FuturHist

Assessment categories and KPIs: a multidimensional approach to performance assessment

Project Overview

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Executive Summary

This report outlines the assessment categories, indicators, key performance indicators (KPIs), and decision criteria developed within the FuturHist project. It forms part of the project's broader effort to develop an integrated, typology-based approach to support the energy retrofit of historic buildings. The selected categories reflect a holistic understanding of building performance, encompassing not only energy performance and life cycle assessment, but also heritage significance, technical compatibility, financial aspects, and user-related parameters including indoor environmental quality. Each category includes a set of indicators and decision criteria and a smaller number of KPIs, selected for their relevance, measurability, and potential for cross-case comparison.

The indicators are applied across three central use cases within the project: the FuturHist planning toolkit, ex-ante assessment of whole-building retrofit strategies, and ex-post evaluation of interventions in demonstration cases. The applicability to different use cases ensures that indicators inform both planning and evaluation, strengthening the evidence base for effective, scalable, and conservation-sensitive retrofitting practices. By promoting a transparent and multidimensional approach to performance assessment, the work contributes directly to the project's objectives of enabling more systematic decision-making, supporting replicability, and addressing the unique challenges of retrofitting historic buildings.

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Disclaimer

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Abbreviations and definitions

Assessment Categories	These are thematic areas that provide a structured framework for evaluating the impact and feasibility of retrofit interventions. Assessment categories serve as broad evaluative dimensions. These categories help in structuring decision-making by ensuring that multiple dimensions are considered when assessing retrofit measures.
Archetype building	Theoretically defined building based on the typical or average census values (Berg, 2015).
Assessment method	An assessment method is a systematic and transparent way of establishing the value of an indicator.
Authenticity	Grade of preservation of original state of a property in terms of function and use, form and materials, and environment (Code wallon du Patrimoine, 2023).
Decision Criteria	Decision criteria are factors that should be taken into account when making decisions, even if they are secondary or difficult to quantify. It can be because of their interpretative nature (e.g. impact on heritage significance) or because there is no well established assessment method or metric (e.g. circularity of materials). In addition, indicators are added here that are not primarily relevant for energy retrofit goals, but can be critical for feasability or acceptance (e.g. fire safety).
Energy consumption for heating and cooling	Energy input required to satisfy the heating and cooling demand of a building. This quantity considers also efficiency and losses of systems and user behaviour (Hotmaps, 2020).
Energy demand for heating and cooling	Calculated amount of energy required to cover heating and cooling of a building (Hotmaps, 2020).
Energy retrofit	A general concept for all types of renovations where reduced energy consumption is the main goal for the renovation (Eriksson, 2021). It is used for the entire renovation process, from planning to evaluation, and is closely related to sustainable renovation (Thuvander et al., 2012). Sustainable renovation of existing buildings is a way of extending the lifespan of a building and improving its living and working conditions, which includes lowering the energy

	used for those purposes (Asdrubali and Desideri, 2018, chapter 9).
EPC	Energy Performance Certificate.
Heritage value	Aspect of importance that individuals or society assign(s) to a building (EN 16883:2017).
Historic building	Within EN 16883:2017 defined as “a building of cultural significance.” A more elaborated definition is stated by the Institute of historic building conservation that states: “Is generally considered to be a building or structure that has some kind of 'historic value', i.e. people in the present are connected to it via past events in some way. This value warrants it being afforded consideration in planning decisions that have to be made concerning it. A building may hold special historic interest because of its importance with respect to a particular historical event or period, or be associated with nationally important people. Alternatively, there might be special historic interest in the building itself, i.e. its construction methods, design, architectural significance, and so on (IHBC 2021).”
Indicators	On a generic level, indicators are used to understand the state of a phenomenon of interest. An indicator can be the result of a single measurement, the combined result of multiple measurements, or the outcome of a qualitative assessment (e.g. Likert scale assessments). Indicators serve as tools for monitoring, diagnosing issues, and supporting decision-making. Indicators can support different stages of the whole retrofit process - initial assessment, design, implementation, and performance assessment after completion.
Integrity	Grade of homogeneity and coherence of a property in terms of physical integrity of the building. This criterion evaluates the condition of the building compared to what it was at the time of its construction, from the point of view of the physical composition of the materials and the construction techniques of the building period (Code wallon du Patrimoine, 2023).
Key Performance Indicators (KPIs)	KPIs are a subset of indicators that are selected as the key ones to measure the success and effectiveness of a retrofit project or tracking the performance during the operational phase. They provide benchmarks for tracking progress toward project objectives and enable comparison across projects.
Rarity	Grade of uniqueness of a property in terms of typology, style, dating, or interest, whether social or historic (Code wallon du Patrimoine,

	2023).
Representativeness	Grade of preservation of property's architectural characteristics linked to a specific function (Code wallon du Patrimoine, 2023).
Retrofit Indicators/KPIs	These are Indicators/KPIs used to assess a retrofit intervention. Examples are the life cycle impacts of an intervention, the energy saving achieved from a retrofit or the waste generated during the process. They are often derived by comparing a use phase indicator before and after retrofit.
Target	A target is the desired level of an indicator.
Toolkit	Skills and knowledge that are useful for a particular purpose or activity, considered together (Cambridge dictionary). In the context of FuturHist a toolkit contains knowledge and guidance to support the decision-making process of implementing energy retrofits in historic buildings.
Use phase Indicators/KPIs	These are Indicators/KPIs used to assess the use phase before and after retrofit. Examples are operational energy use and thermal comfort.

1. Introduction

This report outlines the use of performance indicators in the FuturHist project. The introduction chapter gives a background to the project and an overview of previous research on the selection and use of indicators for whole building retrofit. Chapter 2 describes the methodology used in FuturHist to select and define assessment categories, indicators, key performance indicators (KPIs) and decision criteria. Chapter 3 explains the use cases within the project. Finally, selected key performance indicators and assessment methods are presented in chapter 4. Each indicator is described in more detail in the annex.

1.1.Overview of FuturHist

The FuturHist project is dedicated to addressing the challenge of energy retrofitting historic buildings while ensuring their long-term preservation and sustainability. Historic and traditionally built buildings constitute a significant portion of the European building stock and represent a key area of focus in the transition towards a low-carbon built environment. However, retrofitting these buildings is inherently complex due to their diverse construction techniques, material compositions, and heritage significance. Unlike modern structures, historic buildings require tailored solutions that balance energy efficiency improvements with the preservation of their heritage attributes.

To bridge this gap, FuturHist adopts a typology-based approach that allows for the identification and characterization of recurring building features in different regions. By defining common characteristics at the typology level, the project develops intervention strategies that can be standardized and replicated with minor adaptations, facilitating broader application across Europe. This approach enables a shift from a case-by-case assessment towards a more structured and scalable process, ensuring higher renovation rates and deeper interventions.

The project builds upon established methodologies such as the European Standard EN 16883:2017, which provides guidelines for improving the energy performance of historic buildings. FuturHist advances these efforts by integrating performance indicators, decision support systems, and innovative technical solutions, ultimately streamlining the planning process for energy retrofits. The project also emphasizes the need for holistic assessment methods, ensuring that technical interventions are compatible with the built heritage while optimizing energy efficiency, indoor environmental quality, and cost-effectiveness.

Through the development of assessment categories and indicators, FuturHist provides a structured framework for evaluating retrofit measures and monitoring their impact. The project's outcomes will support practitioners (architects, engineers, owners etc.), policymakers (planners, heritage authorities etc.), and researchers in making informed decisions about energy retrofits in historic buildings, contributing to the broader goal of scaling up the sustainable transformation of existing buildings across Europe.

1.2.Definitions

Assessment categories, indicators, key performance indicators (KPIs) and decision criteria are related concepts used for evaluating and guiding the energy retrofit of historic buildings.

Assessment Categories: These are thematic areas that provide a structured framework for evaluating the impact and feasibility of retrofit interventions. Assessment categories serve as broad evaluative dimensions. These categories help in structuring decision-making by ensuring that multiple dimensions are considered when assessing retrofit measures.

Indicators: On a generic level, indicators are used to understand the state of a phenomenon of interest. An indicator can be the result of a single measurement, the combined result of multiple measurements, or the outcome of a qualitative assessment (e.g. Likert scale assessments). Indicators serve as tools for monitoring, diagnosing issues, and supporting decision-making. Indicators can support different stages of the whole retrofit process - initial assessment, design, implementation, and performance assessment after completion.

Key Performance Indicators (KPIs): KPIs are a subset of indicators that are selected as the key ones to measure the success and effectiveness of a retrofit project or tracking the performance during the operational phase. They provide benchmarks for tracking progress toward project objectives and enable comparison across projects.

Use phase Indicators/KPIs: These are Indicators/KPIs used to assess the use phase before and after retrofit. Examples are operational energy use and thermal comfort.

Retrofit Indicators/KPIs: These are Indicators/KPIs used to assess a retrofit intervention. Examples are the life cycle impacts of an intervention, the energy saving achieved from a retrofit or the waste generated during the process. They are often derived by comparing a use phase indicator before and after retrofit.

Decision Criteria are factors that should be taken into account when making decisions, even if they are secondary or difficult to quantify. It can be because of their interpretative nature (e.g. impact on heritage significance) or because there is no well established assessment method or metric (e.g. circularity of materials). In addition, indicators are added here that are not primarily relevant for energy retrofit goals, but can be critical for feasability or acceptance (e.g. fire safety).

An **assessment method** is a systematic and transparent way of establishing the value of an indicator. A **target** is the desired level of an indicator. They ensure that interventions align with broader sustainability and efficiency goals.

The aspiration of the FuturHist project is to promote holistic assessments of retrofit projects, covering technical, environmental, financial and social dimensions. The suggested assessment categories cover potentially conflicting objectives and decisionmakers will have to balancedifferent criteria and make compromises based on the specific circumstances for each case (cf Herrera et al 2019). All the targets cannot be expected to be achieved for all projects. It is important to remember that the legal frameworks will always set minimum requirements and the client or project lead should define its own requirements.

By defining and differentiating these concepts, FuturHist establishes a structured approach for evaluating retrofit of historic buildings. Assessment categories define the key dimensions of evaluation, Indicators and KPIs provide measurable insights into specific factors and track overarching progress, ensuring a comprehensive and strategic approach to improving the energy performance of historic buildings. Decision criteria complements the indicators with qualitative or secondary factors that should be considered when making decisions. A standardized set of indicators and KPIs is useful to demonstrate the benefit of retrofits across different sustainability dimensions, as well as to identify causes for differences in performance of retrofit solutions and technologies (McGinley et al., 2022).

1.3.Purpose and scope of the report

This report defines the assessment categories, indicators, key performance indicators (KPIs) and decision criteria used in FuturHist to guide and evaluate energy retrofit strategies for historic buildings. Its purpose is to support structured and comparable assessments pre and post retrofit, including the planning toolkit, ex-ante analysis of demonstration sites, and ex-post performance monitoring.

The scope includes six assessment categories covering energy, heritage, environmental, technical, financial, and user aspects. Indicators are selected for their relevance, measurability, and applicability to both planning and evaluation phases. A limited number of KPIs are highlighted to support clear communication and cross-case comparison.

The framework is intended to support decision-making by balancing multiple objectives. Not all targets can be achieved in every case, and compromises will be necessary without risking solutions that risk unacceptable impacts on heritage or building performance - legal requirements must always be met

1.4.Role of KPIs in the overall project

The report builds on work done in previous tasks in Work package 1 related to identifying existing practice (task 1.2+1.5), understanding multi-scale barriers (task 1.1) and the policy context (task 1.3). Previous guidelines and tools have been identified in task 1.4 and has informed the state-of-the-art in the field.

The use cases in the remaining parts of the project will be described in more detail below, but this report will essentially inform the assessments performed in all remaining activities of the project, and will act as a common point of departure.

2. Methodology

2.1.Desktop study

This report draws on previous projects about energy retrofit of historic buildings, but to a large extent also on research in the neighbouring broader fields of adaptive reuse and sustainable renovation, where the use of indicators has been more widely investigated. These fields do not necessarily deal with historic buildings, but they contribute to the broader goal of making existing buildings viable in a low-carbon future. Adaptive reuse is focused on repurposing existing buildings for new functions, ensuring their continued relevance and economic viability, but not all projects have a sustainability focus. Sustainable renovation encompasses both approaches by integrating energy-efficient measures with resource-conscious upgrades, ensuring that existing buildings remain functional, resilient, and environmentally responsible. Energy retrofit of historic buildings focuses on improving the energy efficiency of buildings while maintaining their heritage significance.

A desktop study was conducted to establish a strong foundation for understanding the use of performance metrics in the energy retrofit of historic buildings. The study included a review of academic literature, previous projects, and grey literature. Google Scholar was utilized to identify the most relevant publications, using keyword searches related to energy retrofits, sustainable renovation, adaptive reuse and performance metrics. We also traced literature through citation tracking, employing both backward and forward referencing to uncover key contributions in the field.

In addition to academic sources, significant projects and initiatives were reviewed to provide a broader perspective on best practices and methodological frameworks. The most influential projects and frameworks examined include:

- Level(s) – The EU framework for sustainable buildings, which provides a common language for assessing sustainability performance across a building life cycle stages (https://environment.ec.europa.eu/topics/circular-economy/levels_en).
- Energy Performance of Buildings Directive (EPBD) – The revised EU policy explicitly including some performance indicators, such as Smart Readiness.
- EN 16883:2017 – The European standard offering guidelines for improving the energy performance of historic buildings while maintaining their heritage significance.
- Horizon 2020 Projects (CLIC and INHERIT) – CLIC (www.clicproject.eu) focuses on circular economy approaches for adaptive reuse of cultural heritage, while INHERIT (https://inheritproject.eu) explores sustainable practices for management of built heritage.

An important consideration, and an important basis for the whole FuturHist project, is the context of the European Green Deal in general and the Horizon funding call for the project in particular. For example, the Horizon call HORIZON-CL5-2023-D4-01-02[1] explicitly mentions key outcomes in terms of improved smart readiness, waste reduction, reduced maintenance costs, increased Renewable Energy Source (RES) uptake and an increased potential for replicability.

This desktop study forms the basis for the selection of assessment categories, indicators, KPIs and decision criteria in FuturHist, ensuring that the project's methodology is aligned with existing research and best practices in the field.

2.2. Workshops with FuturHist Partners

Key insights and conclusions from previous project tasks were gathered as a foundation for Task 1.6. Two online workshops were conducted with the FuturHist partners to collaboratively discuss the selection of assessment categories and performance indicators.

The first workshop utilized a virtual blackboard to explore how different performance metrics could be applied across various aspects of the FuturHist project. In the second workshop, the results from the first session were transferred to a spreadsheet, where partners worked individually to provide comments and refine indicators for different assessment categories. These inputs were then synthesized into a structured draft.

The final selection of indicators was made by a working group using feedback from all work packages in FuturHist.

2.3. Criteria for selecting Indicators

Hundreds of indicators are to be found in the previous literature related to sustainable renovation, but there is no consensus on a standardized set (Angelakoglou et al., 2023; Bosone et al., 2021; Kylili et al., 2016; McGinley et al., 2022). The most widely used indicators are related to techno-economic and environmental criteria, and indicators measuring social aspects are not as common (McGinley et al., 2022). There are plenty of guidelines available in the literature on how to select indicators in general and KPIs in particular. Focusing on a limited number of KPIs is widely recommended in the literature to ensure effective performance measurement and management.[2] To guide the selection of indicators we have used the following criteria suggested by Angelakoglou et al (2023):

Relevance – Indicators should align with the project's objectives. They must provide meaningful

[1] https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/horizon-cl5-2023-d4-01-02
[2] see e.g. www.kpi.org

insights about energy retrofit of historic buildings, avoiding ambiguous or misleading signals.

Availability – Data required for measuring an indicator should be accessible with limited effort and cost.

Measurability – Indicators must be quantifiable or, where necessary, systematically assessed using standardized methods.

Reliability – The definition and assessment method of an indicator should be clear and universally understood to prevent misinterpretation. Any factors that influence data collection, such as spatial and temporal variations, should be accounted for to maintain consistency and comparability.

Comprehensibility – Indicators should be easily interpretable to facilitate communication among diverse stakeholders, including policymakers, practitioners, and building owners. Where possible, the project will rely on existing frameworks that ensure comprehensibility without compromising technical accuracy.

In the FuturHist project there is an aspiration to streamline and simplify existing approaches, which points in the direction of a small number of KPIs to enable resource efficient monitoring, clear communication and effective assessment. On the other hand, the FuturHist project emphasizes the need for holistic assessment, indicating the need for a broad set of indicators and decision criteria that go beyond techno-economic ones. The chosen approach is to have a broad set of indicators and decision criteria, but only a few KPIs. The KPIs recommended by FuturHist are those indicators that are most relevant for tracking the progress of whole-building retrofits, while also being measurable with standardized methods and enabling cross-case comparison.

3. Use Cases and assessment categories

Indicators play a crucial role in different stages of the retrofit process, serving both ex-ante and ex-post purposes. Ex-ante indicators help guide decision-making before interventions take place by expressing the goals and expected results, while ex-post indicators are used to assess the impact of completed retrofit measures, being useful for monitoring and evaluation and adding to the evidence-base of actual results (Gravagnuolo et al., 2024). In FuturHist, KPIs are applied across multiple use cases, reflecting the diverse aspects of the project. One part of the project focuses on developing and evaluating passive and active retrofit solutions, ensuring their compatibility with historic buildings. Another part is dedicated to the FuturHist toolkit, a decision support system (DSS) that relies on ex-ante assessment to assist stakeholders in selecting appropriate renovation strategies. Finally, the project includes demonstration cases where whole-building retrofits are being implemented, requiring a comprehensive set of KPIs to monitor and evaluate performance across technical, environmental, financial and social dimensions.

van Laar et al (2024) reviewed the literature on the use of decision criteria in different stages of the adaptive reuse process, asking "What matters when?". They differentiated between the following phases:

Pre-project phase: The phase where a decision is made to initiate the planning process.

Preparation phase: The phase where different intervention options are weighed, and a decision is made on which one to implement.

Implementation phase: The phase when interventions are implemented in buildings

Post-completion phase: The phase where projects are evaluated post-completion. It also includes decision making on maintenance or conservation actions.

In their analysis, the implementation phase was discarded for analysis due to a lack of data. The major finding of van Laar et al is that there was a minimal difference in decision criteria between the remaining three phases, but the ways to measure and assess criteria varied greatly. In the preparation phase it was more common with ordinal scales (e.g. 1-5), while quantitative measurements were more common in the post-completion phase. The weight given to different criteria also varied; for example, investment risk and political support were assigned relatively more weight in the pre-project phase compared to the post-completion phase. In the pre-project and preparation phases, criteria are used to make *ex-ante decisions*, while in the post-completions phase criteria are used to make *ex-post evaluations*. A more specific finding of interest for FuturHist is that while circularity criteria were commonly reported, they did not seem to foster the implementation of circular strategies.

3.1. The FuturHist Integrated Planning Toolkit

The first use case for structured assessment in FuturHist is the development of a multidimensional decision-making methodology and an integrated decision support system (DSS), referred to as the FuturHist Toolkit. This toolkit is designed to support the planning process of historic building renovation by providing a structured, step-by-step approach for selecting and evaluating retrofit solutions. It will build on tools and methodologies from previous research projects and the knowledge developed in WP1, WP2, and WP3 to create a holistic framework for decision-making.

WP2 and WP3 will collect information about existing retrofit solutions and develop new ones, aiming to improve the energy performance, durability, and sustainability of historic buildings while ensuring conservation compatibility. WP2 concentrates on passive solutions such as internal and external insulation systems, moisture-buffering materials, and window retrofits, while WP3 focuses on active systems, including heating, ventilation, and cooling technologies adapted to historic buildings.

In the toolkit, the solutions will be applied to the typologies. Indicators will play a crucial role in this use case by guiding the assessment and validation of the implementation of the solutions in the typologies. Indicators will be used to measure performance aspects of the solutions in relation to the typologies. A structured assessment of these technologies will ensure that the solutions recommended in FuturHist meet both technical and conservation requirements and can be successfully applied in the typologies.

Indicators will play a central role in the functionality of the FuturHist Toolkit. They will be used to evaluate different renovation scenarios in the early planning phase by assessing their impact on key aspects. The toolkit will use a holistic approach that will help users to identify and combine compatible retrofit measures while considering potential interactions between solutions. The set of indicators aims to provide a transparent and systematic way to compare different options.

3.2. Ex-ante assessment of whole-building energy retrofits

The second use case for structured assessment focuses on whole-building retrofits. In FuturHist this is tested in the demonstration cases, where whole-building retrofits will be tested in case study buildings. WP5 is dedicated to testing the FuturHist approach and solutions in five demonstration cases across Europe, representing different climatic and regulatory contexts. These sites serve as practical testbeds to validate the effectiveness of the developed retrofit solutions and decision-making tools while engaging with local stakeholders to ensure the applicability and replicability of the approach.

Indicators will be instrumental in assessing the success of whole-building retrofits in the demo sites. Before interventions (ex-ante), indicators will be used to guide the renovation approach to each demonstration building. In comparison to the toolkit, there is an opportunity to perform more comprehensive and detailed assessments.

3.3. Ex-post assessment of whole-building energy retrofits

The third use case focuses on the ex-post assessment that will be used to evaluate the retrofit intervention using retrofit KPIs. The assessment will be continued into the use phase for some indicators, in order to understand the continuous performance of the buildings. These use phase KPIs will be partly based on real time monitoring of the buildings and show real time performance in a dashboard interface. The data can be used to track changes in use and/or how the technical systems of the building perform. They can also be used for comparison with other buildings. The ex-post assessment provides a structured means to compare actual performance against expected outcomes, facilitating lessons learned and refinement of the FuturHist methodology.

A set of indicators are used to understand the performance of buildings in the use phase. The indicators are based on real time monitoring of the buildings and show real time performance in a dashboard interface. The data can be used to track changes in use or in system functionality, but also for comparison with other buildings.

The three use cases in FuturHist are relevant for policy makers, heritage authorities, and practitioners, who will use indicators to validate retrofit solutions in real-world applications and inform future policies and best practices. Researchers and developers will get feedback on how theoretical models and laboratory-tested solutions perform in practice, leading to further refinement of methodologies. Building owners and facility managers will benefit from indicators to understand the performance of their buildings, and to use the information to guide renovation efforts. By applying indicators systematically in the Toolkit and in the demonstration cases, FuturHist ensures that its approach to historic building retrofits is not only innovative but also scalable and adaptable to diverse European contexts.

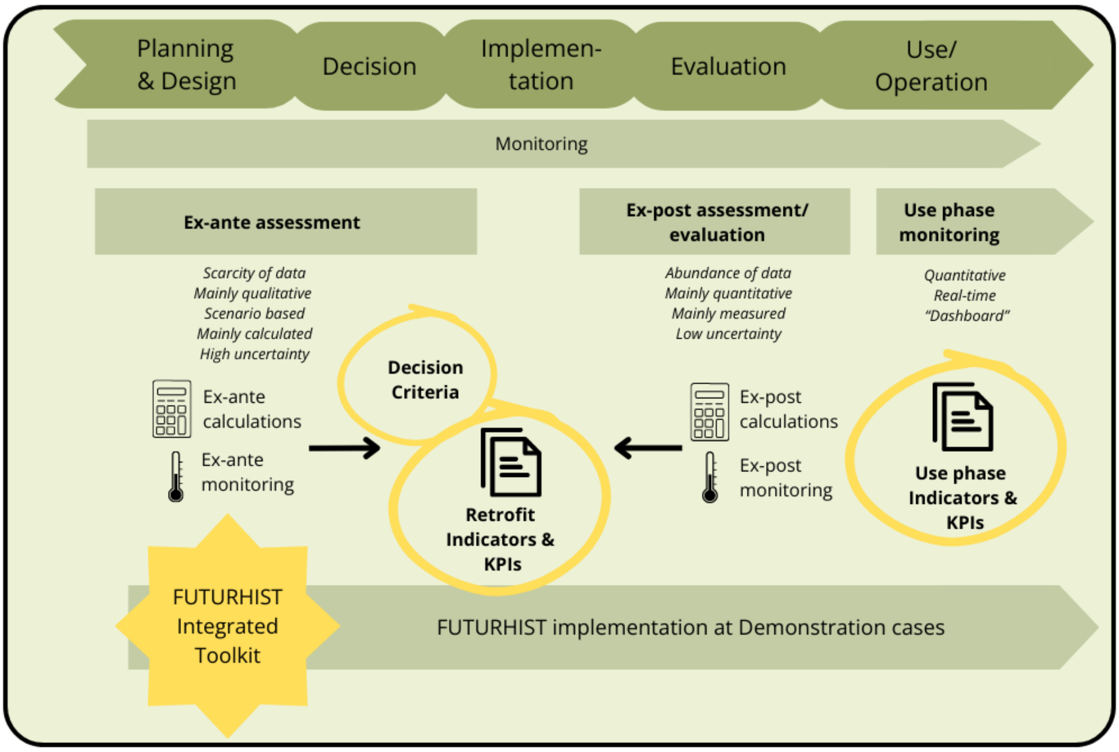

Figure 1. Use of indicators for different phases in the renovation process and in FuturHist (based on Gravagnuolo et al., 2024; van Laar et al., 2024).

3.4.Selection of Assessment Categories

Performance measurements (indicators/KPIs) can be divided into overarching assessment categories in different ways. An overview of ways of categorizing found in the literature is presented in table 1.

The FuturHist methodology takes a point of departure from the European guidelines on energy retrofit in historic buildings (EN 16883:2017) that outlines a holistic assessment framework. A slightly different wording of the assessment categories have been made to improve understanding (e.g. Impact on the outdoor environment → Life cycle assessment) and the user aspects have been integrated with indoor environmental quality to a single category. The resulting assessment categories proposed by FuturHist are:

- Energy Performance
- Heritage significance
- Life cycle assessment (LCA)
- Technical compatibility
- Financial aspects
- User aspects and Indoor Environmental Quality (IEQ)

Source	Context	Assessment category						
(Kylili et al., 2016)	Sustainable renovation	Economic	Environmental	Social	Technological	Time	Project administration	Quality
(van Laar et al., 2024)*	Adaptive reuse	Economic	Environmental	Social	Technological	Legal	Architectural/ physical	Cultural
(Angelakoglou et al., 2023)**	Sustainable renovation	Economic/ Techno-logical	Societal/ Environ-mental	Scientific				
(Bosone et al., 2021)***	Adaptive reuse	Economic	Environmental	Social	Cultural			
(McGinley et al., 2022)	Energy retrofit	Economic	Environmental	Social				
(Bartolucci et al., 2024)	Energy retrofit	Economic	Environmental	Social	Techno-logical	Political	Legislative	
CLIC (Gravagnuolo et al., 2024)	Adaptive Reuse	Economic-financial	Environmental	Social	Cultural			
INHERIT (Alonso, 2025)	Sustainable renovation	Energy Performance and IEQ	Resource efficiency, Circularity and LCC	Resilience to climate and human-made hazards	Accessibility, inclusiveness, openness and socioeconomic sustainability			
Level(s) (European Commission, 2025)	Sustainable renovation	Greenhouse gas emissions along a buildings life cycle	Resource efficient and circular material life cycles	Efficient use of water resources	Healthy and comfortable spaces	Adaption and resilience to climate change	Optimised life cycle cost and value	
EN 16883:2017 (CEN, 2017)	Energy Retrofit	Economic viability	Heritage significance	Technical compatibility	Energy	Indoor environ-mental quality	Impact on the outdoor environment	Aspects of use
FuturHist	Energy Retrofit	Energy Performance	Heritage Significance	Life Cycle Assessment (LCA)	Technical Compatibility	Financial aspects	User aspects (including IEQ)	

*Table 1. Assessment categories found in previous reviews and in recent projects/initiatives. *Categories identified for the "Preparation phase", **The categories are labeled "Key Impact Pathways". ***Categories are labeled "Sustainability Dimensions".*

4. Assessment categories, KPIs and decision criteria

The recommended KPIs are marked with green background colour.

4.1. Energy Performance

ENERGY PERFORMANCE						
Name	**Description**	**Unit**	**Assessment method**	**Target for FuturHist typologies**	**Retrofit indicator /KPI**	**Use phase indicator /KPI**
Non-renewable primary energy demand	Amount of non-renewable primary energy needed to meet the energy demand associated with a typical use of the building, which includes energy used for heating, cooling, ventilation and domestic hot water	kWh/(m^2*year)	Calculated in accordance with Annex I of the EPBD	Defined for each typology		KPI
Non-renewable primary energy savings	Difference in non-renewable primary energy demand before and after retrofit	%	Calculated in accordance with Annex I of the EPBD	60 %	KPI	
Energy consumption	Energy consumed for heating, cooling, ventilation and domestic hot water	kWh/(m^2*year)	Measured in accordance with Annex I of the EPBD	NA		x
Self-sufficiency	Share of energy demand met by on-site production	%	(Amount of energy generated and used on-site / energy demand) * 100	NA	x	x

Self-consumption	Share of total energy produced on-site used by the building itself	%	(Amount of energy generated and used on-site / total amount of energy produced on-site) * 100	NA	x	x

Other decision criteria to consider related to energy performance:

U-value of components. The U-value measures the rate of heat transfer through a building component. Lowering U-values is essential for reducing energy demand and improving thermal comfort. The average U-value is a simplified yet comprehensive measure of the overall thermal performance of a building envelope. In historic buildings it might be unacceptable to lower the U-value of components protected by heritage laws, and it is therefore important to make a comprehensive investigation if other components can be improved in order to lower the overall heat losses.

Airtightness. The extent to which unwanted air leakage occurs through the building envelope. An airtight building limits moisture movement from the interior into the envelope, reducing the risk of condensation and damage, while also minimizing heat losses from uncontrolled infiltration and unwanted convection within insulation materials. Note that airtightness differs from diffusion tightness, as it addresses air movement rather than vapor diffusion.

Efficiency of heating and cooling systems. Reflects how effectively a system converts input energy—whether electricity, gas, or another source—into usable heating or cooling for the indoor environment. High-efficiency systems reduce energy consumption, lower operating costs, and contribute to carbon emissions reductions, making them a central target in the energy retrofit of buildings. In historic buildings, system efficiency is particularly important because it can significantly improve performance without invasive changes to the historic fabric.

Efficiency of heating and cooling recovery. Measures how effectively a ventilation system can reclaim thermal energy from outgoing air and transfer it to incoming fresh air, thereby reducing the need for additional heating or cooling. High recovery efficiency leads to lower energy consumption and improved indoor air quality without compromising thermal comfort. In historic buildings, where airtightness improvements may be restricted due to preservation requirements, efficient recovery systems provide a minimally invasive strategy to enhance overall energy performance while maintaining the building's heritage value.

Variability management. Refers to a building's ability to adapt its energy demand in response to fluctuations in energy supply, playing an active role in supporting grid stability. Through strategies such as demand-side flexibility, leveraging the thermal inertia of the building, and passive control measures (e.g. natural ventilation or shading), buildings can shift or reduce energy use during peak periods without compromising comfort. This capability is increasingly valuable in energy systems with high shares of variable renewable energy. In historic buildings, where active technologies may be limited by conservation requirements, smart use of passive design and building physics can offer effective means of variability management. See also Smart readiness below.

Importance of passive measures. Passive measures are particularly important in hot climates to reduce or eliminate the need for active cooling systems like air conditioning. These measures include strategies such as improved shading, natural ventilation, reflective surfaces, thermal mass optimization, and envelope improvements that limit heat gains. In historic buildings, passive solutions are especially valuable because they can often be implemented with minimal visual or structural impact. Prioritizing passive measures not only reduces energy demand and operational costs but also enhances long-term resilience to climate change. As a criterion in retrofit planning, passive performance underscores the importance of design-first approaches before introducing energy-intensive systems.

Thermal bridges. Represent areas in the building envelope where heat transfer is significantly higher than in surrounding areas. These can occur at junctions between materials, around windows, or where insulation is interrupted, leading to increased heat loss, reduced thermal comfort, and a higher risk of condensation. Identifying and mitigating thermal bridges is essential to improving overall energy performance.

4.2.Heritage Significance

The FuturHist project deals with historic buildings – buildings that have heritage values, with or without statutory protection. An aspiration of the project is that such values should be understood and managed in the decision making process at a very early stage (pre-design stage) and the recommended retrofit interventions should balance the preservation of heritage values with other objectives. A heritage impact assessment should guide the choice of the retrofit interventions and inform their specifications. A key question for the project is therefore which decision criteria and performance measures that can be used to assess heritage values. Since the late 1990s, the evaluation of cultural heritage and the development of thematic criteria and indicators have been explored at the international level (Bosone et al., 2021). This ongoing evolution is reflected in a continuous stream of publications on the subject, underscoring the demand for structured heritage assessment frameworks (Bosone et al., 2021). However, despite the large body of literature on heritage assessment frameworks and indicators there is little agreement on which ones to use, and no research where the effectiveness of different approaches have been compared. There may be different approaches per country and the default position in the heritage sector is to consider historic building retrofit on a case-by-case basis. An overview of heritage assessment tools & frameworks is presented in the FuturHist Deliverable 1.4. In conclusion, there is a lack of evidence of the validity and reliability of approaches to quantify heritage values and use them as performance indicators. FuturHist will therefore work with heritage impact assessments as decision criteria, informing decision making at the early stage of the planning process.

FuturHist will follow the approach outlined in EN 16883:2017 to assess the impact on heritage significance of the building and its setting, differentiating between material, visual and spatial impacts. Reversibility, which in the standard is categorized under technical compatibility, is also added here as a decision criterion. This approach, focusing on impacts (or risks) has the benefit that it can be used irrespective of the nature of the heritage values that contribute to the overall heritage significance, as well as irrespective of the numerous heritage assessment practices and traditions that exist in different regions.

For buildings with statutory protection, a listed building consent (or equivalent statutory permission) is mandatory for all interventions. For buildings without statutory protection there can still be a need to take heritage significance into account. The legal frameworks on heritage protection show significant differences between EU member states, and it is therefore difficult to give generic guidance based on statutory protection. One extreme example is Sweden that has quite few protected buildings where listed building consent for interventions will be mandatory. However, the spatial planning law in Sweden states that heritage values have to be considered for all interventions to buildings, also non-protected ones. For an in-depth discussion of heritage protection policies see FuturHist Deliverable 1.3.

The FuturHist approach to deal with heritage values in non-protected buildings is to assess, for every typology, the impacts for each energy efficiency solution. This will not give a definite answer about the impact on an individual building as the local context and the specifics of the individual building are omitted, but it will be good enough for owners of non-protected historic buildings to make informed choices. It will currently address a major gap as there is little or no advice on heritage significance for owners of non-protected historic buildings.

The details of how the heritage impact assessments will be carried out will be further elaborated in WP4. There remain questions for example if there should be a quantitative scale used (as suggested in the annex of EN 16883:2017), and if there can be quantitative targets set for the typologies.

Decision criteria to be used for heritage significance:

Material impact. The extent to which the physical interventions introduced during a retrofit alter the historic building's existing fabric or its setting — and how this affects the heritage significance of the building and its settings.

Visual impact. The extent of visual alterations to the building and its setting, both internally and externally, such as changes in color, style, or the addition of new visual elements that affect its character — and how this affects the heritage significance of the building and its settings

Spatial impact. Spatial impact evaluates how the retrofit intervention alters the building's interior layout, volume, or external footprint, affecting its historic function, spatial experience, and relationship with its surroundings — and how this affect the heritage significance of the building and its settings.

Reversibility. The potential of retrofit measures (materials, components, or alterations) to be removed, dismantled, or reversed without causing physical damage to the historic building's structure, finishes, or setting. Note: inappropriate retrofit interventions that would undermine the heritage significance of the building, even if they are reversible, should be discarded.

Taking back the terminology used in the definition of FuturHist's typologies (see Deliverable 1.2), these are all impacts that will influence the *authenticity* and *integrity* of a building. Whereas archetypes have been defined based on their *representativeness*, the vulnerability to different kinds of impacts will depend also on the *rarity* of the case.

4.3.Life cycle assessment (LCA)

LIFE CYCLE ASSESSMENT (LCA)						
Name	**Description**	**Unit**	**Assessment method**	**Target**	**Retrofit indicator/ KPI**	**Use phase indicator/ KPI**
Operational GHG emissions	Greenhouse gas emissions associated with the energy consumption of the technical building systems during the use and operation of the building	kg CO_2eq/ (m²*year)	Primary energy demand * carbon intensity of energy source	Defined for each typology	KPI	KPI
Global Warming Potential	Life cycle global warming potential / whole life carbon. CO_2 equivalent impact over 50 years from the phases A1-A3 product, A4-A5 construction process, B1-B7 Use & C1-C4 End of Life	kg CO_2eq/ m²	EN15804/EN15978	NA	x	
Embodied GHG emissions	Additional emissions from the energy retrofit measures	kg CO_2eq/ m²/year	Level(s)	Should not exceed the savings in operational carbon emissions	x	
Total waste generated	Total waste generated from all retrofit activities	kg/m²	Level(s). (i.e. tracked on-site via waste management logs.)	NA (No baseline identified)	x	

Other decision criteria to consider related to LCA:

Natural resource use. Materials and constructions should be chosen that lower natural resource use, reducing the demand on finite materials and energy. Examples are the reuse of salvaged materials like original timber beams or bricks for repairs to minimize new resource extraction, and the selection of renewable insulation materials to lower embodied resource impacts compared to non-renewable alternatives.

Circularity of materials. Solutions should be chosen that enhance the circularity of materials, promoting reuse and recyclability to extend the lifecycle of resources used for the retrofit. Examples are the incorporation of modular, demountable insulation panels that can be dismantled and reused elsewhere, the prioritization of reclaimed stone or timber from local salvage yards for repairs instead of new quarried materials, and the selection of recyclable metal fittings for heating systems that can be repurposed at end-of-life. These strategies foster a circular economy approach, minimizing waste and environmental impact over the whole life cycle.

Biodiversity impact. Solutions should be chosen that minimize biodiversity impact when materials are extracted and as well as on the intervention site. Examples are the selection of retrofit materials sourced sustainably to reduce habitat destruction, the avoidance of external cladding or extensions that disrupt nesting sites for bats or birds common in historic structures, and the use of green roofs with native plants where feasible to enhance local flora and fauna without altering the building’s silhouette.

4.4.Technical compatibility

TECHNICAL COMPATIBILITY						
Name	**Description**	**Unit**	**Assessment method**	**Target**	**Retrofit indicator/ KPI**	**Use phase indicator/ KPI**
Smart Readiness	The building's capacity to interact with its occupants and energy systems efficiently.	Smart Readiness Index	Smart Readiness Index as defined in the EPBD.	Class C	KPI	KPI
Mould risk	The likelihood of mould growth due to temperature and humidity conditions.	Mould Growth Index 0-6	Hygrothermal assessment of the building envelope based on measured or calculated values.	0 (no risk)	x	

Other decision criteria to consider related to Technical compatibility:

Fire resistance. Fires are a major long-term risk to historic buildings. Solutions should therefore be chosen that improve fire resistance. Examples are the use of materials with high fire resistance, the installation of fire-rated partitions to contain potential spread without altering spatial layouts, and the upgrading of electrical systems.

Structural risk. Solutions should be chosen that reduce structural risk, ensuring the historic building's stability and longevity post-retrofit without undue alteration to its original design. Examples are the reinforcement of weakened timber joists with reversible steel brackets rather than full replacement to maintain structural integrity and designing insulation systems that do not increase the load on existing walls.

Freeze-thaw risk. The potential for moisture in porous materials to freeze and cause damage. Moisture trapped within porous building materials—such as brick, stone, or lime-based mortars—can freeze, expand, and cause physical degradation over time. Retrofit measures that alter the moisture dynamics of a building envelope, such as added insulation or changes in vapor permeability, may unintentionally increase this risk. Therefore, assessing freeze-thaw vulnerability is critical to ensuring the long-term durability of historic fabric. It requires careful consideration of hygrothermal performance, local climate conditions, and material properties.

Resilience to climate change impacts. Solutions should be chosen that enhance resilience to climate change impacts, safeguarding the historic building and its residents against a range of escalating environmental hazards. These hazards include rising temperatures and heatwaves that strain thermal regulation, increased precipitation and flooding that threaten structural stability and moisture ingress, stronger storms and high winds that challenge roof and facade integrity, and prolonged droughts that affect material durability and water availability.

Constructability. Evaluates how seamlessly and efficiently a proposed intervention can be implemented within the existing building structure. It encompasses several key factors related to technical compatibility such as installation complexity, required labor and expertise, and potential disruptions the use of the building. A retrofit measure with good constructability should allow for straightforward installation without extensive modifications to the existing structure, minimizing risks due to misalignment, or unintended performance trade-offs. Additionally, it considers accessibility constraints, such as whether the building's layout allows for easy transportation and assembly of retrofit components. Poor constructability can lead to extended project timelines, cost overruns, and increased uncertainty, making it a critical factor in selecting retrofit solutions that are not only effective in theory but also feasible in real-world implementation.

Availability. The availability of materials and/or ability of the supply chain to deliver the retrofit interventions (e.g. workforce trained on how to install specific products and willingness to install them).

Precautionary principle. The precautionary principle should be a fundamental decision criterion in the energy retrofit of historic buildings, ensuring that interventions do not risk a long-term negative impact. Given the irreversible nature of many retrofit measures, decisions must be guided by a risk-averse approach, prioritizing methods that allow for reversibility, adaptability, and minimal intervention. This principle is crucial when assessing new solutions with uncertainties related to moisture dynamics, material compatibility, and long-term performance, as energy efficiency measures can lead to unintended consequences such as structural deterioration, moisture problems, or loss of historic fabric. By applying the precautionary principle, decision-makers can balance energy efficiency goals with heritage conservation, favoring solutions that have been thoroughly tested on traditional constructions, or can be assessed with low remining uncertainties. In cases where risks are uncertain or not fully understood, the default approach should be to err on the side of caution, opting for incremental, reversible, and well-documented interventions rather than potentially damaging modifications.

4.5.Financial aspects

FINANCIAL ASPECTS						
Name	**Description**	**Unit**	**Assessment method**	**Target**	**Retrofit indicator/ KPI**	**Use phase indicator/ KPI**
Life cycle cost (LCC)	Life cycle cost for an intervention. Calculated for a period of 50 years.	Monetary unit/ m²	Calculated based on national data sets.	Reduction of 20 % compared to the baseline defined for each typology	KPI	
Operational energy cost	Energy costs for the building energy demand per year. Includes all expenses related to the use of various energy sources	Monetary unit/ (m²*year)	Calculated or measured based on local cost of energy	Defined for each typology	x	x
Investment cost	Investment cost of energy retrofit	Monetary unit/ m²	Calculated based on national data sets.	NA	x	
Energy poverty	Energy poverty occurs when a household must reduce its energy consumption to a degree that negatively impacts the inhabitants' health and wellbeing. Here defined as operational energy costs as a proportion of total household expenditure	%	Calculated based on available socio-economic data	NA	x	x

Other decision criteria to consider related to financial aspects:

Revenue. Change in revenue, or yield, can serve as an important decision criterion, particularly when the building is used for commercial purposes. Potential changes in income—whether through increased rental value, improved occupancy rates, or enhanced visitor appeal—can significantly influence the feasibility and attractiveness of retrofit options. For example, improved thermal comfort or reduced energy bills may justify higher rents or attract more stable tenants, thereby increasing yield over time. Conversely, interventions that compromise the heritage significance may reduce appeal or conflict with heritage-based branding, potentially lowering revenue. Although change in revenue may be difficult to predict with precision, especially in heritage contexts, it remains a critical criterion to consider alongside other factors when assessing retrofit strategies.

Funding. Potential for funding is often a key decision criterion in the energy retrofit of historic buildings, as it can greatly affect the financial viability of the whole project. Access to grants, subsidies, or heritage-specific funding streams can enable more ambitious or conservation-sensitive retrofit solutions that might otherwise be economically unviable. This is especially relevant in historic contexts where balancing energy efficiency with preservation often entails higher costs. The availability of funding can also influence timing and phasing decisions, or incentivize collaboration between stakeholders. Funding potential might play a strategic role in decision-making and can tip the balance between different retrofit scenarios, particularly when budgets are constrained.

4.6.User aspects (including Indoor Environmental Quality)

USER ASPECTS (including Indoor Environmental Quality)						
Name	**Description**	**Unit**	**Assessment method**	**Target**	**Retrofit indicator/ KPI**	**Use phase indicator/ KPI**
Thermal comfort	Share of time when T&RH are within acceptable levels during occupancy hours	%	Calculated for ex-ante assessment, measured for ex-post assessment and use phase	Defined for each typology	KPI	KPI
CO_2 Levels	Share of time when the concentration of indoor CO_2 are within acceptable levels during occupancy hours	%	Measured	95 %		x
PM and TVOC	Share of time when the concentration of indoor particulate matter (PM) and total volatile organic compounds (TVOC) are within acceptable levels during occupancy hours	%	Measured	95 %		x

Other decision criteria to consider related to User aspects:

Acoustic and visual comfort. Solutions should be chosen that improve acoustic and visual comfort while respecting the building's historic character and functionality post-retrofit. Examples are the installation of secondary glazing to reduce external noise infiltration while preserving original window aesthetics, the use of soft furnishings like curtains or rugs to dampen internal sound reverberation without altering spatial integrity, and the addition of discreet, adjustable lighting to enhance visibility and highlight architectural features without invasive rewiring. These measures ensure a balance between modern comfort and the preservation of the building.

Draft and cold surfaces. Draft (unwanted air currents) and cold surfaces are common in historic buildings due to their traditional construction and have to be considered in decision making. Blower door tests in combination with tracer smoke tests can aid in indicating the location and extent of drafts. Thermal imaging or temperature measurements then identify areas with cold surfaces.

Occupant relocation. Decisions should consider the occupant relocation impact, reducing disruption to residents' lives while enabling efficient retrofit works, especially in multi-family residential buildings. Examples are the use of phased retrofit schedules to upgrade one section at a time, allowing residents to remain in unaffected areas, the deployment of external scaffolding and weather-tight enclosures to facilitate envelope improvements (e.g., insulation, glazing) without interior access, and the prefabrication of modular components off-site to shorten on-site work duration.

Accessibility aspects. Solutions should be chosen that enhance accessibility aspects, improving usability for all residents, including those with mobility or sensory impairments, while respecting the historic building's character post-retrofit. Examples are the installation of discreet ramps with materials matching the original stone or brick to provide step-free entry without clashing with the facade, the addition of tactile floor indicators or contrasting colors in communal areas to aid visually impaired residents while blending with historic aesthetics, and the retrofitting of wider doorways using reversible framing techniques to maintain original spatial layouts.

Impact on functionality. Solutions should be chosen that maintain or improve the functionality of the building, preserving or enhancing the building's practical use for residents during and after the retrofit process. Examples are the strategic placement of new heating or ventilation systems in underutilized spaces like basements to avoid disrupting living areas, and zoning of thermal comfort to accommodate new functionalities.

Potential for reuse. If it is possible, solutions should be chosen that maximize potential for reuse, ensuring the historic building can accommodate diverse future uses such as commercial, cultural, or mixed residential. Examples are the preservation of open, flexible floor plans by avoiding permanent subdivisions, allowing spaces to transition from apartments to offices or galleries, the reinforcement of structural capacity with reversible techniques to support varied occupancy loads without compromising original design, and the installation of adaptable utility infrastructure to suit different tenant needs.

Digitization. Digitization is an increasingly relevant decision criterion in the energy retrofit of historic buildings, offering both practical and strategic benefits. The integration of digital tools—such as 3D scanning, building information modeling (BIM), or digital twins - can enhance planning, coordination, and long-term maintenance of retrofit interventions. Digitization also supports accurate documentation, reversibility, and transparency. Digitization is partly covered by the smart readiness indicator.

5. Conclusions and next steps

This report presents a structured framework for the assessment of energy retrofit measures in historic buildings, focusing on the identification and definition of assessment categories, indicators, and key performance indicators (KPIs). Building on established standards, prior research, and collaborative input from project partners, this work aims to strike a balance between a streamlined/simplified approach and the comprehensive assessment required to support holistic sustainability goals. By introducing a typology-based approach and differentiating between KPIs, indicators and decision criteria, the methodology supports a scalable evaluation process, applicable across the FuturHist use cases.

The approach emphasizes multidimensional assessment across six core categories: energy performance, heritage significance, life cycle assessment (LCA), technical compatibility, financial aspects, and user aspects including indoor environmental quality. While the development of a streamlined set of KPIs aims to enhance comparability and facilitate decision-making, it is acknowledged that this process involves necessary simplifications. Consequently, a disclaimer is warranted: all outputs from Task 1.6, including the selection and definition of KPIs, should be regarded as provisional and may be subject to adjustment based on ongoing work in other work packages. As the project progresses, further input from demonstration case assessments, technical developments, and stakeholder feedback may necessitate refinement of the performance indicators or assessment methods.

Caution must be exercised in the application and interpretation of the proposed performance indicators. While indicators can serve as powerful tools for structuring evaluation and guiding decision-making, there are inherent risks if they are defined too narrowly or applied without sufficient contextual understanding. For example, assessing the efficiency of a single measure - such as wall insulation - in isolation from the overall building design may result in misleading conclusions. Similarly, applying airtightness as a universal target without regard to the building’s construction or ventilation strategy may prompt inappropriate interventions, resulting in moisture problems. Some metrics may also be difficult to calculate meaningfully in practice due to data limitations or methodological uncertainty. As such, the selection and use of each indicator must be informed by professional judgment and adapted to the specific context of the building and retrofit scenario.

It is important to acknowledge the risk of sub-optimization when applying performance indicators and targets across multiple assessment categories. While the use of indicators supports comparability and structured decision-making, all targets cannot realistically be achieved in every project. Retrofit planning for historic buildings inherently involves trade-offs between competing objectives – mainly about balancing energy efficiency and heritage preservation within given budget constraints. Compromises are needed, and decision makers have to identify the most appropriate solutions for each individual building. This requires careful balancing rather than a purely target-driven approach. At the same time, it is crucial to avoid solutions that are clearly inappropriate or would result in unacceptable damage to heritage values or long-term functionality. All interventions must of course comply with relevant legal requirements, including building codes and heritage protection laws, which set the non-negotiable baseline for any retrofit activity.

Future work in the FuturHist project will focus on operationalizing and testing the proposed framework in the contexts of the planning toolkit and demonstration cases. Special attention will be given to the practical feasibility and interpretability of indicators in real-world settings, with the goal of producing an evidence-based, user-friendly framework that supports robust and replicable retrofit decision-making. Ultimately, this work aims to contribute to the development of a common platform and methodology for assessing retrofit interventions in historic buildings - one that is both rigorous and sensitive to the challenges of the heritage context.

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7. Annexes

7.1.Energy Performance Indicators/KPIs

KPI name	Non-renewable primary energy demand	
Unit	kWh/ m²/year	
Description	Amount of non-renewable primary energy needed to meet the energy demand associated with a typical use of the building, which includes energy used for heating, cooling, ventilation and domestic hot water. The indicator measures the energy performance of a building, on the basis of the calculated energy that is consumed. The primary energy use is calculated based on the quantities of energy carriers required and the primary energy factors associated with each energy carrier. The primary energy factors may be based on national or regional annual weighted averages or a specific value for on-site production. At the design stage, the starting point is to calculate energy needs which, after accounting for the efficiency of the relevant technical building system inside the assessment boundary, are converted into the required quantity of delivered energy. Then it is a case of defining the energy carrier that is delivered to the system and multiplying by the primary energy factor, which accounts for any losses and inefficiencies outside of the assessment boundary.	
Target	Defined by each typology	
Assessment method	Ex-ante	In accordance with Annex I of the EPBD
	Ex-post	In accordance with Annex I of the EPBD
	Use-phase	In accordance with Annex I of the EPBD
Sources	Level(s) indicator 1.1. EN ISO 5200 series.	

KPI name	Non-renewable primary energy savings
Unit	%
Description	Difference in non-renewable primary energy demand before and after retrofit

Target	60 %	
Assessment method	Ex-ante	TBD
	Ex-post	TBD
	Use-phase	NA
Sources	Level(s) indicator 1.1. EN ISO 5200 series.	

Indicator name	Energy consumption	
Unit	kWh/ m^2/year	
Description	Energy consumed for heating, cooling, ventilation and domestic hot water. This is the actual measured consumption and it will vary with the use of the building.	
Target	No	
Assessment method	Ex-ante	NA
	Ex-post	NA
	Use-phase	Measured either by monitoring on site or by utility/fuel bills
Sources	Level(s) indicator 1.1. EN ISO 5200 series.	

Indicator name	Self-sufficiency	
Unit	%	
Description	Energy produced on-site or in the vicinity of the building can be used for the building's energy demand. This indicator measures the share of the building's energy demand met by on-site production.	
Target	No	
Assessme	Ex-ante	Calculated

nt method	Ex-post	Calculated
	Use-phase	Measured by on site monitoring
Sources		

Indicator name	Self-consumption	
Unit	%	
Description	Share of total energy produced on-site used by the building itself	
Target	No	
Assessment method	Ex-ante	Calculated
	Ex-post	Calculated
	Use-phase	Measured by on site monitoring
Sources		

7.2. Life cycle assessment (LCA) Indicators/KPIs

KPI name	Operational GHG emissions	
Unit	kg CO_2e/m²/year	
Description	Greenhouse gas emissions associated with the energy consumption of the technical building systems during the use and operation of the building.	
Target	Defined for each typology	
Assessment method	Ex-ante	Primary energy demand * carbon intensity of energy source

	Ex-post	Primary energy demand * carbon intensity of energy source
	Use-phase	Primary energy demand * carbon intensity of energy source. The primary energy demand will be calculated based on measured consumption.
Sources	EN15804/EN15978, Level(s) 1.2	

Indicator name	Global Warming Potential	
Unit	kg CO_2e/m²/50 years	
Description	Life cycle global warming potential / whole life carbon. CO2e impact over 50 years from the phases A1-A3 product, A4-A5 construction process, B1-B7 Use & C1-C4 End of Life	
Target	No	
Assessment method	Ex-ante	EN15804/EN15978
	Ex-post	EN15804/EN15978
	Use-phase	N/A
Sources	EN15804/EN15978	

Indicator name	Embodied GHG emissions
Unit	kg CO_2e/m²
Description	Additional embodied GHG emissions refer to the extra greenhouse gas emissions, expressed as kg CO2/m², arising from the materials, products, and processes introduced during energy retrofit measures. These emissions are distinct from operational emissions and cover the production, transport, installation, maintenance, replacement, and disposal of retrofit elements aimed at improving energy efficiency. Quantifies the carbon footprint of energy retrofit measures, revealing trade-offs between upfront emissions (e.g., from manufacturing insulation) and long-term operational savings (e.g., reduced heating emissions).

Target	No	
Assessment method	Ex-ante	EN15804/EN15978
	Ex-post	EN15804/EN15978
	Use-phase	N/A
Sources	EN15804/EN15978	

Indicator name	Total waste generated	
Unit	kg/m²	
Description	Total waste generated from all retrofit activities. This indicator will vary with the extent of the retrofit. It also does not differentiate between different kinds of waste.	
Target	No (A baseline has not been established despite attempts in task 1.5)	
Assessment method	Ex-ante	NA
	Ex-post	Level(s). (i.e. tracked on-site via waste management logs.)
	Use-phase	NA
Sources	Level(s)	

7.3.Technical compatibility Indicators/KPIs

KPI name	Smart Readiness
Unit	Smart Readiness Indicator (SRI)
Description	The building's capacity to interact with its occupants and energy systems efficiently, including nine technical domains, namely 1) Heating, 2) Domestic hot water (DHW), 3) Cooling, 4) Ventilation, 5) Lighting, 6) Dynamic building envelope, 7) Electricity, 8) Electric vehicle charging and 9) Monitoring and control.

Target	Class C	
Assessment method	Ex-ante	Smart Readiness Index as defined in the EPBD, using the simplified checklist method. Tool TBD
	Ex-post	Smart Readiness Index as defined in the EPBD, using the simplified checklist method. Tool TBD
	Use-phase	Smart Readiness Index as defined in the EPBD, using the simplified checklist method. Tool TBD
Sources	https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/smart-readiness-indicator_en	

Indicator name	Mould risk	
Unit	Mould Growth Index (0-6)	
Description	The likelihood of mould growth due to temperature and humidity conditions. This indicator is also a proxy for other humidity related damages in building components due to high relative humidity/condensation on surfaces or within constructions.	
Target	0 (= no risk for mould growth)	
Assessment method	Ex-ante	Hygrothermal assessment based on calculated values
	Ex-post	Verification of calculated moisture levels with monitoring of building components where appropriate.
	Use-phase	NA
Sources	https://wufi.de/en/2017/03/31/wufi-mould-index-vtt/	

7.4. Financial aspects Indicators/KPIs

KPI name	Life cycle cost (LCC)
Unit	Monetary unit/m²/50 years Average discounted cost per m²/year over 50 years (based on Net Present Value

Description	Life Cycle Costing (LCC) for a building renovation quantifies the total costs associated with the renovation project over its entire life cycle, from planning and execution through operation, maintenance, and eventual end-of-life. It captures both initial investment costs and long-term expenses tied to energy use, upkeep, and replacement of renovated elements, expressed in monetary terms. LCC also includes revenues associated with the intervention. It is calculated based on: Acquisition Non-recurring cost Maintenance (relevant for HVAC) Replacement (occurs when the building part is replaced again, retrofitted parts will also need replacement) Management (relevant for HVAC) Supply (heating, water, electricity etc.) Recurring income (rent, etc) Non-recurring income (grants, sale of property etc)	
Target	Reduction of 20 % compared to the baseline established for each typology	
Assessment method	Ex-ante	Calculated based on national data sets.
	Ex-post	Calculated based on national data sets.
	Use-phase	NA
Sources	EN 16627:2015, Level(s) 6.1	

Indicator name	**Operational energy cost**	
Unit	Euros/ m² /year	
Description	Represents the total costs associated with a building's energy services, encompassing energy consumption, operation, and maintenance. It includes all expenses related to the use of various energy sources.	
Target	Defined for each typology	
Assessment method	Ex-ante	Calculated by multiplying the energy demand for each fuel type (e.g., electricity, gas) by the corresponding cost per unit of that fuel, and estimating costs for operation and maintenance.
	Ex-post	Measured
	Use-phase	Measured
Sources	EN 16627:2015	

Indicator name	**Investment cost**	
Unit	Euros/ m²	
Description	The total upfront cost incurred for purchasing, installing, and commissioning energy efficiency measures or renewable energy systems as part of a retrofit project. Typically includes: • Design & Planning Costs • Equipment and Materials • Installation & Labor Costs • Project Management & Administration • Commissioning & Testing	
Target	No.	
Assessment method	Ex-ante	Calculated based on national data sets
	Ex-post	Measured
	Use-phase	NA
Sources	EN 16627:2015	

Indicator name	**Energy poverty**	
Unit	Euros/ m²	
Description	Energy poverty occurs when a household must reduce its energy consumption to a degree that negatively impacts the inhabitants' health and wellbeing. It is here defined as the operational energy cost as a proportion of total household expenditure.	
Target	No.	
Assessment method	Ex-ante	Calculated based on available socio-economic data
	Ex-post	Calculated based on available socio-economic data
	Use-phase	Calculated based on available socio-economic data
Sources	Semple et al 2024	

7.5. User aspects and IAQ Indicators/KPIs

KPI name	Thermal comfort	
Unit	%	
Description	Share of time when T&RH are within acceptable levels during occupancy hours, defined as Category III of EN 16798-1:2019 (moderate level of expectation).	
Target	Defined for each typology	
Assessment method	Ex-ante	Calculated
	Ex-post	Measured
	Use-phase	Measured
Sources	EN 16798-1:2019	

Indicator name	CO_2 level	
Unit	%	
Description	Share of time during occupancy hours that the concentration of indoor CO2 is within acceptable levels, defined here by the values given by EN 16798-1:2019 Category II (<550 ppm above outdoor levels).	
Target	95 %	
Assessment method	Ex-ante	NA
	Ex-post	NA
	Use-phase	Measured
Sources	EN 16798-1:2019	

Indicator name	**PM and TVOC**	
Unit	%	
Description	Share of time when the concentration of indoor (PM) and total volatile organic compounds (TVOC) are within acceptable levels during occupancy hours. Acceptable levels are here defined as values below: PM10 45 μg/m³ PM2.5 15 μg/m³ TVOC 1000 μg/m³	
Target	95 %	
Assessment method	Ex-ante	NA
	Ex-post	NA
	Use-phase	Measured
Sources	WHO guidelines	

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PROJECT COORDINATOR eurac research

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