QUEST Methodology

Quality Management for Building Projects

QUEST

The QUEST project has received funding from the EU's Horizon 2020 research and innovation programme under grant agreement No 846739

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1 MANAGEMENT SUMMARY

Poorly performing or even failing systems in commercial buildings are a massive risk for investments in sustainable buildings. While anecdotal evidence is widely published, and a few studies have shown the magnitude and likelihood of individual faults, financial actors often still have difficulties to statistically evaluate the technical risks involved in specific construction and real estate investments.

In this context, the term "technical risk" refers to technical building services like heating or ventilation. Malfunction or failure of these technical systems negatively impact building performance, increase CO_2-emissions and thus become a risk for real estate investments.

The objective of QUEST is to gather scientific empirical data to verify that there is a significant technical risk in modern buildings and that well defined quality management services (QMS) can effectively mitigate these deficits, help to improve building performance and reduce investment risks related to the building performance. Due to the complexity of this issue, existing data on building performance and the impact of QMS is scarce so that the value add of QMS is not yet widely understood and used in real estate projects.

The "QUEST" consortium, consisting of financial stakeholders, academic, engineering and

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 €
What are the expected operating expenses per m² per year (OPEX/ m²/ year)? (Energy, operation & maintenance)	20 €
What is the expected rental income (per m² per year) If there is no rent value (ex. hospital or public building), use local Office rent values and adjust to reflect the rental profile of the building	400 €
Define the time horizon that the rating should consider for your QM-investment (5 to 20 years; the value is used to capitalise annual savings)	10

De-risking solutions		Value-add (per m²) over investment lifetime of 10 years		
CERTIFIED SERVICES*	Investment cost**	OPEX improvement	Rent & Occupancy improvement	TOTAL: OPEX + Rent & Occupancy improvement
Certified Technical Monitoring (ex. COPILOT)	1 €	4 €	52 €	**57 €**
Certified Building Commissioning (ex. COPILOT)	10 €	36 €	139 €	**175 €**
Certified Green Buildings (ex. LEED)	20 €	4 €	157 €	**161 €**

Figure 1: Snapshot of the QUEST Tool. Download the tool here: https://project-quest.eu/news/try-out-the-quest-predictive-valuation-tool

certification expert was created to solve this problem. The consortium used independent research and empiric data to create statistical algorithms that predicts the cost and risk impacts of QMS on the value of real estate assets. These algorithms have been packaged in the "QUEST Tool" to predict the cost and value-add of QMS for specific construction and real estate investment projects.

A reliable and useful tool could be developed but more empirical data will help to further fine-tune its practical application. In order to test and increase the QUEST Tool's accuracy and trust, QUEST has set up an iterative loop – the QUEST data engine – where proven value-add data from projects is continuously gathered, aggregated and statistically evaluated to widen and deepen the empiric database. The QUEST tool (prediction) and QUEST data engine (evaluation) can be applied in real estate projects both generating value add and – through their harmonized data set – will create a trusted database for the impact of QMS.

Both the QUEST tool and the QUEST data engine shall be the core of a private, non-profit service to establish a continuous and trusted source of data on the value-add of quality management services that help to de-risk investments in sustainable real estate.

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2 INTRODUCTION

It has been a well-known fact that new buildings and buildings where major alterations have been made (alterations involving design) have performed poorly, have had long run-in periods and have had significant additional operating costs in the first years, all due to bad quality. Bad quality is here related to the quality of the work in all phases of the project, from setting the requirements over design, construction and the operations.

While market studies and previous research provide numerous examples of buildings (e.g. certified buildings) in which better technical building performance correlates with better financial performance, including high(er) market value, to this day the methodologies (and mathematical models) describing these two performance categories have not been sufficiently well interlinked to reliably predict or visualize the financial benefits of quality management in buildings based on their technical performance.

To achieve this, the causal relationships between very specific aspects of technical building performance (e.g. indoor climate quality, energy efficiency or service quality) and very specific aspects of financial building performance such as cash flow, rent level, market value or risk level need to be clearly established and presented in a way that is understandable to both engineers and financiers, particularly investors.

While unequivocal examples of technical-financial building performance linkage exist, this information has not yet been adequately adopted by the market, and it has not yet been incorporated on any significant scale either in business models or investment plans.

The professional languages spoken by the groups measuring technical performance and the stakeholders interested in economic performance are, indeed, so different, that to this day it remains difficult to explain - and prove - to an investor why it makes good sense to invest in building quality management, and why good building quality management is a key tool for successfully achieving technical and economic/financial building performance.

Based on a solid understanding of the relationships between technical and financial building performance, and the crucial value of quality management (QM), the QUEST methodology is intended to become the basis for a user-friendly tool that can ultimately assist investors in understanding and managing key risks and values related to investments into quality management services.

The term “quality” is a colloquial noun generally used to refer to the characteristics of an object or to something “good”. In engineering, “quality” describes the degree, to which a set of inherent characteristics of an object fulfils requirements [1]. Consequently, quality management is a process of supporting the fulfilment of requirements [2].

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Quality management is of course already a part of any building. Construction statics are engineered and cross-checked, concepts for fire protection need to be defined in early design stages and should be tested before handover and every elevator is frequently inspected. Usually, these tests are carried out by a third party using well-defined testing procedures by technical experts for the specific field. But they have a limited scope and do not cover for example the performance of heating or cooling systems in operation, the maintainability of HVAC systems or the indoor environmental quality. Mandatory regular inspections of HVAC systems introduced by the former Energy Performance of Buildings Directive (EPBD) in 2010 have not been successfully implemented yet to a significant extend [3]. A report on the German market found that of all ventilation and air conditioning systems that needed to be inspected, in 2015 only about 10% actually had undergone an inspection [4]. Building performance as such is not yet covered by effective quality management processes. In fact, third-party testing is often only applied in the relatively limited number of buildings undergoing a certification process for sustainability, e.g. DGNB, HQE, BREEAM or LEED; of these processes it is only LEED that requires the Commissioning Process done by an independent third party, and the sustainability certification itself is usually done by the design firm. They give credits for the application of certain quality management procedures and have proven their effectiveness.

In order to help financial stakeholders to manage quality risks, QUEST has identified three Quality Management Services that help reduce risk exposure on building projects related to new constructions and major renovations[1].

Technical Monitoring applies procedures to compare measured values from building operation versus design target values providing a transparent result to the owner. It is undertaken by experts who does most of their work digitally.

Building Commissioning is a quality-focused process for enhancing the delivery of a building project. The process focuses on verifying and documenting that all commissioned systems are planned, designed, installed, tested, operated, and maintained to meet the Owners Project Requirements. It is undertaken by a skilled expert verifying the building project from planning and design through construction to operation.

Green Buildings Certification verifies environmental and social aspects of the building projects and their ecosystem. International certificates s are available as well as national certificates for particular markets.

[1] "Major renovations" defined as renovations where professional design is involved, and/or with a budget > 100.000 € or an expected improvement of energy label with 2 steps, for example from "C" to "A".

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To ensure that the services are well-defined and reliably applied, QUEST has focused on third-party certified QMS only. QUEST developed a tool to predict value-add generated by these Quality Management Services for different project profiles and a process to continuously gather data to create and successively improve a trusted data base on their impact and improve value-add prediction.

To de-risk investments into the sustainability of buildings, QUEST proposes two solutions: the **QUEST tool** to forecast the value add of cost, savings and additional income of a building project – and the **QUEST data engine** to gather data on building performance and the impact of quality management.

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3 THE QUEST TOOL

The QUEST tool helps investors and developers to understand the potential of quality management services (QMS) and offers an easy-to-use way to estimate appropriate cost and value-add in the early stage of their projects when budgets are setup and quality management services should be implemented. The QUEST tool is based on a science-based methodology using the existing data on QMS application and impact.

3.1 The QUEST Methodology

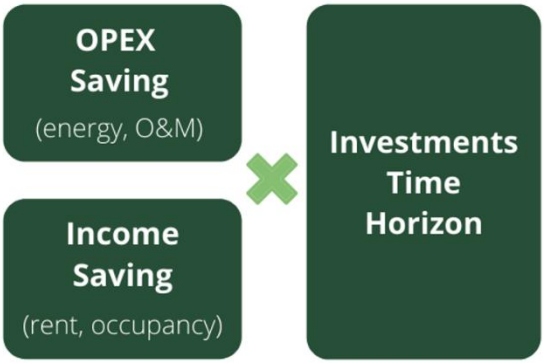
The impact of risk on construction and real estate projects can be examined by considering the following financial data, technical risk ("technical" here referring to building technology, not to financial mechanisms) and the impact of quality management services.

3.1.1 Financial data

Investment analysis should consider construction and real estate projects taking into account expected Capital and Revenue impacts:

1. **Capital**:
    a. Construction/renovation cost
    b. Resale value

2. **Revenue**:
    a. Income
    b. Operating expenses



3.1.2 Technical risk

Technical risk is often excluded from financial calculations which concentrate on other parameters such as client risk. Even when technical risk is considered, it is often limited to operating expenses which are only the tip of the iceberg described above.

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3.1.3 Technical risk relationship to financial data

Investment analysis should consider how technical risk impacts Capital and Revenue:

1. **Capital**:
    a. **Construction/renovation cost:** Quality-related cost overruns are the norm in construction and refurbishment. These supplementary costs are quasi-invisible as they occur so often that the industry often treats them as normal. If we assume that quality for the owner is related to the quality of the building in operation, it is important that the quality management used is targeted at operating requirements. Typically, however, it is requirements related to construction economics and construction time that are critical for the construction organization and the parameters on which they are evaluated. This leads to tasks related to the quality of the building in operation are not carried out before hand-over and expenses related to improving the quality are thus transferred from the construction budget to the operating budget, CAPEX & OPEX.[2]
    b. **Resale value**: In the market until 2025, this is relatively straightforward - unless the building suffers from critical technical problems, the key consideration is location and building profile. In coming years, however, resale value is going to become an increasingly important consideration as the financial industry comes under increasing pressure to risk-score buildings. The EU Taxonomy, for example, is likely to result in huge volumes of "stranded assets" that are regarded as obsolete and devalued.

As re-sale value is impacted by too many factors, QUEST focuses on the cost and savings aspect of capital.

2. **Revenue**:
    a. **Income**: Risk of decreased income stream due to rent depreciation on dysfunctional buildings and decreased occupancy rate due to downtime and reputational impact. Relating technical risk to income is particularly complex given the multitude of tangible and intangible factors that influence rent and occupancy.
    b. **Operating expenses**: Where risk results in problems, the first visible impact will typically concern operating expenses such as energy costs.

[2] Rasmussen, H. L. (2020). *Integrating operational knowledge in design of new buildings to improve facility performance - A comparative study of building and large ship projects*. https://doi.org/10.11581/dtu:00000083

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QUEST has created algorithms to model predicted value add. These algorithms take the following financial & technical parameters into account:

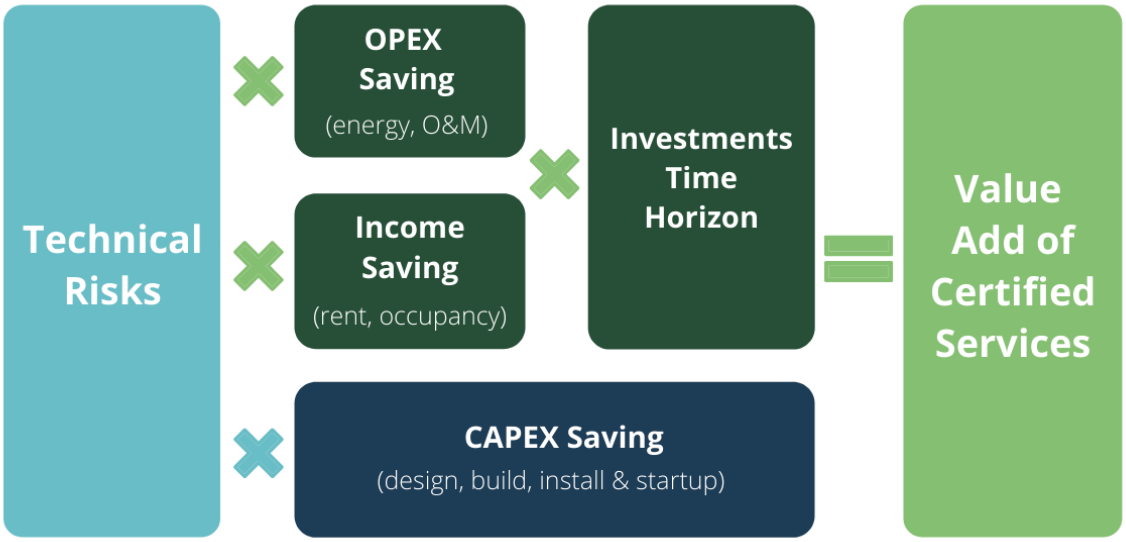

Figure 2: QUEST Tool covers Capital & Revenue elements.

3.1.4 Technical risk indicators

QUEST stakeholder interviews concluded that the confidence to assess technical risk varies across different stakeholder profiles. This is further complicated by the fact that a confident assessment of risk is not necessarily an accurate assessment.

QUEST methodology initially relied on self-assessment of different technical risks in a building or building project:

- Technical risk impact on energy consumption and costs
- Technical risk impact on operation & maintenance work and costs
- Technical risk impact rental income
- Technical risk impact on occupancy rate

In order to reduce variability of this self-assessment, QUEST decided to propose technical risk profiles which depend on user feedback regarding:

- Building type (ex. laboratory deemed higher risk profile than residential property)
- User confidence/experience in the technical teams managing the project

QUEST is designing a solution for financial stakeholders who do not have the expertise to directly assess building technical risk. However, they can evaluate their risk perception of technical management teams based on their experience and/or confidence in these teams. Work together on, and results from, past projects can contribute to this assessment.

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3.1.5 Quality management services

The model above appears complete but does not yet contain a parameter permitting controlled risk limitation.

While a particular situation may have an innate level of technical risk, that risk can be reduced by application of standardized and verifiable processes. QUEST defined these standardized solutions as Quality Management Services (QMS).

To achieve internationally replicable technical risk modulation via QMS, QUEST relies on widely accepted building certification schemes. All these QMS can be applied to new construction, existing buildings or any level of partial refurbishment. It considers schemes that can impact building Capital and/or Revenue:

- **Technical Monitoring Certification** that specifies and verifies correct functioning and operation of installed technical systems based on building management system data
  Example: COPILOT Technical Monitoring Certification

- **Building Commissioning Certification** that verifies compliance with Client Project Requirements through planning, design, construction/renovation & installation, and initial operation of a new building through a well-defined expert service
  Example: COPILOT Building Commissioning Certification

- **Sustainable (or Green) Certifications** that verify compliance with environmental and related standards with broad expert auditing schemes.
  Example: DGNB, HQE, LEED, BREEAM

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3.2 The "QUEST Tool"

QUEST combines the elements of its model in a tool that predicts cost and value-add of Quality Management Services:

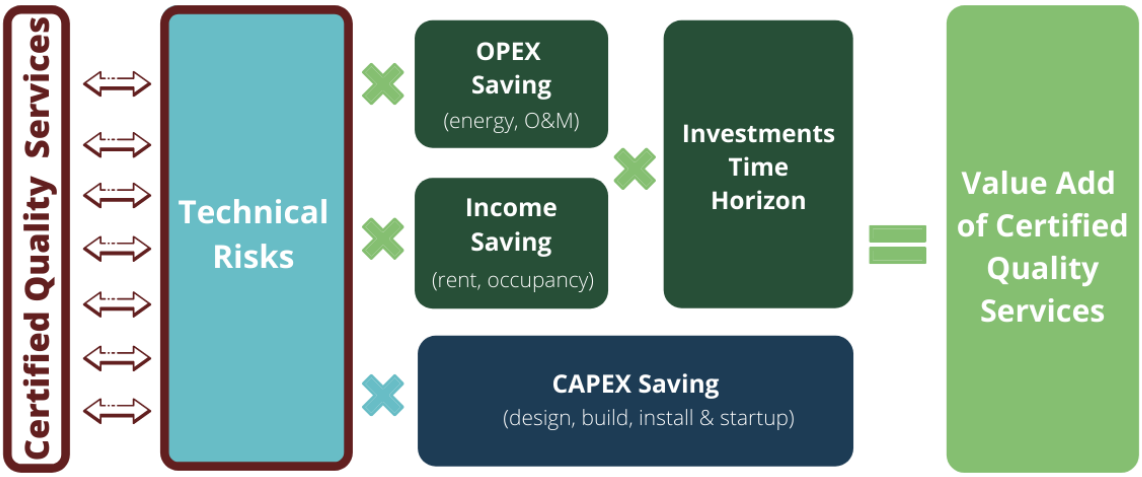

Figure 3: The schematic structure of the QUEST methodology as basis for the QUEST Tool.

3.2.1 Tool input

Based on user feedback, the tool has been progressively simplified. Users input requires 6 project characteristics:

- Building type
- Experience/confidence in the technical teams
- Project build cost (*Capital saving calculation*)

} Technical risk surrogates

- Building systems operating cost (*Income saving calculation*)
- Rental income (*Income saving calculation*)
- Time horizon of investment (*Capital saving calculation*)

For each of these elements the Tool automatically proposes default values which users can adapt according to the building projects.

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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 €
What are the expected operating expenses per m² per year (OPEX/ m²/ year)? (Energy, operation & maintenance)	20 €
What is the expected rental income (per m² per year) If there is no rent value (ex. hospital or public building), use local Office rent values and adjust to reflect the rental profile of the building	400 €
Define the time horizon that the rating should consider for your QM-investment (5 to 20 years; the value is used to capitalise annual savings)	10

Figure 4: QUEST Tool Input Page.

"What is the type of building?"

QUEST has defined default risk profiles for the following types of buildings: Residential, Office, Public, Hotel, Specialised/Technical and Health sector buildings. In case of mixed uses, the main use shall be applied.

Should this menu prove insufficient, the user has the option of selecting generic risk profiles: Low complexity, Mid complexity and High complexity buildings.

"How do you rate the experience in the technical teams managing the project?"

This question acts as a bridge between technical expertise and non-technical stakeholders. Users, who typically have little or no building expertise, grade their experience and confidence in the technical teams involved in the building project. If for example the market Situation for engineering and construction services is very tight and you have to contract a new technical team, you might choose Low confidence. In case of a standard design, high confidence might be a proper choice.

"What is the estimated project cost (per m²)?"

QUEST Tool looks for the total estimated project cost. It includes design, construction and installation work. The project may be new build, renovation, refurbishment or technical installations. The input is based on the costs per square meter.

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"What are the expected operating expenses per m² per year (OPEX/ m²/ year)?"

Expected operating expenses of the building are input. They cover building running costs, notably operation and maintenance costs including facilities management and energy expense. These expenses are input as a cost per square meter per year.

"What is the expected rental income (per m² per year)?"

Stakeholders input either expected rental income of the building in question or an estimate. If the building is not for rental – for example a public building – the user should input their best estimate of its rental value.

If there is no suitable benchmark, we suggest that the user evaluates the rental value of an office building of similar standing and adjusts this valuation upwards or downwards depending on the relative sophistication (compared to an office building) of the building in question.

"Define the time horizon that the rating should consider for your QM-investment"

Stakeholders base their capital investment calculations on a defined time frame. They judge investments decisions, inter alia, on whether the return on investment will be generated within X years.

The stakeholder inputs the time horizon he uses for this type of building investment. QUEST Tool accepts input between 5 and 20 years which are typical investment horizons. Input less than 5 years or more than 20 years is not accepted.

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3.2.2 Tool output

Based on these elements, the Tool predicts value add of the following Quality Management Services:

De-risking solutions		Value-add (per m²) over investment lifetime of 10 years		
CERTIFIED SERVICES*	**Investment cost****	**OPEX improvement**	**Rent & Occupancy improvement**	**TOTAL: OPEX + Rent & Occupancy improvement**
Certified Technical Monitoring (ex. COPILOT)	1 €	13 €	52 €	**66 €**
Certified Building Commissioning (ex. COPILOT)	10 €	63 €	139 €	**202 €**
Certified Green Buildings (ex. LEED)	20 €	20 €	157 €	**177 €**

* Certified quality services provided by independent third parties to approved certification rules

** indicative costs (verification by accredited expert + certification fees) based on Building > 2000 m² with significant project cost

Figure 5: QUEST Tool Output.

QUEST Tool predicts value-add per square meter. It presents its analysis in 4 columns:

1. Investment cost of Quality Management Services for the building project. This is an indicative cost covering expenses – typically verification fees and certification costs - related to the Quality Management Service.
2. The amount indicated is the savings in OPEX operating expenses (capitalised over the investment time horizon; for example: ten times annual savings for a ten year time horizon). OPEX savings are the aggregate of operation and maintenance and energy savings.
3. Revenue gain from improved occupancy and rental income (capitalised over the investment time horizon). Revenue is improved by reduced down-time and inoccupancy as well as rent premium for improved quality. The revenue gain algorithm is a beta-version.
4. The final column is the total of columns 2 + 3. It aggregates OPEX savings with Revenue gains to predict total value-add per square meter.

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In the example of Figure 5, the value-add is presented for a 10-year time horizon as per user input to the "*Define the time horizon…*" field. Here, the QUEST tool predicts investment cost for the QMS of 1, 10 respectively 20€/m². The expected savings in OPEX improvement are estimated to amount to 13, 63 and 20€/(m²a) respectively while the savings (or avoided losses) in rent and occupancy are expected to be 52, 139 and 157€/(m²a). The right-hand column shows the sum of the OPEX savings and improvements in rent and occupancy. These are the overall savings that are expected to be generated through the application of QMS.

As mentioned in the introduction, the available data on cost and benefits of QMS are still limited. The results given by the tool are therefore still under the reservation of a thin data base. Nevertheless, examples indicate that the proportion of cost and savings provide an extremely attractive value add for quality management services. This is because the services can be provided at comparatively low prices while at the same time help to use the low hanging fruits of avoiding poor services in projects today. Therefore, the tool might already be used for early budgeting of QMS in projects.

3.2.3 QUEST tool application

The QUEST tool is available online as an MS Excel-application and can be accessed at https://project-quest.eu/news/try-out-the-quest-predictive-valuation-tool

The consortium is preparing to create a web-browser-based solution for professional services beyond QUEST. To improve the database of the QUEST tool, the consortium has created the QUEST data engine as an approach to continuously gather data for a more solid data basis.

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4 THE QUEST DATA ENGINE

The QUEST project identified a significant lack of data on building performance and even more on the impact of QMS on building performance. The QUEST tool is therefore only a starting point. The QUEST data engine has been created as an additional tool to gather more and precise data to overcome this deficit. To create a motivation to provide this data, QUEST will link the data acquisition with a due diligence service that provides a value add to stakeholders by itself and a unified data set to collect data on new construction measures, retrofit measures of any kind and the impact of QMS on these measures.

The unified data set consists of three parts:

1. **Evaluation of Building Performance**
   The first part gathers data on individual building projects, the buildings performance and the risk evaluation as applied in the QUEST tool. This data set applies to new construction and deep refurbishment only.
2. **Evaluation of Measures**
   Since many investments in sustainability will be made in existing buildings and potentially cover only partial improvements, the second part of the data set collects data on individual measures of improvement in buildings, ranging from simple adjustments of operations to comprehensive refurbishments.
3. **Evaluation of QMS**
   This third part collects data on the QMS that have been applied and on the perceived effect of the QMS on the project and building performance.

The data sets can be applied individually according to the individual scope of a project. Cost do not include VAT.

4.1 Definition of Measures

The following table lists definitions for measures of improvement or upholding of a building's performance. "Evaluation of Buildings" is applied to new construction and total refurbishment only. All other measures are evaluated using the "Evaluation of Measures". The "Evaluation of QMS" is applied equally to both types.

Name	Definition	Examples
Evaluation of whole Buildings		
New construction	Construction of a new building	- New construction
Total refurbishment	Refurbishment of a building after total demolition down to its skeleton	- Reconstruction of an existing building after the complete deconstruction of all walls, facades and technical and interior systems
Evaluation of Measures		
Partial refurbishment	Refurbishment of a building after partial deconstruction	- Reconstruction of an existing building after the partial deconstruction of walls, facades

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		and technical and interior systems
Addition	Additional equipment, services or functions are added to an existing building	- Addition of external sun shading to a façade - Addition of a heat recovery wheel to an air handling unit - Addition of a load management function to a building management system that formerly did not manage loads
Modernisation	Existing equipment, services or functions in a building are replaced by newer ones with improved performance	- Addition of a time schedule function to a formerly continuously operating system - Replacement of a light bulb system by an LED lighting system - Replacement of an uncontrolled pump by a electronically controlled pump
Renewal	Existing equipment, services or functions in a building are replaced by newer ones with equal performance (usually on a system level)	- Replacement of a time schedule function by a new system with identical functions - Replacement of a LED lighting system by an identical LED lighting system - Replacement of an electronically controlled pump by a new, identical electronically controlled pump
Repair	Existing equipment, services or functions in a building are fixed to perform as they performed originally (may included renewal of components)	- Re-Balancing of a heating system - Fixing a cable breakage - Fixing a ambient air temperature sensor that was torn off by the wind
Maintenance & Inspection	Existing equipment, services or functions in a building are regularly controlled and maintained to uphold their performance	- Regular replacement of a broken lamp - Regular replacement of filters in an air handling unit - Regular lubrication of bearings
Operation management	Continuous human service supervising and	- Supervision of energy consumption

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	where necessary adjust operation parameters to uphold performance	- Adjustment of operation schedules to user needs - Adjustment of set points to user needs
Improved use	Activity to improve user behavior	- Information of users on energy consumption - Information of users on improved user behavior - Stimulation of better user behavior e.g. through gaming, benchmarking or user specific accounting
Energy Performance Contracting (EPC)	In this context, EPC are considered all services for which the payment depends on the actual savings achieved through the service. EPCs usually include one or more of the measures above and may also include QMS internally or externally.	

4.2 Evaluation of Building Performance

4.2.1 Building Data

The first data set gathers meta data on the asset or building.

Name	Unit	Selection list
ID	-	Number for unique identification
Project name	-	Name of the project
Start of Design Phase	-	Date on which design started
Start of Construction Phase	-	Date on which construction started
Start of Use Phase	-	Date on which the building was handed over to users
Project type	-	Type of Measure: - New construction - Deep refurbishment
Country	-	Country in which the building is located
Postal code	-	Number

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	City	-	Name of the City
	Street	-	Name of the Street
	House number	-	Number
	Year of construction	-	DD.MM.YYYY
	Last comprehensive renovation	-	DD.MM.YYYY
	Original construction date of the building	-	DD.MM.YYYY
	Gross floor area	-	Area of all floors including the area of construction
	Net floor area	-	Area of all floors excluding the area of construction
	Number of storeys above ground	-	Number
	Number of storeys below ground	-	Number
	Main use type		Type of building - Office - Retail - Hotel - Residential - Other
	Main use percentage	%	Percentage of floor area that the main use occupies
	Name of the owner	-	Optional
	Owner's contact details	-	Optional
	Owner type	Tick box	- Owner-occupier (self use) - Public - Private investor - Banks or insurance companies - Other corporate investors

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		- Other: free indication
Renting Situation		- Self-use - Single Tenant - Multi-Tenant
Facilities Management company	-	Optional
Building partner (contact person at QUEST)	-	If applicable, please indicate the person in charge of the QUEST project: - SYNAVISION - COPILOT - KTH - SWECO - LINKS - REHVA - AMICE

4.2.2 Building Performance Data

The second step is to collect the data that will be used in the budgeting tool. Data that can be collected before / after the completion of a building to describe the expected / achieved performance of the building. For all cost data, VAT is excluded.

Name	Unit	Selection list
Are the data provided an expression of an expected performance or of an achieved performance?	-	Data collected before the completion of a building will describe the expected / planned performance: - Expected - Achieved
Year for which data is provided	YYYY	Provide the year for which the following data is provided
Build / renovation cost	€	Cost for design/engineering and construction
Energy cost	€/a	Total cost of energy for the building (including energy consumed by tenants)
Operation & Maintenance Cost	€/a	Total cost for operation & maintenance for the building

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Rent	€/a	Total rent for the building
Average rent level	€/(m²a)	Average rent level of the building
Occupancy	%	Percentage occupied (rented) spaces for the whole year

I available, more detailed data may be provided for the project. Consumption, emissions and cost refer to quantities that have crossed the boundaries of the building site (e.g. district heating is considered, but not cooling energy produced by chillers within the building using electricity).

Name	Unit	Selection option
Energy Consumption Electricity	€/a	Total consumption of electrical energy of the building
Energy Consumption Heat	€/a	Total consumption of heat energy of the building (heat, steam, gas equivalent)
Energy Consumption Cooling	€/a	Total consumption of cooling energy of the building (if delivered to the building from outside)
CO2-Emissions Electricity	tCO2/a	Total CO_2-emissions of electrical energy of the building
CO2-Emissions Heat	tCO2/a	Total CO_2-emissions of heat energy of the building (heat, steam, gas equivalent)
CO2-Emissions Cooling	tCO2/a	Total CO_2-emissions of cooling energy of the building (if delivered to the building from outside)
Energy Cost Electricity	€/a	Total cost of electrical energy of the building
Energy Cost Heat	€/a	Total cost of heat energy of the building (heat, steam, gas equivalent)
Energy Cost Cooling	€/a	Total cost of cooling energy of the building (if delivered to the building from outside)
Operation & Maintenance Cost	€/a	Total cost of operation and maintenance of the building

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4.2.3 Risk Evaluation

The next step is to retroactively assess the risk situation for the project. The assessment refers to the point in time when the project started, and the budgeting tool would have been used. Comparative answers ask for personal judgements in comparison to similar projects on a scale from 1 to 7.

Question	Type	Selection options
How would you rate your experience as a client regarding the construction task?	Scale	1: No experience 4: Normal 7: Very experienced Please explain your evaluation (optional):
How do you assess the market offer for design service providers?	Scale	1: Bad 4: Normal 7: Very good Please explain your evaluation (optional):
Have you had contact with the planning team in past projects?	Scale	1: No cooperation so far 4: Normal cooperation 7: Very tested cooperation Please explain your evaluation (optional):
How would you rate the competence of the planning team in the project?	Scale	1: Bad 4: Normal 7: Very good Please explain your evaluation (optional):
How do you assess the market situation of contractors/installers?	Scale	1: bad 4: normal 7: very good Please explain your evaluation (optional):
Have you already had projects with the contractors/installation team in past projects?	Scale	1: No cooperation so far 4: Normal cooperation 7: Very tested cooperation Please explain your evaluation (optional):
How would you rate the competence of the contractors/installation	Scale	1: Bad 4: Normal 7: Very good

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team in the project?		Please explain your evaluation (optional):
Please estimate the time pressure in the project to be evaluated.	Scale	1: Very low 4: Normal 7: Very high Please explain your evaluation (optional):
Please assess the cost pressures in the project to be evaluated.	Scale	1: Very low 4: Normal 7: Very high Please explain your evaluation (optional):
Please assess the quality pressure in the project to be evaluated.	Scale	1: Very low 4: Normal 7: Very high Please explain your evaluation (optional):

4.3 Evaluation of Measures

Buildings and investments in buildings do not always address a whole building but may focus on a limited scope to improve or maintain performance. To be able to develop a more detailed technical assessment of individual measures and a more precise forecast for future measures, details on individual measures can be documented.

See also definition of “Major renovations” in chapter 2.2 (footnote).

4.3.1 General Documentation of the Measure

For any measure to be documented, the general characteristics shall be collected.

Name	Unit	Selection list
Type of measure	Tick box	Type of Measure: - New construction - Total refurbishment - Partial refurbishment - Modernisation - Renewal - Repair - Maintenance & Inspection - Operational management - Improved use - Other: free indication
Reason for the measure	Tick box	Description / justification why the measure was implemented: - User complaints - Safety and security

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		- Value retention / value enhancement - - Other:
Main trade concerned (except for new construction and refurbishment)	Tick box	System or part of the building on which the measure has been applied: - Total building - Facade total - Facade opaque - Windows - Sun protection - TGA total - Heating - Cooling - Ventilation - Lighting - Sanitary - Building automation - Equipment - - Other: free indication
Plant size	Number	If the measures is applied to a certain central plant, the nominal power before implementation shall be given: - Thermal power - Electrical power - Volume flow (air/water)
Has a QMS been applied?	Tick box	Indication of the type of QMS that has been applied. - Technical Monitoring - Commissioning Management - Green Building Certification - Other (please explain)
Has the measure been applied as part of an Energy Performance Contracting (EPC)?	Y/N	Yes No

4.3.2 Prognosis of the Measure

The following data set is applied before a measure is to be implemented and shall gather forecasted data for the measure.

Name	Unit	Selection list
Plant size	-	If the measures is applied to a certain central plant, the planned nominal power shall be given. - Thermal power - Electrical power - Volume flow (air/water)
Costs of the measure	€	Projected design and construction costs associated with the measure

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Total savings	kWh/a	Energy in kWh/a that shall be saved in all areas through the measure
Electricity saving	kWh/a	Energy in kWh/a that shall be saved in terms of electricity through the measure.
Savings heat	kWh/a	Energy in kWh/a that shall be saved in terms of heat through the measure.
Savings cold	kWh/a	Energy in kWh/a that shall be saved with regard to cooling through the measure.
Total savings CO_2	tCO2/a	Emissions in tCO2/a that shall be saved in all areas through the measure
CO_2 savings Electricity	tCO2/a	Emissions in tCO2/a that can be saved with regard to electricity through the measure
CO_2 Savings heat	tCO2/a	Emissions in tCO2/a that can be saved with regard to heat through the measure
CO_2 Savings cold	tCO2/a	Emissions in tCO2/a that can be saved with regard to cooling through the measure
Total cost savings	€/a	Energy Costs in €/a that can be saved in all areas through the measure
Electricity cost saving	€/a	Energy Costs in €/a that can be saved with regard to electricity through the measure
Savings cost heat	€/a	Energy Costs in €/a that can be saved with regard to heat through the measure
Savings cost cold	€/a	Energy Costs in €/a that can be saved with regard to cooling through the measure
Date of Identification of the saving potential	-	The point in time when it was recognised that the system was not running in optimal operation.
Planned Date of Decision of the implementation of the measure	-	The point in time at which an improvement measure was defined
Planned Date of Implementation finish	-	The date when the implementation of the measure started
Comment	-	Further descriptions of abnormalities

4.3.3 Evaluation of the Measure

This data set is applied after a measure has been implemented and an evaluation of its impact has been carried out. This should be created at least once after implementation but might be collected repeatedly to evaluate the sustainability of the impact.

Name	Unit	Selection list
Plant size	-	If the measures is applied to a certain central plant, the actual nominal power after the implementation shall be given: - Thermal power - Electrical power - Volume flow (air/water)

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Costs of the measure	€ (netto)	All costs associated with the measure
Total energy savings	kWh/a	Energy in kWh/a that could be saved in all areas through the measure
Energy savings electricity	kWh/a	Energy in kWh/a that could be saved in terms of electricity through the measure
Energy savings heat	kWh/a	Energy in kWh/a that could be saved in terms of heat through the measure
Energy savings cold	kWh/a	Energy in kWh/a that could be saved with regard to cooling through the measure
Total savings emissions	tCO2/a	Emissions in tCO2/a that could be saved in all areas through the measure
Emissions savings electricity	tCO2/a	Emissions in tCO2/a that could be saved with regard to electricity through the measure
Emissions savings heat	tCO2/a	Emissions in tCO2/a that could be saved with regard to heat through the measure
Emissions saving cold	tCO2/a	Emissions in tCO2/a that could be saved with regard to cooling through the measure
Total cost savings	€/a	Costs in €/a that could be saved in all areas through the measure
Cost savings heat	€/a	Costs in €/a that could be saved with regard to electricity through the measure
Cost savings heat	€/a	Costs in €/a that could be saved with regard to heat through the measure
Cost savings cold	€/a	Costs in €/a that could be saved with regard to cooling through the measure
Actual date of implementation	-	The date when the implementation of the measure started
Comment	-	

4.4 Evaluation of QMS

While parts 1 and 2 defined the evaluation of the performance of a building or a measure, this chapter defines the evaluation of the impact which the QMS had on the building performance.

4.4.1 QMS evaluation

This part of the data engine describes the QMS that has been applied to the building or measure.

Name	Unit	Selection list
Year for which data is provided (existing buildings only)	YYYY	Provide the year for which the following data is provided.
Which QMS has been applied?	Tick box	Indication of the type of QMS that has been applied: - Technical Monitoring - Commissioning Management

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		- Green Building Certification - Other (please explain)
Has the service been third-party-certified within a certification scheme?	Tick box	Yes, by … - DGNB - LEED - BREEAM - HQE - DGE - COPILOT - Other - None.
What phases of the project was covered by QMS	Tick box	Indication of the earliest phase in which the QMS has been applied. - Pre-design - Design - Construction - Operation - - Other (please explain)
Did the QMS scope cover the entire build / renovation project? Please indicate scope?	Tick box	Indication of the scope of the QMS that might have been limited to certain systems or parts of the building. - Shell - Technical systems - HVAC systems - Building Management Systems - Other (please explain)
What was the direct cost of the QMS service?	€	Total cost of the QMS (not including any additional cost caused by the QMS e.g. for metering or construction)
Have there been additional cost to enable or caused by the QMS?	€	Cost to enable the QMS (e.g. metering devices, data connectivity) or other investments (green roof, showers, sustainable wood etc.) to reach the certification. Please provide the additional cost and give examples.
Can you provide the contracted description of the QMS service?	Y/N	Yes – attachment Please provide the contract of the QMS provider. No

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Can you provide the final QMS report?	Y/N	Yes – attachment Please provide an example of the QMS provider (if possible, the final report). No

4.4.2 QMS impact evaluation

This part of the data engine describes data on the QMS' impact on building performance.

Name	Unit	Selection list
How did the QMS impact annual energy cost?	Scale	1. Strongly positive (reduction) 7. No significant impact
… as a percentage cost saving?	%	Percentage by which the annual energy cost has been reduced through the QMS.
… in annual cost reduction?	€/a	Amount by which the annual energy cost has been reduced through the QMS.
Can you give an example?		Example of how the QMS helped to reduce energy cost saving.
Can you provide an issues log?		Please attach a Report/document showing an example of the QMS impact.
How did the QMS impact annual O&M cost?	Scale	1. Strongly positive (reduction) 7. No significant impact
… as a percentage saving?	%	Percentage by which the annual cost for operation and maintenance has been reduced through the QMS.
… in annual cost reduction?	€/a	Amount by which the annual cost for operation and maintenance has been reduced through the QMS.
Can you give an example?		Example of how the QMS helped to reduce operation and maintenance cost.
Can you provide a report?		Please attach a Report/document showing an example of the QMS impact.
How did the QMS impact the rent level?	Scale	1. Strongly positive (reduction) 7. No significant impact
… as a percentage increase?	%	Percentage by which the annual income has been improved through the QMS.

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… in annual income increase?	€/a	Amount by which the annual income has been reduced through the QMS.
Can you give an example?		Example of how the QMS helped to increase the rent level.
Can you provide a report?		Please attach a Report/document showing an example of the QMS impact.
Compared to similar projects: How did the QMS impact the occupancy level?	Scale	1. Strongly positive (reduction) 7. No significant impact
… as a percentage increase?	%	Percentage by which the annual occupancy level has been improved through the QMS.
Can you give an example?	-	Example of how the QMS helped to increase the occupancy level.
Can you provide a report?	-	Please attach a Report/document showing an example of the QMS impact.
Compared to similar projects: **Did the QMS help to reduce any delay of hand over (new/retrofit only)?**	Scale	1. Strongly positive (reduction) 7. No significant impact
By of how many weeks did the QMS help to reduce delays?	-	Number of weeks by which the QMS helped to reduce delays.
Can you give an example?	-	Example of how the QMS helped to reduce delays.
Can you provide a report?	-	Please attach a Report/document showing an example of the QMS impact.
In which phase did the QMS have the strongest impact (new/retrofit only)?	Scale	
In phase …		- Pre-design - Design - Construction - Start-up and occupancy - Operation
Can you give an example?	-	Example of how the QMS helped to reduce delays.
Can you provide a report?	-	Please attach a Report/document showing an example of the QMS impact.

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Compared to similar projects: **Did the QMS help to avoid or mitigate any legal claims in or after the project?**	Scale	
The effect was …		1. Strongly positive (reduction) 7. Not significant.
Can you give an example?		Example of how the QMS helped to mitigate legal claims.
Can you provide a report?		Please attach a Report/document showing an example of the QMS impact.
Compared to similar projects: Did the QMS help to improve user acceptance?	Scale	1. Strongly positive 7. No significant impact
The effect was …		1. Strongly positive (reduction) 7. Not significant.
Can you give an example?	-	Example of how the QMS helped to improve user acceptance.
Can you provide a report?	-	Please attach a Report/document showing an example of the QMS impact.

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5 QUEST – DE-RISKING INVESTMENTS THROUGH TRUSTED DATA

The QUEST methodology – tool and data engine – has been created as a reaction to the massive lack of data on building performance, especially of commercial buildings, and the impact of quality management on the performance. Despite an abundance of anecdotal evidence and an urgent need for data to build on, until today the real estate industry does not have access to the needed empiric data to de-risk investments in the sustainability of buildings.

QUEST proposes a tool to use the value add of QMS in buildings by estimating cost and savings that can be achieved with QMS. At the same time, QUEST provides an open-source data set to collect the missing data on commercial and residential buildings and QMS impact.

After completion of the QUEST project, the data set will be available and free to use for all stakeholders. The unified methodology may help the industry to de-risk their investments by investing more reliably in quality management. The data described above will help to collect data on building performance and the impact that QMS had on it. While some of the answers can be used directly to enlarge the statistical data base for individual KPIs (energy cost, rent level etc.), others will help to get a deeper understanding of how QMS have achieved the impact. This shall in consequence enable an even more comprehensive and detailed analysis in future questionnaires.

If those who apply the tool share the data providing it to the national QUEST partners, it might even be possible to not only compare with each other but to build a European data base that will help to de-risk investments in sustainable buildings as it is urgently needed.

5.1 The Green Deal

Making Europe the first climate neutral continent in the world is the goal for the European Union.

The proposals under the Green Deal aim to make all sectors of the EU's economy fit to meet this challenge. They set the EU on a path to reach its climate targets by 2030 in a fair, cost effective and competitive way.

All 27 EU Member States committed to turning the EU into the first climate neutral continent by 2050. To get there, they pledged to reduce emissions by at least 55% by 2030, compared to 1990 levels.

The European Green Deal set the blueprint for this transformational change.

Buildings account for about 40% of the EU energy consumption. Europe must be climate neutral by 2050 and as a step in this direction, 35 million buildings are to be renovated until 2030. The EU is launching major incentive programs, both as part of the Green Deal and as part of post-covid recovery investments, to ensure that building owners embrace the idea of energy renovation.

Massive investment in sustainability means a large amount of new technology installed in the buildings in a hurry. We have seen on previous occasions what an overheated market means for the quality of the construction work, and QUEST has a role to play in ensuring, that the individual buildings and renovations have a quality that ensures the reduced climate footprint.

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5.1.1 The Renovation Wave

To pursue the dual ambition of energy gains and economic growth, in 2020 the Commission published a new strategy to boost renovation called "A Renovation Wave for Europe – Greening our buildings, creating jobs, improving lives".

This strategy aims to double annual energy renovation rates in the next 10 years. As well as reducing emissions, these renovations will enhance quality of life for people living in and using the buildings, and should create many additional green jobs in the construction sector.

5.1.2 The Taxonomy on Sustainable Finance

The EU taxonomy is a classification system, establishing a list of environmentally sustainable economic activities. It could play an important role helping the EU scale up sustainable investment and implement the European green deal. The EU taxonomy would provide companies, investors and policymakers with appropriate definitions for which economic activities can be considered environmentally sustainable. In this way, it should create security for investors, protect private investors from greenwashing, help companies to become more climate-friendly, mitigate market fragmentation and help shift investments where they are most needed.

The QUEST tool can visualize the cost and benefit of adapting the Taxonomy to the individual investor.

The QUEST Data Engine can harvest feedback from specific Taxonomy-targeted QM processes, e.g. “Taxonomy Due Diligence” or “ESG Due Diligence”

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5.1.3 The QUEST tool where does it fit?

Figure 6 COM(2020) 21 final – Communication from the Commission on the Sustainable Europe Investment Plan. Source: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020DC0021&from=EN

Part of the Green Deal is to reduce the emissions from the existing building mass but also make sure that the new buildings have as low as possible climate impact. Research, including the QUEST research, has revealed that new buildings are not able to perform as well as they are designed partly because of lack of quality management in the construction phase.

Regarding the taxonomy, a significant part of it is the ability to efficiently operate a given building and it´s technical installations/ HVAC, and successively monitor and measure the operations and the energy consumption

In both cases QUEST can play an active role of achieving exactly that. QUEST can budget and evaluate the tools to make sure that the technical installations perform as intended, are monitored, and that the installations are taxonomy compliant. QUEST can provide an estimate on Return of Investment and the added value to the given building/ portfolio.

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6 ANNEX

6.1 Glossary

The following paragraphs give a list of financial, technical and social terms and KPIs that are being used for the QUEST methodology. These definitions are particularly important to create a common understanding of the financial and technical world.

6.1.1 Financial Terminology

- **Building type:** User selects from a menu of building types including residential, office buildings. Users may alternatively directly indicate low/mid/high-complexity. (Default value is Office Building).
- **Rating of technical teams:** User indicates their experience and confidence in the technical teams managing the building project as low/mid/high confidence. (Default value is Mid Confidence).
- **Project cost**: The total cost of the building process (excluding land cost), ie. the cost of design, engineering, building & installation work. (Default value 1.000 €/m2).
- **Operating expenses:** Cost of operation & maintenance of the building and its systems including energy costs. This can vary considerably due to variables such as the type of facilities management contract and building age (with energy costs often about 50 kWh/m2/yr in new buildings while old buildings may be over 200 kWh/m2/yr). (Default value 20 €/m2).
- **Rent:** Expected rental income - market rent the building is worth per annum at expected occupancy level (Default value 400 €/m2/year).
- **Time horizon of investment payback**: Number of years to breakeven used in property investment decisions (Default value is 10 years with minimum 5 years, maximum 20 years).

6.1.2 Technical glossary

- **Quality Management Indicator** (QMI) is the key indicator introduced by QUEST to evaluate the economics of quality management services for projects. The QUEST tool will use QMIs to inform building owners about the potential of QMS, to give an indication of appropriate budgets and amortization periods.
- **Quality Management Service** (QMS): A service that is carried out to support a good delivery of work in a building project. The QMS is a third-party service and, in contrast to designers, engineers contractors and facilities management, neither responsible for the management nor of the results of the project or other services. Its task is usually to define and check requirements for a project. Within QUEST, three types of services will be included: Technical Monitoring, Building Commissioning and Green Building Certification.
- **Technical Monitoring** (TMon) is the process of measuring and verifying the compliance of actual building performance with design specifications and (contracted) performance requirements.
- **Building Commissioning** (Cx) is a quality-focused process for enhancing the delivery of a new building or major renovated existing building project. The process focuses on verifying and documenting that all of the commissioned systems and assemblies

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are planned, designed, installed, tested, operated, and maintained to meet the OPR (Owners Project Requirements).

- **Green or Sustainable Certification of buildings** is the assessment and certification of actual building performance in relation to defined performance standards/levels and rating protocols (schemes) describing complex aspects of building performance, including environmental performance and compliance with defined sustainability aspects.
- **Measure**: Any activity on buildings can be defined as a measure. IN the context of QUEST, this will mainly be a new construction, retrofit, partial retrofit and re-commissioning. A measure can be one of these activities as a whole or a part of this activity, e.g. the installation of new pumps as part of a retrofit or the adjustment of set point as part of a re-commissioning.
- **Attribute**: Characteristics used to describe and evaluate the measures implemented and QM services applied. Two types of attributes are required for the measures: those that are relevant for internal company use (descriptions, forecasts, time periods) and data that serve to evaluate measures (actual and target states, implementation, evaluation) and enable comparison.

6.1.3 Social glossary

- **Evaluation process**: A systematic enquiry before and after the construction process to assess the project.
- **Pre-Project evaluation**: A survey of the actual and target states for already existing buildings and the goals set as well as expectations regarding quality, the project and the building.
- **Post-project evaluation**: A query on the implementation of measures and the evaluation of quality management services used. It is recorded whether the objectives have been achieved and the expectations fulfilled.

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6.2 Key references

Holterman, R. and N. Kok. (2017). On the Value of Environmental Certification in the Commercial Real Estate Market. *Real Estate Economics*, https://doi.org/10.1111/1540-6229.12223

Leskinen, N., Vimpari, J. and Junnila, S. (2020a), "Using real estate market fundamentals to determine the correct discount rate for decentralised energy investments", Sustainable Cities and Society, Vol. 53. https://doi.org/10.1016/j.scs.2019.101953

Leskinen, N., Vimpari, J. and Junnila, S. (2020b), "The impact of renewable on-site energy production on property values", *Journal of European Real Estate Research*, Vol. ahead-of-print No. ahead-of-print. https://doi.org/10.1108/JERER-11-2019-0041

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Mangialardo, A.; Micelli, E.; Saccani, F. (2018). Does sustainability affect real estate market values? Empirical evidence from the office buildings market in Milan (Italy). *Sustainability*, 11(1), 12. https://doi.org/10.3390/su11010012

Porumb, V-A., Gunther Maier, and Anghel G. I. (2020). The impact of building location on green certification price premiums: Evidence from three European countries, *Journal of Cleaner Production*, Vol: 272. https://doi.org/10.1016/j.jclepro.2020.122080

Wadu Mesthrige, J., & Chan, H.-T. (2019). Environmental certification schemes and property values: evidence from the Hong Kong prime commercial office market. *International Journal of Strategic Property Management*, 23(2), 81-95. https://doi.org/10.3846/ijspm.2019.7434

Yau, Y., Ho, D. (2009). The effects of building management practices on residential property prices in Hong Kong. ournal of Building Appraisal, 4, 157–167.

6.2.1 Operation & Maintenance

Operation & Maintenance cost risk is estimated at up to 10% of Operation & Maintenance costs. Energy cost risk is estimated at up to 10% of energy costs.

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Research literature review has uncovered negligible research applicable to Operation and Maintenance cost risk as required by QUEST. As Operation & Maintenance is impacted by many of the same factors as Energy performance (ex. usage habits, functional quality), it was decided to develop hypotheses based on research literature on energy costs.

Leskinen, N., Vimpari, J. and Junnila, S. (2020a), "Using real estate market fundamentals to determine the correct discount rate for decentralised energy investments", Sustainable Cities and Society, Vol. 53. https://doi.org/10.1016/j.scs.2019.101953

- In the following Leskinen et. al. (2020a) review, we can read that

  "As on-site energy production decreases the underlying property's operating expenses (by cutting energy bills), the value of the property increases, as suggested by property appraisal standards (International Valuation Standards Council, 2017). According to the International Energy Agency (IEA) (International Energy Agency, 2019), the cost savings of on-site energy production could amount to 30 % on average based on savings in transmission and distribution. On-site energy production could potentially help to reduce expensive peak loads (Jurasz & Campana, 2019) and protect against rising energy prices and taxes. In addition to savings in operating expenses, many property investors may also see additional indirect economic benefits. Increased sustainability may appeal to tenants and increase the occupancy ratio or rent level and, consequently, the value of the buildings (Eichholtz, Kok, & Quigley, 2010; Fuerst, 2015; Fuerst & McAllister, 2009; Fuerst & McAllister, 2011a, 2011b)." (See Leskinen et. al. (2020a) for references.)

Leskinen, N., Vimpari, J. and Junnila, S. (2020b), "The impact of renewable on-site energy production on property values", *Journal of European Real Estate Research*, Vol. ahead-of-print No. ahead-of-print. https://doi.org/10.1108/JERER-11-2019-0041

- "There is significant financial potential in on-site energy production investments that is not yet widely acknowledged. In the presented case study, the value increase (€2.048m) in the property exceeded the investment costs (€1.56m) by over €490,000 when decreased operating expenses were capitalised into the value of the property."

6.2.2 Rental income

QMI with a strong reputational value-add may compensate for up to 50% of Rent income risk and up to 50% of Occupancy income risk.

Yau, Y., Ho, D. (2009). The effects of building management practices on residential property prices in Hong Kong. ournal of Building Appraisal, 4, 157–167. https://doi.org/10.1057/jba.2008.42

- "The analysis results indicated that properties in buildings with good documentations (eg keeping of as-built architectural drawings and incident records), thoughtful

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emergency planning (eg presence of emergency plan and regular fire drills) and property-all-risk insurance coverage were sold at a premium, ceteris paribus."

Holterman, R. and N. Kok. (2017). On the Value of Environmental Certification in the Commercial Real Estate Market. *Real Estate Economics*, https://doi.org/10.1111/1540-6229.12223

"Energy Star or LEED certified buildings command a rent premium of 2.2%."

"Energy Star rated buildings rent for 1.5% more than non-rated buildings; the rent increment for LEED certified office buildings is slightly higher, at 1.9%. In case an office building has achieved both certifications, the aggregate rent premium is 3.4%"

"Buildings with either an Energy Star or LEED certificate transact for 10.1% more as compared to non-certified buildings."

"Differentiating between the Energy Star and LEED certificate in column (6) shows that Energy Star rated buildings transact for 6.6% more, while a LEED certificate commands an 14.8% premium, on average."

Porumb, V-A., Gunther Maier, and Anghel G. I. (2020). The impact of building location on green certification price premiums: Evidence from three European countries, *Journal of Cleaner Production*, Vol: 272. https://doi.org/10.1016/j.jclepro.2020.122080

- "Empirical tests suggest that office buildings with green certification have a 19 percent higher price relative to non-certified buildings".
- In the Porumb *et. al*. (2020) article, following table summarizes their literature review that cover commercial buildings. For references, please see the Porumb *et. al*. (2020) article.

An overview of the literature on the impact of green certification for *commercial* buildings.

Study	Country	Main results
Wiley et al. (2010)	US	Rental premium is between 7 and 17 percent. The occupancy rate is 10–18 percent higher for green certified properties
Eichholtz et al. (2010)	US	Certified buildings receive around 3 percent rental premium and 16 percent price premium.
Das et al. (2011)	US	Green commercial buildings receive 2.4 percent rental premium in down-market and 0.1 percent in growing market.
Fuerst and McAllister (2011a)	US	The green buildings receive a rental premium between 4 and 5 percent and around 25–26 percent sale price premium.
Chegut et al. (2011)	UK	21 percent rental premium and 26 percent price premium for certification. The green premium decreasing with the overall number of green buildings.
Fuerst and McAllister (2011b)	UK	No significant impact of energy ratings on market value of commercial office space.
Kok and Jennen (2012)	Nederlands	Commercial green buildings are traded with a 6.5 percent discount
Reichardt et al. (2012)	US	Energy efficient commercial buildings receive an average rent premium between 2.5 and 2.9 percent. Also, positive relationship with the occupancy rate.
Eichholtz et al. (2010)	US	The green premium is 3 percent for rental rates and 8 percent for effective rents. There is a sales price premium at 13 percent.
Chegut et al. (2014)	UK	The green premium in London is 19.7 percent for rents and 14.7 percent for transactions (BREEAM certification vs non-certification).
Devine and Kok (2015)	US, Canada	Higher occupancy rate for certified buildings. Price rental premium 9–10 percent buildings class A and B vs class C. Larger buildings receive higher rents, doubling building size increases rents with 8. Rent concession 11 percent non-certified vs 7 percent certified (brand effect).
An and Pivo (2015)	US	Negative association between commercial building green certification and commercial mortgage default.
Holtermans and Kok (2017)	US	Rental premium of 2.2 percent and a price premium of 10.1 percent for certified buildings

- In the Porumb *et. al*. (2020) article, following table summarizes their literature review that cover residential buildings. For references, please see the Porumb *et. al*. (2020) article.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 846739.

An overview of the literature on the impact of green certification for *residential* buildings.

Study	Country	Main results
Gilmer (1989)	USA	Energy efficient labels shorten search times
Australian Bureau of Statistics (2008)	Australia	House price increasing 1.9 percent in 2006 for each increase in efficiency scale
Zheng et al. (2012)	China	Green buildings receive an initial sales price premium. Reselling is done with a price discount.
Caijas and Piazolo (2012)	Germany	1 percent improvement in energy efficiency increases rents with 0.08 percent and market value of the property with 0.45 percent
Kahn and Kok (2011)	USA	Green buildings obtain 9 percent price premium.
Yuan et al. (2016)	Japan	Buildings certified as green receive a price premium of approximately 5.5 percent
Amecke (2012)	Germany	There is a limited effect in acquiring decision of the energy performance certificate.
Hyland et al. (2013)	Ireland	An energy rated properties received 9,3 percent premium vs D energy rating.
Chegut et al. (2016)	Nederlands	6.3 percent premium a dwelling A label vs similar property with C label and 2 percent in comparison with homes having a B level certification.
Taltavull et al. (2017)	Romania	Average 3.5 percent price premium for apartments in retrofitted buildings

6.2.3 Occupancy rate

Income risk due to vacancies is estimated at up to 8% of year's expected rental income.

Leskinen, N., Vimpari, J. and Junnila, S. (2020c). A Review of the Impact of Green Building Certification on the Cash Flows and Values of Commercial Properties, Sustainability, 12(7). https://doi.org/10.3390/su12072729

- The reviewed studies indicated that certificates might increase the rental income and decrease the operating expenses, vacancy, and risks of a property.
- In the Leskinen *et. al*. (2020) article, following table summarizes their literature review. For references, please see the Leskinen *et. al*. (2020) article.

Table 1. The effect of green certification on the cash flow parameters and sales prices of commercial investment properties. Appendix A specifies the studies on which the figures of the table are based.

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]

6.2.4 Rental income

Income risk is estimated at up to 5% of expected rental income.

Wadu Mesthrige, J., & Chan, H.-T. (2019). Environmental certification schemes and property values: evidence from the Hong Kong prime commercial office market. *International Journal of Strategic Property Management*, 23(2), 81-95. https://doi.org/10.3846/ijspm.2019.7434

- "The rental value of office properties certified by HKBEAM, BEAM Plus and LEED is about 10.9% higher than for non-certified office buildings. More specifically, tenants/users are willing to pay a premium of 10.9% for green-certified office properties."

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 846739.

Mangialardo, A.; Micelli, E.; Saccani, F. (2018). Does sustainability affect real estate market values? Empirical evidence from the office buildings market in Milan (Italy). *Sustainability*, 11(1), 12. https://doi.org/10.3390/su11010012

- "With a higher construction cost of about 3–4% for the first two levels of LEED certification and about 5–7% for the Gold and Platinum levels, better certification show higher returns on investment and lower operating costs over the life of the property."
- "There is a significant premium price for properties certified at the highest levels (Gold and Platinum) with price differentials of 7% and 11% respectively."
- "A more in-depth investigation of certified asset absorption rates reflects market preferences for certified properties. Absorption rates are four times higher for the pre-let segment. Within six months the percentage leased is 80% for certified properties and 21% for non-certified properties."
- In the Mangialardo *et. al*. (2020) article, following table summarizes their literature review. For references, please see the Mangialardo *et. al*. (2020) article.

Table 1. Summary of investigations in the international literature about the premium price—for rent and market value—in green buildings.

Increased Market Value (%)	Rental Premium (%)	Type of Certificate	Data Origin	References	Country
Average: 10.90	Average: 6.10	LEED	Perception	[5]	USA
Average: 6.80	Average: 1.00	LEED	Perception	[28]	USA
LEED: 9.94; Energy Star: 5.76	Average: 8.93	Energy Star	Empirical data	[29]	USA
LEED: 16	LEED: 3; Energy Star: 5	Energy Star	Empirical data	[29]	USA
LEED: 35; Energy Star: 31	LEED: 6; Energy Star: 5	LEED-Energy Star	Empirical data	[29]	USA
	LEED: 17.30; Energy Star: 8.62	Energy Star	Empirical data	[23]	USA
LEED: 9; Energy Star: 9		LEED-Energy Star	Empirical data	[36]	USA
	Minimum: 4.71; maximum: 13.60	-	Empirical data	[37]	Germany
	Minimum: 3.97; maximum: 15.17	-	Empirical data	[37]	Germany
Minimum: 6.60; maximum: 15.90	Minimum: 0.41; maximum: 5.87	-	Empirical data	[37]	Switzerland
Relative to D-labelled houses: A/B: 5; C: 1.7; E: −0.7; F: −0.9; G: −6.8		-	Empirical data	[38]	UK
Average: 28		BREEAM	Empirical data	[39]	UK
Average: 10	Average: 6	BREEAM	Empirical data	[7]	UK
Relative to D-labelled houses: A: 9.3; B: 5.2; C: 1.7; E: 0; F/G: −10			Empirical data	[40]	Ireland
Relative to D-labelled houses: A: 10.2; B: 5.5; C: 2.1; E: −0.5; F: −2.3; G: −4.8			Empirical data	[41]	Netherlands
Relative to D-labelled houses: A/B: 6.4; C: 6; E: −0.7; F: −12.3; G: −19.4			Empirical data	[42]	Denmark
Average: 10%			Perception	[11]	Italy

6.2.5 Time value of annual savings

Annual quality gains are capitalized over 10 to 20 years.

QUEST interviews (2020):

- Stakeholder interviews indicate that financial investors multiply annual gains by 10 to 30 in their investment calculations.
- This finding is supported by property investment yields of about 5% which correspond to 20 year payback.
- QUEST uses the investor's investment time horizon as to indicate what factor (minimum 10 years and maximum 20 years) to apply to annual gains to calculate capitalized gains.

6.2.6 One-off quality savings

Construction savings represent up to 10% of build cost.

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Agence Qualité Construction AQC (2010): Sycodés 2010

- Cost of non-quality in total French construction industry sales is over 10% of construction industry turnover

Bauinfoconsult (2020): https://bauinfoconsult.de/presse-baukatastrophen-made-in-germany-fast-21-milliarden-euro-fehlerkosten-in-2019

- Share of error costs in total German construction industry sales in 2019 is 15.40%

6.2.7 Performance gap and transfer of operational knowledge to new projects

Rasmussen, H. L. (2020)

Some new buildings do not live up to expectations when put into operation. For example, research has revealed a gap between expected and actual energy consumption. Other important parameters, such as indoor climate, maintainability or functionality, can also be disappointing in new buildings. This has negative consequences for the activities intended within such buildings…

The PhD includes A typology of 12 performance gap types in new buildings, as seen from a facilities manager's perspective. Additionally, the thesis identifies 35 specific difficulties that facilities managers in new buildings experience.

Integrating operational knowledge in design of new buildings to improve facility performance - A comparative study of building and large ship projects.
https://doi.org/10.11581/dtu:00000083

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