/a			
15	Actual date of implementation	-			
16	How were the data given in this sheet determined?	-			
17	Has a quality management service been applied to the implementation of the measure?	-	Yes, Technical Monitoring		
			Yes, Commissioning Management		
			Yes, Green Buidling Certification		
			Yes, other		
		-	No		
18	According to which methodology defined by IPMVP has the measure been evaluted?	-	A: Partially Measured ECM Isolation		
		-	B: ECM Isolation		
			C: Whole Buidling Comparison		
		-	D: Whole Building Calibrated Simulation		
		-	Other		
19	Comment (further descriptions of abnormalities)	-			-

Section D1 — QMS

No.	Question	Unit	Choices	Answer	Comments
1	Year for which data is provided (existing buildings only)	-			
2	Which QMS has been applied?	-	Technical Monitoring		
		-	Commissioning Management		
		-	Green Building Certification		
		-	Other (please explain)		
3	Has the service been third-party-certified within a certification scheme?	-	No		
		-	Yes, by DGNB		
		-	Yes, by LEED		
		-	Yes, by BREEAM		
		-	Yes, by HQE		
		-	Yes, by DGE		
		-	Yes, by COPILOT		
		-	Yes, by other (please explain)		
4	What phases of the project was covered by QMS	-	Pre-design		
		-	Design		
		-	Construction		
		-	Operation		
		-	Other (please explain)		
5	Did the QMS scope cover the entire building? Please indicate the scope.	-	Shell		
		-	Technical systems		
		-	HVAC systems		
		-	Building Management Systems		
		-	Other (please explain)		
6	What was the direct cost of the QMS service?	€			
7	Have there been additional cost to enable or caused by the QMS?	€			
8	Can you provide the contracted description of the QMS service?	-	Yes – attachment		
		-	No		
9	Can you provide the final QMS report?	-	Yes – attachment		
		-	No		

Section D2 — QMS Achievement

No.	Question	Unit	Choices	Answer	Comments
1	How did the QMS impact annual energy cost?	-	1. Strongly positive (reduction)		
		-	2		
		-	3		
		-	4		
		-	5		
		-	6		
		-	7. No significant impact		
2	How did the QMS impact as a percentage cost saving?	%			
3	How did the QMS impact in annual cost reduction?	€/a			
4	Can you give an example?	-			
5	Can you provide an issues log?	-	Yes – attachment		
		-	No		
6	How did the QMS impact annual O&M cost?	-	1. Strongly positive (reduction)		
		-	2		
		-	3		
		-	4		
		-	5		
		-	6		
		-	7. No significant impact		
7	How did the QMS impact as a percentage saving?	%			
8	How did the QMS impact in annual cost reduction?	€/a			
9	Can you give an example?	-			
10	Can you provide a report?	-	Yes – attachment		
		-	No		
11	How did the QMS impact the rent level?	-	1. Strongly positive (reduction)		
		-	2		
		-	3		
		-	4		
		-	5		
		-	6		
		-	7. No significant impact		
12	How did the QMS impact as a percentage increase?	%			
13	How did the QMS impact in annual income increase?	€/a			
14	Can you give an example?	-			
15	Can you provide a documentation?	-	Yes – attachment		
		-	No		
16	Compared to similar projects: How did the QMS impact the occupancy level?	-	1. Strongly positive (reduction)		
		-	2		
		-	3		
		-	4		
		-	5		
		-	6		
		-	7. No significant impact		

Section D2 — QMS Achievement (continued)

No.	Question	Unit	Choices	Answer	Comments
17	How did the QMS impact as a percentage increase?	%			
18	Can you give an example?	-			
19	Can you provide a documentation?	-	Yes – attachment		
		-	No		
20	Compared to similar projects: Did the QMS help to reduce any delay of hand over (new/retrofit only)?	-	1. Strongly positive (reduction)		
		-	2		
		-	3		
		-	4		
		-	5		
		-	6		
		-	7. No significant impact		
21	By of how many weeks did the QMS help to reduce delays?	-			
22	Can you give an example?	-			
23	Can you provide a documentation?	-	Yes – attachment		
		-	No		
24	In which phase did the QMS have the strongest impact (new/retrofit only)?	-	Pre-design		
		-	Design		
		-	Construction		
		-	Start-up and occupancy		
		-	Operation		
25	Can you give an example?	-			
26	Can you provide a documentation?	-	Yes – attachment		
		-	No		
27	Compared to similar projects: Did the QMS help to avoid or mitigate any legal claims in or after the project? The effect was...	-	1. Strongly positive (reduction)		
		-	2		
		-	3		
		-	4		
		-	5		
		-	6		
		-	7. Not significant		
28	Can you give an example?	-			
29	Can you provide a documentation?	-	Yes – attachment		
		-	No		
30	Compared to similar projects: Did the QMS help to improve user acceptance? The effect was...	-	1. Strongly positive (reduction)		
		-	2		
		-	3		
		-	4		
		-	5		
		-	6		
		-	7. No significant impact		
31	Can you give an example?	-			
32	Can you provide a documentation?	-	Yes – attachment		
		-	No		

Section D3 — Whole Building Post Project Evaluation (PPE)

No.	Question	Answer							Comments
1	How would you rate your experience as a client regarding the construction task?	1: *No experience*	2	3	4: *Normal*	5	6	7: *Very experienced*	
2	How do you assess the market offer for design service providers?	1: *Bad*	2	3	4: *Normal*	5	6	7: *Very good*	
3	Have you had contact with the planning team in past projects?	1: *No cooperation so far*	2	3	4: *Normal cooperation*	5	6	7: *Very tested cooperation*	
4	How would you rate the competence of the planning team in the project?	1: *Bad*	2	3	4: *Normal*	5	6	7: *Very good*	
5	How do you assess the market situation of contractors/installers?	1: *Bad*	2	3	4: *Normal*	5	6	7: *Very good*	
6	Have you already had projects with the contractors/installation team in past projects?	1: *No cooperation so far*	2	3	4: *Normal cooperation*	5	6	7: *Very tested cooperation*	
7	How would you rate the competence of the contractors/installation team in the project?	1: *Bad*	2	3	4: *Normal*	5	6	7: *Very good*	
8	Please estimate the time pressure in the project to be evaluated.	1: *Very low*	2	3	4: *Normal*	5	6	7: *Very high*	
9	Please assess the cost pressures in the project to be evaluated.	1: *Very low*	2	3	4: *Normal*	5	6	7: *Very high*	
10	Please assess the quality pressure in the project to be evaluated.	1: *Very low*	2	3	4: *Normal*	5	6	7: *Very high*	
11	Please assess the continious quality management in the project to be evaluated.	1: *Bad*	2	3	4: *Normal*	5	6	7: *Very good*	

Section D4 — Measure Post Project Evaluation (PPE)

No.	Question	Answer							Comments
1	How would you rate your experience as a client regarding the construction task?	1: *No experience*	2	3	4: *Normal*	5	6	7: *Very experienced*	
2	How do you assess the market offer for design service providers?	1: *Bad*	2	3	4: *Normal*	5	6	7: *Very good*	
3	Have you had contact with the planning team in past projects?	1: *No cooperation so far*	2	3	4: *Normal cooperation*	5	6	7: *Very tested cooperation*	
4	How would you rate the competence of the planning team in the project?	1: *Bad*	2	3	4: *Normal*	5	6	7: *Very good*	
5	How do you assess the market situation of contractors/installers?	1: *Bad*	2	3	4: *Normal*	5	6	7: *Very good*	
6	Have you already had projects with the contractors/installation team in past projects?	1: *No cooperation so far*	2	3	4: *Normal cooperation*	5	6	7: *Very tested cooperation*	
7	How would you rate the competence of the contractors/installation team in the project?	1: *Bad*	2	3	4: *Normal*	5	6	7: *Very good*	
8	Please estimate the time pressure in the project to be evaluated.	1: *Very low*	2	3	4: *Normal*	5	6	7: *Very high*	
9	Please assess the cost pressures in the project to be evaluated.	1: *Very low*	2	3	4: *Normal*	5	6	7: *Very high*	
10	Please assess the quality pressure in the project to be evaluated.	1: *Very low*	2	3	4: *Normal*	5	6	7: *Very high*	
11	Please assess the continious quality management in the project to be evaluated.	1: *Bad*	2	3	4: *Normal*	5	6	7: *Very good*	

Annex IV: Scientific Background of QUEST

The *QUEST data engine* makes it possible to create a standardized data set with standardized QMS performance input and output variables that can be used for internal and external benchmarking across buildings and property owners across cities and countries. The *QUEST data engine* can be used for both internal and external benchmarking. (For an extensive review of the benefits of benchmarking and benchmarking theory, see "A Guide to Benchmarking by Meade (2007)". By performing internal benchmarking, property owners can analyse and compare the performance of each of its buildings from one year to the next (or at any other appropriate interval). The property owner can use internal benchmarking to find answers to questions such as how and why various degrees of investments in QMS affect the performance of its buildings. The *QUEST data engine* also makes it possible for property owners to undertake external benchmarking in which property owners can compare the performance of its buildings with that of buildings owned by competitors and other actors in the real estate industry.

Furthermore, the *QUEST data engine* increases the ability of real estate business actors to quantitatively analyse which QMS activities will increasingly satisfy the EU Taxonomy (on sustainable financing and investment activities in particular), while also creating satisfactory financial returns. As the panel data set becomes larger (both in the number of buildings included in the data set and the number of time periods covered) it can provide its users with increasingly detailed analyses of how to reach technical, financial, physical, and sustainability goals simultaneously (in line with the stated contents and goals of the EU Taxonomy) (see the EU Taxonomy compass here).

In 2021, the European Commission adopted a package of measures to increase the flow of financial capital towards sustainable activities across the European Union (see here, here, and here). One of the packages is (a proposal) for a Corporate Sustainability

Reporting Directive (CSRD) which will amend the existing Non-Financial Reporting Directive (NFRD). According to the European Commission, the CSRD 'aims to improve the flow of sustainability information in the corporate world. It will make sustainability reporting by companies more consistent, so that financial firms, investors and the broader public can use comparable and reliable sustainability information.'

The *QUEST data engine* adopts the CSRD to support the European Union's sustainability goals, for which property owners, and equity and debt investors need comparable and standardized data from the real estate industry. The *QUEST data engine* aims to be the industry standard in its field, with standardized vocabulary and data variable definitions.

In addition to internal and external benchmarking, the *QUEST data engine* also creates opportunities for researchers and analysts to study risk empirically and establish causal relationships between technical risk variables, financial performance variables, and Quality Management Services variables. By analysing causal relationships, it is possible to study how a change in one variable, such as a higher level of Quality Management Service implemented for a certain building, causes a direct effect on other variables, such as lowering technical risks or increasing the financial performance of a building.

A key scientific research question is how to quantify the effect of certain QMS activities on the financial and technical performance of buildings. Once enough QUEST data have been collected for several buildings across locations (e.g., across districts, cities, and countries) for at least two time periods, the QUEST data engine can be used to build so-called treatment effect models, using panel data to deduce causal effects from empirical data.

The variables of key interest are those that contain information about which (if any) QMS treatments a certain building has received. The treatment effect and panel data models can show whether there is any significant causal effect on risk and financial performance variables between properties that receive high-quality property management treatments and those that do not.

In the *QUEST data engine*, data on QMS treatments and their effects are collected through the unified data set in **Annex III**.

The QMS evaluation for a certain building and year, and the type of QMS are recorded. The QMS types are:

- Technical monitoring
- Commissioning management
- Green building certification.

Furthermore, the *QUEST data engine* collects data on (but not limited to):

- Whether the QMS has been third-party-certified according to a certification scheme (e.g., DGNB, LEEDS, BREEAM, HQE, DGE, COPILOT, other)
- During what phase (pre-design, design, construction, operation, or other) the QMS has been applied.
- Which scope the QMS covers (shell, technical systems, HVAC, systems, building management systems, or other).

The treatment effect modelling departs from the creation of the QMS variables. Given that QMS has more dimensions than the different types, it can be important to identify interaction variables to capture interaction effects. Interaction effects exist when the effect of a QMS type variable on a dependent variable, such as financial performance (e.g., rent level), changes, depending on one or more of the related QMS variables (e.g., third-party certifications, property phase, or the scope of the QMS). Indeed, the QUEST data engine expands the possibility of analysing relationships among the QMS variables. This in turn allows for more reliable internal and external performance benchmarking.

In the QUEST data engine for a certain building and year, information about the financial impact of QMS is collected. These financial information variables represent the dependent variables that are impacted by QMS types and related variables in the QUEST data engine. The financial variables that various QMS activities might affect include the following:

- Annual energy costs,
- Annual Q&M costs,
- Rent levels,
- Occupancy level,
- Handover time,
- Legal claims, and
- User acceptance.

The data collected on the above QMS impact variables are both qualitative and quantitative in nature. For instance, the qualitative information on how much QMS has impacted annual energy costs is based on a seven-level Likert-type scale that ranges from (1) strongly positive reduction, to (7) no significant impact. Percentage cost savings and Euro/area cost savings constitute the quantitative information collected on how much QMS has impacted annual energy costs. Similar qualitative and quantitative data are collected for the other financial variables.

By studying how the QMS evaluation variables affect the QMS impact evaluation variables, important knowledge of the impact of QMS is obtained. However, since there are many other variables that also influence the variations in technical risk and financial performance of buildings during given time periods and over time, it is important that the data used to analyse treatment effects also include so-called control variables.

Control variables are important in mitigating problems with, for example, selection bias and omitted variable bias. The goal is to obtain unbiased and consistent estimates of treatment effects. For instance, if the treatment effect analysis yields the result that buildings that have received a certain QMS exhibit 10 percent better annual financial performance (or value-add) on average than buildings that have not received a QMS treatment, it is important that the size of the positive financial effect (of 10% in this instance) can be trusted. Therefore, it is important that data on relevant control variables are included.

In the QUEST data engine, several control variable data items for a building are collected. Relevant control variables can be specific to a building (e.g., property type, such as hotel, office, residential, shopping mall, etc., as well as age, design, number of levels, and location) or reflective of neighbourhood and city characteristics (e.g., CBD, attractive area), urban economics, regional economics, and macroeconomic features. The economic variables are important to include when the data set includes buildings located in several different cities across countries throughout Europe.

Location variables are also important because changes in energy cost savings from one year to another might be highly related to annual local climate conditions. Therefore, certain climate variables should also be included as key control variables. For instance, if a building has received QMS that indeed has resulted in much more efficient energy usage, the building's energy costs might still have increased if the average temperature was much lower the year the QMS was activated. By adding local climate condition control variables, more accurate estimates of the impact of QMS on energy savings can be obtained.

More on Hedonic Modelling to Obtain Reliable Estimations of QMS

Ideally, a hedonic real estate panel data set is built which consists of repeated observations of the same properties over time. A hedonic data set combines information on a building's technical risk and financial performance with information on the level of quality management services it receives and the other control variables that might affect the building's technical risk and financial performance. For each year (or other regular time interval), information on property characteristics (including quality management service level and sustainability characteristics) and estimated financial and technical risk performance is collected. The more detailed the observable, or measurable information is about the technical, financial, and quality management characteristics of a property

(for many properties within different property sub-markets), the more reliable the treatment effect analysis results should be. Therefore, access to large data sets can drastically reduce the uncertainty regarding the existence and size of the causal effect of a change in a property characteristic, such as level of Quality Management Service.

Hedonic multiple regression modelling, which is a commonly used statistical tool in econometric real estate research on determinants of economic performance (e.g., market values and rent levels) of properties, acknowledges that heterogeneous properties can be portrayed by their many different characteristics. That is, in hedonic models, the variation in market values is determined by several property characteristics. Many property characteristics can be grouped into the categories of building characteristics, neighbourhood characteristics, and location characteristics. [3],[4]

In the last decade, considerable research has focused on the impact of various sustainability characteristics (e.g., green certifications) on real estate values and other real estate economic performance variables [5]. Table 6 summarizes the effects of green certifications on some key commercial property cash flow parameters and sales prices.

According to the Table 6, the studies reviewed indicated that green certificates might increase rental income and decrease the operating expenses, vacancy, and risks of a property (by lowering the yields, e.g., the cap rates, which reflects the size of the risk premiums). Leskinen et al. (2020) concluded that these improvements, together with the brand value of certificates, should lead to an increase in property value.

To establish such causal effects, that is, changes in sustainability characteristics that lead to changes in the economic performance of properties, the hedonic model should include as many relevant so-called control variables as possible, in addition to the sustainability characteristics variables. The main purpose of including control variables is to avoid (or at least to considerably reduce) omitted variable bias in the estimated effects of the sustainability variables on market values [6]. If relevant property characteristics are omitted from the econometric model, e.g., due to lack of observable data, the estimated causal effects of sustainability variables on market values might be wrong and directly misleading.

Table 6. *The effect of green certification on the cash flow parameters and sales prices of commercial investment properties. [5]*

Cash Flow Parameter	Effect	Range	Mean	Median	References
Rental income	Increased	0.0%....23.0%	6.3%	4.6%	[37–62]
Occupancy	Increased	0.9%...17.0%	6.0%	4.3%	[40, 41, 44, 51, 54, 63, 64]
Operating costs	Inconclusive	−14.3%...25.8%	−0.4%	−4.9%	[40, 42, 49, 50, 54]
Yield (risks)	Decreased	0.36%...0.55%-point	0.46%-point	0.46%-point	[64,65]
Sales price	Increased	0%...43.0%	14.8%	14.1%	[37–40,45,47,49,53,55–59,61,62,66–71]

The more detailed property characteristics information that can be observed and measured, for many properties within different property sub-markets, the more reliable the econometric results should be. Therefore, access to large data sets can drastically reduce the uncertainty regarding the existence and size of the causal effect of a change in a property characteristic, such as the level of QM service, on real estate market values. Establishing economically and statistically significant causal effects is essential in hedonic econometric modelling.

However, difficulties might arise in identifying, observing, and measuring the relevant or different property characteristics for each property, in addition to data on market values and/or transaction prices. Without relevant data on property characteristics, it will be more difficult to distinguish between different properties and to empirically establish the true causal effect of changes in the level of quality management services on real estate market values (and other technical risk and financial performance data). Such unobservable differences are called unobservable heterogeneity in the economic and econometrics literature [6]. If problems with unobserved heterogeneity cannot be resolved, then there is a risk that the size and sign of the estimated causal effect of the variable of interest might differ from the true but unobservable causal effects, again causing problems with omitted variable bias.

A real estate panel data set would consist of repeated observations on the same properties over time. For instance, for each year, property characteristics information (including high-quality management service levels and sustainability efforts) and estimated valuations (and other technical risk and financial performance data) for several properties are collected. A key advantage of having access to such panel data sets is that hedonic panel data econometric models can be applied, and such models have a better possibility of controlling for unobserved differences or heterogeneity between properties and thus mitigating problems with unobserved heterogeneity and omitted variable bias. Consequently, the causal effects of changes in quality management service levels on real estate market values (estimated when using panel data) might be much more reliable than more simple models.

The primary scientific commercial real estate research comes from the article *The Economics of Green Buildings (2013)* [7]. That article describes a two-period panel data analysis. The basic panel data formulation is shown in equation (1) (page 53).

Annex V: How to Define Building Requirements

Quality refers to the degree to which a unit (e.g., a product) meets the requirements established for it. Therefore, a Quality Management (QM) process must begin with the definition of requirements that will be the foundation for all QM tasks and quality verifications.

Despite the fact that quality assurance (QA) has been known in the construction industry for many years and the fact that QA demands the definition of requirements prior to construction, there are many construction cases where requirements have not received much thought. The fact that the QUEST QM processes begin by setting the client's measurable requirements, target values, and acceptance criteria has resulted in employees of those organizations beginning to think about these criteria and has thus contributes to their popularization.

To assist an owner in setting up requirements, the provider (of the Building Commissioning Process, Technical Monitoring and Sustainability Certification) can focus on performance criteria that will support the building's production, Operation and Maintenance (O&M), and Environmental, Social and Governance (ESG) criteria. Production and O&M have direct economic value, with faster commissioning, for example, and full productivity from day 1, as well as lower running costs, including energy. The values of the ESG parameters depend partly on the increased building value (that a well-known and marketed "green" profile can add) and partly on the access to green cash flows, green loans, bonds, and subsidies, and the profit from production, which can be accounted for as 'green'.

"Greenness" is insufficiently captured in economic terms. 'Green' is about technical performance, and economic performance is derived from technical performance. The challenge is to set requirements that can be managed to achieve a documented influence on quality to some degree. This enables cheaper financing and insurance to be obtained in the investment phase, together with cheaper production and running costs, as expected in the operating phase.

When choosing requirements for the QM process, it is crucial that topics are chosen despite the risk of errors and misunderstandings which exists. It is typically very costly to measure all parameters of a construction project and so certain data must be prioritized. In addition, requirements must be established that directly reflect and substantiate those of standards, guidelines, ESG manuals, etc. Furthermore, requirements must be established that support the QM process itself, requirements for measurement options, for dedicated time slots for QM activities, etc.

Individual Building Performance Criteria

The following types of owner data are typically related to a building's business case:

- Requirements for O&M tools, databases for systems manuals, energy consumption, building automation, monitoring possibilities, etc.
- Requirements for IEQ (preferably referencing national or international norms and standards)
- Tech requirements for equipment installed in the building

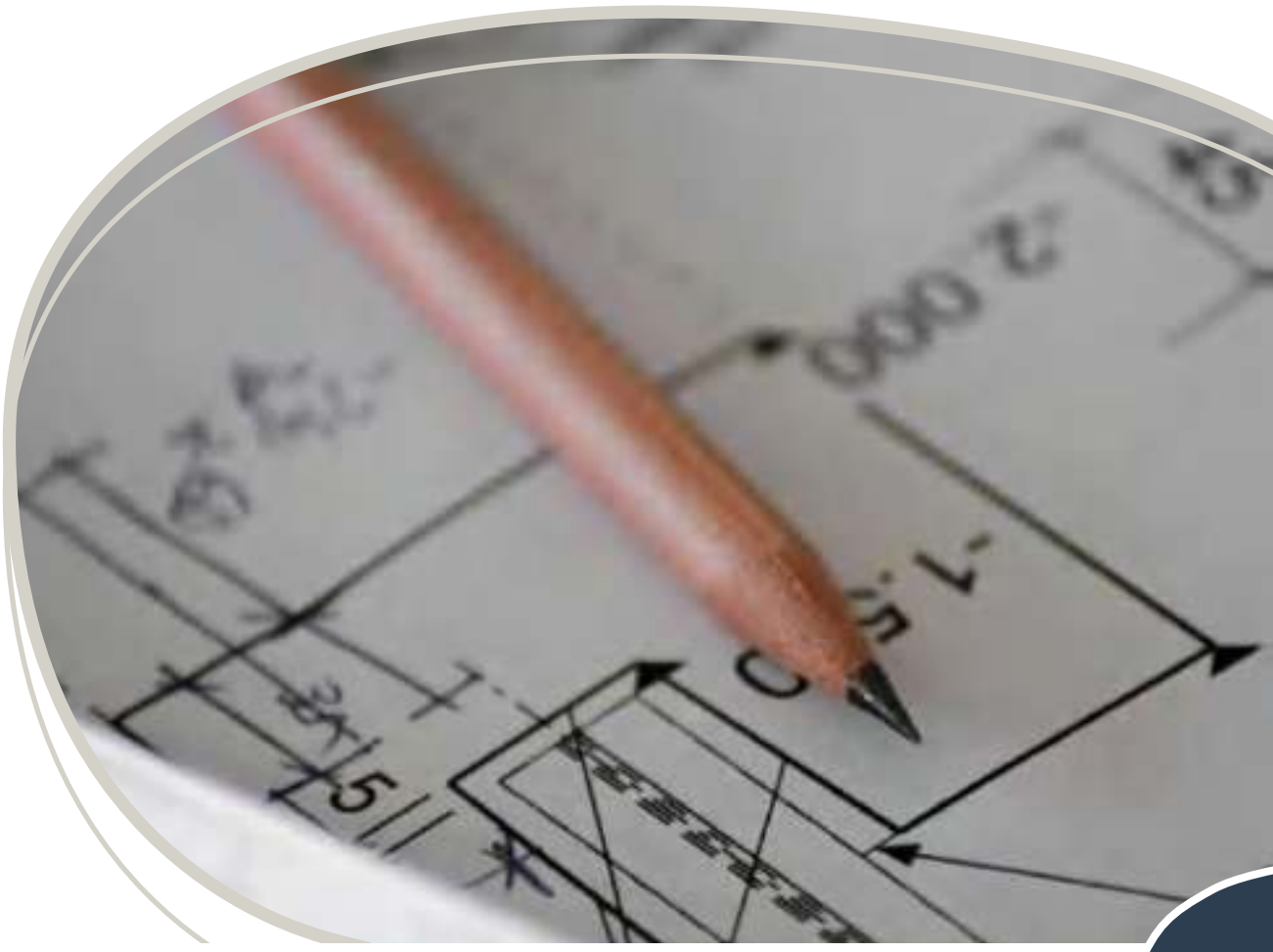
ESG requirements

Suggested sources:

- Requirements related to assessing and reporting sustainability indicators related to carbon, construction materials, water, health, comfort, and climate change impacts on the performance of the building, as described in '**Levels**'. 'Levels' also activate the setting of requirements for 'Life-Cycle Cost' (LCC) and 'Life-Cycle Assessment' (LCA).
- Requirements related to EU Taxonomy Technical Screening Criteria for 'Mitigation', 'Adaptation', and 'Do no significant harm', can be found **here**.
- Requirements from Sustainability Certification Programs, LEED, DGNB, HQE, or others. These requirements can be related to a broad range of sustainability parameters, very few of which are usually mandatory. That means that if, for example, the owner does not want to set requirements for energy consumption, the sustainability certificate can be maintained by addressing other parameters that can supply the total sustainability score. The exercise is mostly on paper, and there is no guarantee that the building performs according well, in good faith. For that reason, sustainability points are given in most sustainability programs when performing QM in the form of a Building Commissioning Process and Technical Monitoring. The QM process thereby serves as the 'Ground Control' of the Sustainability Certificate.

Necessary requirements to facilitate the measurement and verification of 'quality'

- Requirements related to metering energy values in the BACS can be found in several places. Usually, points can be harvested in sustainability verification programs for setting up an energy management plan and the related metering possibilities.
- Waterflow and airflow measurement possibilities must be described as requirements.
- Guidelines for BACS-hosted measurement of technical performance and indoor parameters can be found in REHVA Guidebook 29, Quality Management for Buildings (link).
- Measurement of parameters to track the quality of individual pieces of technical equipment should be designed with field experts.



Annex VI: Assessing the risk profile of a building

The setting up of the requirements above will typically reveal an overall idea of the building's risk profile. Below are the typical topics to be considered when different stakeholders are addressing the building's risks.

Investor:

For the investor the primary considerations historically have been related to the horizon of the investment.

> *"Why bother about O&M and energy consumption when the building is sold before occupancy?"*

Today this approach can be fatal for the investment.

There is scientific evidence for a "Performance Gap" related to bad quality, and there is scientific evidence of impact on rent level and asset value from the parameters causing the "Performance Gap". This has been described in more detail in the upcoming paper by Martinac, I. et al. (2022) *De-Risking Investments in Building Performance Investments by Certified Quality Management Services*. [8]

If the stakeholders are available, the investor should be in close dialogue with the future owner, tenant and the future O&M organization to address the risk profile of the building.

The mapped risk profile should influence the choice of design team and contractors for the work, e.g. if you have a technological complicated laboratory building, it would probably accelerate the risks if you go blind with the cheapest bid for design and construction.

Owner:

The owner can be the investor or can buy from an investor. If the owner cares for the investment and the outcome from the building, Taxonomy criteria should be considered to minimize the risk of exclusion from green revenue streams.

The processes, that generates the outcome of the building can contain risks, for example:

Risks related to health hazards:

- Laboratory
- Chemical production
- Buildings with heavy machinery
- Public transport buildings

Technically risky:

- Data Centre
- Hospital
- Laboratory

Sensitive to indoor climate:

- Office
- Hotel
- Restaurant
- Swimming Complex

Sensitive to O&M and energy expenses:

- Shopping Centre
- Restaurant
- Swimming Complex

Tenant:

The tenant's focus can be more or less the same as the owner's. However, the tenant is expected to have more detail on the production in the building, and if the tenant benefit from OPEX improvements O&M issues should be addressed as risks:

- Cleaning
- Accessibility of technical installations
- O&M material and documentation
- Energy consumption

Glossary

Symbol	Full Term	Description
TMon	Technical Monitoring	The datalogging of selected parameters in a facility and the comparison of the logged parameters to the desired values.
Cx	Building Commissioning Process	The process of building commissioning throughout the planning, design, construction, and operations phases of a building.
CxM	Commissioning Management	The management of the Building Commissioning Process (Cx).
GBC	Green Building Certification	The listing of green parameters and documenting that the parameters are met.
QMS	Quality Management Service	The collective term for TMon, Cx, and GBC.
LCA	Life-Cycle Assessment	The systematic analysis of the environmental impact of buildings over their entire life cycle. This analysis includes the supply of raw materials, the manufacture of construction products, the construction process, operations, and demolition.
LCC	Life-Cycle Cost Analysis	The analysis of lifetime costs of a building project. For construction. It enables design options to be compared from a lifetime perspective to reduce overall costs.
VOC	Volatile Organic Compounds	Harmful, carcinogenic air pollutants that are gases at normal indoor atmospheric conditions. VOCs evaporate from sealants, furniture, carpets, etc in buildings. Some examples include: • Benzene • Formaldehyde • Ethylene glycol • Methylene chloride • Tetrachloroethylene • Toluene
TVOC	Total Volatile Organic Compounds	The total amount of VOCs in a given space. This can be measured with a TVOC sensor, but more accurate measurements should be made by a lab using samples of indoor air collected on site.

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QUEST TECHNICAL MANUAL

Quality Management: De-Risking Green Investments in Building Projects

Stefan Plesser, Cormac Ryan, Ole Teisen, Ivo Martinac, Han-Suck Song, Jasper Vermaut

Climate change presents a tremendous challenge to the real estate sector. Every building in Europe must undergo refurbishment and retrofitting by 2050 to achieve climate neutrality.

The QUEST Technical Manual (which is based on the results of the European QUEST project) helps owners, investors, and developers achieve a higher level of technical quality in their projects with Quality Management Services (QMS), while accelerating the implementation of these services. The Manual introduces QUEST Tool and QUEST Data Engine to support the integration of QMS into building projects.

This Manual explains the underlying technical causes of quality deficits, explains the application of Quality Management Services, gives a short introduction to the application of the QUEST Tool and Data Engine, and provides templates for tender documents and procurements. Their application will help to remove risk from green investments and bring about success in the green transformation of European building stock.

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