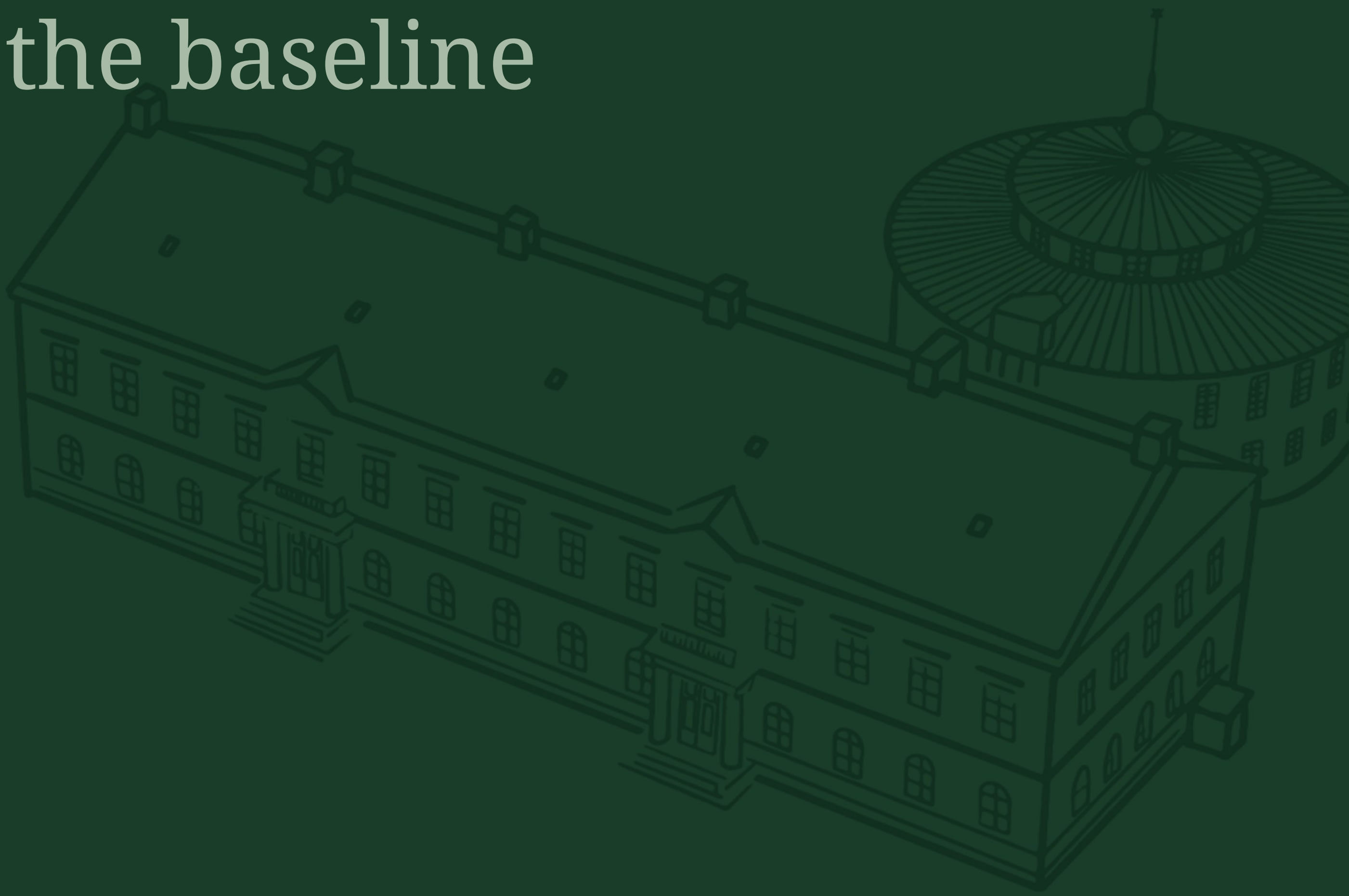
FuturHist

Current practice of renovation: Quantifying the baseline



Project Overview

Principal Authors

Kinga Racoń-Leja, Krzysztof Barnaś, Marzena Nowak-Ocłoń (Politechnika Krakowska)

Contributing Authors

Filip Suchoń, Judyta Rduch (Politechnika Krakowska), Petra Eriksson, Gustaf Leijonhufvud (Uppsala University), Yasser Battikha, Yann Grandgirard (Edinburgh World Heritage), Daniel Herrera-Avellanosa (Eurac Research), Marta Romero (Agencia de Vivienda y Rehabilitación de Andalucía), Barbara Vogt, Keith Boxer (White Arkitekter), Tomasz Jeleński (TSF).

Internal reviewers

Gustaf Leijonhufvud (Uppsala University), Barbara Vogt, Keith Boxer (White Arkitekter)

Date of submission:

30/12/2024

Project title

FuturHist – An integrated typology-based approach to guide the future development of European historic buildings towards a clean energy transition

Grant Agreement 101138562 (Horizon Europe)
Grant Agreement 10105114 and 10110887 (UKRI)
Work package WP1
Deliverable number D1.5
Dissemination level Public
Version 1.1

Version	Date	Lead Beneficiary (Revision comments log)
1.0	30/10/2024	PK (First draft)
1.1	20/12/2024	PK (First version after internal review)
1.2	30/12/2024	PK (Submitted version after second internal review)

Co-funded by the European Union

UK Research and Innovation

Co-funded by the European Union and the UK Research and Innovation. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or European Climate, Infrastructure and Environment Executive Agency. Neither the European Union nor the granting authority can be held responsible for them.

Executive Summary

FuturHist has set out to explore means of enhancing conservation and renovation practice. This document presents the findings of our inquiry, intended to gauge key metrics associated with this practice so that they may be improved upon.

The survey presents the results of a study on how historic buildings are currently being retrofitted and how to determine their performance in terms of energy and comfort. The study addresses issues of construction, and the amount of waste generated, as well as the use phase of buildings in terms of cost efficiency and maintenance. In this report we present our findings concerning current conservation and renovation practice as found in four European countries (Poland, Spain, Sweden and the UK).

We have based our conclusions on a review of the literature, performing structured interviews with renovation project stakeholders as a part of greater project-wide efforts, and examined multiple cases of renovation and energy retrofit projects that targeted historic buildings specifically in each country.

Acknowledgement

The work described in this document has received funding from Horizon Europe Funding Programme under Grant Agreement Nº 101138562 and from UK Research and Innovation (UKRI) under the UK government's Horizon Europe funding guarantee (Grant numbers 10105114 and 10110887).

Disclaimer

Table of Contents

Contents

Abbreviations and definitions

EE	Energy Efficiency
Energy retrofit	All types of renovations where increased energy efficiency is a major goal. It refers to the entire renovation process, from planning to evaluation.
EP	Energy Performance
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certificate
Final energy	Energy consumed by an end user to heat and cool a building, run lights, devices, and appliances, and to power vehicles, machines and factories.
GHG	Greenhouse Gas
HB	Historic Building
Historic building	Building of heritage significance. Includes also buildings that are not statutorily designated as cultural heritage (i.e., “listed buildings”).
IAQ	Indoor Air Quality
IEA SHC	International Energy Agency Solar Heating and Cooling Programme
IEQ	Indoor Environmental Quality
KPI	Key Performance Indicator
LCA	Life Cycle Analysis
Planning process	The process of identifying the need for energy performance improvements and defining appropriate improvement measures that match the requirements for the building in question. It would cover all the steps of the proposed procedure of EN 16883 (from the client's intentions to the final decision), but not the implementation, monitoring or maintenance of the intervention afterwards.
Policy	Rules, regulations, guidelines, or official statements adopted by governments, organizations, or institutions to influence behavior, manage resources, or achieve specific objectives.

Primary energy	Energy harvested directly from natural sources.
RES	Renewable Energy Sources are sources of energy that is replenished on a human timescale.
RES share	Percentage Share of Renewable Energy Sources within a building’s energy balance.
SRI	Smart Readiness Indicator, an indicator that measures building’s capacity to use smart-ready services, key enablers of the decarbonization of the building sector, and a Commission initiative under the Energy Performance of Buildings Directive.
VOC	Volatile Organic Compounds

1. Introduction

This chapter describes the findings of research into contemporary practice in retrofitting historic buildings. It stays in line and supplements the parallel research regrding investigation of the range of barriers (Task 1.1), policies (Task 1.3), tools (Task 1.4) and will feed into determining project KPIs (Task 1.6).

The body of research presented here investigates opportunities for actions leading to improved energy efficiency in historic buildings in compliance with the building stock recognized in terms of primary and secondary typologies (Task 1.2) — enabling the scalability of the results developed within the FuturHist project.

The findings are applicable to a wide audience, including practitioners, public authorities, professional and private owners.

2. Methods and Materials

2.1 Methodology

A literature study was combined with the analysis of data from renovation projects which was collected using standardized datasheets and structured interviews with practitioners, public authorities, professional owners and private owners in the four countries.

Legislation analysis (Task 1.3) provided a framework and an understanding of how it influences a range of actions, implemented through guidelines and tools. Ultimately, the findings of all Tasks will inform the assessment of categories used in FuturHist and Key Performance Indicators developed in Task 1.6.

This report provides an overview of the current practice of renovation as viewed through the lens of the resultant energy efficiency levels, construction waste produced, and cost effectiveness. It also explores key performance indicators (KPIs) used in renovation projects and the degree to which the Smart Readiness Indicator (SRI) is utilized.

The following research questions were addressed in this report:

1. What are the national- and professional-level guidelines and practices for each of the investigated areas?
2. What is the uptake of these guidelines in actual renovation projects?
3. What was the energy efficiency attained by typical energy retrofit and renovation projects?
4. What was the indoor air quality and indoor environment quality achieved?
5. How much construction waste was generated throughout the course of such projects?
6. What was the cost-effectiveness of these projects and how was it measured?
7. What were the key project indicators that informed the renovations?
8. What was the smart readiness indicator attained as a result the renovations?

To assess the current practice of renovation for the purposes of the FuturHist project, we based our methodology on three main elements:

- a literature study of relevant legal acts, guidelines, standards and academic literature, including the findings of past projects: RIBuild, 3enCult, EFFESUS, Gotland UBEM, hBATec, HIBERatlas, Niddrie Road Enerphit, the European Building Stock Observatory and CO^{2}OLbricks;
- a survey of renovation project cases, with data collected in the form of standardized

datasheets;

- structured interviews with renovation project stakeholders: Private Owners of HBs, Professional Owners of HBs, Practitioners, and Public Authorities.

The literature study was aimed at determining the context in which renovation projects are executed. This included relevant legal acts and national standards, academic literature, and institutional and professional guidelines and tools. The intent behind capturing this context was to set it against the experiences and approaches of project stakeholders, as well as with actual renovation project cases, to determine the uptake of relevant practices, and what the actual end results of energy efficiency policies and legal frameworks are. Preliminary analysis of past projects found them either to feature information that can be considered unsuitable for use in FuturHist due to the inability to reference it to individual buildings and the overall result of their renovation, the exception being the HIBERatlas project which did include case-specific data. However, as the objective of Task 1.5 was to present an overview of current renovation practice, this data was also considered to have gaps as the objective of HIBERatlas was to serve as a best practice case repository, which in itself is skewed towards high performance. To address this shortcoming, a datasheet detailing multiple renovation project metrics was compiled for the purpose of surveying renovation project cases that the Project Partners had access to. The purpose of the datasheet was to gauge the outcomes of current renovation practice and to determine what passive and active solutions are installed, what the target values for key metrics are, as well as various other aspects of the thermal retrofit process like the KPIs that guide it and what the resultant SRI typically is. The key areas for which we inquired about relevant metrics are as follows:

- Thermal envelope U-values,
- Building services solutions,
- Energy performance and renewable energy source use,
- Cost-effectiveness,
- Construction waste generation,
- Maintenance,
- Comfort and IEQ,
- Energy/fuel poverty,
- Software used to plan and design the retrofit,
- Financial, environmental and public-health–related KPIs,
- Post-retrofit SRI.

The datasheet was designed to collect both quantitative and qualitative information. We aimed to collect the following quantitative data:

- U-values for building elements targeted for intervention;

- Energy performance metrics such as the amount of Primary and Final Energy generated from non-renewable sources, as well as the percentage of energy demand covered by RES;

- The amount of waste generated per square metre of floor area, divided by type as per the case country's guidelines on waste handling;

- IEQ metrics, including indoor air temperature, relative humidity, particulate matter content, CO_2 and volatile organic compound (VOC) levels.

The qualitative information centred on the types of solutions used such as specific materials, technologies or building services systems, whether there were instances of fuel poverty observed in the given case, as well as KPI- and SRI-specific ratings. To further deepen the insight into the current practice of renovation, it was noted whether the values were declarative, namely based on calculations during the design stage, or measured as a part of a post-retrofit evaluation.

2.1.1 Datasheet contents

The following parameters were included in each of the datasheet sections.

Energy performance, envelope insulation, building services and thermal comfort

- Energy performance:
- Non-RES generated Final Energy [kWh/(m^2·year)];
- Non-RES generated Primary Energy [kWh/(m^2·year)];
- percentage share of on-site RES in satisfying Total Final Energy demand.
- U-values [W/(m^2·K)] and solutions for building elements:
    - roof;
    - external walls;
    - party walls;
    - walls between conditioned and unconditioned spaces;
    - floors between conditioned and unconditioned spaces;
    - windows (frames and glazing, where possible);
    - external doors (frames and glazing, where possible);
    - internal doors between conditioned and unconditioned spaces;
    - envelope airtightness.
- Building services (active systems) installed as part of the retrofit:
    - Ventilation systems;
    - Heating systems;
    - Cooling systems;

- Domestic hot water preparation systems;
- Low-temperature heat sources;
- RES solutions (electrical);
- RES solutions (thermal).

Where possible, we also inquired about information on pre-retrofit values, specific solutions used for each building element and whether the relevant value was declarative (i.e., calculated based on design documentation) or measured as a part of an ex-post analysis.

Concerning comfort, IEQ and IAQ, we asked for the following data via the datasheets:

- Pre-retrofit thermal comfort [PMV, PPD, linguistic description];
- Post-retrofit thermal comfort [PMV, PPD, linguistic description];
- Lowest indoor space temperature in conditioned spaces [°C];
- Highest indoor space temperature in conditioned spaces [°C];
- Percentage of indoor relative humidity [%];
- Air change rate in conditioned spaces pre-retrofit [ACH];
- Air change rate in conditioned spaces post-retrofit [ACH];
- CO2 levels in indoor spaces [ppm];
- Particulate matter levels for PM2.5, PM5, PM10 [ppm];
- Information on whether a post-occupancy evaluation of thermal comfort was conducted and whether the users noticed an improvement;
- Toxic substances in indoor air [ppm];
- Information on any problems with mould or unpleasant odours [linguistic description].

Energy/fuel poverty

In the section on fuel poverty, we featured the following questions:

- Did you observe symptoms of energy poverty among occupants before the retrofit? (extreme cases of energy savings on heating to avoid high energy bills);
- If such symptoms had been observed, did the related behaviours change in any way after the retrofit?

Construction waste generated during the retrofit

In the section on construction waste, the following information was collected:

- Individual amounts and types of waste per square meter produced as a result of the retrofit project [t/m^3];

- The amount of construction waste (material packaging) per square meter produced as a result of the retrofit project [t/m^3];
- The amount of construction waste (wasted material) per square meter produced as a result of the retrofit project [t/m^3];
- Information on whether the amount of construction waste was estimated during the design phase, and if so, what was the method used to do it;
- Major discrepancies between the estimated waste quantity and the actual waste generated [%];
- Information about the use of specific waste reduction/management strategies used during the design phase.

Cost-effectiveness

The cost-effectiveness section of the datasheet was dedicated to the following information:

- Cost-effectiveness calculation method used (if any);
- Method-appropriate cost-effectiveness value.

Maintenance

In the section on maintenance included the following:

- Was the retrofit conducted in response to a pre-existing maintenance/renovation plan for the building or building portfolio? If so, what is the time until the next retrofit?
- Was there a maintenance/renovation plan prepared for the building in conjunction with the retrofit? If so, what was the planned yearly budget for maintenance?
- Were any established guidelines on maintaining historical buildings followed?
- What were the expected replacement rates for the main building elements/services in the maintenance plan?
- What were the actual maintenance costs after the retrofit? Did they align with projects?

Software

This section inquired about the computer programs used to design, plan and monitor the retrofit, and included the following questions:

- What software was used to prepare the design documentation for the retrofit?
- What software was used to prepare/simulate the energy-focused parts of the design documentation?
- Is the building's energy performance monitored, and if so, what are the parameters, the measurement frequency and the technical measures used in the monitoring?
- Is the building's indoor air quality monitored, and if so, what are the parameters, the

measurement frequency, and what are the technical measures used in the monitoring?

Key Project Indicators

To investigate the KPIs used to inform and assess retrofit projects, we included the KPI list featured in the study by Kylili, Fokaides and Amparo Lopez Himenez (2016) in the datasheets, along with their respective scoring/rating schemes. This list includes Financial, Environmental and Public Health KPIs. As a part of FuturHist, we surveyed the use of each of these KPIs and what the relevant values were in cases where they had been used.

Smart Readiness Indicator

We investigated the use of SRI in HB energy retrofits as presented by Apostolopoulos et al. (2022) by inquiring about the relevant scores used in its calculation (Verbeke et al., 2020). It is important to note that these scores were not calculated as a part of this task, as the collection of scores already calculated during the projects was intended to measure the uptake of SRI.

2.1.2 Interviews

The structured interviews were conducted as a part of broader project-wide efforts to determine the approaches used by project stakeholders in their renovations. The methodology for the interviews has presented at length in the report on Task 1.3. A summary of this methodology is presented below. The interviews were conducted on a purposive sample of renovation project stakeholders, selected based on their involvement with historic building renovation projects, as well as the FuturHist project demonstration buildings. The stakeholders were divided into the following groups:

- Practitioners — architects, engineers, contractors, heritage experts, energy experts and retrofit experts;
- Public authorities — representatives of local heritage authorities, planning officers, policymakers;
- Professional owners — Professional managers of public buildings, Professional real estate owners, Demo case owners, Demo case users;
- Private owners — Private owners of historic buildings, Historic building users or tenants.

The stakeholders were interviewed either in person or remotely and asked a pre-determined set of questions. The interviews were conducted in local languages, recorded, transcribed, and the responses were translated into English where appropriate, and later analysed. Each group of stakeholders was asked a different set of questions, intended to leverage the specificity of their perspectives on renovation and energy retrofits in historic buildings.

2.1.3 Supplementary methodologies

As it was expected that the data collected from datasheets may be incomplete, we sought to supplement the data collection with calculating some of the parameters ourselves in cases where this was possible and feasible. One such field was retrofit project cost-effectiveness, which was calculated using cost-effectiveness analysis (CEA), cost-benefit analysis (CBA) and net-present value (NPV). In accordance with related EU regulations, the global cost calculation period is defined as follows:

- 30 years for public and residential buildings, reflecting the long lifespan of energy efficiency measures typically associated with such structures.
- 20 years for non-residential and commercial buildings, due to their generally shorter renovation and utility cycles.

Thus, for the purposes of energy efficiency and economic analysis, a 30-year calculation period is typically used for projects involving public and residential buildings as per the directive.

CEA

There are a variety of methods for conducting cost effectiveness analysis (CEA). It is a widely used economic tool to evaluate the relative costs and outcomes of different energy efficiency measures. Unlike cost-benefit analysis, which requires estimating often challenging-to-quantify benefits, CEA focuses on comparing costs directly to measurable outcomes (Tuominen et al., 2015).

Key Parameter: The cost-effectiveness ratio (CER) is central to CEA. It measures the cost per unit of energy savings, providing a straightforward metric for comparing alternatives.

$$\text{CER} = \frac{\text{Total Cost of Investment}}{\text{Total Energy Saving}}$$

Advantages

- Simplifies comparisons by focusing on costs relative to direct outcomes;
- Avoids the need for assigning monetary values to intangible benefits;
- Ideal for scenarios where energy savings can be quantified but broader economic or environmental impacts cannot.

In the article by Karásek, Pojar, Kalocai, and Heralová (2018), in accordance with the guidelines outlined in European Union regulations, particularly in the context of Directive 2010/31/EU on the energy performance of buildings, the Cost-Effectiveness Analysis (CEA) methodology was applied. This method evaluates the relationship between investment costs and resulting energy savings, helping to identify economically efficient energy efficiency measures. Another example where this methodology was used is the work of Alfredsson Mihlzén and Jakobsson (2013), which analysed energy conservation measures in a residential building case study.

CBA

Cost-benefit analysis (CBA) offers a more comprehensive framework by monetizing both the costs and benefits of a project. It aims to determine the net economic value to society, helping stakeholders decide whether an investment is worth pursuing.

Key Parameter: The benefit-cost ratio (BCR) is central to the CBA approach, providing a comparison of the total benefits to the total costs of a project.

$$BCR = \frac{\text{Total Present Value of Benefits}}{\text{Total Cost of Investment}}$$

When applying the Cost-Benefit Analysis (CBA) approach to energy efficiency in buildings, two significant limitations arise:

1. Limited Focus on Comparative Effectiveness:

CBA provides a single numerical result—usually a benefit-cost ratio or net present value—that answers whether a project should be undertaken. While this is valuable for determining the feasibility of a project, it does not offer a comparative perspective on how effectively the project achieves its sustainability goals compared to other options.

2. Difficulty in valuing intangible impacts

CBA requires assigning monetary values to all project impacts, which poses a significant challenge, particularly for external energy costs and the climate change? impacts of carbon emissions. Accurately estimating these elements is inherently difficult and often subjective, leading to potential distortions of the analysis.

NPV

NPV is the value obtained by discounting, separately for each year, the difference between inflows and outflows over the entire period at a constant level of the discount rate. The NPV level depends on the size and type of net cash flows at the time, and on the average discount rate. If NPV > 0, then the project is accepted, if NPV < 0, then the project is rejected. Finally, if NPV = 0, then the decision maker stays indifferent. NPV value is calculated from the formula:

$$NPV = \sum_{i=1}^{n} \frac{CF_i}{(1+r)^n} - I_o$$

where:
CF – cash flow
n – number of time periods
r – discount rate
I_o – investment cost

2.2 Materials

A total of 27 renovation and thermal retrofit projects were investigated to varying degrees depending on data availability. This information was explored alongside structured interview responses from HB retrofit stakeholders.

We supplemented our sample with selected cases from other projects. To do this, we reviewed the following projects and data repositories: HIBERatlas, CO2OLBricks, the EU Building Stock Observatory (BSO) and the Gotland Housing Stock (GHS) research project. Upon investigation, the BSO and GHS data was found to be unsuitable for a case-based analysis in which different characteristics could be attributed to a single building to gauge project-by-project performance increases or target metrics.

To obtain a clearer picture of current renovation practice, a pool of cases was formed from the HIBERatlas project. In addition, it was missing cases from Poland and Spain, two countries where FuturHist's demonstration buildings are located, which is why it was required to expand the case pool to include cases from these countries, in addition to investigating additional cases from Sweden and the UK following FuturHist methodology.

The main selection criteria for the additional cases were data availability and completeness, which meant that for Poland and Spain, the case buildings came from the stocks of AVRA and ZBK, as these organisations held the relevant documentation for their respective retrofits, while cases from the UK and Sweden were selected based on data accessibility. As the range of information for these cases was wider than for those from HIBERatlas, they have been categorised as detailed cases and will be referred to as such throughout this document (Table 1).

Table 1. Overview of cases selected from HIBERatlas for comparison

No	ID	Country	Use	Typology	Name in HIBERatlas directory
1	HBA1	Switzerland	Residential	Row tenement, corner	Apartment building Magnusstrasse, Zürich
2	HBA2	Scotland	Commercial	Detached lodge	Holyrood Park Lodge, Edinburgh
3	HBA3	Austria	Residential	Row tenement, semi-detached	Mariahilferstrasse, Vienna
4	HBA4	Belgium	Residential	Row townhouse	Maison Rubens, Schaerbeek
5	HBA5	France	Education	Detached, L-shaped	Elementary School in Mulhouse
6	HBA6	Austria	Residential	Detached house	Rhine Valley House Irgang, Rankweil
7	HBA7	Italy	Residential	Urban villa	Ansitz Kofler, Bozen
8	HBA8	Switzerland	Residential	Row tenement	Residential and commercial building Feldbergstrasse, Basel
9	HBA9	Austria	Community Hall	Detached building	Community Hall Zwischenwasser

10	HBA10	Austria	Commercial mixed-use	Detached building	Freihof Sulz, Sulz
11	HBA11	Sweden	Student housing	Detached, C-shaped	Rackarberget, Uppsala
12	HBA12	Italy	Residential	Detached, multi-mass stone house	Ruckenzaunerhof, Tarsch
13	HBA13	Sweden	Offices	Early 20th-century brick industrial buildings, block	Trikåfabriken, Malmö
14	HBA14	Sweden	Office	Early 20th-century brick industrial buildings, detached	Magasinet i Varvsstaden, Malmö

Of the 13 detailed cases, 4 were based in Poland, 4 were based in Spain, 1 was based in Sweden and 4 were based in the UK. Efforts were made to find cases that were typologically similar to the demonstration buildings located in each country, but this was not always possible. An overview of the base characteristics of each detailed case is presented in Table 2.

Table 2. Overview of detailed HB energy retrofit cases

No	ID	Country	Use	Typology	Address
1	PL1	Poland	Office	Row tenement (adapted), C-shaped	Biskupia 18, Kraków, Poland
2	PL2	Poland	Residential	Detached tenement	Fredry 4D, Kraków, Poland
3	PL3	Poland	Residential	Row tenement, semi-detached	Kijowska 50, Kraków, Poland
4	PL4	Poland	Residential	Row tenement, terraced and semi-detached	Prokocimska 47-49-51, Kraków, Poland
5	ES1	Spain	Residential	Courtyard tenement	Plaza de la Corredera 43, Córdoba, Spain
6	ES2	Spain	Residential	Detached tenement	Calle Rutilio 7, Cádiz, Spain
7	ES3	Spain	Residential	Courtyard tenement	Calle Ramón de Cala 17, Jerez de la Frontera, Cádiz, Spain
8	ES4	Spain	Residential	Row tenement	Diego Medina nº 20, 22 (18 y 20 según catastro) y Plaza de San Miguel nº 7, Montoro (Córdoba), Spain
9	SE1	Sweden	Office	Detached building	Hus A1, Akademiska sjukhuset Ingång 15, 751 85 Uppsala, Sweden
10	UK1	UK	Residential	Terraced townhouse	Falkland Road, Kentish Town, London, NW5, England, UK

11	UK2	UK	Residential	Semi-detached townhouse	Clapham Town House, 51 Rectory Grove, London, England, UK
12	UK3	UK	Residential	Detached stone house	Foxlow, Marple, Greater Manchester, England, UK
13	UK4	UK	Residential	Detached cottage	11 Annat Road, Perthshire, Scotland, UK

To provide additional context for the retrofit solutions and how they intersect with each case's historic character, a short overview of relevant information has been presented in Table 3 below.

Table 3. Heritage aspects of detailed cases analysed using datasheets

ID	Heritage aspects of the detailed cases
PL1	Listed in municipal monument records; Built in the 1920s and 30s, originally as the Wartime Invalid Association House. Overall building geometry and façade composition, façade detail under conservation, interventions are to be consulted with the Krakow Municipal Conservator of Monuments
PL2	Listed in municipal monument records; Built around 1920, originally a residential building and part of the 'Bonarka' Brickworks complex which included plant buildings, storage halls, an administrative buildings and stables. Overall building geometry and façade composition under conservation, interventions are to be consulted with the Krakow Municipal Conservator of Monuments
PL3	Listed in municipal monument records; Built around 1910, tenement. Overall building geometry and façade composition under conservation, interventions are to be consulted with the Krakow Municipal Conservator of Monuments
PL4	Listed in municipal monument records; Built around 1940, railwaymen's housing, tenement. Overall building geometry and façade composition under conservation, interventions are to be consulted with the Krakow Municipal Conservator of Monuments
ES1	'Casa de pisos' 16th century Listed building: the first bay of the building is declared a National Historic and Artistic Monument by Royal Decree 3551/1981 in the category of Asset of Cultural Interest (BIC- Bien de Interés Cultural). Protection: The building is part of the Plaza de la Corredera, which is a protected element within the protection area of the historic centre of Córdoba, in which interventions in the building are limited in terms of alignment, height, materials and colours to be used on facades, elements to respect, installations, etc. In this area, the use of solar thermal or photovoltaic panels on the roofs of buildings is expressly prohibited. All the elements of the main façade are protected (colour of the walls, coating materials, carpentry and joinery and metalworks, painting and finishings, roof...)
ES2	'Casa de vecinos'. Included in the Architectural Heritage Protection catalogue. Included in the Cádiz Historical centre ensemble (declared by BOE 25/11/1978). Architectural protection grade 2, Assets of Special Interest' and ethnological protection grade 1 "Singular ethnological protection". Conservation, restauration and renovation interventions are allowed in order to avoid damages in the building and to guarantee security and hygienic conditions. In restoration works, the materials to be used must be in accordance with those present in the building. In conservation works, the design elements of the building may not be altered. In works to consolidate the structure, masonry or roof, modern construction techniques may be used. Heritage protection zone

ES3	Listed building: ‘Casa de vecinos’ in a 17th-century palace house affected by asset of cultural interest (BIC) environment. Strict conservation of load-bearing structure, external appearance (façades) and common circulation elements such as main staircases and structuring courtyards with their galleries. Conservation of timber floor slabs and beams able to be replaced by new wood ones, when damaged; conservation of singular and original structures and decorative elements; Conservation of original windows and doors; Preventive archaeological project of walls analysis. Heritage protection zone
ES4	18th-century building, ‘Casa de vecinos’ with Protection Level A (integral protection) and included in the Catalogue of Protected Assets in the Special Plan for the Protection of the Historical Ensemble of Montoro. Only works for conservation of heritage allowed. Forbidden works for total renovation, demolition, replacement, extension and new building. Heritage protection zone
SE1	Historical, listed building, dating to 1867, office building A1 of the Uppsala University Hospital – detached, centrally symmetrical building with avant-corps and two smaller wings, 4 floors and pitched roof. Careful retrofit included insolation of the roof, renovation of windows, external door works, interior renovation, renewal of installations and technology.
UK1	Not listed, in a conservation area, terraced townhouse, 3 storeys with an extension to the back. Works included repairs to the front parapet wall to stop internal ingress of the water. Careful restoration of the wall – exchange of the cement pointing to the lime plaster and internal insulation using a wood fibre. Reparation of the ground floor windows with high-performance sashes in existing boxes; new glazing of the first-floor windows; second-floor windows got exchanged.
UK2	Grade II listed Victorian Townhouse building, in a conservation area, the listing does not state the elements under protection. Insulation of the second floor ceiling (under the cold roof), basement floor, external isolation below ground, internal wall insulation. Original windows got retained, overhauled and draught-proofed, secondary double glazing was added for single glazed sash windows (with original frames). Existing door panels got upgraded, double glazing added.
UK3	No information. Edwardian Manor detached house, located in Foxlow, Marple, Manchester, UK. Refurbishment included: open blow cellulose in attic, wood fibre below joists floor insulation, wood fibre in internal walls, triple glazed new windows.
UK4	Not listed and not in a conservation area. 1927 Interwar period cottage in Perthshire, traditional and historic building. The Gannochy Trust and Historic Scotland wished to upgrade and improve the building fabric (walls, floors and roof space), while maintaining the design, texture and amenity of the original cottage and minimise waste. To retain existing external wall linings blown materials were applied behind existing finishes. Wood fibre boards insulation for the timber floors and attic space – roof pitch.

3. Results and Discussion

3.1 National practice contexts

This section gives an overview of energy retrofit practice in HBs from a policies and guidelines standpoint, which affect the various aspects of conservation practice in terms of which metrics are emphasised or kept track of in each country. The intent behind presenting this information is to give the reader the necessary background to better understand the availability of the various categories of data.

3.1.1 Energy performance

SPAIN

In Spain, as in most European countries, energy efficiency is still a challenge for HBs, as cultural or heritage values impede energy retrofitting measures. Building regulations, such as the Building Technical Code CTE (Real Decreto 314/2006), which is the regulatory framework for building construction in Spain, states that buildings of significant historic value that are under official protection as part of a listed environment are exempt from energy performance provisions. Heritage protection authorities determine which elements of a building cannot be altered during a retrofit. Similarly, extensions or remodelling projects can have certain requirements waived on a case-specific basis.

The Real Decreto 390/2021 (Real Decreto 390/2021) regulates the Buildings Energy Performance Certification and states that EPCs are compulsory for new buildings and existing buildings when they are being sold or rented out, as they must be available for buyers or tenants. They are also compulsory in existing buildings under some circumstances, as if renovation is affecting more than 25% of the envelope or in case of deep renovation of big HVAC installation. However, this law exempts buildings officially protected in case that any energy efficiency improvements would unacceptably alter their character or appearance. In that case, the authority issuing the official protection must determine which elements are unalterable.

On the other hand, in some funding programs for building renovation, energy demand reduction is not required, as envelope measures can be compromised in listed buildings. This is not the case of non-renewable primary energy reduction (30%), even though local regulations forbid in many cases the implementation of RES in historical environments due to visual polution.

POLAND

Energy performance certification for buildings is governed by the Act on the Energy Performance of Buildings (hereinafter: Energy Performance Act, Ustawa z dnia 29 sierpnia 2014). This act stipulates those buildings subject to protection under the Monuments Act (this includes all the three forms of protection including: monuments listed in the Register of Monuments, possessing Monument to History status or included in Municipal Monument Records) (Ustawa z dnia 23 lipca 2003) are exempt from the requirement to prepare and produce energy performance certificates for as-designed and as-built states.

Buildings under central government heritage protection (Monument to History, Register of Monuments) are exempt from energy performance requirements as related to construction regulations and energy performance certification to a degree approved by state conservation, sanitation and fire safety services, as stipulated in the Regulation of the Minister of Infrastructure on the technical conditions to be met by buildings and their placement (Rozporządzenie Ministra Infrastruktury z dnia 12 kwietnia 2002), which also regulates the U-values for the internal and external partitions of buildings. This is verified and approved during all works.

Historical buildings under local government heritage protection (Monument Records) are not exempt from energy performance requirements as related to construction regulations but are exempted from energy performance certification. Compliance with these regulations is verified and approved during energy retrofit works, remodels, and/or extensions, and adaptive reuse projects.

SWEDEN

Listed historic buildings are not exempt from energy performance certification. Recommendations on energy efficiency measures in the EPCs must not risk damaging heritage values. In the law (Boverket, 2007) it is mentioned that measures such as external insulation and change of windows risk damaging heritage values, while e.g. energy efficient control strategies generally do not.

At the municipal level, the Planning and Building Act (PBA) and Swedish Building Regulations (BBR) provide the legal framework for balancing energy efficiency and heritage conservation during renovation and construction projects. The building regulations set specific limits for energy use in both new and renovated buildings. When an alteration, such as an extension, is made, the energy performance requirements for the new parts of the building must meet the same standards as those for newly constructed buildings. If achieving the energy efficiency of a new building is not technically feasible, alternative performance measures, such as maximum U-values for individual building elements (e.g., walls, roofs, and windows), can be used.

The PBA and BBR also provide specific guidelines on how to approach energy renovations in heritage buildings. The regulations allow deviations from standard energy efficiency requirements when they would compromise a building's cultural or architectural values (e.g. replacement of windows and entrance doors of heritage value must be done with deference to the original character of the building).

The BBR recommends that original windows and doors be retained or replaced with custom-made replicas, and alternative measures to improve energy efficiency, such as enhanced insulation or modern glazing techniques, should be considered.

Historic buildings are not exempt from energy performance certification, but there are no demands on energy performance on existing buildings. Recommendations of measures that risk damaging heritage values must not be included in EPCs. Demands on energy performance will be given when a building undergoes major renovation, but deviations from standard requirements can be made to preserve heritage values in the building.

UK/Scotland

In Scotland, EPCs are compulsory when a building is being sold or rented out, or for new buildings. They should be made available to potential buyers or tenants. There are exemptions for stand-alone buildings (other than dwellings) with a useful floor area of less than 50 m^2, temporary buildings with a planned use of two years or less, buildings with a low energy demand, i.e. non-residential agricultural buildings and workshops, or buildings sold for the purpose of demolition. Listed and historic buildings, places of worship are not exempted from having an EPC if they are sold or rented out. The Scottish Government ran two consultations (2021, 2023) on proposed reforms to EPCs, including the introduction of new metrics and the reduction of validity period from 10 to 5 years.

In Scotland, the Building (Scotland) Regulations 2004 (as amended) sets out the regulations and standards buildings must meet to ensure they are safe, efficient and sustainable. These legal requirements are triggered by the construction of a new building (including extensions of existing buildings), the alterations or the conversion (change of use or occupation) of an existing building and are enforced through the building standard system. In any case, the converted building must meet the requirements of the Building Standards and not be worse than before the conversion.

The Scottish Government publishes and regularly updates guidance in relation to building regulations and standards. Additionally, there is specific guidance on the application of building standards during the conversion of traditional buildings: Guide for Practitioners 6: Conversion of Traditional Buildings (Historic Environment Scotland, 2010).

In 2019, Scotland has set an ambitious target to become net-zero by 2045 and has been developing policies and strategies, which include the probable introduction of minimum energy efficiency standards and the phasing out direct carbon emission heating in existing buildings.

There is a recognition by the Scottish Government, across existing and future legislation in relation to energy retrofit, that HBs must be dealt with in a sensitive manner, to preserve their cultural significance and integrity (preventing damages from inappropriate retrofit interventions). Whilst there are exemptions for HB, current legislation, regulation and guidance tend to encourage, when it is technically and financially possible and acceptable from a conservation perspective, the full implementation of energy efficiency standards and requirements. To facilitate the adoption of energy efficiency interventions, planning requirements have recently been relaxed for conservation areas through the implementation of the third phase of Permitted Development Rights (PDRs) for specific interventions (window alteration and installation of renewables), not without concerns.

3.1.2 Waste generated during construction

This section presents our findings concerning the approaches to the estimation, handling and categorisation of waste generated during construction in each demonstration case country.

SPAIN

According to the National Statistics Institute, the Spanish economy generated 115.4 million tonnes of waste in 2021, 37.06 million tonnes of which were construction waste (32%), in line with the European data (Notas de Prensa Instituto Nacional de Estadística, 2021). 54% of waste generated on building sites in Spain is sent to landfills and between 10% and 15% of materials are wasted during the construction process (Green Building Council España, 2021).

Regulatory Framework overview

Aligned with European plans and strategies for a circular economy transition, the Spanish Government has launched some documents such as the Circular Economy for buildings (Green Building Council España, 2021), Its main goals include reducing waste generation by 15% with regard to 2010 waste levels and promoting reuse and reuse enabling activities until reaching 10% of municipal waste and the National Plan for the waste management (Plan Estatal Marco de Gestión de Residuos (PEMAR)) and the National program for waste prevention and management (Programa estatal de prevención y gestión de residuos) is intended to be the instrument for guiding waste policy in Spain, promoting the necessary measures to improve the shortcomings detected and promoting the actions that provide better environmental results and that ensure the achievement of the legal objectives. One of the objectives of the Plan is to allocate the 75% of non-hazardous construction and demolition waste (CDW) to be prepared for re-use, recycling and other recovery operations, including landfilling operations (excluding clean earth and stones). This objective has been reinforced by the EU that requires that 70% by weight of the Construction and Demolition Waste generated in renovations works financed by Next Generation Funds must be prepared for reuse, recycling or other forms of material recovery.

At the national level, **Law 7/2022, of 8 April**, incorporates the amendments introduced by Directive (EU) 2018/851 concerning the generation of waste and aims to set out the principles of the circular economy through basic waste legislation. This Law includes the definition of construction and demolition waste as well as its classification. Since 1 July 2022, initial producers of hazardous waste shall be required to have a minimisation plan that includes the practices they will adopt to reduce the amount of hazardous waste generated and its hazardousness. On the other hand, non-hazardous construction and demolition waste shall be sorted into at least the following fractions: wood, mineral fractions (concrete, bricks, tiles, ceramics and stone), metals, glass, plastic and gypsum. Demolition shall preferably be carried out selectively, and from 1st of January 2024 is compulsory ensuring the removal of at least the fractions of materials indicated above.

The production and management of construction and demolition waste (CDW) in Spain is regulated by **Royal Decree 105/2008 of 1 February regulating the production and management of construction and demolition waste** (Real Decreto 105/2008). Its aim is to establish the legal regime for the production and management of construction and demolition waste, in order to promote, in this order, its prevention, reuse, recycling and other forms of recovery, ensuring that those destined for disposal operations receive appropriate treatment, and to contribute to the sustainable development of construction activity.

According to this regulation, construction and demolition waste is understood as those substances or objects that, in accordance with the definition of "waste", are generated in the construction, renovation, repair, refurbishment or demolition of a real estate property and I the carrying out of works that modify the form or substance of the land or subsoil, such as excavations, injections, urban developments or similar.

This Royal Decree establishes the obligations to include in the construction project a Construction and Demolition Waste Management Study containing, among others, an estimation of the quantity, expressed in tonnes and cubic metres, of construction and demolition waste that will be generated on the site, coded in accordance with the European list of waste and a Construction and Demolition Waste Management Plan specifying how the project management study will be apply during the construction and/or demolition works. In addition, this Royal Decree 105/2008 requires the inventory and separation of hazardous waste.

In accordance with Spanish legislation, Andalusia has exclusive competence in environmental prevention and shared competence in environmental planning instruments matters as well as in the regulation of the prevention and correction of waste generation with origin or destination in Andalusia. However, the Construction and Demolition Waste management from minor domestic works, (at least the collection, transport and disposal) corresponds to local entities.

The Law 7/2007 of 9 July, on the Integrated Management of Environmental Quality in Andalusia, (Ley 7/2007 de Gestión Integrada de la Calidad Ambiental de Andalucía (GICA)) establishes in art. 104. “Production of construction and demolition waste” that all the projects under municipal licence must include an estimation of the quantity of construction and demolition waste to be produced and the measures for its classification and separation by type at source.

Local councils will make the granting of the municipal building permit conditional on the producer of construction and demolition waste posting a deposit or equivalent financial guarantee for the correct management of the waste, which must be returned to the producer when the destination of the waste is accredited. The Andalusian Region's Waste Regulation (Decreto 73/2012) implement Law 7/2007 of 9 July, with the aim of establishing the legal regime regulating the production, possession and management of waste generated and managed in the Andalusia. In Andalusia, administrative responsibility for waste management lies in the Regional Ministry of Sustainability, Environment and Blue Economy.

Construction and demolition waste calculation and management

Waste management studies and plans, required under Spanish law (RD 105/2008), mandate the identification, estimation, prevention, and recovery of waste, alongside monitoring and control during construction. Those documents must also include strategies for handling hazardous waste, which professionals calculate independently.

For this purpose, digital solutions and innovative frameworks like the EU Level(s) system are increasingly used to streamline waste tracking and reporting, ensuring alignment with circular economy principles and fostering sustainable building practices. But there are also other guidelines and tools to support professionals and other actors in construction and demolition waste calculation and management.

The Spanish General Board of Architects and Building Engineers has developed comprehensive guidelines, “Guide for the management of construction and demolition waste in the field of energy retrofitting of dwellings”, for managing Construction and Demolition Waste (CDW) to align with European sustainability and circularity goals, particularly in energy retrofitting projects supported by Next Generation funding. The guides outline CDW classification by origin (construction or demolition) and nature (hazardous or non-hazardous) and emphasize compliance with legal frameworks, including the European Waste List (LER codes). The "Good Practice Guide in the Management and Treatment of Construction and Demolition Waste (CDW) " provides steps for stakeholders to manage CDW during and after construction, ensuring proper waste segregation, documentation, and certification, while requiring waste management companies to submit annual reports to regional environmental authorities.

The "National Ratios" guide addresses inconsistencies in CDW estimation by offering parameterized tables tailored to Spain's climatic regions. These tables, though not official, help pre-dimension waste quantities for various construction and demolition scenarios.

RATIOS APLICABLES A CONSTRUCCIÓN DE EDIFICACIÓN RESIDENCIAL Y TERCIARIO

Región Mediterránea Litoral

Codigo LER	Tipo de Residuo	Porcentaje peso	Volumen	Peso
		%	m3/m2	T/m2
RATIOS GLOBALES		**100**	**0,143**	**0,107**
	RCD: Naturaleza no pétrea			
Asfalto				
17 03 02	Mezclas bituminosas distintas a las del código 17 03 01	3,96	0,004	0,004
Madera				
17 02 01	Madera	3,14	0,010	0,003
Metales				
17 04 01	Cobre, bronce, latón			
17 04 02	Aluminio			
17 04 03	Plomo			
17 04 04	Zinc			
17 04 05	Hierro y acero			
17 04 06	Estaño			
17 04 07	Metales mezclados	1,41	0,002	0,002
17 04 11	Cables distintos de los especificados en el código 17 04 10			
Papel				
20 01 01	Papel-Cartón (codigo espejo)	1,87	0,015	0,002
Plástico				
17 02 03	Plástico	1,40	0,009	0,002
Vidrio				
17 02 02	Vidrio	0,82	0,002	0,001
Yeso				
17 08 02	Materiales de construcción a partir de yeso distintos a los del código 17 08 01	2,77	0,008	0,003
	RCD: Naturaleza pétrea			
Arena Grava y otros áridos				
01 04 08	Residuos de grava y rocas trituradas distintos de código 01 04 07	5,59	0,004	0,006
01 04 09	Residuos de arena y arcilla			
Hormigón				
17 01 01	Hormigón	26,29	0,020	0,028
Ladrillos , azulejos y otros cerámicos				
17 01 02	Ladrillos			
17 01 03	Tejas y materiales cerámicos	31,40	0,032	0,034
17 01 07	Mezclas de hormigón, ladrillos, tejas y materiales cerámicos distintas de las especificadas en el código 17 01 06.	10,85	0,011	0,012
	RCD Mezclados			
17 09 04	RCD mezclados distintos a los de los códigos 17 09 01, 02 y 03	5,83	0,019	0,006
	RCD Potencialmente peligrosos y otros			
Basuras				
20 02 01	Residuos biodegradables			
20 03 01	Mezcla de residuos municipales	3,40	0,004	0,004
Potencialmente peligrosos				
17 09 03*	**Otros residuos de construcción y demolición que contienen SP's**	1,27	0,002	0,001
Otros				

RATIOS APLICABLES A DEMOLICIÓN DE EDIFICACIÓN RESIDENCIAL Y TERCIARIO

Región Mediterránea Litoral

Codigo LER	Tipo de Residuo	Porcentaje peso	Volumen	Peso
		%	m3/m2	T/m2
RATIOS GLOBALES		**100**	**0,849**	**0,945**
	RCD: Naturaleza no pétrea			
Asfalto				
17 03 02	Mezclas bituminosas distintas a las del código 17 03 01	0,10	0,001	0,001
Madera				
17 02 01	Madera	0,97	0,021	0,009
Metales				
17 04 01	Cobre, bronce, latón			
17 04 02	Aluminio			
17 04 03	Plomo			
17 04 04	Zinc			
17 04 05	Hierro y acero			
17 04 06	Estaño			
17 04 07	Metales mezclados	0,79	0,003	0,007
17 04 11	Cables distintos de los especificados en el código 17 04 10			
Papel				
20 01 01	Papel-Cartón (codigo espejo)			
Plástico				
17 02 03	Plástico	0,07	0,001	0,001
Vidrio				
17 02 02	Vidrio	0,13	0,001	0,001
Yeso				
17 08 02	Materiales de construcción a partir de yeso distintos a los del código 17 08 01	4,97	0,047	0,047
	RCD: Naturaleza pétrea			
Arena Grava y otros áridos				
01 04 08	Residuos de grava y rocas trituradas distintos de código 01 04 07			
01 04 09	Residuos de arena y arcilla			
Hormigón				
17 01 01	Hormigón	53,79	0,375	0,507
Ladrillos , azulejos y otros cerámicos				
17 01 02	Ladrillos			
17 01 03	Tejas y materiales cerámicos	38,18	0,376	0,360
17 01 07	Mezclas de hormigón, ladrillos, tejas y materiales cerámicos distintas de las especificadas en el código 17 01 06.			
	RCD Mezclados			
17 09 04	RCD mezclados distintos a los de los códigos 17 09 01, 02 y 03	0,48	0,019	0,006
	RCD Potencialmente peligrosos y otros			
Basuras				
20 02 01	Residuos biodegradables			
20 03 01	Mezcla de residuos municipales	0,10	0,001	0,001
Potencialmente peligrosos				
17 09 03*	**Otros residuos de construcción y demolición que contienen SP's**	0,42	0,003	0,004
Otros				

Figure 1. Example of Ratios applicable to construction and demolition works for mediterranean regions in Spain

Tools like the Valencian Building Institute's Gestion RCD further enhance accuracy by generating waste estimates for demolition, construction, and refurbishment phases, based on standardized parameters from regional and national sources. These tools also facilitate adherence to EU mandates, such as the 70% recycling and recovery target for non-hazardous waste. However, this tool doesn't make estimations of the hazardous waste that will be generated. The professional must calculate it independently and reflect them in the hazardous waste inventory.

Tabla 3: Residuos generados por tipo de actuación t/m^2

Tipo de residuo					Obra nueva			Rehabilitación	Demolición						
					Edificación				Edificio		Nave industrial				
Tipo	Naturaleza	Código LER	Designación	Densidad del residuo t/m^3	Residencial	Industrial	Urbanización		Pórticos de hormigón	Muros de fábrica	Pórticos de hormigón	Muros de fábrica	Pórticos metálicos	Estructura mixta	Viales
No peligrosos	Terrenos	20 02 01	Desbroce y poda	0,80											
		17 05 04	Tierra y piedras	1,80			0,0065	0,0100							0,4500
	Pétreos	17 01 01	Hormigón	1,75	0,0200	0,0300	0,0030	0,0500	0,7100	0,0850	0,7300	0,3500	0,4500	0,5500	0,0500
		17 01 03	Tejas y materiales cerámicos	1,20	0,0500	0,0500	0,0500	0,0500	0,0500	0,0500	0,0500	0,0500	0,0500	0,0500	
	No pétreos	17 04 07	Metales mezclados	1,50	0,0050	0,0080	0,0003	0,0450	0,0150	0,0050	0,0250	0,0080	0,3500	0,2200	
		17 02 01	Madera	0,80	0,0100	0,0080	0,0010	0,0600	0,0170	0,0230	0,0170	0,0230	0,0170	0,0170	
		17 02 02	Vidrio	0,40	0,0010	0,0010	0,0001	0,0050	0,0160	0,0010	0,0010	0,0010	0,0010	0,0010	
		17 02 03	Plástico	0,60	0,0020	0,0020	0,0005	0,0400	0,0010	0,0010	0,0010	0,0010	0,0410	0,0310	
		20 01 01	Papel y cartón	0,75	0,0020	0,0020	0,0001	0,0200							
		17 03 02	Mezclas bituminosas	1,00	0,0020	0,0020	0,0050	0,0200							0,1100
		17 08 02	Materiales de construcción a base de yeso	0,90	0,0050	0,0010		0,1000	0,0500	0,0500	0,0250	0,0250	0,0250	0,0250	
	Mezclados	17 09 04	Residuos mezclados de construcción y demolición	1,25	0,0100	0,0080	0,0010	0,0250	0,0010	0,0040	0,0250	0,0210	0,0250	0,0250	0,0100
Peligrosos y basuras	Potencialmente peligrosos y basuras	17 09 03 *	Otros residuos, incluidos los residuos mezclados, que contienen sustancias peligrosas	0,80	0,0020	0,0020	0,0005	0,0020							
		20 03 01	Mezcla de residuos municipales (basura)	0,60	0,0010	0,0010	0,0001	0,0050	0,0010	0,0010	0,0010	0,0010	0,0010	0,0010	

Figure 2. Example of ratios used by the IVE tool.

To sum up, the Waste Management Study includes not only the estimation of waste, but the measures and indications for the prevention of this waste and the operations aimed at the possible waste re-use and segregation.

During works, contractors must follow a Waste Management Plan adapted to the contents of the Waste Management Study for control, monitoring and withdraw and recycling/recovery of waste. And after finishing works, they must deliver the certificates and other documents accrediting the proper management of CDW (certificates of delivery with input and output of waste and recovery/valorisation categorised by typology according to LER codes (European standards)). Waste managing companies are obliged to deliver a yearly report about CDW to the regional Ministry of Environment.

POLAND

Construction waste types

In Polish literature on construction waste there are two general types of such waste: debris generated during demolition, and general waste produced during new construction as a result of inefficiency, i.e., leftover and unusable material and any relevant packaging. This has been discussed by Adamczyk and Dylewski in the context of sustainable construction (2020).

Calculation standards

The amount of debris is estimated based on on-site assessment and measurement of elements to be demolished based on retroactively preparing a bill of quantities based on the relevant volume of *Katalogi Nakładów Rzeczowych,* or KNR for short (Material Expenditure Catalogue), which is a series of publications on material expenditures needed to build standardised units of building elements. In the case of generalised assessments, *KNP 1 – Roboty transportowe, ziemne, pomocnicze i różne, montaż i demontaż żurawi budowlanych, rozbiórki i wyburzenia budynków, budowa i konserwacja terenów zielonych* is used, specifically chapter 08 on the demolition and dismantling of buildings, and includes estimates on reclaiming masonry elements.

The amount of general waste generated during construction is assessed using material consumption standards based on *Katalog Jednostkowych Norm Zużycia Materiałów Budowlanych* (Per-Unit Construction Material Consumption Catalogue). On average, this catalogue estimates material wastage rates usually at between 1–15% per batch depending on whether a given material is divided into distinct elements (e.g., tiles or bricks) or is a mixture that needs preparation (e.g., concrete, plaster). Additional material that needs to be prepared to account for loss (e.g., due to shrinkage) is estimated using separate values. This catalogue is mostly based on assessments from the 1970s and 80s and can therefore be considered outdated.

We have not found a dedicated Polish tool for construction waste calculation and management, as the prevalent methodology for doing so in the Polish construction sector is to include it in the costing process. Because of this, waste is treated mostly as something that needs to be handled in terms of the costs it generates, and therefore other aspects like recyclability are not typically considered. In cases where a project owner wishes to pursue waste-related sustainability goals, typically foreign tools associated with the major sustainability certification schemes are used (BREEAM, LEED, DGNB, etc.) (Taczalska-Ryniak, 2019).

Waste classification and monitoring

The Polish Ministry of Climate and Environment operates the Waste Database (Baza Danych Odpadów, BDO), established by the Waste Act (Ustawa z dnia 14 grudnia 2012 r. o odpadach, Dz.U. 2023 item 1587 as amended). The Waste Database contains yearly reports by businesses that generate specific types of waste or that transport, handle and process waste. The waste is categorised and construction waste specifically is divided into six fractions: Wood, Metals, Glass, Plastics, Gypsum and Mineral Waste, each of which is further subdivided into more specific categories as based on the Regulation of the Minister of Climate on the waste catalogue (Rozporządzenie Ministra Klimatu z dnia 2 stycznia 2020 r. w sprawie katalogu odpadów, Dz.U. 2020 item 10). For instance, the Wood fraction is divided into Wood waste and Wooden packaging, while Metals are divided into Iron and Steel, Copper and copper alloys, Zinc, etc. The BDO is considered public information and we have accessed it using a public information disclosure request which we sent via a formal letter. Unfortunately, due to the way data is organised in the BDO records, it is not possible to draw conclusions on how much waste is generated during HB energy retrofits.

Construction waste is classified under category 17 – Waste from construction, renovation and demolition of buildings and road infrastructure (including soil and earth from polluted areas) and is presented below in Table 4.

Table 4. Polish construction waste classification (Rozporządzenie Ministra Klimatu z dnia 2 stycznia 2020 r. w sprawie katalogu odpadów, Dz.U. 2020 item 10)

Code	Waste type
17 01	Construction material and element waste and from road infrastructure (e.g., concrete, bricks, tiles, ceramics)
17 01 01	Concrete-related waste, concrete rubble from demolition and renovation

17 01 02	Brick rubble
17 01 03	Waste from other ceramic materials and fitting elements
17 01 06*	Mixed or segregated waste from concrete, brick rubble, waste ceramic materials or fitting elements that contain hazardous substances
17 01 07	Mixed or segregated waste from concrete, brick rubble, waste ceramic materials or fitting elements – other than listed in 17 01 06
17 01 80	Removed plasters, wallpapers, veneers, etc.
17 01 81	Road renovation and remodelling waste
17 01 82	Other, non-listed waste
17 02	Wood, glass and plastics waste
17 02 01	Wood
17 02 02	Glass
17 02 03	Plastics
17 02 04	Wood, glass and plastics waste that contains or is contaminated with hazardous substances (railroad bases)
17 03	Asphalt, tar and tar-related waste
17 03 01	Asphalt that includes tar
17 03 02	Asphalt not listed in 17 03 01
17 03 03	Tar and tar products
17 03 04	Tar waste
17 04	Metal and metal alloy waste and scrap
17 04 01	Copper, bronze, brass
17 04 02	Aluminium
17 04 03	Lead
17 04 04	Zinc
17 04 05	Iron and steel
17 04 06	Tin
17 04 07	Metal mixtures
17 04 09	Metal waste contaminated with hazardous substances
17 04 10	Cables that include
17 04 11	Cables not listed in 17 04 10
17 05	Soil and earth (including soil and earth from contaminated areas and excavation material
17 05 03	Soil and earth, including stones, that contain hazardous substances (e.g., PCB)
17 05 04	Soil and earth, including stones, not listed in 17 05 03
17 05 05	Excavation material that includes or is contaminated by hazardous substances

17 05 06	Excavation material not listed in 17 05 05
17 05 07	Track ballast (aggregate) that includes hazardous substances
17 05 08	Track ballast (aggregate) not listed in 17 05 07
17 06	Insulation materials and structural materials that contain asbestos
17 06 01	Insulation materials that contain asbestos
17 06 03	Other insulation materials that include dangerous substances
17 06 04	Insulation materials not listed in 17 06 01 and 17 06 03
17 06 05	Structural materials that contain asbestos
17 08	Structural materials that contain gypsum
17 08 01	Structural materials that contain gypsum and include hazardous substances
17 08 02	Structural materials that contain gypsum other than those listed in 17 08 01
17 09	Other waste from construction, renovation and demolition
17 09 01	Waste from construction, renovation or demolition that contains mercury
17 09 02	Waste from construction, renovation and demolition that includes PCBs (e.g., substances and objects that contain PCBs: packing, flooring that contains resin, sealed window sets, condensators)
17 09 03	Other waste from construction, renovation and demolition (including mixed waste) that contains dangerous substances
17 09 04	Mixed waste from construction, renovation and demolition that is not listed in 17 09 01, 17 09 02 and 17 09 03

Approaches to material reuse

By law, only new and unused materials or products certified using the CE or B markings can be incorporated into a building. This means that material reuse must take place during the material or product manufacturing process and the product or material must pass certification. Disassembly of elements for reinforcement and reassembly or reincorporation, especially in historic buildings, is exempted from this rule, however the reinforcement must be performed using certified materials or products and the disassembled element must be subjected to testing to determine whether it is fit for reuse.

SWEDEN

The Swedish construction sector generates approximately 13 million tons of construction and demolition waste annually, accounting for a large share of Sweden's total waste. This volume presents a serious environmental challenge, driving the need for more effective waste management practices aligned with sustainability goals. As part of its approach, Sweden is preparing to implement the updated National Waste Plan and Waste Prevention Program on October 31, 2024. These initiatives, led by the Swedish Environmental Protection Agency (Naturvårdsverket), are vital steps toward a circular economy, where resources are reused and waste generation is minimized. Notably, while the plan covers general construction, it lacks specific requirements for managing waste during the renovation of historic buildings.

National Waste Plan and Waste Prevention Program

The National Waste Plan and the "Sweden Thinks Ahead" Waste Prevention Program underscore waste hierarchy principles. This means prioritizing waste prevention and recycling over landfill disposal, aiming to conserve resources, lower costs, and reduce environmental impacts. These strategies encourage companies to select durable, recyclable materials during the design phase, which can reduce waste and promote sustainable resource use throughout the building lifecycle. The "Sverige tänker efter – före!" program particularly emphasizes the reuse and repair of materials, which reduces the demand for new production and lowers the overall waste generated.

Guidelines for Resource and Waste Management in Construction and Demolition

In line with national objectives, the Swedish construction industry has adopted the Resource and Waste Guidelines, which serve as the industry's standards for efficient resource management and waste reduction in projects. These guidelines include:

- Material Inventories Before Demolition: Ensuring a thorough assessment of materials available for reuse and recycling;
- Contracts for Reuse: Integrating reuse-focused contracts for sustainable demolition;
- Source Sorting Standards: Setting on-site waste sorting requirements to comply with the Environmental Code (Miljöbalken) and Waste Ordinance (2020:614).

Compliance with these guidelines ensures construction and demolition waste is sorted into six distinct categories, increasing the potential for recycling and reuse. This standardized approach aids in meeting the objectives set by both Swedish and EU environmental regulations.

Role of Public Procurement in Sustainable Waste Management

Swedish public procurement policies also support sustainable waste practices. The Swedish Public Procurement Agency has established criteria that promote reuse, lower carbon footprints, and resource-efficient construction. By incentivizing these practices through public projects, the sector can move towards sustainable building and demolition processes that align with national waste reduction goals. This approach encourages contractors and suppliers to prioritize sustainable materials and processes across project lifecycles.

Waste Reporting and Documentation Requirements

To maintain transparency and accountability, Swedish law mandates the reporting of waste quantities and types for new constructions and renovations. This reporting, required by both the Environmental Code and the Waste Ordinance, includes details on:

- Waste Types and Quantities: Classified by material type, such as concrete, wood, and metal;
- Waste Handling: Information on sorting and recycling methods;
- Transportation Details: Documentation on how waste is transported and managed.

Such reports are submitted to municipal Building Committees or Environmental Administrations, which review compliance before issuing final project certifications. This thorough documentation process ensures that projects adhere to Sweden's sustainable waste management goals.

Miljöbyggnad Environmental Certification Standards

A key framework for promoting sustainable construction is the Miljöbyggnad certification, a standard with strict waste management requirements. Projects must develop a comprehensive Waste Management Plan outlining sorting, recycling, and disposal strategies before construction begins. Additional criteria include:

- On-site Sorting: Ensuring waste is sorted by material type to optimize recycling and reuse;
- Documentation Standards: Detailed records of waste amounts and disposal methods;
- Hazardous Waste Management: Minimizing hazardous waste and ensuring it is handled safely;
- Sustainable Material Selection: Prioritizing environmentally certified and recyclable materials.

Miljöbyggnad certification offers Gold, Silver, or Bronze ratings, providing incentives for projects to meet high environmental standards and reduce their waste footprint.

The National Waste Plan and the Waste Prevention Program set a foundation for the Swedish construction sector to enhance its waste management practices and support a circular economy. Through industry guidelines, public procurement criteria, and mandatory reporting, Sweden aligns with EU environmental directives while setting high standards for resource efficiency. Certification systems like Miljöbyggnad further support waste reduction, ensuring construction projects contribute to sustainable development goals.

UK/Scotland

In Scotland, there are no statistics about retrofit waste per se. Retrofit work is considered within the broader category of construction waste. According to the Scotland’s Environment Protection Agency (SEPA), which is Scotland’s principal environmental regulator, the construction sector is responsible for about 50% of all waste is Scotland (Scottish Environment Protection Agency, n.d.). This large percentage of waste means a large impact on Scotland’s carbon emissions (Building Research Establishment Centre for Sustainable Products, n.d.). You can view Scotland’s construction waste data in a tool managed by SEPA and named ‘Environment Waste From All Sources Discover Data tool’, that compiles data on waste from various sources – households, construction and demolition waste, and commercial and industrial waste.

There are different ways to classify construction waste in Scotland. For instance, it could be divided into two categories, waste generated from construction activities which means adding new materials, and waste from demolition activities or removing existing materials. Also, we could classify waste based on material type, e.g., stone, wood, metal, etc. The SEPA identified construction waste materials in the following categories: dredging spoils, glass waste, metallic waste (ferrous), mixed metallic waste, and nonferrous metallic waste, mineral waste from construction and demolition, and other mineral waste (Scottish Environment Protection Agency, n.d.). Also, plastic waste, soils, PCB waste, and wood waste. From the previous types, stones and soil contribute to 70% of all construction waste and large amount of this waste ends up in landfill. Other materials like brick, concrete, metal and wood, as well as packaging shapes the other 30% of the total construction waste (Scottish Government, 2022). The SEPA database provides statistics concerning waste sources and management in Scotland. To our knowledge, the SEPA database is the only database available in Scotland.

Finally, waste could be classified based on its hazardous property into hazardous and non-hazardous waste. In the UK it is compulsory to classify waste before sending it for recycling to assure it is handled properly (Scottish Government, n.d.).

From the above, it is possible to look at waste in the following hierarchy:

- Construction waste based on activity (construction or/and demolition);
- Construction waste based on material type (soil, stone, brick, concrete, etc.);
- Construction waste based on its hazardous property (hazardous and non- hazardous).

Policies and legislations

UK construction waste is regulated by the Environmental Protection Act 1990, the Waste (England and Wales) Regulations 2011, and the Environment Act 2021. According to these regulations, the legal responsibility for managing construction waste rests primarily with the person or company that produces it, known as the "producer of waste" (Qualis Flow Limited, 2023).

The producer of waste must keep records of the waste type, quantity, management and disposal method. Waste Transfer Notes (WTN) and Hazardous Waste Consignment Notes (HWCN) are legally required documents which must be completed for all transfers of non-hazardous and hazardous waste (Qualis Flow Limited, 2023). The classification of construction and demolition waste non-hazardous and hazardous is presented in Table 5.

The requirement for a Site Waste Management Plan (SWMP) in the UK stems from the Site Waste Management Plans Regulations 2008. These regulations mandated that construction or demolition projects valued at over £300,000 must develop and implement a SWMP. The purpose of the plan is to manage waste effectively and reduce the environmental impact of construction activities (UK Government, 2008).

However, it's important to note that these regulations were repealed in 2013, so while the legal requirement no longer exists, creating a SWMP is still considered best practice in the construction industry to promote sustainability and efficient waste management (UK Government, 2013). There are SWMP template available for free as this template proposed by Zero Waste Scotland.

The environmental Act 2021 gives national authorities in Scotland the power to create regulations to reduce avoidable waste by 2050.

Also, the Scottish government adopted several targets concerning reducing and managing construction waste. For instance, Scotland aims to achieve 15% waste reduction target in any given year. However, achieving this aim is linked to how much waste is produced which varies from year to year based on construction activities, i.e., Scotland produced 3.7 million tonnes of waste in 2012 compared to 5.8 million tonnes in 2018 (Scottish Government, 2022).

Also, Scotland has met the European Union target of 70% recycling and reuse of construction and demolition waste by 2020 every year since 2011. Recycling construction waste also contributes to achieving another target of sending no more than 5% of all waste to landfill (Scottish Government, 2022).

To achieve the above targets, the Scottish government is calling to adopt circular economy practices, which is part of the Making Things Last: a circular economy strategy for Scotland (Scottish Government, 2016). The Scottish Government has launched two consultations to inform a Circular Economy and Waste Route Map to 2030.

Tools and methodologies

Various organizations and consultancies have addressed the challenge of managing construction waste by developing tools for use during both the design and construction phases.

Zero Waste Scotland, a Scottish Government-funded non-profit organisation, has introduced methodologies and tools based on circular economy principles to manage construction waste. Their "Designing Out Construction Waste" guide (Zero Waste Scotland, n.d.), focuses on reducing waste through efficient design practices. Key aspects include:

- Design for Longevity: Creating durable and adaptable structures to minimize future renovations or demolitions;
- Material Efficiency: Optimizing design to reduce material offcuts and ensure recyclability or reusability;
- Modular Design: Using modular or standardized components to simplify construction and facilitate reuse;
- Collaboration: Working with all project stakeholders to integrate waste reduction strategies throughout the project lifecycle.

The aim is to incorporate these principles early in the design and planning stages to reduce waste and enhance sustainability in construction practices.

Also, Zero Waste Scotland has created the Site Waste Reduction Protocol to standardize and improve the measurement and management of construction waste. This protocol ensures consistent monitoring across different sites and works in conjunction with the Construction Waste Indicative Cost (CWIC) Calculator, which provides cost-saving estimates and other relevant data. Additionally, ZWS offers a Best Practice Guide to enhance waste management on construction sites, providing specific advice on waste prevention, reduction, and material recycling. For more details, see the Site Waste Reduction Protocol and the Best Practice Guide.

In the UK, contractors use the BRE SMARTWaste tool, developed by the Building Research Establishment (BRE), a leading organization focused on improving the built environment. The

SMARTWaste tool is an online platform designed to manage and reduce construction waste during the construction phase. It supports the creation, implementation, and monitoring of Site Waste Management Plans (SWMPs), estimates waste generation, tracks reuse and recycling rates, and manages material disposal. The tool aims to enhance sustainability and lessen the environmental impact of construction projects. For more information, visit the BRE SMARTWaste tool here.

Table 5. UK Classification of construction and demolition waste (UK Government, n.d.)

	Material types	Hazardous or not
Insulation and asbestos materials	Insulation containing asbestos	Hazardous
	Other insulation containing hazardous substances	Hazardous
	Other insulation materials	Non-hazardous
	Other construction materials containing asbestos	Hazardous
Concrete, bricks, tiles and ceramics **This list excludes asbestos-containing material**	Concrete	Non-hazardous
	Bricks	Non-hazardous
	Tiles and ceramics	Non-hazardous
	Concrete, bricks, tiles and ceramics (alone or in mixtures) containing hazardous substances	Hazardous
	Concrete, bricks, tiles and ceramics in mixtures, containing no hazardous substances	Non-hazardous
Wood, glass and plastic **This list excludes packaging wastes and domestic type recyclables**	Wood - untreated	Non-hazardous
	Glass - uncontaminated	Non-hazardous
	Plastic - excludes packaging waste	Non-hazardous
	Treated wood, glass, plastic (alone or in mixtures) containing hazardous substances	Hazardous
Bituminous mixtures, coal tar and tar	Bituminous mixtures containing coal tar	Hazardous
	Other bituminous mixtures	Non-hazardous
	Coal tar and tarred products	Hazardous
Metallic waste, including cable **Most waste electrical and telecommunications (non-WEEE) cable contains hazardous substances. To classify it as non-hazardous**	Copper, bronze and brass	Non-hazardous
	Aluminium	Non-hazardous
	Lead	Non-hazardous
	Iron and steel	Non-hazardous
	Tin	Non-hazardous
	Mixed metals	Non-hazardous
	Metals containing hazardous substances	Hazardous
	Cables containing oil, coal tar and	Hazardous

	other hazardous substances	
	Waste electrical and telecommunications (non-WEEE) cable	Hazardous
Soil, contaminated soil, stones and dredging spoil	Soil and stones containing hazardous substances	Hazardous
	Other soil and stones	Non-hazardous
	Dredging spoil containing hazardous substances	Hazardous
	Other dredging spoil	Non-hazardous
Gypsum	Gypsum materials containing hazardous substances	Hazardous
	Other gypsum materials	Non-hazardous
Cement	Un-used or un-set cement	Hazardous
Paints and varnishes	Containing organic solvents or other hazardous substances	Hazardous
	Not containing organic solvents or other hazardous substances	Non-hazardous
	Paint or varnish remover	Hazardous
	Paint cans	Hazardous
Adhesives and sealants	Containing organic solvents or other hazardous substances	Hazardous
	Not containing organic solvents or other hazardous substances	Non-hazardous
	Adhesive or sealant containers	Hazardous

3.1.3 Cost-effectiveness and maintenance in operational phases

SPAIN

When is retrofit cost-effectiveness assessed?

In general terms, cost-effectiveness assessment in retrofit project may be done in the earlier phases of the project under energy audits, Life Cycle Analysis (LCA) or Energy Performance Certificates (EPCs). Although the EPC regulations in Spain, establishes that the EPC shall also "contain information addressed to the owner, developer, tenant, maintenance company, energy auditor or energy service provider on the cost-effectiveness of the recommendations made in the certificate", and that the assessment of cost-effectiveness* shall be made on the basis of a set of standard criteria, such as the assessment of energy savings, the underlying energy prices and a preliminary cost forecast", this assessment is not always done, as it requires a deep and time consuming analysis, which is not always feasible for many reasons as this will depend on the promotor/owner profile and the own building nature.

Energy audits are obligatory for big enterprises over 250 workers (RD 56/2016), but in other buildings are voluntary. Other certifications systems such as BREEAM, LEEDs etc...also include cost-effectiveness assessments. However, it must be highlighted that in many cases, as, the research project "Rentabilidad en la eficiencia energética de los edificios" states, 'the fact that an energy measure is not economically profitable does not mean that we have to eliminate it from our list of options, as other factors may come into play". One of the points that this study highlight, is the investment to be done in order to add value to the building, but also to accomplish regulations for improving the energy performance of the buildings or to be eligible for subsidies. This would be the case for AVRA, as well as for other social housing managing companies, in which the assessment of the cost-effectiveness of interventions is based on other parameters different than just the pay-back return on investment.

Recommendations for calculation based on Delegated Regulation (EU) No 244/2012 of 16 January 2012 establishing a comparative methodological framework for calculating cost-effectiveness of the minimum energy performance requirements of buildings and their elements. Guidelines for energy audits. There is no standard for how to carry out energy audits, but there is a national regulation for energy audits (Real Decreto 56/2016). This regulation establishes a regulatory framework to develop and promote actions aimed at improving an organisation's energy efficiency, promoting energy savings and reducing greenhouse gas emissions, in order to contribute to the European Union's energy efficiency objectives. However, there are non-official methodologies and guidelines to give orientation to energy auditors and ESCOs.

Methods used to calculate cost-effectiveness

Depending on the size and use of the building and the client's profile, cost effectiveness analysis varies greatly. And for instance, the complexity of the methodology and the information provided, as this will require a deep analysis, or calculations made by professionals or a simpler one. According to this, the most basic or simple method is based on an estimation of the simple pay-back period by comparing the investment done and the energy saving costs per year.

It is convenient to know the payback periods for the investment and the estimated profitability during its useful life cycle. For this purpose, there are more complex methodologies based on static and dynamic assessment criteria, with studies of the return on investment (Payback time and NPV) of such improvements. This is the case of some EPCs calculation tools such as CYPE (CYPE, https://info.cype.com/) or CE3x (simplified procedure). In those methodologies, other concepts may be included such as maintenance costs, interest tax, etc.

Figure 3. Example from the CYPE tool

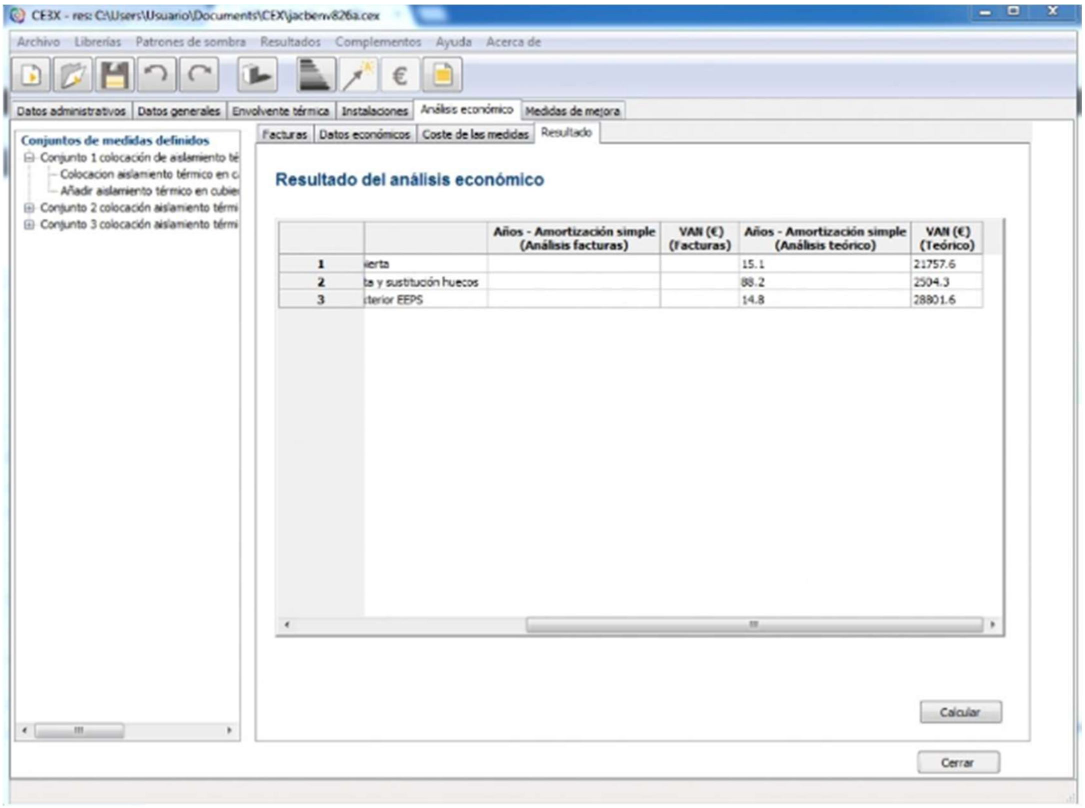


Figure 4. Example from the CE3X tool

Methods used to calculate cost-effectiveness in AVRA

As mentioned before, the assessment of the cost-effectiveness of interventions may be based on other parameters different than just the pay-back return on investment. And this is the case of AVRA's retrofits of buildings from its public social housing stock. Those dwellings usually do not have centralised heating or air conditioning systems, and AVRA does not manage or pay for the energy costs, so the pay-back or return on investment is never effective. On the contrary, these interventions are based on AVRA's responsibility, as owner, for the maintenance of its public housing stock and for achieving the best habitability and comfort conditions for the homes residents, together with the accomplishment of European policies. Many of these dwellings are at risk or in a situation of energy poverty. Another aspect to point out is that most energy retrofitting interventions are carried out by means of passive measures in the envelope, although compliance with the energy efficiency requirements of the CTE is increasingly forcing the implementation of systems that reduce the consumption of non-renewable primary energy. All those measures are implemented to improve the indoor comfort conditions of the dwellings, without affecting the low real energy consumption of the dwellings.

The practice for determining the cost effectiveness of energy retrofitting actions in AVRA is then not based on the results or assessments provided by energy audits or life cycle analyses carried out with real data measured and monitored in very specific actions, but is generally based on quantitative terms, based on previous experience, and to a large extent, on qualitative terms. It should be noted that the vast majority of the energy performance of the buildings is calculated through energy performance certificates which, although they also offer the possibility to analyse the cost-effectiveness of interventions, the experience is that the data of the standard user used by the tool is too theoretical and unreliable for economic purposes. For this reason, the assessment of the cost-effectiveness of interventions in AVRA is based on other parameters. There are two fixed quantitative parameters that need to be achieved to consider the cost-effectiveness of the energy retrofits:

- Achievement of energy improvement targets required by European funding programmes (% and/or improvement in energy rating scale letter). This improvement is based on the data provided by the energy certificate.
- Compliance with Building Technical Code requirements for each climate zone.

But there is a third parameter which would be the budget of the energy retrofits of the buildings based on average cost per dwelling. This average cost per dwelling is extracted from the analysis of the interventions carried out by AVRA in terms of energy retrofitting in recent years with the most common solutions (passive measures) needed to obtain the energy improvement and achieve the requirements of the CTE and which have thrown the best results in terms of maintenance and durability (qualitative criteria). This cost is based on the usual prices of energy retrofitting actions recently tendered by AVRA. The purpose of this is to achieve greater homogeneity and to ensure that they are “market prices”. The passive measures for each climate zone have been economically estimated, so that the selection of these measures, in general, is made on the basis that the cost of these measures is within the range defined in the above-mentioned cost analysis.

In conclusion, AVRA bases its cost-effectiveness on compliance with the CTE and the requirements established by the financing programmes on energy upgrade indicators, with a selection of measures that fall within the range of the average cost of housing refurbishment established according to its calculations.

However, the selection of measures is influenced by other factors that influence the cost-effectiveness of them, which are left to the project designer criteria, and to AVRA's evaluation and approval, but that they cannot be assessed by any kind of tool:

- Initial building condition. There are solutions that both improve the energy performance of the building and solve existing pathologies. For this reason, the fact that the solution may be more expensive a priori, but presents a cost-effectiveness by solving other existing problems, is considered.

- Climatic zone. In general, in cold climatic zones, with the same investment, a greater improvement is obtained in energy terms than in warmer zones, which would require a higher cost for the same achievement of requirements, especially in terms of obtaining the indicators demanded by the financing programmes. For instance, the cost-efficiency in cold areas may be greater than for warm zones with the same cost.

- Location: the real market cost of construction varies depending on the location of the building, being the cost of the same measures more or less expensive depending on where it is located. However, at the level of project cost analysis and tendering, this is not considered.

- Constructive and architectural character of the building: respecting the architectural configuration may require different solutions to the most usual ones that imply a lower profitability, either because the building is listed and does not allow interventions on the outside or require specific materials or more particular solutions, or because the materials and the external appearance of the building must be respected. These circumstances may also mean that more measures have to be taken to accomplish the requirements of compliance with the Building Technical code and to achieve the energy improvement needed, or to implement more special and costly measures, such as, for example, insulation on the inside the required U-value, but with a minimum thickness in order to not reducing the dwelling surface.

- Innovation: AVRA is convinced that the administration should promote the use of new materials and energy retrofitting solutions, whose costs are outside the usual range. However, those measures can have a socio-economic impact on other aspects and areas such as the promotion and extension of the use of more sustainable materials, support for smaller-scale industry, opening up new gaps in the market and in the construction, architecture and engineering sectors, etc.

- Social aspects: the social condition of the residents may determine the selection of solutions that are different from the usual ones, but which involve a sustainability that makes them cost-effective. For example, the social acceptance of some solutions by the residents or the selection of measures based on their durability in terms of use and resistance to aggressions, etc., according to the profile and general behaviour of the building's users.

POLAND

When is retrofit cost-effectiveness assessed?

Cost-effectiveness is assessed as a part of an energy audit and can be done alongside the final bill of costs for a retrofit project. An energy audit is a procedure that assesses a building's existing energy performance through the lens of energy certification parameters and identifies key areas for improvement. A full energy audit includes a retrofit proposal that generally outlines parameter targets for each area, such as ventilation, primary heat source, envelope U-value, etc. This is done using generalised indicators and is prepared during the planning stage of a retrofit, mostly concurrently to early design work. It should be noted that energy audits are not explicitly required by any legal document at act of law or regulation level, and therefore are not officially recognised procedures.

Energy audit guidelines in Poland

There is no single standard for energy audits, but there are guidelines that can be used to perform one depending on its purpose. For instance, the National Environmental Protection and Water Management Fund (Narodowy Fundusz Ochrony Środowiska i Gospodarki Wodnej, NFOŚiGW) published a 2020 set of guidelines for audits that must be attached to retrofit subsidy applications, which, apart from financial costs, also includes CO_2 emissions as a part of the audit (NFOŚiGW, 2020). Another set of guidelines is featured on the website of the Association of Energy Auditors (Zrzeszenie Audytorów Energetycznych, n.d.).

Methods used to calculate cost-effectiveness

The methods typically used to calculate cost-effectiveness in energy audits are SPBT (Simple Pay Back Time), which gives us the number of years needed for cumulative cash-flows to cover initial investment cost without factoring in the cost of capital, NPV (Net Present Value), which returns the total gain of an investment that accounts for all lifetime costs and revenues, and IRR (Internal Rate of Return), which returns the annual rate of growth that the investment is expected to generate. All three of these methods are listed as required for applying for an NFOŚiGW subsidy and these statistics are tracked by this institution.

The NFOŚiGW operates the heavily simplified Ekodom tool (https://ekodom.edu.pl/) which can be used to perform a preliminary analysis of energy performance and displays per-year energy cost values before and after a retrofit, but it does not perform any cost-effectiveness calculations based on the methods outlined above.

Maintenance plans

The methods typically used to calculate cost-effectiveness in energy audits are SPBT (Simple Pay Back Time), Net Present Value (NPV). Based on information given by Zarząd Budynków Komunalnych, property managers in Poland usually base their maintenance plans on pre-scheduled inspections of buildings and their building services, during which the technical condition of each building element is assessed and categorised in terms of repair or replacement urgency. This is a largely reactive approach, as building elements deemed to function correctly are not included in maintenance plans.

SWEDEN

When is retrofit cost-effectiveness assessed?

Cost-effectiveness is not necessarily assessed during all retrofits in Sweden. However, there are several voluntary methods and tools developed and distributed by networks financed by the Swedish Energy Agency.

Energy audit guidelines in Sweden

The law on energy declarations for buildings was established in Sweden in 2006 (Lag (2006:985) om energideklaration för byggnader).

The real estate owner is obligated to provide an energy performance certificate:

- if the total usable floor area of the building is more than 250 m2 and the building is frequently visited by the public;
- or if the building or part of the building is leased;
- or before selling a building or a share in the building.

An energy performance certificate is valid for 10 years. Energy performance certificates are supposed to give suggestions for profitable energy efficient measures, but these are rather rough estimates without a general methodology. Those suggestions might include actions for water saving as well as energy related topics as attic insulation, adjustment of the heating system, replacement of thermostatic radiators, replacement of the circulation pump, computerised substation with room sensors and solar panels.

Methods used to calculate cost-effectiveness

There are several methods to calculate cost-effectiveness in Sweden:

- BeBo (www.bebostad.se) is a method to calculate cost effectiveness for multi-family-houses;
- BELOK (www.belok.se): Total Concept was developed to calculate cost-effectiveness for non-residential buildings;
- "Offentliga Fastigheter" (www.offentligafastigheter.se) – a partnership between municipalities, regions and three state property managers – developed a guide for LCC-calculations. They reference among other tools to Statens Fastighetsverket / National Property Board's LCC method during project development (Microsoft Word - SFV-Projekteringsanvisning-LCC-2022-10-11).

However, the BELOK "Total Concept" method might be the one that is referred to most frequently. The Swedish method was developed further and adapted for a broader market (Norway, Finland, Estonia, Denmark and Sweden) throughout a project (www.totalconcept.se) co-funded by the Intelligent Energy Europe Programme of the European Union, between March 2014 and March 2017. The method is based on three different steps:

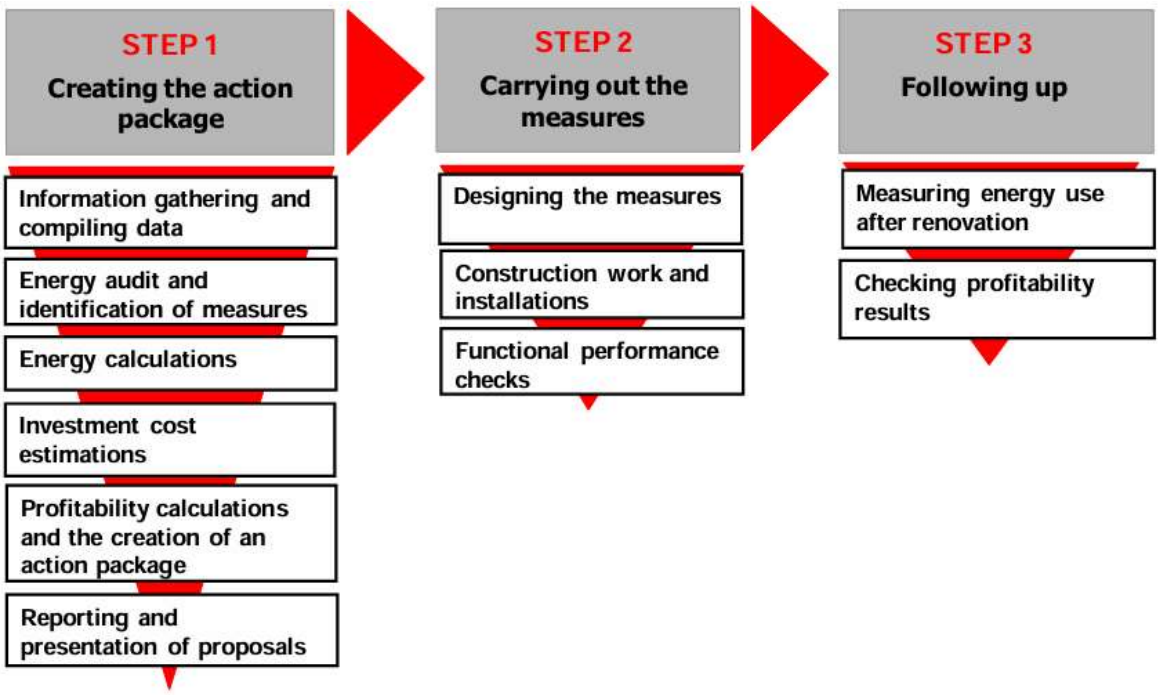


Figure 5. Total Concept, The Total Concept method - Guidebook for implementation and quality assurance, version 1.6, https://totalconcept.se/method/guidelines-tools/ [downloaded 2024-08-29], page 19

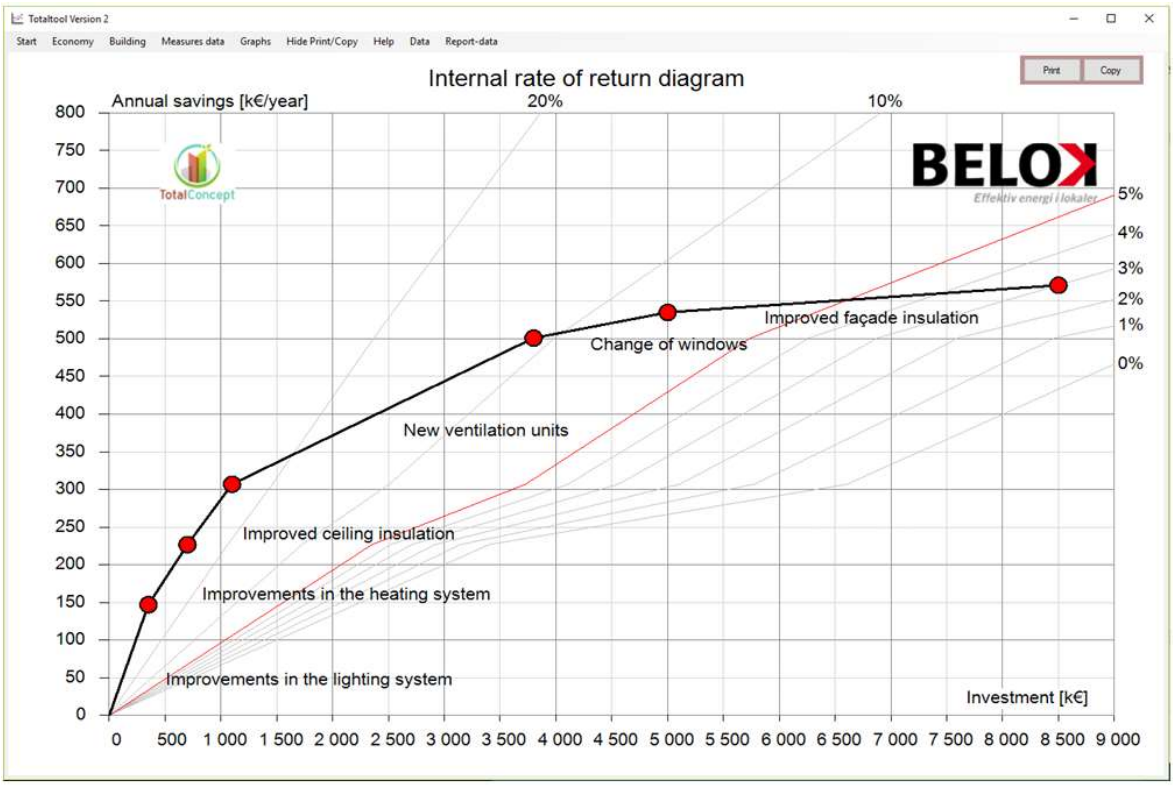


Figure 6. Total Concept, The TotalTool – User's guide, version 1.3, https://totalconcept.se/method/guidelines-tools/ [downloaded 2024-08-29], page 2

UK/Scotland

Overview

In the UK, client access to cost-effectiveness information in relation to retrofit projects, the nature and degree of complexity of the information obtained and the methodology to assess/calculate it, is strongly dependent on two aspects**:**

- **The client's profile –** whether it is an individual or a family owning a house without any technical background, an organisation/company owning and managing a portfolio of several buildings such as city councils, universities or banks for example, or even a public authority that is developing policies such as government.

- **The complexity and nature of the retrofit intervention(s), project or programme –** does the retrofit project involve one measure, a package of measures or a whole programme of retrofit projects on several buildings of an estate or across a specific area.

Depending on the size of the project and the client's profile and its internal processes, requirements for advice on cost effectiveness vary greatly. So does the complexity of the information provided, which can be generic or very specific through bespoke calculations delivered by specialised consultants.

Additionally, there is also a fundamental question about cost-effectiveness: **what does this mean and cover?**

The Scottish Government has commissioned a specific report to define cost effectiveness in 2019 - 'Defining 'Cost Effectiveness' for Energy Efficiency Improvements in Buildings' produced by Cambridge Energy[1]. The Scottish Government needed an evidence-based definition of cost effectiveness to develop its future policies which included the introduction of a mandatory minimum energy efficiency standards.

The report reviewed existing literature including articles and reports on cost effectiveness produced in the UK and worldwide. It listed nine/ten methods of evaluating cost effectiveness:

- Simple payback;
- Net annual savings;
- Consumer cash flow;
- Discounted cash flow;
- Net Present Value (NPV);
- Internal Rate of Return (IRR);
- Return on Investment (ROI);
- Cost-Benefit Ratio (CBR);

- Levelised cost (£/MWh);
- Cost cap (maximum acceptable cost for a given energy efficiency measure).

The report indicated that **simple payback is widely used as it is quite simple**. Additionally, it noted that methods used to calculate cost effectiveness tend to be simpler when used in the domestic sector and more complex when used for businesses. The report found that there is **few literature or case studies detailing benefits and practical issues with the use of cost effectiveness methods**.

The report highlighted that there is a lot of evidence in existing literature on the **difficulty to predict actual energy savings for measures installed in buildings, and that this uncertainty is hindering investment, in particular in domestic buildings** (e.g. predicting future fuel costs is complex). It emphasised that the **reliability of the calculations depends on the extent of the parameters that are considered** (e.g. are maintenance/replacement costs included?) **and the relevance of the assumptions made** – and that this is affected by the client's profile, i.e. an individual owner or a large organisation.

It also mentioned that there is a "trade-off between complexity, completeness, and how easy it is to compare between options and interpret the outcomes" of various cost effectiveness calculation methods.

The report highlighted the fact that the **calculation methods to define cost effectiveness depend on the type of metric used** (payback period, return on investment), **the type of costs and benefits used to run the calculations** (some benefits are difficult to monetise such as comfort, health, etc.), **the default or reference scenario** (i.e. the situation of reference used to compare the cost effectiveness of the proposed energy efficiency interventions), **the moment when the calculations are carried out** (before or after the installation of measures) and **the methodology used to calculate savings** (e.g., energy consumption and costs using a Dynamic Simulation Modelling tool).

The report stressed that the **concept of cost effectiveness is based on the comparison between one or more energy retrofit scenarios and a reference scenario**. This comparison process could be made difficult due to many factors influencing the end result: what is the existing situation (e.g., is the existing heating system a boiler or a heat pump?), the client's intentions and profile (e.g., the business keen to renovate the whole building in any case), or the time period used to run the cost effectiveness calculations and assess the results (i.e. a shorter period could negatively influence the cost effectiveness of a package of retrofit interventions). For instance, the report gave the example of the study of an office building in Italy where the main question was **whether it is more cost effective for the building owner to carry out required maintenance works only or to add energy efficiency improvements at the same time**. To answer this question, one must assess the impact of building element lifespan and replacement costs and compare them to energy savings, amongst other benefits.

Cost effectiveness for individual owners

In projects involving small scale energy efficiency measures, such as window retrofit or replacement of heating systems, individual owners tend to directly commission a contractor to deliver the works. This means they generally do not have access to any cost effectiveness calculation tool – apart from **standardised information** provided by the manufacturer. In the case of a new window or secondary glazing, cost effectiveness would be approached based on **potential savings on energy bills**, as well as improved U-value, and reduction of heat loss. Such information will be based on **standardised calculation methodologies based on a standardised energy behaviour for the occupants** of the flat and **standardised parameters to characterise the building fabric** (e.g., thickness and nature of materials of the walls). For instance, a secondary glazing manufacturer stated that his product could provide heat loss reduction through the glazing 'by as much as 63%' and substantial savings in excess of 22.5% in relation to energy consumption reduction and energy costs. However, information given tends to be vague, as well as the exact nature of savings and their relevance to a given building or household energy habits.

EPCs are another source of information for individual owners, providing **estimates for potential savings on energy bills** if the owner implements a list of proposed retrofit measures, specific to the property, as recommended by the EPC assessor. The savings on energy bills are, again, based on standardised calculation methodologies but take into account the characteristic of the property after having surveyed it – although at a very high level.

For larger retrofit projects, individual owners would be more likely to commission an architect and may get **more, potentially bespoke, information on cost effectiveness** – although this will depend on their budget, their requirements and the skills that their architects will have to do these calculations (or other consultant involved in the project, if any).

3.2 Case-based findings

Below is a presentation of case-based findings. The data collected for each of the cases has been collated into tables for ease of comparison. Cells with the words 'no data' in them indicate that the relevant information was not available, which in many cases indicates that it was not procured or recorded during its corresponding retrofit project or was not archived. Cells with the words 'not retrofitted' in the tables with U-values denote that a given element was not modified during the retrofit.

3.2.1 Energy performance, comfort and envelope insulation

This section presents the solutions and metrics associated with energy performance, comfort and envelope insulation. A brief characterisation of the envelope insulation solutions used in each of the detailed cases has been presented in Table 6 below.

Table 6. Overview of envelope refurbishment solutions employed in detailed FuturHist case projects

ID	Envelope insulation solutions
PL1	Front façade external wall insulated with externally applied expanded polystyrene (EPS) panels
PL2	External walls: 12 cm of extruded polystyrene (EXPS) 30SF boards λ = 0.035 W/(mK) including insulation of the crowning cornice (12 cm); 2 mm silicone plaster SILVER TO-TSS; Window and door jambs insulated with 3 cm polystyrene foam; At the basement level 20 cm of XPS 30SF boards λ = 0.04 W/(mK). Insulation of the basement walls. New windows installed (PVC, double-glazed, aluminium windows in basement)
PL3	East façade insulated with 12 cm thick EPS and mineral wool panels and external render, in places, 10 cm of XPS 20F boards λ = 0.035 W/(mK). New windows installed (PVC, double-glazed)
PL4	External walls insulated with mineral wool finished with plaster. New windows installed (PVC, double-glazed).
ES1	Roof: 10 cm of EPS insulation covered with pine board and joists; external walls: aerogel insulation; cavity wall with 5 cm mineral wool insulation;
ES2	Roof: 5 cm XPS panels; Walls between conditioned and unconditioned spaces: 4 cm fiberglass panels; Window glazing replaced with double-glazed, dehydrated air chamber panes;
ES3	Roof: 8 cm EPS panels, compression mortar and ceramic finish; Ceiling between conditioned/unconditioned spaces: 5 cm XPS panels finished with 4 cm reinforced mortar; External wall: not insulated; Party wall: 4 cm mineral wool and plasterboard partition; Wall between conditioned/unconditioned spaces: 4 cm mineral wool and plasterboard;
ES4	Roof: 6 cm XPS insulation; Ceiling between conditioned/unconditioned spaces: 5 cm XPS panels on concrete slab; External wall: from inside – 5 cm mineral wool and plasterboard; Walls between conditioned/unconditioned spaces: 5 cm of mineral wool covered with plasterboard;
SE1	External walls: additional insulation added, New windows with triple glazing installed
UK1	Roof: blown cellulose fibre c. 300 mm, reduced to c. 150 mm; woodfibre batts; Floor between conditioned/unconditioned spaces: XPS insulation; Party wall: combination of woodfibre and aerogel panels; Windows: various solutions incl. installation of vacuum double glazing, installation of secondary glazing, internal timber shutters; significant improvement in airtightness
UK2	Roof: TGI joists with blown cellulose; Floor insulation between conditioned/unconditioned spaces: 30 cm vacuum-insulated panels with lytag screed; External walls: 15 cm Styrofoam panels; Walls between conditioned/unconditioned spaces: Internal wall insulation including: woodfibre, aerogel, IQtherm, PIR, calsitherm, rigid thermoset insulation. Finished mainly with magnesium board, lime plaster and breathable paint; Windows: secondary argon-filled double glazing added; Doors: upgraded with VIPs with purenit battens and 10 mm VIP sheet; improved envelope airtightness va internal lime plaster and poured screed floor with vapour screen
UK3	Roof: open blow cellulose in attic; Floor insulation between conditioned/unconditioned spaces: Woodfibre below joists; Walls between conditioned/unconditioned spaces: Woodfibre IWI; Windows: triple-glazed new windows; Airtightness: passive purple in subfloor void and roofspace, parge coat on masonry with lime plaster
UK4	Roof: 10 cm woodfibre insulation fitted between vertical hangars and the underside of rafters; existing mineral wool insulation had its gaps filled; vapour-permeable paint; Floor insulation between conditioned/unconditioned spaces: 10 cm wood fibre material in the timber floor in contact with the solum void; Walls between conditioned/unconditioned spaces: icynene

	expanding foam injected into existing wall cavity;

As it can be seen, the solutions used can be considered quite varied and tailored to the specificity of each HB. Notable examples of such tailored solutions include the application of interior insulation using mineral wool under plasterboard cladding or the injection of foam-based insulation into wall cavities.

To present a more complete picture of the retrofits, especially in the context of energy performance characteristics, we have compiled a list of building services installed or remodelled as part of the detailed case projects, which are presented in Table 7.

Table 7. Overview of building services solutions employed in FuturHist case projects

ID	Building services solutions
PL1	Not subjected to retrofit
PL2	Connected to district heating
PL3	Connected to district heating. compact heat centre with casing up to 100 kW. Heat transfer - water central heating from a local heat source located in a heated building - with insulated pipes, fittings and equipment - in unheated rooms. No buffer cylinder. Central heating control - panel/plate radiators with central and local control (P-2K range). Heat generation for domestic hot water preparation – gas-fired instantaneous water heater with electric ignition (60%). Electric storage heater with storage tank without losses (40%). Heat transfer – local preparation directly at the points of consumption – no circulation circuits 4%. No storage tank for heat accumulation.
PL4	Connected to district heating.
ES1	Not subjected to retrofit
ES2	Individual forced ventilation system in each of the 11 homes (200 m^3/h); DHW: Electric boiler with accumulator 150 l; RES: Individual installation of a 150 l solar thermal accumulator collector for each home
ES3	Ventilation: Hybrid community ventilation system using chimneys and mechanical extractors with a flow rate of 950 m^3/h; DHW: Electric boiler with accumulator 100 l; RES: Individual installation of a 150 l solar thermal accumulator collector
ES4	Ventilation: Individual mechanical ventilation system of 110 m^3/h; DHW/RES: Air–water heat pump and 80/110 l storage tank
SE1	Ventilation: air handling units; Heating: connected to district heating; Cooling: district cooling system, DHW: district heating
UK1	Ventilation: mechanical ventilation in wet rooms, central fan; Heating: gas-fired boiler with small radiators and individual radiator controls; DHW: gas-fired boiler
UK2	Ventilation: continuous mechanical extract ventilation for all wet rooms; Heating: Multi-fuel stove: Morsø S11-40; DHW: Gas central heating and radiators
UK3	Ventilation: Mechanical ventilation with heat recovery (MVHR) with openable windows; Heating: heated supply air terminals, electric towel rails, 3 x wood burning stoves as backup; Cooling: Daytime use of MVHR with window night purging during heat waves; DHW: Direct electric

	Mixergy tank; RES: Solar photo voltaic panels with battery storage have been installed to the garage to begin with and further panels are intended to be added in the future.; Heat recovery: recovering 86% of the heat from the outgoing air
UK4	Ventilation: improved natural ventilation via additional grilles; Heating: radiant panel heater in bathroom, heated towel rail

Again, there appears to be considerable variation in both the amount and variety of solutions used, as well as in terms of the presence of RES-based systems. In a few cases, the retrofits were limited to providing a connection to district heating or changing the main heat source and heat distribution systems for space heating. Others also included forms of forced or improved ventilation. It is notable that only one case features heat recovery, and three featured some form of RES-based system.

Below is a table that showcases the energy performance values for the cases from the HIBERatlas project. Information on the solutions used in each case can be found on the project's website.

Table 8. Energy performance achieved in cases listed in the HIBERatlas project

ID	**Non-RES Final Energy Demand [kWh/m^2/year]**	**Non-RES Primary Energy Demand [kWh/m^2/year]**	**Percentage of RES in satisfying Total Final Energy demand [%]**
HBA1	No data	46,76	>0
HBA2	No data	274.00	0
HBA3	No data	27.70	0
HBA4	No data	45.00	0
HBA5	No data	69.00	0
HBA6	No data	45.00	0
HBA7	No data	30.00	0
HBA8	No data	No data	100
HBA9	No data	32.30	0
HBA10	No data	55.77	0
HBA11	No data	44.00	0
HBA12	No data	110.00	0
HBA13	No data	98.00	Unknown
HBA14	No data	94.40	0

There is an observable variety in energy performance among the HIBERatlas cases, but the vast majority, with the notable exception of HBA8, had a Non-RES Primary Energy Demand of a Net-Zero Energy Building (±0.00 kWh/m^2/year) or a Passivhaus (≤15.00 kWh/m^2/year), with case HBA3 coming close to the value required for the EnerPhit certificate (≤25.00 kWh/m^2/year) (Passivhaus

Trust, n.d.).

SPAIN

Out of all the cases, those from Spain attained some of the lowest values in energy performance metrics, specifically Non-RES Final Energy and Non-RES Primary Energy, in addition to having high percentages of RES in their energy mix. As these cases are located in the south of Spain, it is necessary to study them as a separate group as the climate in this area differs significantly from the other countries.

Table 9. Energy performance achieved in Spanish cases

ID	Non-RES Final Energy Demand [kWh/m²/year]	Non-RES Primary Energy Demand [kWh/m²/year]	Percentage of RES in satisfying Total Final Energy demand [%]
ES1	98.51	98.84	0
ES2	57.79	70.49	23.14
ES3	20.09	23.57	62.79
ES4	22.20	40.00	0

It can be seen that in one case, ES3, it was possible to achieve an energy performance that is comparable to EnerPhit levels.

IEQ, IAQ and general thermal comfort data was not available for any of the Spanish cases, as none of the relevant metrics were measured during either ex-ante or ex-post evaluations.

The U-values for envelope elements in the Spanish cases have been presented in Table 10 below. These cases were found to have highly varied U-values between cases, and relatively high U-values for window and door frames and glazing.

Table 10. Envelope insulation U-values for Spanish cases (in W/m²K)

ID	External walls	Window frames // Glazing	Door frames // Glazing	Walls adjacent to unconditioned spaces	Roof
ES1	0.35	1.30 // 1.40	2.20 // 3.30	0.43	0.32
ES2	0.87	2.20 // 2.30	2.20 // 3,30	0.67	0.54
ES3	0.93	2.20 // 5.70	2.20 // 5.70	0.45	0.25
ES4	0.33	1.740 // 2.80	1.90	0.33	0.47

POLAND

The cases from Poland were found to have the highest energy demand values out of the entire sample with RES markedly having no share in covering the demand for energy in all of them.

Table 11. Energy performance in Polish cases

ID	Non-RES Final Energy Demand [kWh/m²/year]	Non-RES Primary Energy Demand [kWh/m²/year]	Percentage of RES in satisfying Total Final Energy demand [%]
PL1	231.40	306.10	0
PL2	122.20	160.40	0
PL3	216.70	210.80	0
PL4	138.70	113.10	0

As in the Spanish cases, IEQ, IAQ and general thermal comfort data was not collected as part of the retrofit and was thus unavailable.

Table 12. Envelope insulation U-values for Polish cases

ID	External walls	Windows (set)	Doors (set)	Walls adjacent to unconditioned spaces	Roof
PL1	0.27	2.80	2.80	Not retrofitted	0.39
PL2	0.26	0.90	No data	Not retrofitted	0.86
PL3	0.27	1.40	3.50	Not retrofitted	0.86
PL4	0.27	1.10	2.40	Not retrofitted	0.17

Based on the U-values presented in the table above, we can see that three out of the four Polish detailed cases had a poorly insulated roof, which may explain the energy performance metrics.

SWEDEN

In the Swedish case, the energy demand values were quite low, as shown below, but still far above values that would make them eligible for certification.

Table 13. Energy performance in the Swedish case

ID	Non-RES Final Energy Demand [kWh/m²/year]	Non-RES Primary Energy Demand [kWh/m²/year]	Percentage of RES in satisfying Total Final Energy demand [%]

SE1	84.40	68.10	0

An ex-post analysis of thermal comfort was conducted for the Swedish case after the retrofit in the form of a survey of building users. It found that the users rated the post-retrofit comfort as worse than before the retrofit.

Table 14. Envelope insulation U-values for the Swedish case

ID	External walls	Windows (set)	Doors (set)	Walls btw conditioned and unconditioned spaces	Roof
SE1	1.00	1.20	1.20	No data	0.27

There is a notable case of a high U-value for external walls, which is at 1.00 W/(m²·K). This was probably necessitated by the rich and articulated façade detailing and the restriction on the application of wall insulation.

UK/Scotland

Even though the cases for study were selected based on access to retrofit data, very little data on energy performance – as defined for the purposes of FuturHist – could be found for the UK cases, with only one metric given in one case.

Table 15. Energy performance in UK cases

ID	Non-RES Final Energy Demand [kWh/m²/year]	Non-RES Primary Energy Demand [kWh/m²/year]	Percentage of RES in satisfying Total Final Energy demand [%]
UK1	No data	No data	No data
UK2	No data	No data	No data
UK3	No data	No data	No data
UK4	No data	285.0	No data

In the single UK case for which relevant data was available, the energy performance can be rated as poor, as it is over ten times higher than indicated for EnerPhit certification.

As for thermal comfort, while it was not assessed per se in any of the cases as either part of an ex-ante or ex-post analysis, case UK4 required another intervention on account of damp-related problems emerging after the initial retrofit, which can be seen as lending further credence to the statement that comfort and, specifically, air humidity, was not duly investigated during the planning of this specific retrofit.

Table 16. Envelope insulation U-values for the UK cases

ID	External walls	Windows (set)	Doors (set)	Walls btw conditioned and unconditioned spaces	Roof
UK1	0.09	1.10	Not retrofitted	Not retrofitted	Not retrofitted
UK2	No data	1.25	0.90	0.11	0.15
UK3	No data	0.75	Not retrofitted	0.20	0.08
UK4	No data	No data	Not retrofitted	0.41	0.14

Comfort, IEQ and IAQ

While inquiries were made as to the thermal comfort, IEQ and IAQ metrics used in the HB projects that formed the sample, it was found that these were generally not monitored ex-ante in any of them, and some form of ex-post analysis was performed during two projects: SE1 and UK2. In the case of SE1, a post-occupancy survey was conducted among the building's users to gauge whether conditions in the building had improved, and in the two UK cases, monitoring focused on humidity and moisture content, as well as temperature and airtightness — metrics that can affect indoor comfort — was conducted but data from this monitoring could not be accessed.

It can therefore be concluded that comprehensive thermal comfort, IEQ and IAQ measurements cannot be considered a standard element of current HB retrofit practice and benchmarking.

3.2.2 Waste generated during construction

Although we set out to collect a wide range of data on waste generated during construction, including demolition waste, the various country-specific construction waste categories and packaging waste, very little relevant data could be procured for the projects analysed in this study and many of the large-scale data repositories cited in previous sections proved to be of little use in pinpointing the amount of waste produced during specific projects. Ultimately, data on waste could only be collected for demolition waste and for overall waste shipped off-site via lorry, and for five main cases, namely PL2 and PL3 from Poland, and ES1, ES2 and ES3 from Spain.

No data was found for metrics that could enable an assessment of waste management or the presence and effectiveness of waste reduction measures during a specific retrofit project, including no breakdowns of waste into categories used in each country for monitoring purposes.

No available waste-related data could be found for cases from past projects.

The data that was found is presented in the table below.

Table 17. Demolition waste generated during a retrofit project in tonnes per square metre of floor area

ID	Demolition waste [t/m^2]

ES1	0.037
ES2	0.037
ES3	0.328
PL2	0.0489
PL3	0.087

It was possible to find data on one UK-based project, a case study by Zero Waste Scotland, namely Kier Construction – Mansion House Refurbishment (2023). This case study used Zero Waste Scotland's waste assessment tools and guidelines and found that mixed construction and demolition waste constituted the majority of the waste produced by the project, both by volume (57%) and weight (62%), with packaging paper and cardboard that had not been recovered by the supplier coming second (19% by volume and 11% by weight). Furthermore, 51% of the waste from this project was deemed mostly recyclable and 25% was deemed suitable for recycling, while 24% was slated for deposition at a landfill.

Project background:

- An existing stone and brick-built hotel in Edinburgh built in the 18th and mostly in the 19th century.
- The project cost is just over £400,000
- Floor area is 776 m^2
- Project was complete in 2022

The site was selected to pilot the Construction Waste Indicative Cost (CWIC) Calculator, which assesses the costs of materials, labour, and indirect expenses associated with individual skips on construction sites. Since subcontractors were financially responsible for their materials, this setup incentivized them to minimize waste and use materials efficiently.

The main contractor used the BRE SMARTWaste tool to manage waste and create a Site Waste Management Plan, while the site manager estimated waste volumes with an internal document. A 12-cubic yard skip was placed at the building's entrance for mixed waste. Waste was manually transported from multiple floors, with a distance of 116 meters considered. Materials were categorized and logged, with specific tracking for screws and bulk documentation for demolition waste. The SMARTWaste tool, aided by the CWIC Calculator, provided a detailed cost analysis, including material cost breakdowns and extrapolated figures based on the skip's capacity. This suggests that the main avenues for lowering the amount of waste generated during retrofit projects are:

- the use of non-invasive solutions that minimise the amount of demolition waste,
- maximising the reuse of a building's original materials wherever possible,
- minimising the amount of unclaimed or non-reusable packaging, especially paper and

carboard.

It is important to note that HB retrofit projects are highly case-specific and a waste-to-area ratio, while providing comparability between cases, may ultimately not be conducive to illustrating the avenues towards reducing waste generation during a project. One reason behind this is that some building typologies require less material expenditure to improve their energy efficiency on account of having more favourable area-to-volume ratios — this is typical for row houses or terraced tenements, which abut other buildings. In turn, detached buildings with complicated shapes require greater material expenditure to properly insulate, generating more waste relative to the energy performance obtained.

Two key papers, Sobotka et al. (2019) and Sagan and Sobotka (2021) offer relevant insights into the sustainability assessment of construction processes and the circularity of building materials. Sobotka et al. (2019) present a comprehensive methodology for evaluating the sustainability of construction processes across environmental, economic, and social dimensions. This approach might match FuturHist's goals, allowing the evaluation of historic building retrofits across multiple criteria. They recommend focusing on core impact categories for the environmental assessment, with weights of relative importance derived from Abbe and Hamilton (2017). The economic analysis involves calculating direct costs, while the social assessment introduces quantitative indicators for factors such as noise, particulate emissions, and vibration impacts on workers and local communities.

The historic buildings retrofit context requires specific adaptations of this proposed methodology. The social assessment could expand to consider occupant comfort, health and well-being, and preservation of heritage values. The economic analysis must account for particular cost structures and funding mechanisms associated with retrofitting historic buildings. Sagan and Sobotka present a systematic framework for analyzing factors influencing building materials' circularity, which aligns with FuturHist's focus on resource-efficient and waste-minimizing retrofit solutions. Using the DEMATEL method, the authors identify causal relationships between over 30 factors related to material circularity and waste minimization (Sagan, Sobotka, 2021).

Principal factors include:

- Waste management knowledge and practice;
- Sustainable design approaches;
- Quality of secondary raw materials;
- Market demand for recycled products.

The study emphasizes the importance of both direct and indirect effects, policy instruments, and stakeholder awareness in driving circularity. The mentioned papers provide valuable methodological guidance and analytical frameworks. Key takeaways include integrating multi-criteria sustainability assessment across environmental, economic, and social dimensions; adapting indicator sets and weights to historic buildings retrofit priorities; systematically examining factors influencing material circularity and waste minimization; and engaging stakeholders to validate and refine assessment frameworks for the historic buildings sector.

Based on the findings presented above, we suggest that the focus be shifted from project-based assessments to solution-based assessments, as these can be more easily modified or changed to more effectively contribute towards typology-specific results.

3.2.3 Cost-effectiveness and maintenance in operational phases

Cost-effectiveness

Due to incomplete data, out of the cases selected for FuturHist, it was possible to only perform calculations for the four Polish cases. These calculations are presented below.

Objectives:

- Discount rate: 2.5%

Time duration analysis: 30 years

Table 18. Cost-effectiveness calculations for case PL1

Key parameters	Result
CER	0.86 €/kWh
BCR	4.07
NPV	€ 64,342.00

Table 19. Cost-effectiveness calculations for case PL2

Key parameters	Result
CER	5.94 €/kWh
BCR	2.01
NPV	-€ 25,603.00

Table 20. Cost-effectiveness calculations for case PL3

Key parameters	Result
CER	2.43 €/kWh
BCR	4.77
NPV	€ 3,429.00

Table 21. Cost-effectiveness calculations for case PL4

Key parameters	Result
CER	1.64 €/kWh
BCR	7.57
NPV	€ 43,617.00

The values presented in the tables above indicate a significant variation between cases. It also shows that, for case PL2, the retrofit could not be considered cost-effective due to a relatively high financial outlay that resulted in a relatively low improvement in energy efficiency. In the case of historic buildings, cost-effectiveness (of energy retrofits?) is often less favourable compared to modern structures. The cost of renovation and thermal retrofits tends to be significantly higher due to several factors. One of the primary reasons is the higher price of materials required for restoration, which often need to meet specific aesthetic, historical, or regulatory standards. For instance, specialized materials or handcrafted elements are frequently necessary to preserve the original character and architectural integrity of the building.

Moreover, in many cases, the condition of historic buildings adds to the complexity and cost of the project. These structures may suffer from extensive damage or deterioration, such as severely degraded facades, structural weaknesses, or outdated building systems. The restoration of elements like ornate elevations or intricate architectural details can be labour-intensive and costly.

Maintenance in operational phases

Notably, maintenance in operational phases was found not to be tracked or considered in any of the cases surveyed. Likewise, best practice cases selected for the investigation from HIBERatlas did not factor it in, as no lifecycle costing or other similar method was employed in them. It can therefore be concluded that current HB retrofit practice does not consider this specifically in project planning and assessment. However, it should also be noted that cost-effectiveness is, overall, seen as a significant factor to a successful HB retrofit project, as lowering energy costs featured prominently in interview responses. It may thus be argued that while it is not assessed per se, providing easier and quicker access to the relevant information during a project's design phase may lead to more attention being given to it by project owners.

Impact on fuel poverty

While the literature on fuel poverty in HBs can be considered extensive, we did not find fuel poverty itself or its related phenomena to be something that is actively monitored as a part of the HB retrofit projects surveyed for FuturHist or in other projects. It is therefore not possible to formulate any conclusions as to the impact of current HB retrofit practice on fuel-poverty–related behaviours. However, it cannot be ruled out that such behaviours may have been present.

According to the literature, factors that contribute to fuel poverty, and to the energy performance gap of HBs relative to newer buildings in general, include:

- the age of the occupants of HBs is on average higher than in newer buildings, which translates to a greater share of pensioners, whose monthly incomes are lower than the average wage (Rutkowski et al., 2018);
- occupant behaviours related to fuel savings (Far et al., 2020);
- HBs are often connected to old and poorly maintained utilities infrastructure, which may contribute to increased energy expenditure required to prepare domestic hot water, as in cooler climates water may be delivered to an HB at a lower temperature (Szulgowska-Zgrzywa et al., 2023);

3.2.4 Software used to plan and design retrofits

Very little data could be procured on the software that was used to plan and model the retrofit or to prepare the relevant design documents. For case UK2, there was general information that the building was monitored using software and equipment provided and handled by Archimetrics for its post-occupancy evaluation, while in case UK3, PHPP software, distributed by the Passivhaus Trust, was used. In terms of design documents, in case PL4 they were prepared using Archicad by Graphisoft.

3.2.5 Retrofit project key performance indicators

It was found that the uptake of the KPIs was minuscule, as only a fraction of financial KPIs were used in the projects, most notably Cost and Capital Investment. One project (UK2) utilised GHG emissions, but this was the sole identifiable environmental KPI use case observed.

Table 22. Capital investment data from datasheets

ID	Capital investment
PL1	PLN 99,916 – equivalent of €23,404 (as of 17.12.2024)
PL2	PLN 149,801 – equivalent of €35,089 (as of 17.12.2024)
PL3	PLN 232,446 – equivalent of €54,448 (as of 17.12.2024)
PL4	PLN 504,201 – equivalent of €118,104 (as of 17.12.2024)
ES1	No data
ES2	No data
ES3	No data
ES4	No data
SE1	SEK 87,000,000 – equivalent of € 7,577,700 (as of 27.12.2024), including interior refurbishment
UK1	£160,000 – equivalent of €193,345 (as of 17.12.2024)

UK2	No data
UK3	No data
UK4	£17,000 – equivalent of €20,551 (as of 17.12.2024)

Our findings suggest that current HB retrofit practice emphasises cost-effectiveness seen from a perspective of initial capital investment and, in rare cases, environmental concerns also play a part, but they should be seen as a sign of best practice and not a standard occurrence. It is also possible that cost-effectiveness calculations had been done but were not documented and archived.

3.2.6 Smart readiness indicators in HB energy retrofits

SRI was not employed in any of the cases surveyed, either those for which data was collected specifically for FuturHist, or those from other past projects. It is important to note that SRI as a concept is still in its testing phase and is not an official requirement in any of the countries where the cases investigated are located. Seeing as HB retrofits do not follow the same development path as new constructions, it can be assumed that until official state-specific standards are drafted and implemented, SRI's implementation will be confined to limited best practice cases.

It is therefore reasonable to conclude that merely adopting SRI in an HB retrofit project sets it apart from current practice.

3.3 Interviews

As a part of broader FuturHist research efforts, a series of structured interviews were conducted with a group of stakeholders for the purposes of collecting information and data for other tasks, most notably tasks 1.1, 1.3 and 1.4, and whereas these tasks were focused on determining how policies affect renovation, what the barriers to renovation are and what tools and guidelines are used in renovation, in the case of Task 1.5 the interviews and responses were looked at from the standpoint of the renovation process itself.

Groups of stakeholders interviewed by the FuturHist project team:

- Practitioners - examples of stakeholders – architects, engineers, contractors/craftsmen, heritage expert, energy expert, retrofit expert; number of reviewed: Spain – 4; Poland – 2, Sweden – 1, UK/Scotland - 1
- Public authorities – e.g. local heritage authority, regional/national heritage authority, planning officers, policy maker (local/regional authority, government; number of reviewed: Spain – 3; Poland – 4, Sweden – 1, UK/Scotland - 1
- Professional owners – e.g. professional manager of public buildings, real estate owner, demo case owner, demo case user; number of reviewed: Spain – 0; Poland – 2, Sweden –

1, UK/Scotland - 1

- Private owners – e.g. building user, tenant; number of reviewed: Poland – Spain – 3; Poland – 1, Sweden – 0, UK/Scotland - 2

Table 23. Respondents ID, stakeholder group, country and role

No	ID	Stakeholder	Country	Role
1	PRAPL1	Practitioner	Poland	Designer (architect)
2	PRAPL2	Practitioner	Poland	Architect
3	PRAES1	Practitioner	Spain	Engineer
4	PRAES2	Practitioner	Spain	Architect
5	PRAES3	Practitioner	Spain	Architect
6	PRAES4	Practitioner	Spain	Researcher (architect)
7	PRASE1	Practitioner	Sweden	Heritage expert at architectural firm
8	PRASE2	Practitioner	Sweden	Heritage expert at architectural firm
9	PRAUK1	Practitioner	UK/Scotland	Designer (architect)
10	PUBPL1	Public Authority	Poland	Planner at heritage authority (architect)
11	PUBPL2	Public Authority	Poland	Administrative official at heritage authority
12	PUBPL3	Public Authority	Poland	Regional conservator at heritage authority
13	PUBPL4	Public Authority	Poland	Regional conservator at heritage authority
14	PUBES1	Public Authority	Spain	Heritage expert
15	PUBES2	Public Authority	Spain	Planner
16	PUBES3	Public Authority	Spain	Officer at heritage authority
17	PUBES1	Public Authority	Sweden	Heritage expert at national heritage authority
18	PUBUK1	Public Authority	UK/Scotland	Policy and Strategy Manager
19	PROPL1	Professional Owner	Poland	Property manager
20	PROPL2	Professional Owner	Poland	Deputy head of real estate company
21	PROUK1	Professional Owner	UK/Scotland	CEO of social housing organisation
22	PROSE1	Professional Owner	Sweden	Trustee, advisor
23	PRIPL1	Private Owner	Poland	Building owner
24	PRIUK1	Private Owner	UK	Owning a flat in a listed building

3.3.1 Results of the interviews

The following questions were included in the research interviews, which relate to the issue of practical activities related to the retrofit of historic buildings, energy efficiency improvements, renovation works carried out and planned. We decided to present the respondents' answers in more detail to better address the background of the issue.

- Question_01: What are the main barriers to making historic buildings **more energy efficient**?
- Question_02: FuturHist deals with the energy retrofit of historic buildings, what do you think about current renovation rate? Are we going to **meet national/European target?**
- Question_03: There is a possibility in the **EPBD to exempt** listed historic buildings from demands on energy efficiency. What do you think about this option?

Additional questions:

- Question_04: What have you done to make your building(s) more energy efficient? Do you have plans for future actions?
- Question_05: Have you done any major renovation in your building(s) in recent years? What was the main reasons for the renovation?
- Question_06: Do you plan any major renovation in your building(s)? What are the main reasons?

Answers are grouped below according to the stakeholders and countries; no. indicates the actual number of interviewed stakeholders.

Question_01: What are the main barriers to making historic buildings more energy efficient?

SPAIN

Practitioners (Spain, no. 4):

- Budget - enormous expense involved on an existing building, compared to the "quick" benefit of new construction. Short-sighted benefits;
- Renovation measures are not compatible with the preservation criteria; Certain flexibility in regulations is needed – the codes may change, the asset will remain;
- Conservation policies for HB (heritage regulations) do not allow the implementation of new technologies;
- Current building regulations (in Spain CTE-technical Building Code) exclude heritage buildings from compliance with energy requirements;
- The need for specific financial public aid;
- The choice of the right professionals (technicians, engineers, architects and contractors) incl. selection procedures and their knowledge (certain training), differences between public and private sector;
- The individual 'nature' of the HB and the material use;

- These building were not designed as energy efficient (incl. orientation, ventilation, etc.), do not meet current standards;
- Cultural, scientific-technical and management barriers.

Public Authorities (Spain, no. 3)

- The regulations - quantitative regulations outmanoeuvre qualitative regulations, not negotiable if not compatible with the building;
- Not enough progress in defining criteria and intervention strategies for the energy retrofitting of HB, not sufficient progress in proposing compensatory measures;
- Lack of knowledge of the methodology of intervention in HB;
- Planning process fails because heritage values are not identified at an early stage, hence the consequences of a decision cannot be assessed;
- Greater complexity in the administrative procedures of the intervention, with longer deadlines for obtaining the necessary authorisations;
- Budget – economic limitations.

POLAND

Practitioners (Poland, no. 2):

- Lack of Budget;
- The pursuit of cost-effectiveness by project sponsors and owners clashes with heritage conservation requirements;
- It is not mandatory to retrofit HB.

Public Authorities (Poland, no. 4, incl. General Assembly):

- Lack of Budget;
- Lack of awareness and knowledge (esp. among contractors) due to procurement procedures. Lack of knowledge of methods of thermal modernization to increase thermo efficiency;
- The need to preserve architectural qualities and building historical/aesthetic features;
- Lack of contractors who have appropriate skills;
- Lack of pre-project data.

Professional Owners (Poland, no. 2):

- Lack of budget, budget is significantly higher in comparison to non-HB buildings;
- Technology - it is not possible to use standard, cheap solutions;
- Lack of cost-effective, proven solutions that would be acceptable to conservation services is a major obstacle.

Private Owner (Poland, no. 1):

- Lack of concern and interest for retrofit for this type of facility.

SWEDEN

Public Authorities (Sweden, no. 1):

- The regulations, objectives and directives do not include HB;
- Lack of information, documentation and guidance of the Swedish National Heritage Board;
- It is a burden to own / manage HB, because the regulations are going in a different direction;
- Lack of knowledge;
- Planning practice does not take heritage values into account to the extent they deserve. The policies are not used as intended;
- Problem to reach out to professionals in the construction sector with information (knowledge gap).

Practitioner (Sweden, no. 1):

- The materials used should correspond with the historic material; they should not alter the appearance of the building, its historic (material) identity;
- Lack of knowledge regarding the possibilities of using materials.

Professional Owner (Sweden, no. 1):

- Lack of solutions that take cultural values into account;
- Reluctance to make changes in the building substance.

UK/Scotland

Public Authorities (UK, no. 1):

- Diversity of buildings traditionally constructed;
- Lack and different culture of maintenance and repair;
- Lack of awareness what retrofit is, there is a need for education and culture shift;
- Lack of skills - retrofit of HB is perceived as (traditional) skills gap in the construction sector;
- The need to integrate policies with respect to HB - zero heating, meeting zero carbon and other climate targets – comprehensive sort of policy landscape;
- The issue of proper measuring the energy efficiency of HB;
- Retrofit is not a separate action, detached from maintenance and other interventions. This is a discursive/cultural barrier.

Professional Owners (UK, no. 1):

- Lack of architect practices skilled in the feasibility of the conversion of HB, of logistic feasibility of retrofitting and improving resident's accommodation;
- Logistic problem: where to accommodate people when renovation takes very long time?

- Cost-effectiveness/funding - here at the expense of governing body (also an issue);
- Planning regulations not aligned with climate policy.

Private Owner (UK, no. 2):

- Cost-effectiveness of the technical solutions aligned with tight regulations (more flexibility for the choice making would be welcomed);
- Non-standard technical solutions are too expensive, sometimes a barrier - you have to abide by a specific standard in terms of that is in line with the protection of the district buildings
- Space restrictions for e.g. heat pumps (no place in the garden)
- Uncertainty about what is actually permitted;
- The attitude of neighbours / cohabitants. If they do not agree to the proposed retrofit solutions, distrust in climate change or heating costs is an issue.

Question_02: FuturHist deals with the energy retrofit of historic buildings, what do you think about current renovation rate? Are we going to meet national/European targets?

SPAIN

Practitioners (Spain, no. 4)

- The objectives cannot be achieved at the current pace;
- There is a commitment from administrations in general, towards the recovery and protection of historic buildings, which necessarily involves their energy rehabilitation (esp. in Andalusia);
- There is a significant HB still awaiting rehabilitation, but beyond the individually listed buildings, many structures within historic complexes are disappearing or get substantially altered;
- The 2030 target of having the entire residential stock classified as E is perhaps possible, although not every single property will be classified, most of them are already at this minimum rating;
- The neutrality targets for 2025 are seriously compromised since, despite the rehabilitation aids offered, current homeowners do not have the financial capacity to rehabilitate their properties today, nor could the administrations, with the current budget commitment;
- There is optimism, since energy retrofitting projects and initiatives are getting underway – but not necessary with HB;
- Convents, which have been changed into hotels, with significant heritage component, which went important energy retrofitting in order to meet certain conditions, got fitted with equipment that has subjugated the building itself;

- Presently we are more sensible and aware to the treatment of HB buildings (considering for example past refurbishment of public administration buildings);
- Heritage building cannot neglect the heritage component and therefore such energy installations and infrastructures can never subjugate the character, spatiality and material for which these buildings were conceived. One aspect should not take priority over the other;
- We should give priority to interventions with a reversibility character because the elements of technological innovation are very changeable, but heritage buildings are not;
- I would like to think that the objective will be met, but it depends on the administration because majority of these buildings belong to the public administration;
- Lack of money; Public administration should developing financial aid (as the funds of the Ministry of Industry and Tourism for projects of up to 3 million Eu for energy retrofitting of heritage buildings);
- We need technicians with qualifications who work in the field of heritage.
- Heritage works take long, are not at all cost-effective, and need a lot of dedication from the architect's side.
- The rate of energy rehabilitation of heritage buildings is very low, especially in heritage housing, where there are fewer resources. I don't think we can reach the renovation rates set by the EU.

Public Authorities (Spain, no. 3)

- There is a concern to bring the needs of the users together with the cultural values of these buildings;
- The energy efficiency projects are for new infrastructure;
- The conservation service has not tackled retrofit projects so far;
- The energy retrofitting of HB requires as well to preserve unique heritage values at the same time;
- The progress was made in research, creating new techniques and materials that can improve the energy efficiency especially of residential buildings;
- The funding calls from the European Union have contributed to promote interventions to improve energy efficiency;
- Even if more extensive renovation is currently taking place, I do not know if it will be possible to reach the targets set both at national and European level;
- The pace of building stock renewal is slow, while investments are concentrating on renewable energy production on rural land, which is easier to develop and more profitable;
- It seems impossible to achieve goals for HB (especially zero emission targets) – we need flexibility, measures respectful to heritage values of individual buildings depending on the function and use.

POLAND

Practitioners (Poland, no. 2):

- Conservation services have the deciding role here and conservation doctrine has evolved over the years. Due to the high number of historical sites, state conservation institutions cannot keep up with these targets and the actual demand;
- There are priority programmes that support project owners and sponsors in retrofits for various groups of buildings, as SKOZK, Norwegian funds and European programmes; They are used effectively and that there is support;
- There are certain administrative bottlenecks;
- I do not think so. This activity is not publicly subsidised enough, and financer are the key problem.

Public Authorities (Poland, no. 4, incl. General Assembly):

- There are evident obstacles, involving - financial resources, awareness, knowledge;
- There has to be a shift from styrofoam (the most popular in Poland) to other solutions. We should use solutions like photovoltaic roof tiles or photovoltaic sheds. The pace of using polystyrene foam insulation it very high;
- There percentage of listed buildings is small, so even if they fail to undergo energy modernization, it will not significantly affect the achievement of the general goals;
- There is a pressure to retrofit HB. Buildings from the municipal records are rationally considered from this perspective;
- Objects covered by area protection can be modernised or equipped with photovoltaics if the new elements or installations are not visible. We also promote energy modernisations, e.g. thermal insulation, inside buildings, e.g. on ceilings of the basement and floors under the roof, as well as the roof itself;
- The pace is fast, which does not favour the appropriately high quality of projects, implementation and supervision;
- The scope is most often limited to the insulation of facades and usually the replacement of windows;
- The goals are right, but in the case of HB, these goals are too narrow and do not take into account other, equally important issues, such as the well-being of the monument, the protection of its heritage value.

Professional Owners (Poland, no. 2):

- The goals are difficult to achieve due to the lack of central and local government support, both in knowledge and financial terms;
- Regarding the goal of improving energy performance (the one I am aware of) - the general pace is much too slow, esp. concerning heating costs;
- The lack of money is the main obstacle here.

SWEDEN

Practitioner (Sweden, no. 1):

- Rather not possible;
- Energy retrofit depends on the type of building and the need to protect it;
- Renovation is not an end in itself if the building does not need it. It is also detrimental to the climate;
- Actions should be neutral, we should renovate rather than replace (e.g. external walls).

Professional Owner (Sweden, no. 1):

- SVK usually finances renovations from its own assets.

UK/Scotland

Public Authorities (UK, no. 1):

- It's going to be a slow process, because of the requirements for meeting targets aren't necessarily joined up with wider policy;
- Lack of skills and understanding of how traditionally constructed buildings function and how to holistically undertake retrofit.

Professional Owners (UK, no. 1):

- Retrofitting requires quite exquisite technical abilities - as the removal of window frames, the removal of doors, the installation of better insulation, the installation of alternative heat source is all quite technically demanding;
- We are at the early adopter stage of retrofit - there is no economies to drive down the cost of these innovative solutions;
- I do not think, we will meet Net Zero target by 2040, there are so many HB in Edinburgh;
- District wide solutions are needed (as district heating system), which require cooperation;
- Economy of scale does not exist yet for HB.

Question_03: There is a possibility in the EPBD to exempt listed historic buildings from demands on energy efficiency. What do you think about this option?

SPAIN

Practitioners (Spain, no. 3):

- Mistake to exempt (it condemns these buildings to energy obsolescence, in some cases prevents the provision of comfortable spaces);
- Mistake to exempt (assuming the possibility of improving some efficiency in most of building), complying as far as possible and as much as the conservation of heritage values allows;
- Makes sense to exempt, interventions may generate pathologies, due to the lack of

knowledge and application solutions to achieve standards without considering their effects on the existing heritage.

Public Authorities (Spain, no. 3):

- It is a mistake to exempt, there is some uncertainty about consequences but a risk worth taking (we have to look for alternative solutions and see if they work);
- More flexibility in the required parameters instead of exemption
- Should not be exempt, but important that there will be no fixed targets (assuming the improvement of the performance); prior to defining programmes of HB, are particularly relevant.

POLAND

Practitioners (Poland, no. 2):

- Doesn't make sense to have EPC for HB;
- Makes sense to exempt; it would lead owners to selling some HBs (possible their homes), since they would not be able to retrofit them on affordable cost.

Public Authorities (Poland, no. 4, incl. General Assembly):

- Makes sense to exempt;
- There should be an option to exclude HB (the policy should be not so restrictive) we could help to modernize or partially improve the efficiency without affecting the loss of value;
- Makes sense to exempt – there are other values than economic ones;
- The exemption is necessary for HB which are listed or are in municipal heritage records. It should concern non-listed buildings constructed with traditional methods as well.

Professional Owners (Poland, no. 2):

- HBs cannot be treated the same as new buildings due to their technical specificity;
- This is a very good instrument, but it is not possible to meet all requirements in HBs.

Private Owner (Poland, no. 1):

- Makes sense to exempt; building technologies of HB are so different.

SWEDEN

Practitioner (Sweden, no. 1):

- On the one hand, historic buildings for cultural-historical reasons should be excluded from the EPBD;
- On the other hand, we should consider the possibility of intervention within reasonable limits.

Public Authorities (Sweden, no. 1)

- Uncertainty about exempt or not to exempt, the right information and guidance and cooperation is needed.

Professional Owner (Sweden, no. 1):

- There should be an exemption;

- However, energy can be saved in other ways (e.g. by changing behaviour).

UK/Scotland

Public Authorities (UK, no. 1):

- Uncertainty; we should normalise and mainstream; aversion to the othering of HB – they should be folded into aspects of construction teaching; there is a sort of interventions to increase energy efficiency;
- Exemption is not a good idea; investment leader should be able to show that either for technical, financial, or social reasons, achieving what might be a standard energy efficiency rating is not not feasible, it's not possible (e.g. In case of Scottish Energy efficiency standards in social housing, you can get an exemption from the standard, if you can demonstrate technical or financial reasons why it's disproportionately unachievable).

Private Owners (UK, no. 1):

- Getting to EPC standards would require some concessions from decision makers (e.g. for window replacements), but maybe it would lead to better energy efficiency.

Additional question_04: What have you done to make your building(s) more energy efficient? Do you have plans for future actions?

POLAND

Professional Owners (Poland, no. 2):

- Connection to district heating networks and replaced heating services;
- Varied insulation works, while focusing on preventing damp;
- Repair and retrofit demand list for each building;
- Needs do not match the budget;
- The documents and permits (for 16 buildings) - are secured to start retrofit as soon as finances allow; buildings are often listed.

SWEDEN

Professional Owner (Sweden, no. 1):

- Additional attic insulation, window sealing, replacement of ventilation fans.

UK/Scotland

Professional Owners (UK, no. 1):

- Water heating exchanged from coal/wood into gas. Exchange of old fossil fuel open fires (coal and wood burning half fires) to a series of gas powered boilers; Still looking for more efficient boilers;
- Maintenance of window frames;
- Energy efficient lightning exchange;
- Better windows introduction; If a Word Heritage site, than retaining single (instead double or triple) pane sash and case glass windows; the exchange of windows is costly;
- Start thinking of loft spaces;

- Looking for more thermally efficient renders;
- Air source heat pumps, although welcomed, would require far better isolation of thick historic stone walls
- Looking for new technology, sustainable energy solutions – like solar energy – which is not allowed on the roofs presently.

Private Owner (UK, no. 2):

- To minimise the time use of central heating;
- To keep shutters and curtains closed through cold months of the year;
- To look for advice of people skilled in energy efficient solutions;
- The glass exchange (double instead of single) was not allowed by permission officer;
- Introduction of an air source heat pump on the hot water tanks was performed.

Additional question_05: Have you done any major renovation in your building(s) in recent years? What was the main reasons for the renovation?

POLAND

Professional Owners (Poland, no. 2):

- Adaptive reuse and remodelling including thermal retrofit for the properties prepared to be sold;
- Retrofit associated with improving general technical conditions of the building;
- Connection of the building to the heating grid;
- In case of not protected buildings (where architectural features were not protected) they were covered with insulation;
- Retrofits are performed on regular basis, recently it involved 33 he healthcare centres, some of which were listed buildings.

Private Owner (Poland, no. 1):

- The renovation aimed at restoring the building to its original appearance.

SWEDEN

Professional Owner (Sweden, no. 1):

- The reason were legal requirements regarding accessibility and evacuation and the general need for renovation.

UK/Scotland

Professional Owners (UK, no. 1):

- The renovation regarded the extension of the one sides of the building, with functional changes (from dormitory type bedrooms into single ensuite occupancy rooms or fewer in number studio flats) – to have a good quality accommodation and meeting the expectations of service users and gatekeepers;

- Exchange of installations – from heating water with coal and wood into gas.

Private Owners (UK, no. 2):

- DIY on some of the windows to get the sashes moving again (not for energy saving but for ventilation (in summer);
- General works on the roof;
- Spatial reconfiguration, including new opening in walls;
- Renovation of the installation – including the extension of plumbing and drains for hot water in the part of the building.

Additional question_06: Have you done any major renovation in your building(s) in recent Do you plan any major renovation in your building(s)? What are the main reasons?

POLAND

Professional Owners (Poland, no. 2):

- There are multi-year renovation plans in most municipal property management agencies, but they are often not fully implemented as their budgets are not fixed;
- We want to improve energy performance and lower heating costs. They are also buildings that are require repair and maintenance due to wear.

SWEDEN

Professional Owner (Sweden, no. 1):

- Yes, the renovation needs.

UK/Scotland

Private Owners (UK, no. 1):

- They would like to exchange single glazed windows, but the cost is a challenge; Application for funding is planned;
- They would like to get a heat pump (instead of gas central heating), but the conservation rules are a challenge.

3.3.2 Summary of interviews findings

The compilation of the analysis of the interviews carried out by the FuturHist team was done on a country-by-country basis. The way in which the analysis was conducted is due to the different climatic characteristics, the different typology of building groups, as well as the different regulations in the individual countries. The nature of the problems posed allows for a demonstration of the distinctiveness of the approach among the respondents.

SPAIN – *group of respondents: public authorities and practitioners;*

What are the main barriers to making historic buildings more energy efficient?

Respondents are aware that the quality regulations relevant to HB do not match the required energy efficiency indicators. Current building regulations (in Spain CTE, technical Building Code) exclude heritage buildings from compliance with energy requirements. There is also a lack of qualified specialists in this area. A final significant obstacle is the high cost of HB measures. Practitioners point out that conservation policies do not allow the implementation of new technologies. Individual 'nature' of HB and particular material use are among the most difficult barriers.

What do you think about current renovation rate? Are we going to meet national/European targets?

The energy retrofit requires the simultaneous protection of unique, individual heritage values at the same time. Among both authorities and practitioners surveyed, doubts prevail as to whether it will be possible to reach the targets set both at national and European level. Flexibility in approach/measures appropriate to individual heritage values of HB is needed. Public authorities point out that EU founding can have an impact on promoting investment to improve energy efficiency. Practitioners point out that progress has been made in research, creating new techniques and materials that can improve the energy efficiency, which (as others point out) should be demountable/recoverable. Despite the apparent interest in rehabilitation, including energy rehabilitation of HB, there is a lack not only of financial capacity but also of technicians with qualifications.

There is a possibility in the EPBD to exempt listed historic buildings from demands on energy efficiency. What do you think about this option? The authorities and most practitioners are of the opinion that it is wrong to exempt, but there should be more flexibility in terms of performance. This may condemn these buildings to energy obsolescence, in some cases making it impossible to provide comfortable spaces. As they declare - we need to look at alternatives and see if they work. Only one of them states that the exemption makes sense because interventions can generate pathologies, due to a lack of knowledge and the use of solutions to achieve standards without considering their impact on the existing heritage.

P O L A N D – *group of respondents: public authorities, practitioners, professional and private owners;*

What are the main barriers to making historic buildings more energy efficient?

Among the main obstacles, respondents point first of all to the lack of adequate funding, much higher than in the case of simple thermal modernisation (e.g. improving the energy performance of the building envelope) Representatives of the authorities speak of deficits in terms of awareness, knowledge and skills, also among contractors. The legacy barrier involves incoherency between decision making processes between the conservation officers.

What do you think about current renovation rate? Are we going to meet national/European targets?

Public authorities argue that the targets are right, but in the case of HB they are too narrow and do not take into account other equally important issues such as well-being or the protection of heritage values. The proportion of historic buildings is small, so their energy retrofitting will not significantly affect the achievement of the overall targets. Authorities point to obvious obstacles including - financial resources, awareness, knowledge. Trends point to low-cost solutions, mainly within facades, including window replacement and (generally) over use of polystyrene. Professional owners note the positive impact of EU, but also Norwegian and local funds, but progress is very slow.

There is a possibility in the EPBD to exempt listed historic buildings from demands on energy efficiency. What do you think about this option?

Most of the interviewees believe that the exclusion of HB makes sense. This is especially true for buildings included in the municipal register of historic buildings, but some offices also mention non-listed buildings built using traditional methods. They believe that efficiency should be upgraded or partly improved without affecting the loss of value. Practitioners note that this would lead owners to sell some HBs because they would not be able to modernise them at an affordable cost.

What have you done to make your building(s) more energy efficient?

With insufficient funds to meet the needs, some professional owners are preparing repair and retrofit demand lists. Among the work they indicate is the connection of district heating networks, varied insulation and damp prevention.

Have you done any major renovation in your building(s) in recent years? What was the main reasons for the renovation?

The professional owners mention adaptation and thermo-modernisation of the building outisde walls related to the improvement of the general technical conditions of the building, connection to the district heating network. A private owner has raised the issue of restoring the building to its original appearance.

Do you plan any major renovation in your building(s)?

Among the main reasons professional owners cite is the need to improve energy performance and reduce heating costs.

S W E D E N – *group of respondents: public authorities, practitioner and professional owner;*

What are the main barriers to making historic buildings more energy efficient?

Planning practice does not take heritage values into account to the extent they deserve. The policies are not used as intended. The authorities indicate that the main barriers are regulations, but also the lack of available information and guidelines from the Swedish National Heritage

Council. In terms of performance, there is a lack of knowledge, but also a problem in reaching contractors - a knowledge gap. The practitioner observes a lack of knowledge about the materials that should be appropriate to the appearance of the building and its historical-material specificity. The professional owner notes resistance to change due to a lack of solutions appropriate to the cultural values of the building.

What do you think about current renovation rate? Are we going to meet national/European targets?

The practitioner notes that this is unlikely to happen. Activities should be neutral - renovation rather than replacement of materials. The professional owner points to the possibility of the usage of SVK funds.

There is a possibility in the EPBD to exempt listed historic buildings from demands on energy efficiency. What do you think about this option?

There is apparent hesitation among the authorities as to whether HB should be an exception or not - adequate information and guidance and cooperation is needed. Practitioners and professional owners alike believe that HBs should be exempt from the EPBD. However, it should be tried within reasonable limits. The owner mentions the economic behaviour of occupants.

What have you done to make your building(s) more energy efficient?

Professional landlord lists additional attic insulation, window sealing and fan replacement.

Have you done any major renovation in your building(s) in recent years? What was the main reasons for the renovation?

The professional owner points out the legal requirements for accessibility and evacuation, as well as the general need for renovation.

Do you plan any major renovation in your building(s)?

The Professional Owner identifies basic renovation needs.

UK/Scotland - *group of respondents: public authorities, professional and private owners;*

What are the main barriers to making historic buildings more energy efficient?

Officials point out the diversity of traditional HB structures. There is a noticeable lack of awareness and skills, a culture of maintenance and renovation - which also requires education in the building sector. Owners also note a lack of architects/professionals skilled in the feasibility of HB conversions, logistical feasibility of retrofitting. In the construction process, they point to the high cost-intensity of using customised, non-standard solutions. Most respondents note that there is a need to integrate planning regulations for residential buildings, which are currently not aligned with climate policy.

What do you think about current renovation rate? Are we going to meet

national/European targets?

The public authorities believe that due to the discrepancy between the stated objectives and the regulations, the process will be slow. In this case, the inability to take a holistic approach to retrofitting traditionally built buildings may be an obstacle. For professional owners, HB retrofit measures require high skills and, on the other hand, solutions that are scalable within neighbourhoods. They are not in a position to finance the huge costs of this innovation.

There is a possibility in the EPBD to exempt listed historic buildings from demands on energy efficiency. What do you think about this option?

In the absence of firm answers, respondents prefer to steer primarily towards finding solutions for the core area of operation. On the other hand, exclusion is not a good idea, as the developer should be able to demonstrate why, on technical, financial or social grounds, an energy efficiency rating standard is not feasible, in line with the Scottish Standards for Energy Efficiency in Social Housing. To quote the opinion of one private landlord - complying with these standards would require some concessions from decision-makers (e.g. when replacing windows), but would perhaps lead to better energy efficiency.

What have you done to make your building(s) more energy efficient?

Professional owners are replacing old fossil fuel fireplaces with gas boilers and water heating from coal/wood to gas, maintaining window frames, energy-efficient lighting replacement and thinking about lofts and more thermally efficient renders. Private owners are minimising the use of central heating by closing blinds and curtains.

Have you done any major renovation in your building(s) in recent years? What was the main reasons for the renovation?

The professional owner extended and renovated the building, making functional changes to better suit the needs of the occupants. He also replaced the installations with gas. The private owner repaired the window sashes, roof, introduced new window openings and extended the building's drainage network.

Do you plan any major renovation in your building(s)? What are the main reasons?

The private owner would like to replace the individual window glazings, but this is expensive. Introducing a heat pump, in view of conservation requirements, including the need to insulate the stone walls, is currently not possible.

3.3.3 Discussion

Upon examining the entirety of the findings, the following became apparent:

Even the most robust of guidelines may have diminished impact in the light of exemptions

based on heritage regulations. It is clear that each of the countries this study focused on had notable bodies of guidance literature and established procedures and guidelines on how to conduct energy retrofits, perform cost-effectiveness assessments and manage waste, along with relevant institutions and progress monitoring mechanisms associated with EU or domestic targets. However, this did not appear to translate to data availability at project scale. Significant gaps were observed in data concerning waste management and cost-effectiveness.

Big data monitoring schemes are largely not suitable for drawing project-specific conclusions, which HBs require. **Heritage-related exemptions may be key obstacle**. Multiple sources of what can be considered big data were examined for usefulness in this study, including the European Building Stock Observatory, the Polish BDO, and the Polish online central register of energy performance certificates. None of these were found to be useful in this study. This was mostly due to the databases not having HBs as separate categories and because of the databases' nature, which either made data for individual projects unobtainable or non-representative due to far-reaching lumping or simplification.

IAQ, IEQ and post-occupancy evaluation can be considered largely outside of the body of current practice. While there were cases were selected IAQ and IEQ parameters were monitored, they were a clear minority. This aligns with the responses from interviews, which stress cost-related factors as crucial in retrofit planning, citing higher project costs in the case of HBs relative to contemporary buildings.

Waste generation was found to be poorly documented. Despite there being evidence of the existence of comprehensive tools and regulations intended to aid in cataloguing and managing waste generation on construction sites, as well as approaches to material reuse, this aspect was found to be largely absent from available project documentation.

KPIs appeared to be focused largely on cost and lowering energy demand, which itself can be interpreted as affecting maintenance costs. This was corroborated by the nearly complete absence of information on the application of any KPIs other than those related to investment cost and the recurrence of costs as a major problem in HB retrofits in interview responses.

Despite being stressed as important, cost appeared to be seen mostly as initial investment cost, with no documentation found on cost-effectiveness or maintenance cost evaluation. This may point to a simplistic view of cost-effectiveness that prioritises budget balancing over a project's financial efficiency. Despite there being multiple methods of assessing retrofit cost-effectiveness, including LCC, we found no evidence of their use in the projects investigated. Information collected on project KPIs from the manager of some of the detailed cases indicated that they treated maintenance as the need to repair or replace only when an element was found to be failing or in a technical condition that severely impacted its operation, and that this logic applied to the need to retrofit entire buildings as well.

No evidence of SRI uptake was found. SRI was not used in any of the projects investigated in this study. In the detailed cases, the active systems used in the retrofits, based on their general descriptions, did not appear to be linked into complex, smart systems, as they often consisted of installing more efficient heat sources and space heating systems coupled with relatively simple ventilation solutions.

Case-specificity of HBs is a major obstacle in drawing generalised conclusions, pointing to the feasibility of a typology-based approach. As shown by the practice context section and indeed by the data on the cases, there are multiple factors that necessitate approaching HB retrofits within the context of their respective typologies, which complicates data acquisition as they form relatively small shares of their respective countries' building stocks. This observation is aligned with the stated goal of FuturHist of developing typology-based approaches.

The results of the analysis of the **interviews** show the peculiarities of each country, but ultimately also show common cross-cutting findings:

- Respondents are aware of the **individual nature of HB**, noting the need for customised solutions. High-quality solutions go hand in hand with requirements for energy efficiency indicators.
- Retrofitting residential buildings is costly and **cost-effectiveness was not associated with energy efficiency.**
- The possibility of exempting residential buildings from the EPBD raises some questions. Although the majority of respondents realise that historic buildings cannot meet them, this directs attempts to find retrofit solutions that also **improve occupancy conditions**.

Many point to a lack of skills, awareness, but also a lack of the necessary information and guidelines for carrying out retrofitting measures in historic buildings. Pointing to the need for educational activities and the dissemination of scalable solutions in neighbouring areas with similar technology.

4. Conclusions and Outlook

This report used a mixed qualitative and quantitative methodology that combined comparisons of national practice contexts in areas of key interest in Task 1.5 of FuturHist in four European countries, case buildings from these countries, data from past projects, together with an analysis of retrofit cases from past projects and new, detailed cases from the countries where the FuturHist demonstration buildings are located. The key conclusions with respect to the research questions presented in the Methodology section are presented below:

1. What are the national- and professional-level guidelines and practices for each of the investigated areas?

Each of the analysed countries has well-established national and professional level-guidelines in place for the general energy retrofit of buildings and some guidelines that specifically focus on historic buildings. These guidelines took on the form of guidance documents, best-practice catalogues, official letters and guidelines from heritage institutions and subsidy granting bodies. In terms of acts of law, listed historic buildings of the highest value were found to be generally exempt from having to meet energy efficiency standards and regulations, and in cases where a multi-tiered heritage protection system was in place, these standards became stricter but still allowed some exemptions.

2. What is the uptake of these guidelines in actual renovation projects?

Given the elective nature and relative vagueness of guidelines and the inherent case-specificity of every project that targets a historic building, it is difficult to draw clear conclusions as the matter is highly nuanced. For instance, on the one hand, guidelines by some subsidy granting institutions were highly comprehensive and clearly intended for specialists, but it could be argued they had been formulated this way to ensure that any grants given would be spent with due diligence. On the other, some guidelines by institutional bodies appeared to be very general in nature and could technically be applied to any renovation project, not necessarily one that targets a historic building.

Based on the data collected from the datasheets, it can be argued that while base-level legal guidelines are, of course, implemented, the proliferation of best practices is hard to determine. Out of the detailed cases investigated, only two featured post-occupancy evaluations of some sort. And less than half included relied on some sort of renewable energy.

3. What was the energy efficiency attained by typical energy retrofit and renovation projects?

As a complete set of data for all metrics commonly used to define energy efficiency could not be collected, it can only be stated that, in the fields for which data were collected, one could observe significant disparities between cases. Whereas the U-values for external partitions were comparable within their respective climates, with the notable exception of windows, there were differences in Final non-RES Energy Demand between cases, sometimes drastic ones, with the Polish cases especially displaying high energy demand post-retrofit. However, this may be associated with the fact that in these cases the retrofits focused mostly on passive measures like the application of additional thermal insulation, and in some cases connecting the building to the district heating system.

4. What was the indoor air quality and indoor environment quality achieved?

Indoor air and environment quality measurements were found to be an exception among all the cases investigated, both those from the HIBERatlas project and the detailed cases chosen as a part of FuturHist, and in those cases in which they were carried out, the data was either not sufficiently comprehensive to paint a complete picture, or there were summaries that showed mixed results. It can therefore be stated that IAQ and IEQ measurements are not part of standard HB retrofit practice and there is insufficient data to state what the typical levels for their respective metrics are.

5. How much construction waste was generated throughout the course of such projects?

Despite the existence of robust waste cataloguing and estimation methods, guidelines and regulations, which were presented in the context section of this report, we could not access data that would provide insight into project-specific values or characteristics beyond case studies available in the literature. Considering the fact that other findings point that in the case of HBs the main decision factors are heritage values protection, overall project cost and energy efficiency, and these have been found to be relatively well documented, the same could not be said for waste-related parameters. In those cases where waste-related data was available, it was given either for demolition waste (design and costing phase), mixed (demolition and other waste) waste or even simply as the number of skips that were needed to transport waste off-site (post-delivery phase).

In addition, when examining the amount of construction waste generated by a project, said project's specificity must always be considered, as the building's typology, heritage protection and the associated restrictions on the use of destructive retrofit solutions may lead to significant differences in the amount of waste generated per m^2, but result in significantly higher project cost or lower energy performance, as it is difficult to improve energy performance of a building whose substance cannot be intervened in.

6. What was the cost-effectiveness of these projects and how was it measured?

Data on the cost-effectiveness of the projects was difficult to obtain. and no original calculations made during the projects themselves could be accessed for any of the detailed cases or those from past projects. Seeing as cost-effectiveness calculations require knowledge of pre-retrofit conditions, we calculated it for four cases. In addition, it should be noted that cost-effectiveness can be expected to differ significantly between HB retrofit projects, just as HBs and their heritage protection level and scope differ.

In terms of the cost in operational phases, we found no evidence of the use of relevant methodologies like Life Cycle Costing (LCC), and although interview and datasheet responses indicated that maintenance and retrofit planning was factored into the decision-making processes of retrofit projects, especially in the case of professional property owners and managers who managed significant portfolios of HBs

7. What were the key project indicators that informed the renovations?

It was found that the most prevalent KPIs revolved around the cost of the project, which was aligned with interview responses which stressed that HB retrofits are more costly than those of regular buildings, and that one of the main aims of retrofitting HBs was energy cost reduction. Other KPIs were generally not used, with the noted exception of lowering CO2 emissions in one detailed case, where this parameter was measured as a part of a post-occupancy analysis.

8. What was the smart readiness indicator attained as a result the renovations?

We found no evidence of the specific application of the SRI in any of the projects surveyed as a part of this study. It is highly probable that SRI is much too recent a development to have found its way into general retrofit practice, especially in the case of HBs. It can also be argued that, seeing as building services, with which SRI is closely tied, can be severely restricted by conservation regulations due to the need to install vents and guide cables through partitions, are particularly affected by the case-specificity of HB retrofits.

The interviews showed that respondents are aware of the case-specific nature of HB. They note a lack of skills, awareness, necessary guidelines, and educational activities. Retrofitting HBs is costly, and cost-effectiveness translates poorly into energy efficiency in their fall. The possibility of exempting HBs from the EPBD raises many questions, but the search for feasible, scalable solutions should be supported.

Future outlook

This study will provide one of the cornerstones for establishing FuturHist methodology and KPIs. Its findings lend credence to the following diagnoses:

- There is significant case-specificity when it comes to assessing, comparing, and attempting to find correlations between HB retrofit project metrics in any given field;
- Considerable gaps in data availability — when viewed against the background of national guidelines and regulations — may indicate little overlap between what is considered best and typical practice;
- There exists a need to formulate a tailored approach to HB retrofitting that can bridge the gap between the various areas in which this activity can be measured;

It is key to gain insight into current HB retrofit practice from both a qualitative and quantitative standpoint so as to provide a basis on which a comprehensive methodology fit for all EU countries can be developed. Future work will focus on setting the findings set out in this report with those of other FuturHist tasks, most notably task 1.2 and especially task 1.6 which focuses on establishing Key Performance Indicators. Afterwards, the results will feed into WP4 (Integrated Planning Toolkit) and WP5 (Demonstration), where they can serve as references.

5. References

Abbe, O., Hamilton, L. (2017). *BRE Global Environmental Weighting for Construction Products using Selected Parameters from EN 15804*. Watford.

Adamczyk, J. & Dylewski, R. (2010). Recycling of Construction Waste in Terms of Sustainable Building, *Problemy Ekorozwoju – Problems of Sustainable Development*, 5(2), 125–131.

Alfredsson Mihlzén, L., & Jakobsson, R. (2013). *A cost-effectiveness analysis of energy conservation: A case study of Katjas Gata 119*. Bachelor Thesis, Department of Economics, University of Gothenburg.

Apostolopulos V., Giourka P., Martinopoulos G., Angelakoglou K., Kourtzanidis K., Nikolopoulos N. (2022). Smart readiness indicator evaluation and cost estimation of smart retrofitting scenarios - A comparative case-study in European residential buildings. *Sustainable Cities and Society*, 82, 103921. https://doi.org/10.1016/j.scs.2022.103921 (accessed: 22.10.2024).

Boverket. (2007). Boverkets föreskrifter och allmänna råd (2007:4) om energideklaration för byggnader. Karlskrona: Boverket. Available at: https://rinfo.boverket.se/BFS2007-4/pdf/BFS2007-4.pdf (accessed: 17.12.2024).

BRE Global. (2014). *The Green Guide*.

Building Research Establishment Centre for Sustainable Products. (n.d.). *Sustainable refurbishment – how to better understand, measure and reduce embodied impacts*. Available at: https://files.bregroup.com/corporate/BRE%2098660-Sustainable-Refurb-Briefing-Paper.pdf (accessed: 22.10.2024).

Commission Delegated Regulation (EU) No 244/2012 of 16 January 2012. (2012). Supplementing Directive 2010/31/EU of the European Parliament and of the Council on the energy performance of buildings by establishing a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements.

Decreto 73/2012, de 20 de marzo. (2012).

EN 15459-1. (2017). Energy performance of buildings – Economic evaluation procedure for energy systems in buildings, Part 1: Calculation Procedures, Module M1-142017. Comite Europeen de Normalisation.

EN 15643-2:2011. (2011). Sustainability of construction works - Assessment of buildings - Part 2: Framework for the assessment of environmental performance.

EN 15643-3:2012. (2012). Sustainability of construction works - Assessment of buildings - Part 3: Framework for the assessment of social performance.

European Union Directive 2012/27/EU. (2012). Of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC. Official Journal of the European Union, L 315, 1–56. Available at: http://data.europa.eu/eli/dir/2012/27/2023-05-04 (accessed: 04.05.2023).

Far, C., Ahmed, I., Mackee, J. (2022). Significance of Occupant Behaviour on the Energy Performance Gap in Residential Buildings. *Architecture* 2, 424–433. Available at: https://doi.org/10.3390/architecture2020023 (accessed: 28.12.2024).

Green Building Council España. (2021). *Economía circular en la edificación.* Available at: Informe_Economia-Circular.pdf. (accessed: 22.10.2024).

Historic Environment Scotland. (2010). *Guide for Practitioners 6: Conversion of Traditional Buildings,* at:

https://www.gov.scot/publications/guide-for-practitioners-6-conversion-of-traditional-buildings/ (accessed: 22.10.2024).

Hodgson F., Essen M., Coxon H. (2022). *Construction Waste and the Environment Act 2021*. Womble Bond Dickinson. Available at: https://www.womblebonddickinson.com/uk/insights/articles-and-briefings/rebuild-construction-waste-environment-act-2021#:~:text=A%20tougher%20stance%20on%20waste,Waste%20enforcement%20and%20regulation (accessed: 22.10.2024).

Hossain, M. U., Ng, S. T., Antwi-Afari, P., & Amor, B. (2020). Circular economy and the construction industry: Existing trends, challenges and prospective framework for sustainable construction. *Renewable and Sustainable Energy Reviews*, 130, 109948. https://doi.org/10.1016/j.rser.2020.109948 (accessed: 22.10.2024).

International Organization for Standardization. (2006). Environmental management – Life Cycle Assessment – Principles and Framework. ISO 14040:2006.Instituto Nacional de Estadistica. (2021). Notas de Prensa Instituto Nacional de Estadística.Residuos generados por sectores de actividad y hogares.

Karásek, J., Pojar, J., Kalocai, L., & Heralová, R. S. (2018). Cost optimum calculation of energy efficiency measures in the Czech Republic. *Energy Policy*, 123, 155–166.

KNP 1 (n.d). Katalog Nakładów Rzeczowych. Roboty transportowe, ziemne, pomocnicze i różne, montaż i demontaż żurawi budowlanych, rozbiórki i wyburzenia budynków, budowa i konserwacja terenów zielonych.

Kylili A., Fokaides P.A. Amparo Lopez Himenez P. (2016). Key Performance Indicators (KPIs) approach in buildings renovation for the sustainability of the built environment: A review. *Renewable and Sustainable Energy Reviews*, 56, 906–915, https://doi.org/10.1088/1757-899x/471/11/112051 (accessed: 22.10.2024).

Ley 7/2007. (2007). de Gestión Integrada de la Calidad Ambiental de Andalucía.

NFOŚiGW. (2020). Opracowanie zakresu oraz zasad wykonania audytu efektywności energetycznej do wniosku o dofinansowanie projektu ze środków Narodowego Funduszu Ochrony Środowiska i Gospodarki Wodnej. Available at: https://www.gov.pl/attachment/90256ab2-7f83-475f-ae69-9735ebf4d2e3 (accessed: 04.12.2024).

Notas de Prensa Instituto Nacional de Estadística (2010). Residuos generados por sectores de actividad y hogares.

OECD. (2007). *Handbook for appraisal of environmental projects financed from public funds*. Paris: Organization for Economic Co-operation and Development.

Park, C. S., & Sharp-Bette, G. P. (1990). *Advanced engineering economics.* John Wiley & Sons, Inc.

Passivhaus Trust (n.d.). What is Passivhaus? Passivhaus Trust website. Available at: https://www.passivhaustrust.org.uk/what_is_passivhaus.php#2 (accessed: 18.12.2024).

Qualis Flow Limited, (2023). *The UK Construction Industry Annual Waste Report 2023*. Available at: https://5865761.fs1.hubspotusercontent-na1.net/hubfs/5865761/The%20UK%20Construction%20Industry%20Waste%20Report%202023.pdf?__hstc=146187243.caed881f47195f5633f13fc4ee0abf8f.1725961279349.1725961279349.1725961279349.1&__hssc=146187243.1.1725961279349&__hsfp=82456295 (accessed: 22.10.2024).

Real Decreto 105/2008, de 1 de febrero. (2008). Por el que se regula la producción y gestión de los residuos de construcción y demolición.

Real Decreto 314/2006, de 17 de marzo. (2006). Por el cual entra en vigor el Código Técnico de la Edificación.

Real Decreto 390/2021, de 1 de junio. (2021). Por el que se aprueba el procedimiento básico para la certificación de la eficiencia energética de los edificios.

Real Decreto 56/2016, de 12 de febrero. (2016). Available at: Real Decreto 56/2016, de 12 de febrero, por el que se transpone la Directiva 2012/27/UE del Parlamento Europeo y del Consejo, de 25 de octubre de 2012, relativa a la eficiencia energética, en lo referente a auditorías energéticas, acreditación de proveedores de servicios y auditores energéticos y promoción de la eficiencia del suministro de energía. (accessed: 22.10.2024).

Real Decreto 732/2019 de 20 de diciembre. (2019). Por el que se modifica el Código Técnico de la Edificación, aprobado por el Real Decreto 314/2006, de 17 de marzo.

Rentabilidad en la eficiencia energética de los edificios". (n.d.). Horizon 2020.

Rozporządzenie Ministra Infrastruktury z dnia 12 kwietnia 2002 r. (2002). W sprawie warunków technicznych, jakim powinny odpowiadać budynki i ich usytuowanie (Dz.U. 2022 item 1225 as amended).

Rozporządzenie Ministra Klimatu z dnia 2 stycznia 2020 r. (2020). W sprawie katalogu odpadów (Dz.U. 2020 item 10).

Rutkowski, J., Sałach, K., Szpor, A.. Ziółkowska, K. (2018). How to reduce energy poverty in Poland? Instytut Badań Strukturalnych, Warszawa. Available at: https://ibs.org.pl/wp-content/uploads/2022/12/IBS_Policy_Paper_01_2018_en.pdf (accessed 08.05.2024).

Sagan, J., Sobotka, A. (2021). Analysis of Factors Affecting the Circularity of Building Materials. Materials, 14(23), 7296. https://doi.org/10.3390/ma14237296 (accessed: 22.10.2024).

Scottish Environment Protection Agency. (n.d.). Scotland's Environment Waste Discover Data tool. Available at: https://informatics.sepa.org.uk/WasteAllSources/ (accessed: 22.10.2024).

Scottish Government. (2016). *Making Things Last: a circular economy strategy for Scotland*. Available at: https://www.gov.scot/publications/making-things-last-circular-economy-strategy-scotland/pages/2/ (accessed: 22.10.2024).

Scottish Government. (2022). *Delivering Scotland's circular economy - route map to 2025 and beyond: consultation*. Available at: https://www.gov.scot/publications/consultation-delivering-scotlands-circular-economy-route-map-2025-beyond/pages/10/ (accessed: 22.10.2024).

Scottish Government. (n.d.). *Classify different types of waste*. Available at: https://www.gov.uk/how-to-classify-different-types-of-waste (accessed: 22.10.2024).

Sobotka, A., Sagan, J., Gicala, M. (2019). Sustainability of Construction Processes – Requirements, Criteria, Evaluation Concept. IOP Conference Series: Materials Science and Engineering, 471, 112051. https://doi.org/10.1088/1757-899x/471/11/112051 (accessed: 22.10.2024).

Swedish Government. (2007). Boverkets föreskrifter och allmänna råd (2007:4) om energideklaration för byggnader.

Taczalska-Ryniak, A. (2019). Wielokryterialna certyfikacja budynków biurowych jako wyznacznik nowoczesności i jakości środowiska pracy. *Zeszyty Naukowe Małopolskiej Wyższej Szkoły Ekonomicznej w Tarnowie.* 1(41). 103–124. http://dx.doi.org/10.25944/znmwse.2019.01.103124 (accessed: 22.10.2024).

Tuominen, P., Reda, F., Dawoud, W., Elboshy, B., Elshafei, G., & Negm, A. (2015). Economic appraisal of energy efficiency in buildings using cost-effectiveness assessment. *Procedia Economics and Finance.* 21. 422–430. https://doi.org/10.1016/S2212-5671(15)00195-1 (accessed: 22.10.2024).

UK Government. (2008). *Site Waste Management Plans Regulations 2008*. Available at: https://www.legislation.gov.uk/uksi/2008/314 (accessed: 22.10.2024).

UK Government. (2013). *The Site Waste Management Plans Regulations 2008 (Revocation) Regulations 2013*. Available at: https://www.legislation.gov.uk/uksi/2013/2510 (accessed: 22.10.2024).

UK Government. (n.d.). Classify different types of waste, Available at: https://www.gov.uk/how-to-classify-different-types-of-waste/construction-and-demolition-waste (accessed: 24.11.2024).

Ustawa z dnia 14 grudnia 2012 r. (2012). O odpadach. Dz.U. 2023 item 1587 as amended.

Ustawa z dnia 23 lipca 2003 r. (2003). O ochronie zabytków i opiece nad zabytkami. Dz.U. 2024 item 1292 as amended.

Ustawa z dnia 29 sierpnia 2014 r. (2004). Dz.U. 2024 item 101 as amended.

Ustawa z dnia 29 sierpnia 2014 r. (2014). O charakterystyce energetycznej budynków. Dz.U. 2024 item 101 as amended.

Ustawa z dnia 7 lipca 1994 r. (1994). Prawo budowlane. Dz.U. 2024 item 725 as amended.

Verbeke S., Aerts D., Reynders G., Ma Y., Waide P. (2020). *Final Report on the Technical Support to the Development of a Smart Readiness Indicator for Buildings: Final Report*. Publications Office of the European Union. LU. ISBN 978-92-76-19197-1.

Zero Waste Scotland. (2023). Kier Construction – Mansion House Refurbishment. Available at: https://cdn.zerowastescotland.org.uk/managed-downloads/mf-vl6zedb4-1681920278d (accessed: 18.11.2024).

Zero Waste Scotland. (n.d.). Designing Out Construction Waste: A guide for project design teams, Available at: https://cdn.zerowastescotland.org.uk/managed-downloads/mf--f-vhqz9-1677499848d (accessed: 04.12.2024)

Zrzeszenie Audytorów Energetycznych. (n.d.). Audyty energetyczne i inne dokumenty opracowywane przez audytorów energetycznych. Available at: https://zae.org.pl/zrzeszenie/audyty-energetyczne/ (accessed: 15.12.2024).

6. Annexes

The appendix includes the groups of questions used in the interviews for each category – practitioners, public authorities, professional owners and private owners, as well as the complete list of items included in the datasheets used to collect information on detailed cases.

Table 24. Interview questions for a group of Practitioners.

Q No	WP Task	Interview question	Comments
Q1		What is your professional role in relation to energy retrofit of historic buildings? For how long have you been working in the field?	
Q2	1.1,1.3,1.5	FuturHist deals with the energy retrofit of historic buildings, what do you think about current renovation rate? Are we going to meet national/European targets?	
Q3	1.1, 1.5	What are the main barriers to making historic buildings more energy efficient?	
Q4	1.1	Barriers can be divided into technical, regulatory, financial and social. Can you think of any technical barriers, and how important would they be? Technical barriers are challenges related to the specific needs of historic buildings because of their construction and the materials used. It can also be lack of competence regarding such needs.	
Q5	1.1	Can you think of any regulatory barriers, and how important would they be? Regulatory barriers are related to policies in different sectors, as well as lack of information to stakeholders regarding such policies.	
Q6	1.1	Can you think of any economic barriers, and how important would they be? Economic barriers are challenges to make energy retrofit projects financially viable for historic buildings.	
Q7	1.1	Can you think of any social barriers, and how important would they be? Social barriers are related to attitudes and awareness related to energy retrofit in historic buildings.	
Q8	1.3	How well does current policy related to energy retrofit work in practice? What are strengths and weaknesses with current policies?	
Q9	1.3	There is a possibility in the EPBD to exempt listed historic buildings from demands on energy efficiency. What do you think about this option?	
Q10	1.3	Can current policies on energy efficiency hinder other dimensions of sustainability?	Prompt: Ghg-emissions, Waste, IEQ, Resource use
Q11	1.3	If yes, what can be done to avoid negative effects on other sustainability dimensions?	
Q12	1.3	In sum, what do you think could be improved at the level of policy-making regarding energy retrofit of historic buildings?	
Q13	1.4, 1.5	Are there guidelines/standards for the overall planning process of energy retrofit in historic buildings? How are they used?	
Q14	1.4	Which guidelines/standards, tools/softwares, practices do you use for the different steps in the planning process as described below?	Use form to fill in during interview
Q15	1.4	Are there any guidelines/tools that you would like to be developed?	

Q16	1.5	How are energy retrofit projects in historic buildings generally assessed? (both before and after implementation)	Prompt: energy performance, IEQ, moisture risk, thermal comfort.
Q17	1.5	What is generally monitored in retrofit projects? What stages (before, during, after?) Do you have internal routines/guidelines?	Prompt: Energy use, resource use, on-site waste, thermal comfort, IEQ
Q18		This was the last question. Is there anything you would like to add (related to the themes we have discussed?)	

Table 25. Interview questions for a group of Public Authority representatives.

Q No	WP Task	Interview question	Comments
Q1		What is your professional role in relation to energy retrofit of historic buildings? For how long have you been working in the field?	
Q2	1.1,1.3,1.5	FuturHist deals with the energy retrofit of historic buildings, what do you think about current renovation rate? Are we going to meet national/european targets?	
Q3	1.1, 1.5	What are the main barriers to making historic buildings more energy efficient?	
Q4	1.1	Barriers can be divided into technical, regulatory, financial and social. Can you think of any technical barriers, and how important would they be? Technical barriers are challenges related to the specific needs of historic buildings because of their construction and the materials used. It can also be lack of competence regarding such needs.	
Q5	1.1	Can you think of any regulatory barriers, and how important would they be? Regulatory barriers are related to policies in different sectors, as well as lack of information to stakeholders regarding such policies.	
Q6	1.1	Can you think of any economic barriers, and how important would they be? Economic barriers are challenges to make energy retrofit projects financially viable for historic buildings.	
Q7	1.1	Can you think of any social barriers, and how important would they be? Social barriers are related to attitudes and awareness related to energy retrofit in historic buildings.	
Q8	1.3	How well does current policy related to energy retrofit work in practice? What are strengths and weaknesses with current policies?	
Q9	1.3	There is a possibility in the EPBD to exempt listed historic buildings from demands on energy efficiency. What do you think about this option?	
Q10	1.3	Can current policies on energy efficiency hinder other dimensions of sustainability?	
Q11	1.3	If yes, what can be done to avoid negative effects on other sustainability dimensions?	Prompt: Ghg-emissions, Waste, IEQ, Resource use
Q12	1.3	In sum, what do you think could be improved at the level of policy-making regarding energy retrofit of historic buildings?	
Q13	1.4,1.5	Are there guidelines/standards for the overall planning process of energy retrofit in historic buildings? How are they used?	
Q14	1.5	How are energy retrofit projects in historic buildings generally assessed?	Prompt: energy

		(both before and after implementation)	performance, IEQ, moisture risk, thermal comfort.
Q15	1.5	What is generally monitored in retrofit projects? What stages (before, during, after?)	Prompt: Energy use, resource use, on-site waste, thermal comfort, IEQ
Q16		This was the last question. Is there anything you would like to add (related to the themes we have discussed?)	

Table 26. Interview questions for a group of Professional Owners.

Q No	WP Task	Interview question	Comments
Q1		What is your professional role in relation to energy retrofit of historic buildings? For how long have you been working in the field?	
Q2	1.1, 1.5	Have you done any major renovation in your building(s) in recent years? What was the main reasons for the renovation?	
Q3	1.1	Do you plan any major renovation in your building(s)? What are the main reasons?	
Q4	1.1, 1.5	What have you done to make your building(s) more energy efficient? Do you have plans for future actions?	
Q5	1.1, 1.3, 1.5	FuturHist deals with the energy retrofit of historic buildings, what do you think about current renovation rate? Are we going to meet national/European targets?	
Q6	1.1, 1.5	What are the main barriers to making historic buildings more energy efficient?	
Q7	1.1	Barriers can be divided into technical, regulatory, financial and social. Can you think of any technical barriers, and how important would they be? Technical barriers are challenges related to the specific needs of historic buildings because of their construction and the materials used. It can also be lack of competence regarding such needs.	
Q8	1.1	Can you think of any regulatory barriers, and how important would they be? Regulatory barriers are related to policies in different sectors, as well as lack of information to stakeholders regarding such policies.	
Q9	1.1	Can you think of any economic barriers, and how important would they be? Economic barriers are challenges to make energy retrofit projects financially viable for historic buildings.	
Q10	1.1	Can you think of any social barriers, and how important would they be? Social barriers are related to attitudes and awareness related to energy retrofit in historic buildings.	
Q11	1.3	Do you know of any case where the protection of heritage values came into conflict with aspirations of energy efficiency? Can you describe the case and how it unfolded?	
Q12	1.3	How well does current policy related to energy retrofit work in practice? What are strengths and weaknesses with current policies?	
Q13	1.3	There is a possibility in the EPBD to exempt listed historic buildings from demands on energy efficiency. What do you think about this option?	
Q14	1.4, 1.5	Are there guidelines/standards for the overall planning process of energy retrofit in historic buildings? How are they used?	

Q15	1.5	How are energy retrofit projects in historic buildings generally assessed? (both before and after implementation)	Prompt: energy performance, IEQ, moisture risk, thermal comfort.
Q16	1.5	What is generally monitored in retrofit projects? What stages (before, during, after?)	Prompt: Energy use, resource use, on-site waste, thermal comfort, IEQ
Q17		This was the last question. Is there anything you would like to add (related to the themes we have discussed?)	

Table 27. Interview questions for a group of Private Owners.

Q No	WP Task	Interview question	Comments
Q1	1.1, 1.5	Have you done any major renovation in your building in recent years? What was the main reasons for the renovation?	
Q2	1.1	Do you plan any major renovation in your building? What are the main reasons?	
Q3	1.1, 1.5	What have you done to make your building more energy efficient? Do you have plans for future actions?	
Q4	1.1	Why is it important to save energy in your building (if you think so)?	
Q5	1.1	Have your ambitions to make the building more energy efficient come into conflict with the preservation of heritage values?	
Q6	1.1, 1.5	What are the main barriers to making historic buildings more energy efficient?	
Q7	1.1	Barriers can be divided into technical, regulatory, financial and social. Can you think of any technical barriers, and how important would they be? Technical barriers are challenges related to the specific needs of historic buildings because of their construction and the materials used. It can also be lack of competence regarding such needs.	
Q8	1.1	Can you think of any regulatory barriers, and how important would they be? Regulatory barriers are related to policies in different sectors, as well as lack of information to stakeholders regarding such policies.	
Q9	1.1	Can you think of any economic barriers, and how important would they be? Economic barriers are challenges to make energy retrofit projects financially viable for historic buildings.	
Q10	1.1	Can you think of any social barriers, and how important would they be? Social barriers are related to attitudes and awareness related to energy retrofit in historic buildings.	
Q11	1.3	There is a possibility in the EPBD to exempt listed historic buildings from demands on energy efficiency. What do you think about this option?	
Q12	1.3	Are you aware of any subsidies that are relevant for the energy retrofit of historic buildings (in particular for HBs)? Can you get subsidies for energy efficiency measures? Have you applied for such subsidies?	
Q13	1.3	How well does current policy related to energy retrofit work in practice? What are strengths and weaknesses with current policies?	
Q14	1.3	Do you know where you could go to find good advice?	
Q15	1.4	Is there any kind or information (guidelines, best practice, etc) that you are missing (in relation to energy retrofit).	

Q16	1.5	What do you monitor (IEQ, energy use) in your building? What stages (before, during, after?)	
Q17	1.5	How do you use the monitoring data?	
Q18	1.5	Would you like to monitor more and if so, why?	
Q19	1.5	This was the last question. Is there anything you would like to add (related to the themes we have discussed?)	

Table 28. Datasheet used to collect information on detailed cases

Item no.	General information			Instruction
1.1	Project type and name			
1.2	Building use(s)			Please list the building uses
1.3	Main typology			Please state which of these typologies best describes the building: detached, semi-detached, terraced, row
1.4	Address			
1.5	Building form			Please briefly describe the number of floors, the shape of the plan, the overall dimensions, the shape of the roof, etc.
1.6	Total floor area			
1.7	Total floor area of conditioned spaces			
	Please list the solutions used in Your thermal retrofit project	Unit (if applicable)	Value (before/after - if applicable).	Instruction *Is the value declarative [D] (as on an energy certificate) or has it been measured [M] as in through monitoring? Please write either D or M in the field below.* *Describe the retrofit solution applied to the partition / building element*
	THERMAL ENVELOPE			
2.1	Roof thermal insulation and finish	$W/(m^2 \cdot K)$		Please describe the insulation and finish solutions applied to the roof. Please state whether it was possible to form a continuous barrier.

2.2	Floor insulation between conditioned / unconditioned spaces	W/(m²·K)		Please describe the insulation and finish solutions of a ceiling separating a conditioned (insulated, heated or cooled, e.g., an apartment) space from an unconditioned space (uninsulated, not heated or not cooled, e.g., an attic)
2.3	External wall insulation and finish	W/(m²·K)		Please describe the insulation and finish of the external wall. If multiple solutions were used, please add additional rows to this sheet and document them separately. Please state whether it was possible to form a continuous barrier.
2.4	Party wall insulation and finish	W/(m²·K)		If applicable, please describe the insulation and finish solutions applied to the party wall
2.5	Walls between conditioned / unconditioned spaces - insulation	W/(m²·K)		Please describe the insulation and finish solutions of walls separating conditioned indoor spaces (insulated, heated or cooled spaces, e.g., an apartment) from unconditioned indoor spaces (uninsulated, unheated or not cooled, e.g., an attic)
2.6	Windows - replacement or original?	linguistic response		If the windows were replaced, write yes, and fill out fields 2.7-2.8 for the newly installed windows
2.7	Windows - replacement - jambs/frames	W/(m²·K)		Please describe the type and material of window jambs/frames installed during the retrofit, as well as whether or not they were equipped with seals/gaskets
2.8	Windows - replacement - glazing	W/(m²·K)		Please describe the type of glazing fitted in the new windows
2.9	Windows - existing - jambs/frames	W/(m²·K)		If the retrofit included the upscaling/renovation of existing windows by improving their thermal insulation capacity, please list the solutions that were implemented in the upscaling of existing jambs/frames that was done to achieve this

2.10	Windows - existing - glazing	W/(m²·K)		If the retrofit included the upscaling/renovation of existing windows by improving their thermal insulation capacity, please report the solution used to improve relevant parameters in the glazing
2.11	External doors - new - jambs/leaves	W/(m²·K)		Please describe the type and material of door jambs/frames installed during the retrofit, as well as whether or not they were equipped with seals/gaskets
2.12	External doors - new - glazing	W/(m²·K)		Please describe the type of door glazing, if applicable
2.13	Internal doors between conditioned / unconditioned spaces - frames/leaves - new	W/(m²·K)		Please describe the type and material of internal door jambs/frames installed during the retrofit, as well as whether or not they were equipped with seals/gaskets
2.14	External doors - existing- jambs/leaves	W/(m²·K)		If the retrofit included the upscaling/renovation of existing doors by improving their thermal insulation capacity, please list the solutions that were implemented in the upscaling of existing jambs/frames that was done to achieve this
2.15	External doors - exisitng - glazing	W/(m²·K)		If the retrofit included the upscaling/renovation of existing doors by improving their thermal insulation capacity, please report the solution used to improve relevant parameters in the glazing
2.16	Internal doors between conditioned / unconditioned spaces - frames/leaves - existing	W/(m²·K)		Please describe the type and material of internal door jambs/frames installed during the retrofit, as well as whether or not they were equipped with seals/gaskets
2.17	Envelope airtightness	n50		Please report the envelope airtightness value.
	BUILDING SERVICES			
3.1	Ventilation	Linguistic description		Please describe the type of ventilation system installed in the building during the retrofit
3.2	Heating	Linguistic description		Please describe the type of heating system installed in the building during the retrofit

3.3	Cooling	Linguistic description		Please describe the type of cooling system installed in the building during the retrofit
3.4	Domestic hot water preparation	Linguistic description		Please describe the type of domestic hot water system installed in the building during the retrofit
3.5	Low-temperature heat source	Linguistic description		Please describe the low-temperature heat source (e.g., heat pump) installed in the building during the retrofit
3.6	RES solution (electrical)	kWp		Please describe any RES solutions installed in the building that produce electrical energy
3.7	RES solution (thermal)	kWh/(m²·year)		Please describe any RES solutions installed in the building that produce thermal energy
3.8	Heat recovery	Linguistic description		Please describe any heat recovery solutions used in the retrofit
	ENERGY PERFORMANCE			
4.1	Percentage share of RES in satisfying Final Energy demand	%		
4.2	Non-RES generated Final Energy for HVAC (annual per m2)	kWh/(m²·year)		
4.3	Non-RES generated Primary Energy for HVAC (annual per m2)	kWh/(m²·year)		
	COST-EFFECTIVENESS			
6.1	Cost-effectiveness calculation method used (if any)			
6.2	Method-appropriate cost-effectiveness value	method-appropriate		
	CONSTRUCTION WASTE			
7.1	Please list the individual amounts of the types of construction waste per square meter produced in Your historic building energy retrofit projects (as per DC country guidelines)	t/m²		
7.2	Please list the amount of construction waste (material packaging) per square meter produced in Your historic building energy retrofit project	t/m²		
7.3	Please list the amount of construction waste (wasted material) per square meter produced in Your historic building energy retrofit project	t/m²		
7.4	If a construction waste report was drafted for the project, please attach a copy to the datasheet, if possible.	n/a		
7.5	Was the amount of construction waste estimated during the design phase, and if so,			

	what was the method used to do so?			
7.6	Were there any major discrepancies between the estimated waste quantity and the actual waste quantity? If so, how big were they, percentagewise?	%		
7.7	Was any specific waste reduction/management strategy used during the design phase?	Linguistic response		
	MAINTENANCE			
8.1	Was the retrofit conducted in response to a pre-existing maintenance/renovation plan for the building or building portfolio? If so, in what time is another retrofit planned for the building?	Linguistic response		
8.2	During the design phase, was there a maintenance/renovation plan prepared for the building in conjunction with the retrofit? If so, what was the yearly budget for maintenance planned?	Linguistic response		
8.3	Do You follow any established guidelines on how to maintain historical buildings? If so, please list them.	Linguistic response		
8.4	What are the expected replacement rates for the main building elements/services in Your maintenance plan?	Linguistic response		
8.5	What were the maintenance costs after the retrofit? Were they aligned with projections?	Linguistic response		
	COMFORT AND IEQ			
9.1	What was the thermal comfort in the building prior to the retrofit?	Pre-retrofit PMV,, PPD, linguistic description		
9.2	What was the thermal comfort after the retrofit?	Post-retrofit PMV, PPD, linguistic description		
9.3	What was the lowest indoor space temperature recorded in the building's conditioned spaces? (excessive cold)	°C		
9.4	What was the highest indoor space temperature recorded in the building's conditioned spaces? (overheating)	°C		
9.5	Were there problems with high humidity in the building's conditioned spaces? If so, then during what period of the year and what was the relative humidity?	%		
9.6	What was the air change rate in the building's conditioned spaces before the retrofit?	ACH		
9.7	What was the air change rate in the building's conditioned spaces after the retrofit?	ACH		
9.8	Were there problems with high CO or CO_2 in the building? If so, what were the readings?	ppm		
9.9	Were there problems with particulate matter content in the air inside the building? If so, what were the readings?	$PM_{2.5}$, PM_5, PM_{10}		
9.10	Was a post-occupancy evaluation of thermal comfort performed after the retrofit? Did the occupants report improved or worsened	Linguistic description		

	thermal comfort?			
9.11	Were there problems with toxic substances in the indoor air? If so, please list these substances and their ppm values.	ppm		
9.12	Where there problems with mould or other odours reported by occupants/noticed during inspections?	Linguistic description		
	ENERGY/FUEL POVERTY			
10.1	Did You observe symptoms of energy poverty among occupants before the retrofit? (extreme cases of energy savings on heating to avoid high energy bills)	Linguistic description		
10.2	If such symptoms had been observed, did the related behaviours change in any way after the retrofit?	Linguistic description		
	SOFTWARE			
11.1	What software was used to prepare the design documentation for the retrofit?	Linguistic description		
11.2	What software was used to prepare/simulate the energy-focused parts of the design documentation?	Linguistic description		
11.3	Is the building's energy performance monitored, and if so, what are the parameters, the measurement frequency and the technical measures used in the monitoring?	Linguistic description		
11.4	Is the building's indoor air quality monitored, and if so, what are the parameters, the measurement frequency, and what are the technical measures used in the monitoring?	Linguistic description		
	FINANCIAL KPIS			
12.1	Capital investment	currency		
12.2	Cost	Likert scale 1-5 (least-most significant)		
12.3	Economic performance and affordability (EP)	Priority level (1-10)		
12.4	Equipment at prebudgeted rates	yes/no		
12.5	Initial cost	Likert scale 1-5 (least-most significant)		
12.6	Life cycle cost	Likert scale 1-5 (least-most significant)		
12.7	Net Present Cost	currency		
12.8	Project profitability	Likert scale 1-5 (least-most significant)		
12.9	Adverse effect on quality of groundwater level	Likert scale 1-5 (strongly disagree-agree)		
12.10	adverse impact on tourism values	Likert scale 1-5 (least-most significant)		
12.11	Employment of labout	Likert scale 1-5 (not suitable-very		

		suitable)		
12.12	Flexibility and adaptability	Priority level (1-10)		
12.13	Minimum variations cost	Likert scale 1-5 (strongly disagree-agree)		
12.13	No financial claims at completion	Likert scale 1-5 (strongly disagree-agree)		
12.14	No increase materials cost	Likert scale 1-5 (strongly disagree-agree)		
12.15	Rehabilitating cost of ecosystem	Likert scale 1-5 (not suitable-very suitable)		
12.16	Resettling cost of people	Likert scale 1-5 (not suitable-very suitable)		
12.17	Stable labour costs	yes/no		
	ENVIRONMENTAL KPIS			
13.1	Environmental friendliness	Likert scale 1-5 (least-most significant)		
13.2	Shadow cost	currency		
13.3	Utilised environmentally friendly technology	Likert scale 1-5 (least-most significant)		
13.4	Annual carbon emission:	kg CO_2 eq		
13.5	Destruction of the stratospheric ozone layer	Likert scale 1-5 (below current practice-best practice)		
13.6	Embodied carbon	kg		
13.7	Emissions	Likert scale 1-5 (below current practice-best practice)		
13.8	Emissions Payback Time	yrs		
13.9	Formation of ground-level ozone	Likert scale 1-5 (below current practice-best practice)		
13.10	GHG emissions	kg CO_2 eq/kg emissions		
13.11	Global warming potential	Likert scale 1-5 (below current practice-best practice)		
13.12	Impact as to assessment under EIAR (Air)	Likert scale 1-5 (not suitable-very suitable)		
13.13	Project has led to air pollution	Likert scale 1-5 (strongly disagree-agree)		
13.14	Resistance to climate change	Likert scale 1-5		

		(below current practice-best practice)		
13.15	Abiotic depletion potential	Likert scale 1-5 (below current practice-best practice)		
13.16	Acidification of land and water resources	Likert scale 1-5 (below current practice-best practice)		
13.17	Connectivity with hinterland	Likert scale 1-5 (not suitable-very suitable)		
13.18	Extent of land acquisition	Likert scale 1-5 (not suitable-very suitable)		
13.19	Freshwater resources	Likert scale 1-5 (below current practice-best practice)		
13.20	Impact as to assessment under EIAR (Water)	Likert scale 1-5 (not suitable-very suitable)		
13.21	Quality of water use in buildings	Likert scale 1-5 (below current practice-best practice)		
13.22	Water reuse	Likert scale 1-5 (not suitable-very suitable)		
13.23	Eutrophication	Likert scale 1-5 (below current practice-best practice)		
13.24	Extent of loss of habitat or feeding grounds	Likert scale 1-5 (not suitable-very suitable)		
13.25	Extent of tree felling	Likert scale 1-5 (not suitable-very suitable)		
13.26	Impact as to assessment under EI AR (Ecology)	Likert scale 1-5 (not suitable-very suitable)		
13.27	Mineral resource depletion	kg Sb equivalent / USS		
13.28	Project has led to depletion natural resources (EV4)	Likert scale 1-5 (strongly disagree-agree)		
13.29	Reprovision of habitat	Likert scale 1-5 (not suitable-very suitable)		
13.30	Acoustic performance	Likert scale 1-5 (below current practice-best practice)		
13.31	Design flexibility towards noise reduction measures	Likert scale 1-5 (not suitable-very		

		suitable)		
13.32	Impact as to assessment under EIAR (Noise)	Likert scale 1-5 (not suitable-very suitable)		
13.33	Noise	Likert scale 1-5 (below current practice-best practice)		
13.34	Glare	Likert scale 1-5 (below current practice-best practice)		
13.35	Harmony with surrounding	Likert scale 1-5 (not suitable-very suitable)		
13.36	Impact as to assessment under EIAR (visual impact)	Likert scale 1-5 (not suitable-very suitable)		
13.37	View from assessor on visual impact	Likert scale 1-5 (not suitable-very suitable)		
13.38	Visual comfort	Likert scale 1-5 (not suitable-very suitable)		
13.39	Air outlet design	Likert scale 1-5 (not suitable-very suitable)		
13.40	Humidity	Likert scale 1-5 (below current practice-best practice)		
13.41	Indoor air quality	Likert scale 1-5 (below current practice-best practice)		
13.42	Indoor Environmental Quality-Health and Well being (IEQ)	Priority level (1-10)		
13.43	Overheating risk	%		
13.44	Ventilation design—during construction	Likert scale 1-5 (not suitable-very suitable)		
13.45	Ventilation design—service stage	Likert scale 1-5 (not suitable-very suitable)		
13.46	Annual electrical energy conservation (E6)			
13.47	Energy consumption and resources saving			
13.48	Energy management			
13.49	Energy Payback Time	yrs		
13.50	Energy policy and audit (E7	Priority level (1-10)		
13.51	Energy Return Ratio			
13.52	Energy savings per annum	%		
13.53	Exported energy			
13.54	Materials for energy recovery	Likert scale 1-5 (below current		

		practice-best practice)		
13.55	Peak Energy Demand Reduction for building operations (E5)	Priority level (1-10)		
13.56	Renewable primary energy	Likert scale 1-5 (below current practice-best practice)		
13.57	Site orientation to maximise passive solar potential (E2)	Priority level (1-10)		
13.58	Thermal performance	Likert scale 1-5 (below current practice-best practice)		
13.59	Total life cycle primary from renewable energy (E3)	Priority level (1-10)		
13.60	Total life cycle primary non-renewable energy (E1):	Priority level (1-10)		
13.61	Use of Daylight in the primary areas (E4):	Priority level (1-10)		
13.62	Use of non-renewable primary energy	Likert scale 1-5 (below current practice-best practice)		
	WASTE KPIS			
14.1	Components for reuse	Likert scale 1-5 (below current practice-best practice)		
14.2	Materials for recycling	Likert scale 1-5 (below current practice-best practice)		
14.3	Secondary fuels	Likert scale 1-5 (below current practice-best practice)		
14.4	Secondary materials	Likert scale 1-5 (below current practice-best practice)		
14.5	Hazardous waste to disposal	Likert scale 1-5 (below current practice-best practice)		
14.6	Increased solid waste (EV2)	Likert scale 1-5 (strongly disagree-agree)		
14.7	Materials used, Durability and Waste (M)	Priority level (1-10)		
14.8	Non-hazardous waste to disposal	Likert scale 1-5 (below current practice-best practice)		
14.9	Radioactive waste to disposal	Likert scale 1-5 (below current practice-best practice)		

14.10	Route(s) for waste disposal	Likert scale 1-5 (not suitable-very suitable)		
14.11	Waste management non-toxic liquid waste	Likert scale 1-5 (not suitable-very suitable)		
14.12	Waste management solid—construction material	Likert scale 1-5 (not suitable-very suitable)		
14.13	Waste management—solid dredged/excavated material	Likert scale 1-5 (not suitable-very suitable)		
14.14	Waste management toxic liquid waste	Likert scale 1-5 (not suitable-very suitable)		
	PUBLIC HEALTH KPIS			
15.1	Public health	Likert scale 1-5 (not suitable-very suitable)		
15.2	Public safety	Likert scale 1-5 (not suitable-very suitable)		
	SRI			
			Value + Linguistic response	
16.1	Has an SRI assessment been done during the retrofit? If so, what was the SRI score and SRI class?	yes/no / SRI score and class		
16.2	What was the functionality level for energy efficiency? How was it achieved?	Functionality level (0-4)		
16.3	What was the functionality level for maintenance and fault prediction? How was it achieved?	Functionality level (0-4)		
16.4	What was the functionality level for comfort? How was it achieved?	Functionality level (0-4)		
16.5	What was the functionality level for convenience? How was it achieved?	Functionality level (0-4)		
16.6	What was the functionality level for health, well-being and accessibility? How was it achieved?	Functionality level (0-4)		
16.7	What was the functionality level for information to occupants? How was it achieved?	Functionality level (0-4)		
16.8	What was the functionality level for energy flexibility and storage? How was it achieved?	Functionality level (0-4)		
16.9	Were any Building Automation and Control Systems applied in the retrofit? If so, what were they?	linguistic response		

FuturHist

Tailored intervention solutions for future-proofing historic buildings

At FuturHist, we research and test energy-efficient retrofit interventions tailored to historic building typologies. We implement these solutions in real-life demonstration cases in Poland, Spain, Sweden and the UK. We focus on innovative solutions such as bio-based materials, internal insulation systems, window retrofits, HVAC, and RES integration.

DURATION OF THE PROJECT: JANUARY 2024 – DECEMBER 2027

COORDINATOR

Co-funded by the European Union

Co-funded by the European Union and the UK Research and Innovation. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or European Climate, Infrastructure and Environment Executive Agency. Neither the European Union nor the granting authority can be held responsible for them.