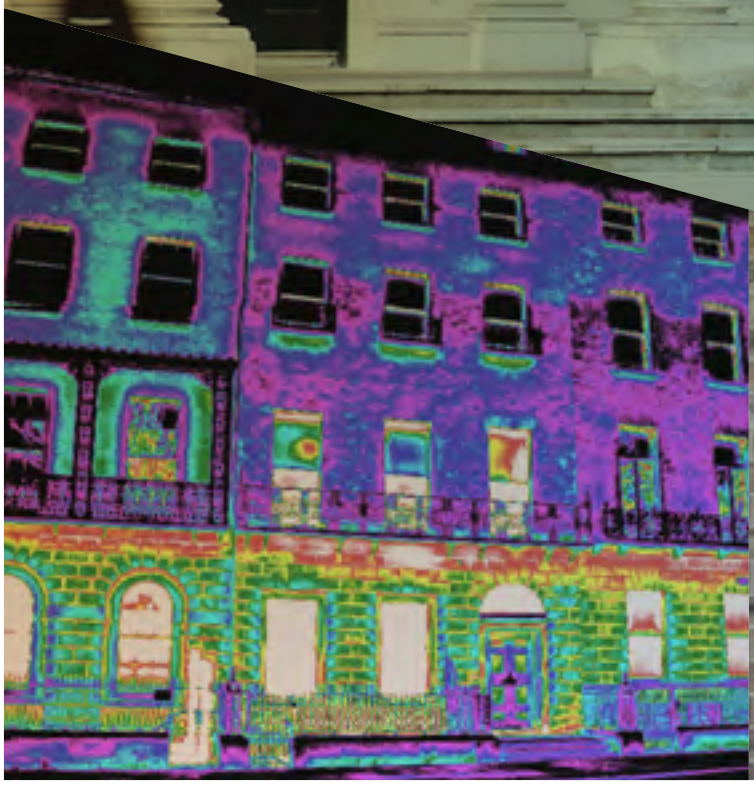
OPW
Oifig na nOibreacha Poiblí
Office of Public Works

Approaches to Improving the Energy Performance of Heritage Properties in State Care



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Acronyms

ACA	Architectural Conservation Area
ACO	Architectural Heritage Officer
BER	Building Energy Rating
BRP	Building Renovation Passport
CAP	Climate Action Plan
DEAP	Dwelling Energy Assessment Procedure
DEC	Display Energy Certificate
DECC	Department of Environment, Climate and Communications
DHLGH	Department of Housing, Local Government and Heritage
EPBD	Energy Performance Building Directive
EPD	Environmental Product Declaration
EWI	External Wall Insulation
HLI	Heat Loss Indicator
IAQ	Indoor Air Quality
IGBC	Irish Green Building Council
IWI	Internal Wall Insulation
LED	Light Emitting Diode
MHRV	Mechanical Heat Recovery Ventilation
NEAP	Non-Dwelling Energy Assessment Procedure
NIAH	National Inventory of Architectural Heritage
O&M	Operation and Maintenance
OPW	The Office of Public Works
PS	Protected Structure
PV	Photovoltaic
RMP	Record of Monuments and Places
SEAI	Sustainable Energy Authority of Ireland
TGD	Technical Guidance Document
VCL	Vapour Control Layer





Background

1 Introduction

Established in 1831, the Office of Public Works (OPW) is a central government office responsible for managing the Government's estate portfolio, maintaining and presenting Ireland's built heritage and managing Ireland's flood risk. Increasingly, these responsibilities will require an improved harmony between our built and natural environments, including how we respond to new challenges such as climate change.

In response to climate change, the Government is creating and implementing policies and strategies to achieve its long-term goal of transitioning to a low-carbon, climate-resilient and environmentally sustainable economy by 2050. These ambitions are set out in the Government's Climate Action Plan and the OPW has a significant role to play in implementing its actions and achieving its targets. On mitigation, the Climate Action Plan has set 2030 targets for the Public Sector to reduce CO_2 equivalent emissions from the sector by 51% and to improve energy efficiency by 50%.

This guidance document is intended as a roadmap to support professionals within the OPW in improving the energy performance of historic buildings in state care. OPW properties range from iconic heritage sites to the more every-day buildings for essential government and public services. These include two World Heritage Sites – Brú na Bóinne and Skellig Michael – hundreds of National Monuments, Garda properties, office buildings and thousands of acres of gardens and parklands. The guidance provides practical advice on the steps necessary to arrive at rigorously assessed and suitable solutions that can be tailored to each building and its particular requirements and constraints.

The guidance, therefore, is not intended to provide universal answers. Instead it sets out the procedure to follow to allow the user to arrive at an informed position when assessing aspects of the energy performance upgrade, from setting goals to identifying strategies to material selection. It provides general advice on the steps involved and highlights useful tips to be aware of at various stages. The guidance largely follows the framework suggested in the European standard I.S. EN 16883:2017 Conservation of cultural heritage – Guidelines for improving the energy performance of historic buildings (European Committee for Standardization, 2017) to show how each step of the standard can be carried out in practice.

This document is structured into three main parts. The first section provides background information on why the guidance document was developed, the relevant statutory context and additional considerations to be aware of. The second section comprises the step-by-step energy renovation guidance based

← *Previous pages*
Dublin Castle, Dublin

on I.S. EN 16883:2017 from project initiation to post-occupancy evaluation and monitoring. The third section – the appendices – includes useful resources such as the project stage checklist, an energy renovation report template and sources for further information.

It is widely known that a dry building is a warm building. Regular maintenance and essential repairs should be prioritised at the start of any energy renovation project. To emphasise the importance of this work, Stage 4 of the guidance – Design and Specification – begins with recommendations to assess, document and address existing defects.

In addition to the general guidelines, case studies provide examples of the process and show the steps taken. They also serve to highlight any learnings or pitfalls along the way. It is worth remembering the solutions shown in the case study are specific to that particular building and should not be taken as the default approach in similar buildings. Each building should be assessed on its own merits and solutions should be identified based on that assessment. One case study has been published as part of this guidance and the intention is to publish more as more energy renovation works are undertaken at OPW properties.

Energy upgrades are often part of a wider project or alterations to a building. While this guidance focuses solely on improving the energy performance, in practice this will often need to be done in conjunction with other considerations. These considerations often overlap, and sometimes will be compatible. However, when conflicting interests are present, this guidance is intended to assist in working through those considerations to arrive at the most suitable solution.

It is expected that the guidance will be read by professionals familiar with this type of work, therefore a level of professional expertise related to the project has been assumed. Notwithstanding this, the guidance is set out in a clear and concise manner to appeal to a wider audience.

This guide sits alongside and supports the recently published guidance from the Department of Housing, Local Government and Heritage, *Improving the Energy Efficiency of Traditional Buildings: Guidance for Specifiers and Installers* (2023) as well as the *Architectural Heritage Protection Guidelines for Planning Authorities* (2011). The Department's guide provides essential background information on what defines a traditional building, the physics of traditional construction, performance assessment methods and potential health risks in addition to guidance on specifying safe and effective energy upgrade measures and materials. Rather than repeat this good work, the OPW guide applies these principles through a detailed fabric and services upgrade strategy and Georgian townhouse energy renovation case study. This case study is the first of many which will be used to build up a repository of practice-based knowledge, highlight both what went well and lessons learned along the way.

2 Guidance Document Use

The decisions involved in the energy upgrading of a building impact all stages of a project, from high-level strategy decisions at concept stage to material specification at tender and construction stages to management and monitoring during occupancy. This guidance document however is focused primarily on the earlier stages of a project. During these early stages decisions are made on the direction of the improvements, preferred material selection, energy/services systems, fire and accessibility interventions and appropriateness of the building and its internal spaces for the proposed use. There may be external factors that impact on the strategy during later stages of the project that require the energy upgrade strategy to evolve and adapt. However a clear vision at this early stage provides a strong foundation for the project.

While this document will serve as a useful reference throughout the course of a project, it is most beneficial at the beginning and early stages of a project when setting out the goals and strategies. Critically, it will inform the interventions and alterations which may require planning permission, and direct such interventions in a manner which is appropriate for the particular building, requiring understanding and assessment of the architectural heritage values of the structure. The importance of having a clear vision of the energy upgrade strategy at the outset cannot be overstated.

It is also worth noting that this area of historic building energy upgrading is, in many respects, a new and emerging field. As more of this type of work is undertaken, materials tested and project experience recorded, this OPW knowledge base will develop through active participation and feedback. It is intended that the guidance in this document will also evolve and be refined as greater empirical knowledge is gained.

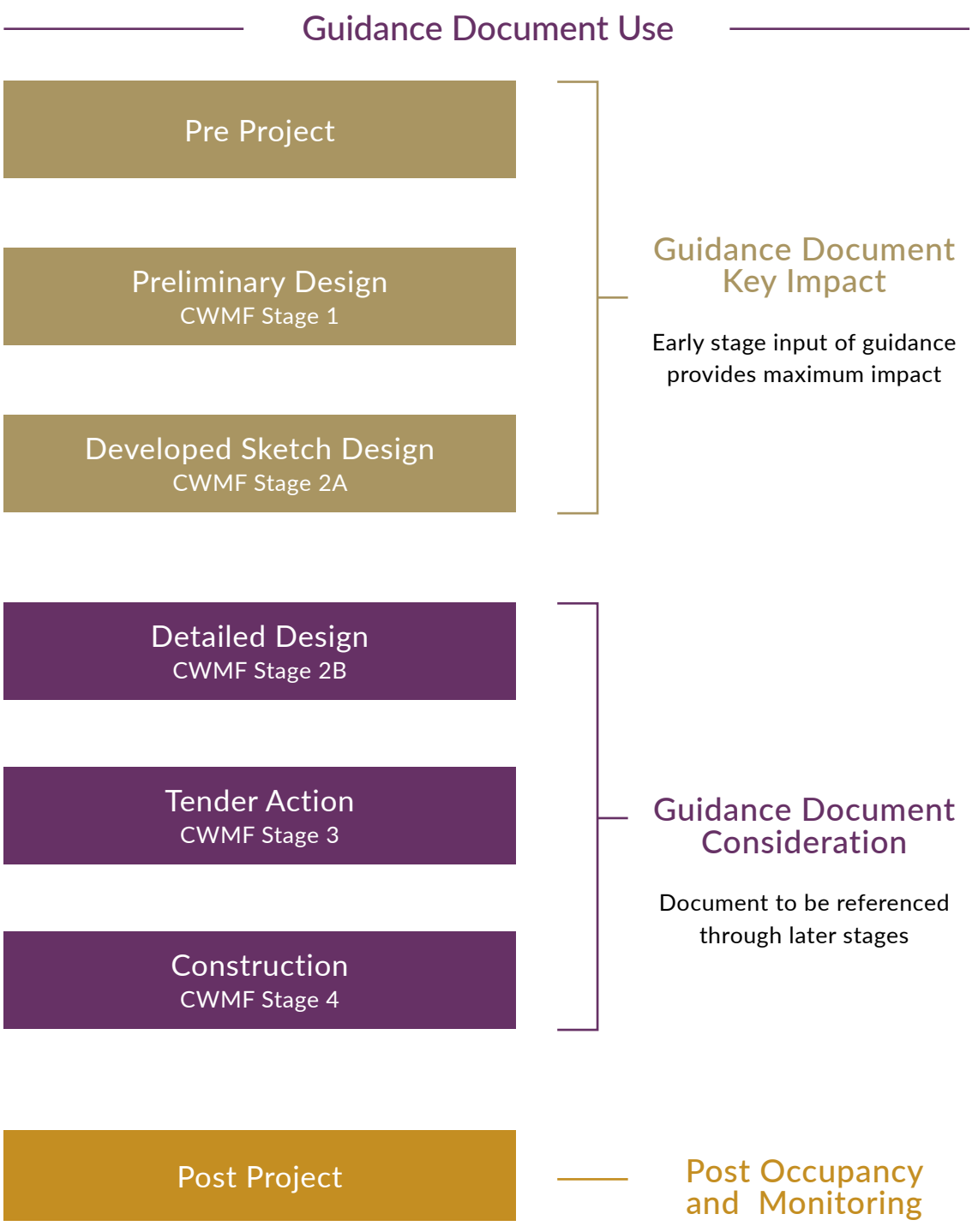


Figure 1: Primary and secondary impacts of this guidance at all stages of the design and construction process

3 Policy Context

3.1 National Bodies with Responsibility for the Built Environment

Over the last two decades, a number of energy conservation and decarbonisation related policies have been introduced at both the domestic and European level. These directives and regulations inform Ireland's response to the climate change crisis in a politically and economically sensitive framework.

The key departments and bodies responsible for implementing climate change policy in the built environment are:

- Department of Housing, Local Government and Heritage, DHLGH (responsible for planning law, heritage, building standards and regulations, Ministerial Guidelines, and non-statutory advice guidance.)
- Department of Environment, Climate and Communications, DECC (implements the European Energy Directive, EED)
- Climate Change Advisory Council, CCAC
- Sustainable Energy Authority of Ireland, SEAI
- National Standards Authority of Ireland, NSAI
- Office of Public Works, OPW
- Office of Government Procurement, OGP



→ OPW website home page

The website home pages for these government departments play a critical role in keeping the construction industry and the custodians of our built environment informed on what is now required when taking on new-build and conservation/renovation projects. These internet sites are now the main forum for dissemination, sharing and updating of standards and guidance documents.

These pages attempt to summarise the key aspects of recent policy and statutory requirements that prevail in early 2024.

3.2 Regulations and Policy Drivers for Improving Energy Efficiency

The key EU and national statutory and policy initiatives driving improved energy efficiency and decarbonisation of buildings are:

- SI 243 of 2012 implementing the Energy Performance of Buildings Directive, EPBD (2010/31/EU);
- EU (Energy Performance of Buildings) Regulations 2012-2021;
- SI 426 of 2014 implementing the EU Energy Efficiency Directive 2012/27/EU;
- Ireland's Long-term Renovation Strategy 2020 as required by EU Directive 2018/844/EU;
- National Climate and Energy Action Plan 2021-2030;
- National Climate Action Plan 2023;
- Building Regulations Part L 2022 (Conservation of Fuel and Energy – Dwellings);
- Building Regulations Part L 2022 (Conservation of Fuel and Energy – Buildings Other than Dwellings);
- National Energy Efficiency Action Plan 4 – NEEAP4;
- Improving Energy Efficiency in Traditional Buildings (DHLGH, 2023);
- Climate Action and Low Carbon Development (Amendment) Act 2021.

Improving the energy performance of buildings is key to tackling the Climate Crisis and to achieving the EU Climate and Energy objectives. The EPBD energy performance requirements for new and existing buildings are transposed into Irish law through:

- EC Energy Performance of Buildings Regulations
- Part L (Conservation of Fuel and Energy) of the Building Regulations
- European Union (Energy Performance of Buildings) Regulations 2021, and
- Part L Technical Guidance Document

These provide for the implementation of the requirements of Articles 2, 3, 4, 6 (part of), 7, 8 (part of) and 9 (3, b) of the EU Energy Performance of Buildings Directive – EPBD (recast) 2010/31/EU of 19 May 2010 andamending directive 2018/844 of 30 May 2018.

Improving the energy performance of buildings is key to tackling the climate crisis and to achieving the EU climate and energy objectives.

Through the Energy Performance of Buildings Directive (2010/31/EU), and its subsequent re-cast EPBD amendments in EU/2023/1791 Member States must apply minimum requirements as regards the energy performance of new and renovated buildings, and energy certification of buildings, when they are being leased or sold.

The key requirements for renovation projects are noted as follows.

1. Section 2 for existing buildings in Part L for Dwellings, and in Part L for Buildings Other than Dwellings, sets out key requirements for fabric insulation levels, thermal bridging, air permeability, efficiency of HVAC plant, Lighting, (all to achieve a minimum BER of 'B'), electric vehicle charging infrastructure and information relating to the commissioning, operation and maintenance of the building and the systems within it.
2. Notwithstanding Part L, Section 0.6, which notes that Building Regulations Part L do not apply to protected structures, due consideration should be given to conservation and protection of buildings of architectural or historical interest. The aim should be to improve energy efficiency as far as is reasonably practicable. The work should not prejudice the character of the building or increase the risk of long-term deterioration of the building fabric. Reference is made to the following guides and standards:
    - I.S. EN 16883:2017, Conservation of Cultural Heritage — Guidelines for Improving the Energy Performance of Historic Buildings (2017, NSAI)
    - Architectural Heritage Protection – Guidelines for Planning Authorities (2011, DAHG)
    - Improving Energy Efficiency in Traditional Buildings (2023, DHGLH)

Other key legislative requirements are set out in the Energy Efficiency Regulations (SI 426 of 2014), and in particular Part 2 (Public Sector) and Part 3 (Energy Audits), the key requirements noted as follows:

- **Regulation 5:** public bodies shall fulfil an exemplary role with regard to energy efficiency as set out in the National Energy Efficiency Action Plan, now at revision 4.
- **Regulation 7:** A public body with an individual building with a useful floor area of more than 500m² or an annual energy spend of more than €35,000 shall comply with Regulation 14 which requires energy audits to be undertaken every four years (or implement ISO 50001 – the Energy Management Standard).
- **Regulation 8:** A public body must not purchase or lease a building unless that building has a Building Energy Rating (BER) of A3 or better.
- **Regulation 9:** The Commissioners of Public Works in Ireland is required to make available an inventory of heated and cooled central government buildings that have a useful floor area of more than 250m². This aligns with the OPW Optimising Power at Work initiative that has been running since 2014.
- **Regulation 10:** the Office of Government Procurement (OGP) shall ensure that central government purchases only products, services and buildings with high energy efficiency performance in so far as that is consistent with other government procurement guidelines and Annex III of EU Directive for Energy Efficiency – 2012/27/EU.

Other policy driven targets include those set out in the Long-term Renovation Strategy 2020 and the Climate Action Plan (CAP). These targets for our existing building stock include:

- Renovation of 500,000 homes in each of the next three decades to upgrade a total of 1.5 million buildings by 2050 to a B2 level BER standard or better.
- Installing heat pumps in 400,000 dwellings by 2030, starting with 13,000 units in 2021 and increasing to in excess of 56,000 units a year by 2024.
- Upgrade one third of all commercial premises to a B level BER standard or better by 2030, two-thirds by 2040 and all buildings by 2050.
- Installing heat pumps in over 8000 commercial/public sector buildings by 2030.
- CAP2023 renewed pressure to get Display Energy Certificates in place for public sector buildings. Energy reporting and comparison against the predicted energy use through the BER will provide important feedback on building performance for retrofitting of historic buildings.



In the context of improving the national, regional and local electricity grid resilience, the roll-out of the smart energy metering programme by ESB Networks coupled with an assessment of the 'Smart Readiness Indicator' for buildings will play an important part in the successful adoption of renewable energy technologies (principally heat-pumps for space and water heating, and photovoltaics with access to electric vehicle charging facilities). While this guidance focusses on the improvement of the thermal fabric and the energy consuming systems serving the building, the retrofitting of intelligent energy management infrastructure will also play an important role in the decarbonisation of our building stock (both new-build and existing). For example the use of electrically powered heat pumps to heat our hot water or the building itself at times when there is excess low carbon, renewable, electricity available on the grid will need interaction between the building's control systems and the electricity grid distribution system operator (DSO).

All of the above shows that continued progress is required in the building industry to achieve these ambitious targets. The purpose of this good-practice guide is to help practitioners to adopt such decarbonisation principles in a way that protects and preserves the historic features of our existing buildings.

3.3 Statutory Planning Context

Statutory obligations regarding control of development are covered in a number of government policy and legislative Acts. Planning permission is required for any development of land or property unless the development is specifically exempted. This is to ensure the proposed works are in line with the National Planning Framework and Local Authority Development Plans. Exempted developments are outlined in the Planning and Development Regulations 2001 (as amended) and exist to avoid restrictions on minor development.

It is important to remember to balance the need to improve the energy performance of the building with maintaining and protecting its special architectural heritage.

The Planning and Development Act 2000 (as amended) and Planning and Development Regulations 2001 (as amended) also include provisions for preserving Protected Structures (or Proposed Protected Structures) and structures within Architectural Conservation Areas (ACA). Details of Protected Structures are added by the planning authority to the Record of Protected Structures (RPS), which forms part of each Development Plan. The State also maintains a National Inventory of Architectural Heritage (NIAH) for post 1700 architectural heritage. The planning authority can assess the content of, and the evaluations in, the NIAH survey with a view to the inclusion of structures recorded in the NIAH (generally those assessed as being of Regional or higher importance rating) in the RPS.

The National Monuments Act provides legal protection for archaeological sites and monuments by way of inclusion in the statutory Record of Monuments and Places, as established in the National Monuments (Amendment) Act 1994. Any person proposing to carry out works to a Recorded Monument must give notice in writing to the Minister for Housing, Local Government and Heritage two months before commencing that work. A similar level of protection is provided to monuments included in the Register of Historic Monuments, though this contains fewer monuments than the Record of Monuments and Places. For National Monuments in the ownership/guardianship of the Minister or local authority, prior written consent of the Minister is required for works at or in proximity to the monument.

While not all historic buildings have additional statutory protection, many structures under the remit of the OPW will fall under the status of some, or all, of the above. The classification of these buildings as a Recorded Monument, Protected Structure or within an ACA bestows additional statutory protection on that structure, and as such can define or possibly limit interventions that can be proposed. This could mean not all the objectives set out in the energy upgrade strategy can be achieved. Therefore, it is important to remember to balance the need to improve the energy performance of the building with maintaining and protecting its special architectural heritage.

Early engagement with the local planning authority and, if necessary, the National Monuments Service is crucial to develop an energy retrofit strategy that is not in conflict with the concerns of the statutory body. This avoids developing proposals that might be refused at planning application stage. It is also important to ensure any interventions which will involve material alteration to the special character of the protected structure, get the necessary planning consents in a timely way. This is crucial to avoiding potential delays or negative impacts on subsequent stages of the project.

For exempted developments, a Section 5 declaration, or Section 57 declaration for a Protected Structure, can be sought from the Planning Authority. This would establish whether proposed works would materially affect the character of the structure and whether they would require planning permission.

3.4 Regulations in Relation to Historic Structures

In relation to historic structures, it is worth noting that the EU (Energy Performance of Buildings) Regulations 2012-2021 and Part L of the Second Schedule to the Building Regulations do not apply to the following categories of buildings:

- a national monument for the purposes of the National Monuments Act 1930 (No. 2 of 1930), including a recorded monument under the provisions of Section 12 of the National Monuments (Amendment) Act 1994 (No. 17 of 1994) or a registered historic monument under the provisions of Section 5 of the National Monuments (Amendment) Act 1987 (No. 17 of 1987);
- a protected structure or proposed protected structure within the meaning of the Planning and Development Act 2000
- a building used as a place of worship or for the religious activities of any religion; and,
- other special categories (including military buildings)

It is noted that a BER and DEC (Display Energy Cert) are currently not required for these buildings.

Early engagement with the local planning authority and, if necessary, the National Monuments Service is crucial to develop an energy retrofit strategy that is not in conflict with the concerns of the statutory body.

The application of Part L and of the European Union (Energy Performance of Buildings) Regulations 2021 may pose particular difficulties for habitable buildings which, although not protected structures or proposed protected structures, may be of architectural or historical interest. These include buildings of traditional construction, many of which have a permeable fabric that both absorbs and readily allows the evaporation of moisture.

When undertaking works on, or in connection with, a building that is of architectural or historical interest or permeable traditional construction, the aim should be to improve the energy efficiency as far as is reasonably practicable. The work should not prejudice the character of the building or increase the risk of long-term deterioration.

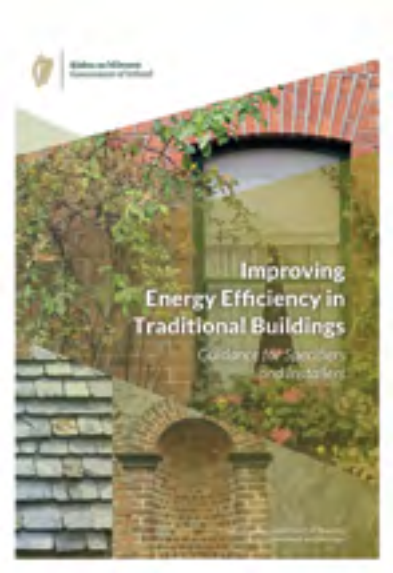
Section 6.8 of Ireland's Long-term Renovation Strategy 2020 notes the challenges faced in upgrading historical buildings with traditional building fabric formed from 'breathable' construction materials and systems. The Department of Housing, Local Government and Heritage has since commissioned the production of a guidance document *Improving Energy Efficiency in Traditional Buildings (2023)* to assist building professionals in the design and retrofit of energy conservation works to historic buildings.

3.5 Key Objectives for Renovating Heritage Buildings

The Climate Action Plan (CAP) sets a national-level roadmap for transitioning to a 'climate resilient, biodiversity rich and climate neutral economy by no later than 2050'.

One objective of the CAP is to achieve at least a 51% reduction in greenhouse gas emissions and a 50% improvement in energy efficiency in public sector buildings by 2030. There are about 12,500 public sector buildings and these account for approximately half of the sector's overall greenhouse gas emissions. The CAP notes that in order to achieve the 51% emissions reduction and 50% energy efficiency targets, buildings will need to undergo deep retrofit.

Upgrading the thermal performance and energy efficiency of the existing building stock presents numerous challenges, particularly where the building was built using traditional materials and construction methods and is of architectural and/or historical interest. In such cases, additional considerations are warranted.



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Improving Energy Efficiency in Traditional Buildings (DHLGH, 2023)

When undertaking works on, or in connection with, a building that is of architectural or historical interest or permeable traditional construction, the aim should be to improve the energy efficiency as far as is reasonably practicable.

Due to the wide range of the OPW building types, uses, and differing levels of historic significance it is very difficult to adopt a one-size-fits-all solution to upgrading the whole of this portfolio. The strategies employed to improve the performance of a simple warehouse used for storage, for example, will inevitably be different to those employed in an office located within an 18th Century former townhouse. Even within similar use classes, any strategy that may be undertaken to address a late 20th Century concrete frame office building, such as Tom Johnson House, or a mid-20th Century protected structure such as Busáras, may not be suitable to address an early 18th Century solid masonry building.

While an upgrade strategy to a building may be based on the set of principles discussed in this guidance document, each building must be taken on its own merits. As such, in each case we must develop a specific approach that will address the criteria required without having a negative impact on the building or structure.

3.6 Renovation of Existing Buildings

The revised EPBD (EU/2023/1791), sets out Ireland's long-term framework for the renovation of existing buildings. The revised Technical Guidance Document L 2022 (Conservation of Fuel and Energy) Dwellings and Buildings Other Than Dwellings have been published to accompany the Regulations.

The Directive requires that where major renovations (defined as a renovation where more than 25% of the surface envelope of the building undergoes renovation) are carried out on a building, the building should achieve a cost optimal energy performance. This applies insofar as is technically, functionally and economically feasible.



→
Iveagh House, Dublin

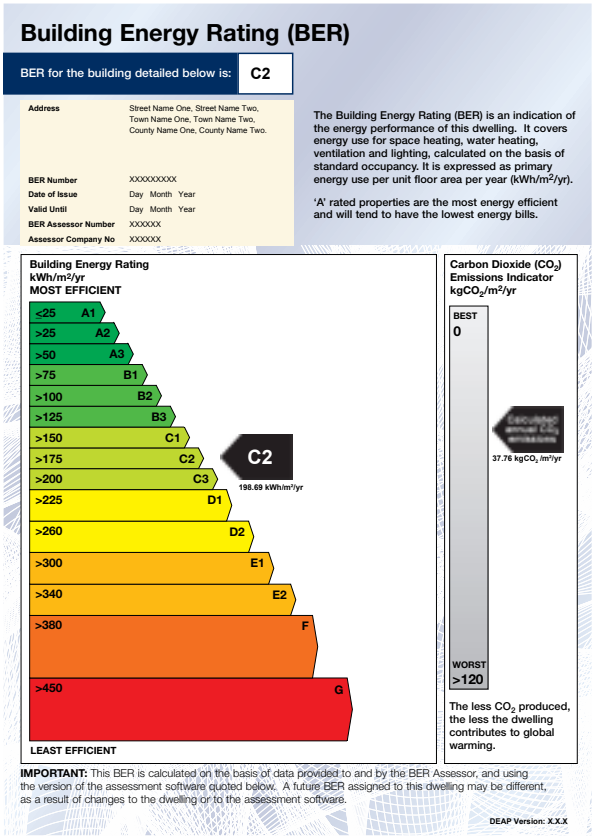
The main benefits of the new regulations are cited as reduced energy bills, leviation of fuel poverty, health improvements and reduced greenhouse gas emissions.

3.7 Building Energy Rating (BER)

The Energy Performance of Buildings Directive (2010/31/EU) and subsequent re-cast EPBD amendmentsin EU/2023/1791 requires all new and certain existing buildings in Member States to have an energy performance certificate. In Ireland this process is implemented by Sustainable Energy Authority of Ireland (SEAI) and takes the form of a Building Energy Rating (BER) certificate.

For dwellings, this is calculated using Domestic Energy Assessment Procedure (DEAP) software, whereas for non-domestic buildings this uses Non-Domestic Energy Assessment Procedure (NEAP), both published by SEAI and provide the methodology for calculating the energy performance of buildings to the requirements of the EPBD (recast) Annex I and EN 13790. The result is a Building Energy Rating (BER).

The DEAP and NEAP methodologies calculate the predicted primary energy use, the associated CO2 emissions and the renewable energy provided for space heating/cooling, ventilation, water heating and lighting under standardised conditions of use.



→ Sample BER Certificate

The objective of the BER rating is to provide a system for rating a building that is easily recognisable and comparable, similar to the ratings found on domestic appliances. The BER rating displays both the Primary Energy rating and the resultant carbon dioxide emissions.

Calculated Psi values for heat loss through thermal bridges are readily acceptable for use in DEAP and NEAP however in-situ U-values are not and it will be up to the BER assessor to gain approval for their use from the local Building Control Authorities.

The Primary Energy is a combination of the 'Delivered Energy' – i.e. the energy consumption that typically appears on energy bills - and the 'overhead energy' – i.e. energy incurred in extracting, processing or generating, and transporting a fuel or other energy carrier to the building. It is the Primary Energy rating that is used to assess the Cost Optimal level.

All new buildings and existing buildings being leased or sold are required to have a BER certificate. However, buildings protected under the National Monuments Act, Protected Structures and proposed Protected Structures are exempt. The EU does not see this as a free pass for owners of historic buildings, however, and measures are currently being reviewed to ensure historic buildings are also put on a pathway to zero carbon emissions by 2050.

Under the Climate Action Plan, 500,000 homes must be retrofitted to a B2 Building Energy Rating (BER) or cost optimal or carbon equivalent by 2030. All public sector buildings, as per Ireland's Long-term Renovation Strategy, of which around 15% are traditional buildings, are to achieve a BER of B by 2030. There is no requirement for existing buildings not undergoing works to achieve a particular rating.

At present, the BER assessment for traditional buildings relies on default U-values when calculating heat loss through a building fabric. However, recent research has shown that these default U-values may not accurately represent the existing condition. The general guidance set out in this document recommends carrying out site specific testing to gain a more accurate representation of the heat loss and hygrothermal behaviour, until such a time as default values may be revised to better reflect in-situ values.

Calculated Psi values for heat loss through thermal bridges are readily acceptable for use in DEAP and NEAP however in-situ U-values are not and it will be up to the BER assessor to gain approval for their use from the local Building Control Authorities. Therefore, there may be a need to carry out two sets of calculations, one using in-situ test values to measure the impact of design interventions on the existing fabric, and one relying on default values to determine what the published BER rating will be. In some instances, the published BER rating may be different to the actual energy performance of the building.

Assessing BER rating values

The BER for Domestic and Non-Domestic ratings are calculated in slightly different, but significant, ways. In DEAP, for Domestic buildings, the rating is simply expressed as a primary energy unit per floor area per year (kWh/m2/yr).

However, for Non-Domestic buildings, the SEAI approved NEAP software takes the form and layout of the building into greater account. It does so by comparing this to a larger database of buildings, and calculates an output as an alphanumeric rating as well as a ratio of the notional building. The BER rating is expressed as respective ratios of primary energy and CO2 emissions, relative to what would apply for a similar building generally satisfying the Building Regulations 2005. These values are referred to as the Energy Performance Coefficient (EPC) and Carbon Performance Coefficient (CPC) respectively. At the time of writing, the maximum permitted EPC is 1.0 and the maximum permitted CPC is 1.15.

This difference means that, in some instances, the Primary Energy rating of one building type may give a particular alphanumeric rating, but in a different building type the same Primary Energy rating may give a different alphanumeric rating.

When assessing the BER for Non-Domestic buildings, it is therefore important to take into account both the alphanumeric rating (i.e. C1) and the Primary Energy value (i.e. kWh/m_2/yr).

3.8 Setting an Agenda for Quality

In addition to National and European policy, a number of initiatives and guidelines exist that may be a useful resource when approaching energy upgrades. These initiatives can assist decision-making and judgement calls in relation to:

- interventions to existing heritage,
- identifying examples of exemplar projects, and
- providing innovative instruments for assessing quality in the built environment.



Places for People – National Policy on Architecture, 2021

Places for People is Ireland's National Policy on Architecture. It outlines ways to promote and embed quality inarchitecture and the built and natural environment as well as to boost public engagement with architecture andempower the architectural profession, especially within the public service. It also aims to raise design quality and improve data and research on our built environment.

The policy has a framework of practical actions that can be taken to help deliver buildings and public spacesthat work for all. These actions will help to create, sustain and regenerate local areas as vibrant, welcoming and sustainable places in which communities can flourish.

New European Bauhaus – 'Sustainable, Beautiful, Together'

The New European Bauhaus is a creative and interdisciplinary initiative that seeks to combine design, sustainability, accessibility, affordability and investment in order to help deliver the European Green Deal.

The New European Bauhaus brings citizens, experts, businesses, and institutions together to re-imagine sustainable living in Europe and beyond. In addition to creating a platform for experimentation and connection, the initiative supports positive change also by providing access to EU funding for beautiful, sustainable, and inclusive projects.

Davos Baukultur Quality System (2021)

High-quality *Baukultur*, as defined by the Davos Declaration of 2018, is characterised by well-designed, enjoyable living spaces that preserve the historical value of the built environment, respond to societal needs and are good for people's well-being and health. The recently published Davos Baukultur Quality System will enable the assessment of *Baukultur* qualities of places with the help of eight criteria, each one of them accompanied by assessment forms to facilitate evaluation and support planning. The Quality System is a major contribution to the New European Bauhaus initiative.

ICOMOS European Quality Principles for EU funded Interventions with potential impact upon Cultural Heritage (Revised edition November 2020)

The ICOMOS document focuses on the core issue of quality in EU-funded interventions that could have an impact on cultural heritage (mainly built heritage and cultural landscapes). It does so by providing a summaryof key concepts, international charters, European and international conventions, and standards and changesin understanding and practice of heritage conservation.

Given that the recognition of cultural heritage as a common good is a precondition of quality, the adoption of quality measures is proposed by raising awareness and strengthening the implementation of conservation principles and standards at every stage of a project, from conception to completion.

A set of selection criteria is proposed at the end of the ICOMOS document, as a tool for decision makers to assess the quality of projects with potential impact on cultural heritage.

4 Building Control and Cost Optimal

4.1 Building Control and Regulations

The design and construction of buildings is regulated in order to ensure the safety of people within the built environment. The relevant legislation are under the Building Control Acts 1990 to 2014, which is supported with the Building Control Regulations 1997 to 2021. The latter provide guidance on compliance, as well as Technical Guidance Documents showing how these requirements can be achieved in practice.



Figure 2: Technical Guidance Documents have been developed to demonstrate the application of the Building Regulations in practice

In general, the Building Regulations apply to the construction of new buildings and extensions and material alterations to existing buildings. In addition, certain parts of the Regulations apply to existing buildings where a material change of use, or a major renovation takes place. However, the TGDs acknowledge that in existing buildings there may be particular difficulties with adherence to the guidance without affecting the historic character of the building. Therefore, alternative approaches to achieving compliance while protecting the character of the building are also acceptable.

This is noted in the preamble of each TGD in relation to existing buildings. As stated there, the aim of these initiatives should be to improve the energy efficiency as far as is reasonably practicable without harming the character of the building or increasing the risk of long term deterioration of the building fabric.

The Building Regulations also acknowledges that currently TGD Part L does not apply to existing buildings that are Protected Structures or Proposed Protected Structures within the meaning of the Planning and Development Act 2000 (as amended). It also highlights that buildings of architectural or historical interest that are not Protected Structures or Proposed Protected Structures may be challenging to bring into full compliance with TGD Part L. Therefore, a relaxation of the values proposed may be acceptable if it can be shown that it is necessary to preserve the architectural integrity of the building. There are similar acknowledgements in the current TGD Part B, Part F and Part M.

Section 4 of the Building Control Act 1990 to 2014 allows for certain dispensations or relaxation of, any requirements of building regulations and sets out the procedures to be followed when applying for a dispensation or relaxation. Early engagement with the local authority is important to discuss any dispensation or relaxation and to clarify any issues or concerns.

Major Renovation Consideration

TGD Part L 2022 stipulated that, where an existing building undergoes 'major renovation' that the renovation systems and components meet minimum thermal performance requirements in so far as this is technically, functionally and economically feasible. A 'major renovation' is one where more than 25% of the surface area of the building envelope undergoes renovation. The surface area of the building envelope means the entire surface area through which it can lose heat to the external environment or the ground. This includes walls, floors, roofs, windows and doors. In this instance the energy performance of the whole building should be improved to Cost Optimal level, in so far as this is technically, functionally, and economically feasible. Section 2.3 of the current TGD Part L 2022 Buildings other than Dwellings and table 6 TGD Part L 2022 Dwellings identify what elements are considered in calculating the 25% of the surface area.

The initial stages of a step-by-step energy renovation may not cross the 25% threshold, however, additional stages could result in going beyond that, where 'major renovation' requirements would then apply.

It is important to note the 25% surface area requirement, particularly in the case where a project is carried out in a series of stages. The initial stages of a step-by-step energy renovation may not cross the 25% threshold, however, additional stages could result in going beyond that, where 'major renovation' requirements would then apply. This could mean a higher level of requirements applying that previously were not considered when the works fell below the 25% threshold. This also highlights the importance of creating a whole building strategy, to avoid a 'lock-in effect'.

4.2 Cost Optimal Description

'Cost Optimal' is defined in the Energy Performance of Buildings Directive 2010/31/EU as the energy performance level which leads to the lowest cost during the estimated economic lifecycle, where:

(a) the lowest cost is determined by taking into account energy-related investment costs, maintenance and operating costs (including energy costs and savings, the category of building concerned, earnings from energy produced), where applicable, and disposal costs, where applicable; and

(b) the estimated economic lifecycle is determined by each Member State. It refers to the remaining estimated economic lifecycle of a building where energy performance requirements are set for the building as a whole, or to the estimated economic lifecycle of a building element where energy performance requirements are set for building elements.

Each member state determines the Cost Optimal level by considering a range of costs including investments, maintenance, operating costs and energy savings. The economic lifecycle is defined in the Cost-Optimal Delegated Regulation of the Commission. The life cycle is performed using the net present value method for a period of 30 years for residential buildings and for a period of 20 years for non-residential buildings.



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Dublin Castle, Block M

Technical Guidance Document (TGD) Part L 2022 – Buildings other than Dwellings provides detailed guidance on compliance with the requirements. For 'major renovation', the Regulations require that the building is upgraded to the cost-optimal level of energy performance in so far as this is technically, functionally, and economically feasible. As the majority of buildings under the OPW's remit are non-residential this will be the focus of the guidance. However, there are also similar requirements to achieve cost optimal in dwellings, which is set out in TGD Part L 2022 – Dwellings.

TGD Part L 2022 – Buildings other than Dwellings provides two means of achieving cost optimal level:

1. Specific service energy performance improvements (Section 2.3.4); or
2. Achieving a defined Cost Optimal Energy Performance Level (Section 2.3.5) Cost Optimal energy performance levels are defined for several building types.

Table 13 Whole Building Cost Optimal Level	
Building Type	**Major Renovation - Cost Optimal Performance kWh/m²/yr primary energy**
Retail Air-Conditioned	338
Office Naturally Ventilated Offices and Other Buildings	124
Office Air-Conditioned	180
Hotel Air-Conditioned	342
Schools	60
Other Air-Conditioned Buildings	338
Other Naturally Ventilated Buildings	124

Figure 3: Current Cost Optimal Level as per Technical Guidance Document Part L – Buildings other than Dwellings (2022)

The guidance in 2.3.4 identifies a number of services improvements that can be undertaken that would typically achieve cost optimal level and be economically feasible when more than 25% of the surface area of a building is upgraded.

The second route, as specified in 2.3.5, is where the whole building primary energy is calculated in NEAP. If the primary energy is less than that specified in Table 13 of Part L, then this is considered cost optimal. To allow a degree of flexibility in application, the values can be increased by 15%. It is worth noting that the cost optimal Levels may change in future revisions of the technical guidance documents.

Using the second route to achieve cost optimal is the preferred route. This is because it involves much more project specific calculations and therefore more accurate interventions. This route also stresses the importance of highlighting the Primary Energy rating as part of the BER calculation, since the Primary Energy rating is specifically related to the cost optimal level.

5 Additional Considerations

5.1 Avoiding Lock-in Effect

The preferred strategy for improving energy performance is to plan for and implement upgrades to the entirety of a building in a single cohesive plan. This is to ensure that the greatest benefit can be achieved while avoiding potential unintentional consequences of a piecemeal approach. By planning for a complete and comprehensive retrofit, all the interventions can be tested in full against each other and the whole building model.

The greatest risk of planning and implementing works incrementally is creating a 'lock-in effect'. This is where previous works that are carried out make it harder or more expensive to implement other measures in the future.

In other instances, the initial scope of works may only include minor repairs or interventions to a building, which then grow to incorporate other elements. In all instances it is important to have a long-term whole building strategy for energy retrofit. This will help to avoid the risk of the 'lock-in effect'.

It is critical when commencing a project that due consideration is given to the sequence of upgrades and any potential future works, so that abortive works can be avoided.



Figure 4: iBRoad step-by-step renovation roadmap for a dwelling (iBroad-project.eu)

The adoption of a Building Renovation Passport (BRP) is seen as one means of tracking and encouraging the adoption of retrofit improvements to existing buildings. The Irish Green Building Council (IGBC, 2020) undertook a feasibility study in 2020 for the adoption of BRP on 20 existing dwellings in Ireland in collaboration with iBRoad, an EU Horizon 2020 research project. The feasibility study found that Building Renovation Passports could have a positive impact on the rate and depth of energy renovation.

In any case, whether BRPs are implemented or not, having a roadmap in place would help ensure that works are planned and implemented in a holistic manner, particularly where a phased approach is envisioned.

5.2 Life Cycle Assessment

Whole life cycle assessments provide an accurate representation of a building's carbon impact on the environment over its lifetime, including its demolition and disposal.

High levels of embodied carbon are mainly driven by the materials used in the production and transport phase of construction, but these levels can be tracked throughout all lifecycle stages of any building per EN 15978[1]:





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Environment Product Declaration for wood fibre insulating boards ©GUTEX

[1] Embodied carbon include lifecycle stages of a building under EN 15978: material extraction (module A1), transport to manufacturer (module A2), manufacturing (module A3), transport to site (module A4), construction (module A5), use phase emissions (module B1, e.g. refrigerant leakage but excluding operational carbon), maintenance (module B2), repair (module B3), replacement (module B4), refurbishment (module B5), deconstruction (module C1), transport to end of life facilities (module C2), processing (module C3), disposal (module C4).

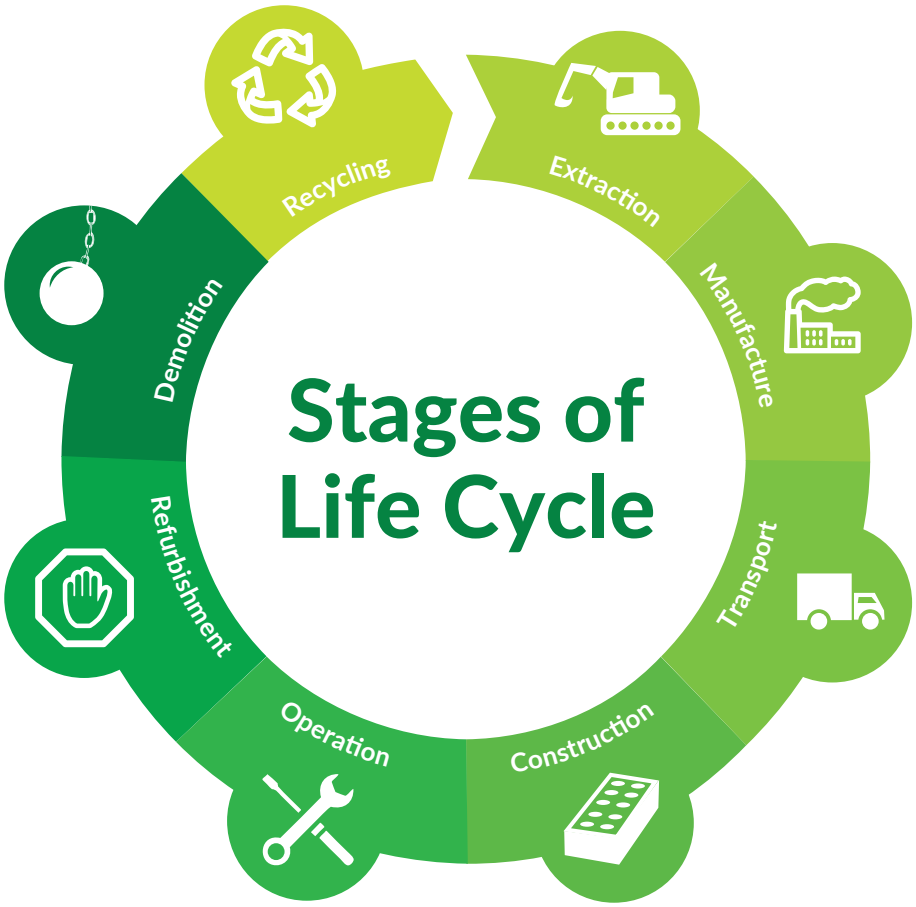


Figure 5: Life cycle stages of building materials from extraction to recycling (IGBC)

Some of the most carbon intensive materials are concrete, steel, aluminium and brick. Reducing the demand for these materials by reusing existing structures, and by prioritising re-use instead of demolition is a key step to reducing embodied carbon in construction.

Designers should be aware of the environmental impacts of the materials specified in a project and ideally choose the lowest carbon options, while also protecting the existing fabric of the building. Environmental Product Declarations (EPDs) provide data about the environmental impacts of a product through the product life cycle under EN 15804.

This means that EPDs can be used to compare potential construction products against carbon impacts as part of any proposed building works assessment. EPDs not only inform us about the embodied carbon levels (called also Global Warming Potential – GWP) of the selected material, but also can include other environmental impacts: acidification (AP), eutrophication (EP), ozone depletion, ozone creation and abiotic depletion.

It is up to the designer and specifier to make an informed decision on the material choice, based on EPDs and compatibility with the existing building fabric. This should start at the early stage of the design concept and continue to be reviewed throughout the project. At the final stage of the project and before the tendering process, the Whole Life Cycle Assessment of the building should be conducted. This assessment should follow the EN 15978 methodology for calculating the environmental performance of buildings covering each stage of the life cycle.

For more details on the Whole Life Cycle Assessment process please refer to "Green Public Procurement and the roadmap to low-carbon building materials in construction" developed by the State Architect Office (forthcoming).

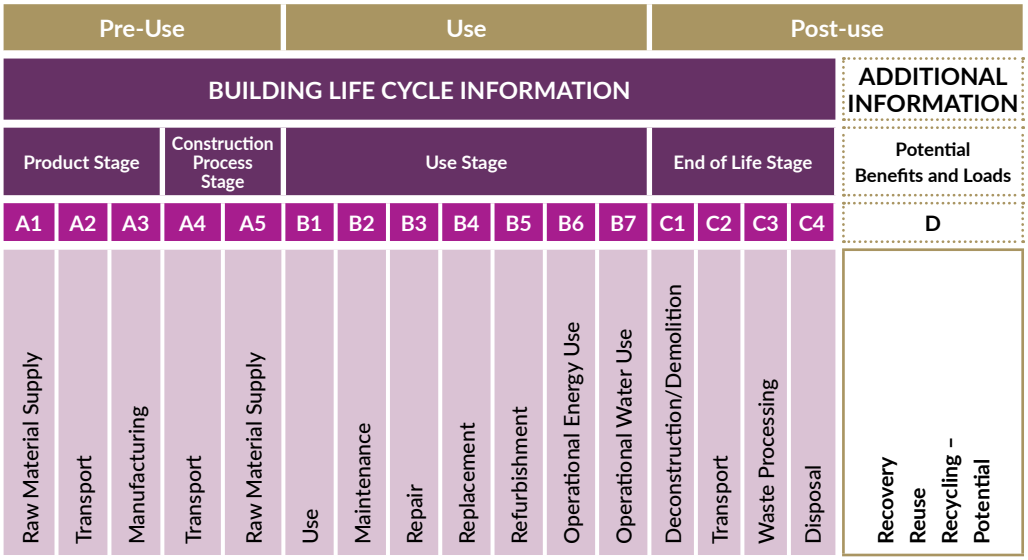
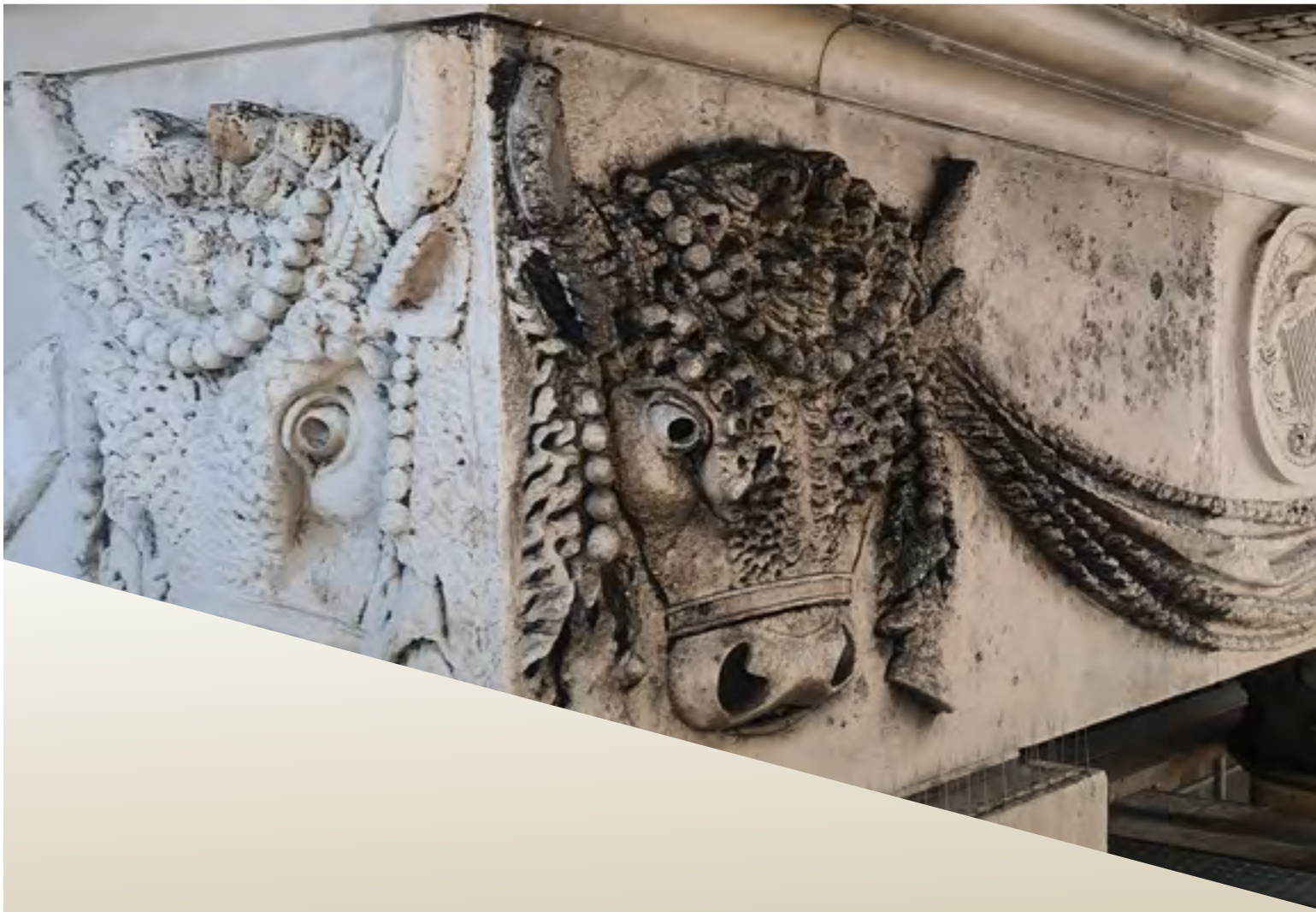


Figure 6: Life cycle stages for calculation of whole life carbon (Source: based on EN15978)





General Guidance

6 Fundamental Principles

IS EN 16883:2017 is devised to facilitate decision-making by balancing the need for energy performance with heritage preservation. It presents a generic procedure to follow when making decisions, with the aim to achieve the most appropriate decision in each case. The following stages in this guidance document are based on IS EN 16883:2017 and provide a roadmap to help guide the process. This is an iterative process and there is often overlap between the different stages. However, following these stages will assist in working through a project.



←
Previous page
Custom House, Dublin

Stages of an energy renovation project



Stage 1: Initiating the Process

- Establish the context and initial brief;
- Appoint the project Design Team;
- Identify initial project aims;
- Prepare the brief.



Stage 2: Building Assessment

- Analyse the architectural heritage significance of the building and adverse impacts of alterations;
- Review the impact of the local environment conditions, setting and contributing landscape elements;
- Gain insight into make-up of the existing building, including design and construction techniques;
- Understand the behaviour and performance of the existing building fabric;
- Assess the existing condition of the building and any defects that may affect energy performance.



Stage 3: Refining Objectives and Setting Targets

- Set out objectives;
- Prepare realistic/achievable goals based on the assessments carried out.



Stage 4: Design and Specification

- Review opportunities and constraints in building fabric, mechanical services, etc.;
- Develop strategies for energy upgrades to building fabric and mechanical systems;
- Test solutions based on available information and technology;
- Ensure the design follows a holistic approach.



Stage 5: Implementation, Post-Occupancy Evaluation and Monitoring

- Review design as constructed against goals and evaluate outcomes;
- Monitor post-occupancy to assess design versus actual performance.

Table 1: Stages of an energy renovation project based on the recommended process outlined in I.S. EN 16883:2017

7 Stage 1 - Initiating the Process



Stage 1: Initiating the Process

- Establish the context and initial brief;
- Appoint the project Design Team;
- Identify initial project aims;
- Prepare the brief.

Establishing the context: It is important to understand the wider context and to gather basic fundamental information about the building at the outset of a project.

This stage looks at high level questions about the project, such as:

- What is the overall aim of the project?
- What is the budget?
- What is the programme for the works?
- What is the overall condition of the building?
- What is the current/historic/proposed use of the building?
- Are there obvious problems or limitations?
- Who are the stakeholders?
- What expertise is needed?
- What is the planning status/any statutory protection?

Early input from relevant professionals at this stage is important. Without early engagement with suitable expertise, there is a significant risk that the project takes a direction, which may be costly or disruptive to modifyat a later stage.

Appointing the Project Design Team: The required skills of the Design Team vary from project to project. As such, it is important to appoint the correct expertise, and at an early stage, to minimise the risk of abortive work. This will help facilitate integrated and collaborative working methodologies from the outset. It is also important that the approach to energy performance upgrade is integrated as part of the whole process. For projects involving energy performance upgrades to historic buildings, the following will typically be required as a minimum:

- Conservation Architects;
- Building experts with specialism in building pathology;
- Engineers, who may also require conservation expertise.

The project leader should make sure that appropriate responsibilities are assigned to each Design Team member, and that clear lines of communication are established between the different departments. The responsibilities should be circulated to and understood by each member of the team.

A site visit should be carried out at this stage with the Design Team. Although this is only a visual inspection, it will nevertheless help feed back into establishing the context stage and to assist in preparing a robust clear brief. Early dialogue with the local planning authority, conservation office and building control is also useful at this stage in order to raise any concerns and to discuss potential issues and solutions.

Identifying initial project aims: It is likely at this stage that initial high-level discussions have taken place regarding the aims for the project and a general proposal. (e.g., to renovate an existing building currently used for storage into office use). It is presumed that by virtue of engaging with this guidance document that a decision has been made to include for energy upgrade as part of a project.

The project aims will inevitably evolve and be refined as the process develops and more information becomes available during the following stages, particularly the Building Assessment Stage. However, identifying initial aims (even if only high level) at this stage sets a clear direction for the project and Design Team.

Preparing the brief: The preparation of a clear brief is vital to setting out the core aims of the project. This will guide the Design Team throughout the project and post-occupancy period. In addition to typical considerations when preparing any brief, it is worth considering the following in the context of energy performance upgrades:

Use profile: Identify the existing use, including occupancy levels and tasks carried out in the building. The current use may impact the sequencing of the works or how the proposed interventions are assessed. For instance, if the building has been vacant/exposed for long periods it may require a period of drying out prior to undertaking improvement works which would need to be identified at an early stage.

Capacity for change/adaptation: A high level assessment of the building will identify if there are any fundamental issues regarding the proposed use. For instance, if the building is currently used as an office and the proposal is for an exhibition space, this may place a greater demand for mechanical systems, which could have a detrimental impact on the building fabric.

Phasing: An understanding of whether the works are to be undertaken in a phased manner or whether any future works are likely and should be planned for at this stage.

Overall energy strategy: It is critical to have in place a strategy for the energy performance of the whole building at the very outset, even if the initial brief is for a certain section only of the building. This will guide future works in a coherent and compatible way.

The brief should be reviewed as part of the stage 1 feasibility stage and updated to reflect information gathered at that point.

Wider considerations: This guidance, and IS EN 16883:2017, typically focus on individual buildings as stand-alone projects, however, in some instances the project could be part of a wider development or require interaction with other projects. The decision framework can easily be applied to more than one building or to instances outside of the project scope. A proactive approach to the wider context should be encouraged to identify any benefits from working with adjacent buildings, such as district heating or shared facilities.

7.1 Stage 1 Checklist

- ☐ Define the initial overall aims of the project.
- ☐ Gather a multidisciplinary team of experts.
- ☐ Review the budget for the project.
- ☐ Ensure the budget accounts for post-occupancy evaluation and monitoring.
- ☐ Outline initial programme.
- ☐ Identify the statutory status of the building.
- ☐ Contact the conservation/planning/building control authorities and discuss the project aims.
- ☐ Make a preliminary visual inspection of the building with the multi-disciplinary team.



→
Casino Marino, Dublin

8 Stage 2 – Building Assessment



Stage 2: Building Assessment

- Analyse the architectural heritage significance of the building and adverse impacts of alterations;
- Review the impact of the local environment conditions, setting and contributing landscape elements;
- Gain insight into make-up of the existing building, including design and construction techniques;
- Understand the behaviour and performance of the existing building fabric;
- Assess the existing condition of the building and any defects that may affect energy performance.

A multidisciplinary understanding of the building is the key basis upon which all decisions about the project should be made. Without proper information on the building condition, heritage value, and performance, it is difficult to assess the impact proposals will have. A thorough assessment of the existing building condition will provide the necessary information for specifiers to make informed decisions about energy performance improvements. This assessment also provides the information necessary to establish a baseline energy model that identifies the existing building energy performance.

The extent of the surveys should be proportionate to the complexity of the building and project. This is important to avoid gathering excessive information that is of little use, which may inadvertently conceal relevant useful information.

Using IS EN 16883:2017 as a reference, the building survey is divided into 6 key areas of assessment. While there is likely to be crossover between the different assessment areas, it is useful to set out these steps sequentially to build a picture of the building –

- General information on building;
- Heritage value;
- Use;
- Building construction and condition;
- Environment;
- Energy performance.

8.1 General Information on the Building

First, a desktop survey should be conducted in order to gather general information on the type, use and status of the building. Some of this information will have been gathered during the "Initiating the Process" stage. This step builds on that information and formalises it in a clear concise manner. It is necessary to set out some key areas to consider when gathering general information on the building. This might include:

Building identification

- Describe the physical attributes of the building.
- Identify the building typology, including apparent construction technologies and materials.
- Confirm what is the current and historic use.
- Confirm if the building is occupied, and if vacant, for how long and when it was last occupied.

Heritage designation identification

- Identify when the building was constructed including any alterations and additions.
- Gauge significance of the building, (for example, has it been recorded on the NIAH?).
- Identify the defining elements of special interest character of the building.

Statutory identification

- Determine whether the building is within an ACA, a Protected Structure, and/or Recorded Monument.
- Confirm what the regulatory requirements are in relation to Building Regulations.

The outcome of this step is a concise description of the building, its significance and its associated statutory regulations and requirements. At this stage potential conflicts between the expectations of the brief and the building status start to be identifiable.



→
Doneraile House, Co. Cork

8.2 Heritage Value

Assessing the heritage value of the existing building is an essential step in all projects involving historic buildings. Understanding the physical features and the tangible and intangible heritage of the building will make it possible to identify the building's capacity for change and the nature of potentially acceptable interventions. The special architectural heritage interest and significance of the building, including decorative elements, fixtures and fittings, its setting, its character-defining elements and history, should be established at the outset. This will highlight where measures will have a negative impact on the building's heritage value and which measures may have an acceptable or positive impact. This will be vital in identifying appropriate solutions and interventions.

The assessment should also identify:

- Areas vulnerable to change for the whole building and its character-defining elements;
- The conservation aspiration on behalf of the clients; and
- Any conservation priorities or constraints on behalf of the relevant conservation authorities.

Not all historic buildings in the OPW's remit are statutorily protected and some will be more sensitive to change than others. However, this process is a fundamental step for assessing all buildings. It is worth considering that some non-statutorily protected buildings may still have elements of significant heritage value. This process is key to discerning where intervention may be possible or more restricted.

The heritage assessment should be carried out by a conservation architectural professional with expertise in building typology.

Useful sources of information to inform assessments include:

- Original drawings and other documentary material relating to design, specification, construction and any alterations, and/or additions;
- Previous planning history documentation;
- Record of Protected Structures;
- National Monuments Surveys/NIAH surveys;
- Historic maps;
- Irish Architectural Archive;
- National Library of Ireland;
- OPW Archives
- National Archives
- Local Archives/Libraries
- Local Historical Publications and Organisations

The heritage value of the building may extend beyond the building's physical boundaries. Contemporary international conservation guidelines recognise architectural significance within the broader cultural landscape (e.g. broader historic urban landscape, etc.) as well as the historic uses, building technologies and intangible dimensions.

The assessment criteria for determining significance refers to the Architectural Heritage Protection Guidelines for Planning Authorities; Guidance on Part IV of the Planning and Development Act 2000 (DoAHG 2011) as issued under Section 52 of the Planning and Development Act, 2000. This provides an in-depth definition of each assessment criteria and should be referred to as a primary resource when assessing the building's heritage value. Below is a summary of each criteria:

Table 2: Summary of the Architectural Heritage Protection Guidelines Criteria

	**Architectural:** Architectural value is directly related to aesthetic value. Naturally, the visual qualities, design, and evolution of a building, object or site and the sensory experience it offers are critical aspects of this. However, the integrity of a building's components is also valuable insofar as it represents the specific and unique building technology of its period.
	**Historical:** This is value derived from the ways in which people draw sensory and stimulation from a place. It also considers the capacity of a place to convey, embody, or stimulate a relation or reaction to the past. Historical value can accrue in several ways: from the heritage material's age, from its association with people or events, from its rarity and/or uniqueness, from its technological qualities, or from its archival/documentary potential.
	**Archaeological:** Special archaeological interest is defined by the degree to which material remains can contribute to our understanding of any period or set of social conditions in the past (usually, but not always, the study of past societies). Structures can have the characteristics of both archaeological and architectural interest as these are not mutually exclusive. A complex of industrial buildings may have archaeological interest because of its potential to reveal artefacts and information about the evolution of industry.
	**Artistic:** Objects showing imaginative skill in arrangement or execution considered to be aesthetically satisfying that is creative or that requires a special art or craft skill. This could be related to particular craftsmanship of decorative elements within a building, for instance.
	**Cultural:** The characteristic of cultural interest permeates the architectural heritage and can, in the broadest terms, include aesthetic, historic, scientific, economic or social values of past and present generations.
	**Scientific:** The scientific interest, or research value, of a structure will depend on the importance of the data involved, as well as on its rarity and/or quality. Its scientific interest should also be assessed as to how well it represents the area of research in question and the degree to which the structure may contribute further objective information.
	**Social:** Social value encompasses the significance of the historic environment to contemporary communities, including people's sense of identity, belonging and place, as well as forms of memory and spiritual association.
	**Technical:** Technical interest in a structure relates to engineering solutions in its construction which are important examples of virtuoso, innovation or unusual engineering design or use of materials.

8.3 Use

Understanding the existing, historic and proposed uses of a building is important for appreciating the functionality of the building and how it might adapt to change of use in the future.

This requires the description and assessment of the:

- Present use(s) of the building;
- Historic use(s) of the building;
- Proposed use(s) of the building.

Present use(s) of the building: Understanding the existing use of a structure informs the proposed interventions. As such, familiarity with the existing building infrastructure can assist in identifying how the building should be used. A survey of present use should be holistic. For best results, consider the experiences of current occupants, whose personal familiarity will inform your own observations.

During your assessment, consider:

- the profiles of the existing types of use (any issues/problems that need to be addressed);
- information that can be taken from the present use (i.e. whether it provides a comfortable environment and is fit for purpose);
- the existing energy profile/use of the building and how efficient is it; and
- the existing facilities within the building are performing optimally or if there are any local issues.



→ The Ballroom of Castletown House, Co. Kildare

Historic use(s) of the building: Understanding the historic use for which the building was constructed can highlight areas which may conflict with the proposed use. Changes in use can often cause adverse impacts on the efficiency of the building. However, it is important to remember that past uses are not inherently in conflict with modernisation initiatives. In fact, historic use cases can provide insight into how the building might be reused in a sustainable way in the future. Consider, for example, certain period buildings whose original room layouts encouraged air circulation and temperature control. A specifier might consider working from such a layout to achieve this same effect while still following modern guidance. In this way, tweaking the historic uses and designs of buildings can be more effective and less disruptive than whole-cloth renovations.

Proposed use(s) of the building: The future use of the building should be considered critically to determine if and how the building can meet modern needs without adversely affecting its heritage significance. Regulatory requirements for the new use might impose different requirements that the renovation would not be feasible without major negative impacts on the building. Alternative scenarios for future use should also be considered in such cases.

During your assessment, consider:

- Whether the proposed design results in a material change of use as defined in the Building Control Act, and, if so, what the implications of this are for the building and anticipated alterations to ensure compliance;
- Whether the use change will require changes to how the space is used, accessed, heated, and ventilated;
- Whether a change of use will impose more or less strict regulations in terms of meeting BER or Cost Optimal requirements.

It is important to understand the current occupancy rates and loading factors of the existing building to determine if the proposed use will involve a more intense use. A change in occupancy rates could place a higher level of requirements on the environmental services as well as the structural systems.

Wider considerations

The Cost Optimal rating is based on the use of the building, and therefore, consider whether a change of use will impose higher or lower Cost Optimal targets. For instance, if the current use is a naturally ventilated office and the proposed use is a mechanically ventilated office this changes the Cost Optimal requirement.

8.4 Building Construction and Condition

To plan an energy upgrade strategy, it is necessary to understand how the building is performing technically. This involves understanding the construction type, undertaking a condition survey on the building, and carrying out in-situ testing.

Description of architectural and construction type: Identify, where possible, the type of construction to determine how the existing building performs. Often traditional buildings were constructed so that the building fabric had a level of vapour permeability. The key to understanding traditional buildings in terms of energy performance is how air, moisture and vapour is dealt with in the building. Maintaining this permeability ensures the correct functioning of the building and, therefore, its future. It is also important to note that buildings may include a number of different types of construction and may perform differently in different parts of the building. For further information on Traditional Construction types refer to *Improving Energy Efficiency in Traditional Buildings* (DHLGH, 2023), Section 1.2.

Condition survey of the building fabric: A thorough condition survey of the building is essential to identifying how the building is performing, including any defects, moisture damage, infestations, mould growth, corrosion, etc. The survey should follow the process in I.S. EN 16096: 2012 Conservation of Cultural Property – Condition Survey and Report of Building Cultural Heritage.



Example mould from roof water ingress

Site Visit Assessments for Energy Renovation Projects

A site visit is key to preparing a condition survey. This assessment typically involves:

- **Visual inspection:** Identify cracks, wet spots, rising damp, mould, etc. Ideally, the visual assessment takes place directly after a rain event, firstly to clearly recognise damage in the splash water zone and the roof drainage and its consequences, and secondly to capture a visual impression of the capillary water absorption of the façade and thus its protective state.
- **Identifying defect causes:** Locating the likely cause of damage/defect, such as broken downpipe, raised external ground level, blocked drains, impermeable and cracked render, missing slates, etc.
- **Opening up works:** Opening up works may be required to confirm existing construction, such as trial pits for foundation depth, lifting of floorboards, or cutting an access panel in a stud wall. It is important to allow for opening up works in the project programme. Statutory consent may be required for opening up works - consult Local Authority Conservation Officer or Planning Officer if the building is a Protected Structure and/or National Monuments Service if it is a Recorded Monument. Where opening up sensitive fabric, ensure that suitably skilled operatives are engaged and other necessary measures are put in place to avoid damage.
- **Measurements:** Procure a measured survey, provided by specialists with suitable equipment to capture the level of detail required. The level of detail required should be proportionate to the project scope and complexity. Additional measurements may be required to identify the likely construction build-up in certain areas, or important decorative elements in a space.

The survey should be well documented with drawings. Sketch details of the build-ups are a useful resource to explain the construction build-up, especially when assumptions about the structure have been made. It is important to confirm assumptions at later stages of the project. Ensure assumptions are clearly documented for review as the project progresses. This information should be fed back into the overall measured survey model. This is further discussed in Section 9.1.

Wider considerations

- Any damage or defects need to be addressed as part of the upgrade strategy, otherwise if not dealt with they are likely to adversely affect the performance of the building fabric.
- If opening up works are required, they may require statutory consent.

It is necessary to identify and understand the difference between a defect and damage. A defect is the source of the problem, whereas often damage is only the manifestation of the problem.

Defects: Typical defects in historical buildings are caused by –

- Material degradation;
- Moisture ingress movement;
- Air/vapour infiltration.

It is important to be aware of the indoor environment as this may have an impact on whether defects are apparent or not For instance, if there is no heating in a building and condensation is showing up on the windows, this may not necessarily be caused by a defect.

Damage: Typical damage found in historical buildings are -

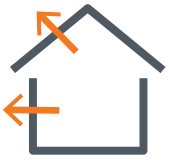
- Moisture damage due to defective roof covering, water pipes, drainage, water installation, etc.;
- Moisture damage from ground water due to missing sealing, horizontal barrier, etc.;
- Moisture damage to embedded timbers;
- Ingress of moisture through external walls caused by failed of pointing and plasters/render; and
- Infestation of timber components (fungus, mould, wood rot etc.)

There are numerous useful reference guides to identify defects in historic building, such as the *Improving Energy Efficiency in Traditional Buildings* (DHLGH, 2023) and RI Build, which is a European Union's Horizon 2020 funded research project that looks into defects and damage to walls in historic buildings.

Table 3: Summary of typical in-situ tests for existing buildings

In-situ tests analyse the existing building fabric and provide more scientific feedback on how the fabric is performing. Some tests are quicker and can be carried out with relative ease, while other tests are more invasive and require specialist input and equipment. Some of the more typical tests that can be carried out are –

In-situ U-value







External in-situ U-value measurement equipment

Description: The thermal performance of building elements can be assessed in-situ using sensors to measure the rate at which heat flows through them. Contemporary construction materials will often have test data to confirm their thermal performance. However, for materials used in traditional construction, often the only available data is either conservative default values or relying on a small number of tests carried out on similar materials.

This is particularly important for historic walls where there is little or no available thermal performance data and there can be significant variations between the properties of materials that may appear similar (i.e. brick).

While in-situ U-value tests can be carried out on any surface with access on both sides, they are typically only carried out on walls. The number of points tested should be proportionate to the complexity of the building. Tests should ideally be carried out on each construction type and on opposite sides of the building to determine the effect of exposure to external weather and sunlight.

Test requirement: Measurements are carried out over a minimum of 72 hours (in accordance with ISO 9869-1:2014 Thermal insulation - building elements). A temperature difference of minimum 5°C between inside and outside is required in order to achieve ISO compliant results.

In-situ U-value tests are ideally carried out during the colder months of the year, as this is when it is easier to achieve a temperature difference between inside and outside. Nevertheless, they can be carried out at any time of year if weather conditions are suitable.

To achieve compliant ISO results, the temperature difference needs to be maintained for a continuous 72 hours, therefore, each test can typically take up to 2 weeks to return reliable, valid measurements. Therefore, it is important to programme in these tests at an early stage to avoid delays in getting usable information.

Application: The results provide an accurate U-value for the existing construction and are critical when specifying proposed interventions. Relying on default values instead of in-situ U-values could result in over-specifying material interventions and have negative consequences. Among other things, the results are also used when carrying out a thermal modelling assessment to calculate the risk of surface condensation and mould growth. NEAP does not currently accept in-situ U-value results so default values must be used. To be acceptable for regulatory compliance, the surface condensation risk assessment must use the DEAP/NEAP U-values that were entered into the energy calculation.

Thermography





Thermal image of No. 7 Merrion Square ©Greenbuild Ltd.

Description: Thermography, or thermal imaging, captures infra-red light. A thermographic image records the amount of infra-red light emitted by an object and translate it into a multi-coloured images with each colour representing a different temperature. This identifies which parts of the building fabric are performing better or worse thermally, such as areas of dampness. It also helps in locating thinner depths of wall, cracking and voids.

Thermal imaging, when used during an air pressurisation test, highlights colder outside air traversing the fabric of the building and thus identifies the location of air infiltration entrance points.

Thermal imaging is particularly useful as it is a non-invasive, non-destructive test.

Test requirement: Images should comply with EN 13187:1998 Thermal performance of buildings. Qualitative detection of thermal irregularities in building envelopes. Infrared method.

A thermal image shows the highest to lowest temperatures within the range detected and therefore expertise is required to avoid a misinterpretation of reading.

Thermal imaging works best in winter because of the greater difference between the temperature indoors and outdoors, allowing for easier identification of thermal bridging areas, gaps or air infiltration in the building fabric. This test is relatively straightforward to carry out and, once the conditions are right, does not require a long survey time on site.

Application: Thermography is used to identify heat loss through planar elements, thermal bridging and gaps in the building fabric. It is therefore a useful, non-invasive and non-destructive tool for identifying areas where improved air tightness interventions may be required.

Air pressurisation





Air pressurisation testing of No. 7 Merrion Square ©Greenbuild Ltd.

Description: This test is used to determine the airtightness of a building in accordance with ISO 9972. A fan is set temporarily into a doorway to create a pressure differential that allows the amount of air leakage through the building envelope to be quantified. The results will show how much air infiltration is happening in the building. Combined with a smoke test, thermography or thermal anemometer this can identify where leaks occur as well as their severity.

A smoke test uses a machine to blow smoke near potential gaps and observe whether the smoke penetrates the building fabric, and if so, how much. A thermal anemometer gives an indication of the severity of the leaks by measuring the air speed at the infiltration points.

An air pressurisation test must also be carried out post-completion of the works to confirm the airtightness level following the works.

Test requirements: During the test, a pressure difference is achieved between inside and outside of 50 Pascals, and the amount of air through the fan is then measured, to give results in compliance with I.S. EN ISO 9972:2015.

The external weather conditions will have an impact on the test results. This means it is preferable to carry out the test on a calm day. On windy days, leaks located downwind and upwind won't have the same pressure difference.

Therefore, the flowrate through each leak will depend on its location on the building envelope: the impact of some leaks will be overestimated and some others will be underestimated.

Application: Air pressurisation confirms the air tightness of a building which impacts the efficiency of mechanical systems. The air tightness level will dictate the type of ventilation strategy required as well as the suitability of the heating system.

The air pressurisation results following completion of the works are required for NEAP and DEAP calculations.

Moisture absorption



Karsten tube test on brick face and mortar joints

Description: The Karsten Tube test is essentially a way to test water absorption in a material, usually masonry, in a controlled way such that it can be measured. The rate of absorption gives an indication of the 'capillary action' of a material, i.e. how quickly it redistributes liquid water from wetter zones to drier zones. The results are used in conjunction with hygrothermal risk assessment in accordance with ISO 15026 to provide a more accurate assessment of driving-rain absorption and its effects on the wall.

Test requirements: The test uses a series of tubes temporarily fixed to a wall filled with water and absorbs into the wall material. The rate of absorption is monitored to give an absorption value for that material. If the wall is made up of multiple elements it is vital to measure each material and situation. For instance with a brick wall it is necessary to test the centre of brick, centre of perpend brick, side of brick, and centre of mortar joints. The results are area-weighted over the percentage of brick to mortar ratio in order to provide a single value for that wall surface.

Application: The material absorption rate is required to carry out a hygrothermal assessment of a build-up, using dedicated hygrothermal analysis software. Hygrothermal analysis examines the intrinsic movement of heat, air and moisture flow through building enclosure assemblies over time. This analysis tests whether proposed changes to the fabric build up (i.e. introducing insulation) will cause unacceptable risk of trapped moisture. The results provide information on moisture contents in all material layers at the end of the assessment, and the user then exercises professional judgement to determine whether any risk exists.

Material analysis



Description: It may be necessary to test the properties of certain materials.

This can be relatively straightforward, such as testing moisture measurements of timber elements, or more invasive such as removal of a sample brick to test absorption properties in a lab environment. The extent of material analysis should be proportionate to the complexity of the project as material analysis often requires the removal and destruction of existing material.

Additional Tests

There are a number of additional tests that may be required, or helpful, to provide more information about the existing building fabric. These are often more invasive/specialist tests that are usually only necessary in certain instances where it is critical to fully understand exactly an existing construction, as they require a high level of skill and expertise and can be costly. These include radar, ultrasound and endoscopy but are usually reserved for very specific circumstances.

Refer to *Improving Energy Efficiency in Traditional Buildings* (DHLGH, 2023), Section 2.2 for further details on assessment methods and benefits of tests.

8.5 Environment and Context

A comprehensive assessment will consider the current context and condition of the building in order to identify constraints and potential opportunities for improvements. This allows for informed decisions to be made regarding energy efficiency improvements to protect the architectural heritage and occupants' health.

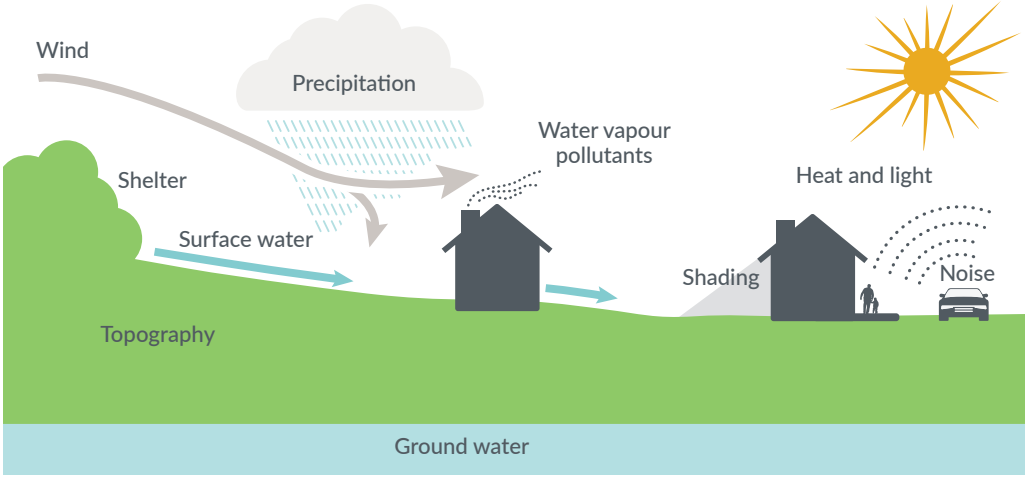


Figure 7: Numerous aspects of a building's setting that can affect the building's energy efficiency and can offer opportunities for improvement. (©McCaig et. al., 2018) Historic England.

Many aspects of the building context and environment can affect the energy efficiency and the opportunities and constraints of possible solutions.

These include orientation, exposure to wind/rain and sun. For example, if a building is subjected to prolonged periods of driving rain the walls will likely become saturated. This may limit the types of wall insulation that can be used. Similarly, if parts of the building are exposed to intense sun this may lead to summer overheating.

Nearby features, such as neighbouring buildings or landscape, should also be considered, as they too may affect the building's micro-climate.

Climate/Weather: Alongside understanding the local environment it is important to be cognisant of the wider climate and weather events and how they might play out in relation to the building and area.

The government Climate Action Plan 2023 reflects the 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015, which identifies Climate Action as one of the key Global Goals (SDG Goal 13) to address. SDG Goal 13 identifies that climate change is increasing the frequency and intensity of extreme weather events such as heat waves, floods, aggravating water management problems, and interrupting the provision of basic services such as water and sanitation, energy and transport.

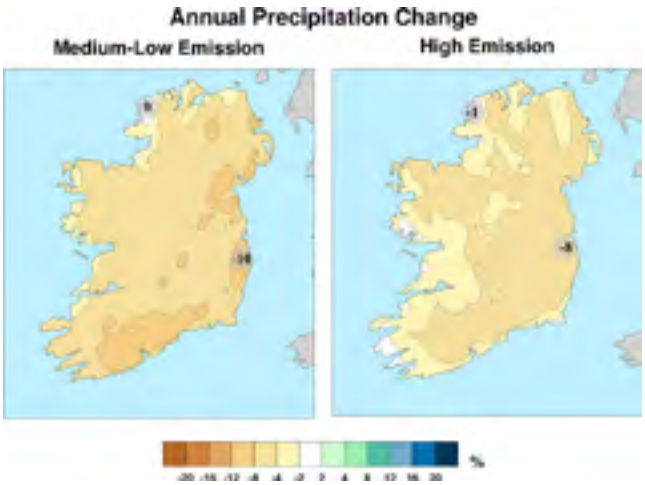


Figure 8: Annual precipitation change for Ireland in the future period 2041-2060 as compared to 1981-2000 under medium-low and high emission scenarios (Nolan, 2015)

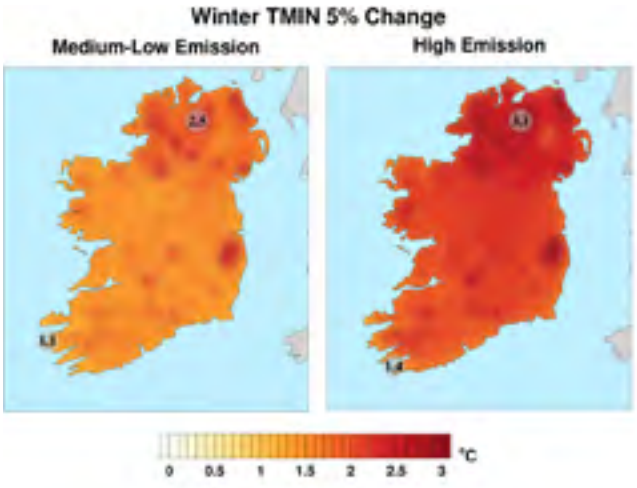


Figure 9: Temperature projects for Ireland for winter in the future period 2041-2060 as compared to 1981-2000 under medium-low and high emission scenarios (Nolan, 2015)

Met Eireann's projected scenarios calculate that by the middle of this century Ireland will experience a decrease in mean annual precipitation amounts. Decreases in rainfall will be largest during the summer, however, the frequency of heavier precipitation events will increase significantly. With extreme weather events more likely to occur the design of mitigation measures need to be considered in ways that may not have previously been deemed necessary – such as larger rainwater outlets or increased storm water drainage capacity. It is worth considering when addressing the issue of rainwater drainage to increase the capacity to safeguard in the future above what is specified in national standards or in current Building Regulations. In addition, if the building or parts of the building could potentially experience flooding in the future, it is worth considering how to mitigate against this and what the areas at risk are used for. For example, in a building with a basement, it may not be sensible to place the IT equipment in the basement rooms to avoid loss of data in the event of a flood.

8.6 Energy Performance

An assessment of the energy performance of the existing building before intervention is used to estimate the impact of different proposed energy strategies. It is also necessary to have a baseline model to compare energy use before and after interventions are proposed. The more accurate information on the existing condition, the more accurate the interventions will be, avoiding over- or under-specifying of materials. This baseline model requires information on the thermal performance of the building fabric as well as the existing building services.

Guidance is provided by the following standards –

- EN 16247-2:2022 outlines the requirements, methodology and deliverables for energy audits of buildings or groups of buildings,
- EN 15603:2008 provides a frameworks for the assessment of overall energy use and calculation of energy ratings in buildings, and
- EN 15643:2021 describes the procedures to used to assess the economic, social and environmental performance of buildings.

Building Fabric: A baseline model requires certain information about the building fabric to determine the thermal performance. Each surface envelope will need to be assigned a U-value, an air tightness level, and a thermal bridging value. A number of different values can be applied to these depending on the information available or whether specific tests have been carried out. The more accurate information that can be provided at an early stage, the more useful the baseline model will be.

These tests might include:

- **In-situ Tests:** In-situ tests should be carried out as early as possible to determine the actual performance of the fabric. The number and types of tests will be determined by the project scale and complexity however, in most instances, in-situ U-value tests and Karsten tube tests will be required as a minimum. An air pressurisation test can be beneficial to determine the existing level of air tightness and to identify the scope of air tightness upgrades required. These tests are extremely beneficial and should be encouraged to be carried out however, in some instances it might not be possible to undertake some or any testing.

- **Default Values:** Where no information is available on the construction of an element, default values can be used from relevant tables in accordance with the DEAP/NEAP methodology. This is often the first method of establishing the baseline of the existing building. However, the default values may not be completely accurate and some building elements, such as solid brick walls, can vary greatly depending on location, orientation, workmanship, condition, moisture level, etc. Nevertheless, the default values are a useful guide in the early days of a project, particularly where testing is delayed or not suitable.

The type and timing of testing varies between projects. However, the more accurate and early that information can be calculated, the more useful this information will be to identifying a suitable energy renovation strategy. Ideally, in-situ testing should be carried out at an early stage with a programme in place for long term planning. While default values are a useful starting point, these can vary greatly from on-site conditions. This could have a negative consequence on the strategy resulting in specifying incorrect materials or systems which could ultimately negatively impact the performance and risk more damage to the existing building.

Building Services: A baseline model also requires information on the existing services, such as heating/cooling systems, lighting, hot water services, and ventilation. This information can be obtained from the building users and management as well as through a visual survey.

Energy bills can be obtained from the client, to include electricity and any fuel sources, while a site survey will determine the heating system, fuel type, capacity, efficiency, distribution system properties etc. In addition, a schedule of all pumps, fans and HVAC should be identified along with an assessment of the existing lighting provision.



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Building Performance Simulation Model of Block 11 at Collins Barracks constructed using IES Virtual Environment Software ©Passivate & Passive Dynamics

Baseline Model: The result of establishing the baseline model, whether through default values or through testing, is to create a basis of what condition the existing building is in. This sets up a starting position from which to test proposed energy strategies. The baseline model should be tested in NEAP and an existing BER rating assigned to the building. The baseline model should be updated each time new information or test results become available.

8.7 Stage 2 Checklist

Heritage Value

- ☐ Make sure that the team member performing the assessment has the necessary expertise.
- ☐ Specify the aim for the assessment.
- ☐ Identify if any existing assessments done.
- ☐ Document the assessment process.
- ☐ Assess building under each special interest criteria.
- ☐ Identify specific elements that contribute to the heritage significance of building.
- ☐ Identify areas vulnerable to change.
- ☐ Highlight Client's conservation aspirations.
- ☐ Highlight any local authority/statutory body concerns.

Building Construction and Condition

- ☐ Site visit carried out with relevant team members to assess condition.
- ☐ Identify team members who will undertake condition survey.
- ☐ Make sure there is sufficient allowance in the programme for opening up works and ensure competent operatives carry out the works.
- ☐ Apply for statutory consent for opening up work, if necessary.
- ☐ Ensure a comprehensive photographic and measured survey is carried out of the whole building.
- ☐ Make sure all known defects/damage are documented.
- ☐ Provide drawings and sketches to compliment survey information.

In-situ Testing and Analysis

- ☐ Identify the necessary in-situ tests to be carried out, and any restrictions/ limitations.
- ☐ Make sure there is sufficient time in the programme forcarrying out in-situ tests, noting that some tests take alonger time or can only be carried out at certain times of the year.
- ☐ Ensure tests are carried out by suitable professionalswith relevant expertise.

9 Stage 3 – Refining Objectives and Setting Targets



Stage 3: Refining Objectives and Setting Targets

- Set out objectives;
- Prepare realistic/achievable goals based on the assessments carried out;

9.1 Setting Objectives

At this stage in the process, the objectives for the improved energy upgrades would be specified. It is likely that some of the main objectives will have been provisionally identified at Stage 1, however, following the Stage 2 assessment of the building and gaining a better understanding of the existing building, these objectives can now be refined and agreed upon. The objectives may have to be revised later in the process as the project develops, however, it is necessary to set out the main objectives at this stage.

The general intention of the objectives is to achieve the best possible energy performance upgrades while also respecting the heritage significance of the building.

This step will set out both short- and long-term objectives for the project. These will later be used to identify the most appropriate measures to pursue and to develop a suitable energy renovation strategy.

In many practical situations this step is not carried out in a linear and systematic way. Often these discussions will be happening on an on-going basis. This is particularly true during the assessment stage while more information is being gathered. However, what is important is that the objectives are clearly identified at this stage and that they are communicated to the entire team. Setting the objectives may require as little as a short discussion where the stakeholders involved are present, or in other instances a dedicated workshop may be necessary where the objectives can be assessed and defined together.

The general intention of the objectives is to achieve the best possible energy performance upgrades while also respecting the heritage significance of the building. Objectives should be checked against the following criteria to assess their suitability. It is worth stressing that this does not need to be an overly

onerous task and the assessment of the objectives may be as simple as an open discussion comparing an objective against the following criteria below, as referred to in IS EN 16883:2017:

- Technical compatibility with the existing structural, constructional, technical systems;
- Heritage significance of the building and its settings;
- Economic viability;
- Energy performance – sustainability;
- Indoor environmental quality;
- Impact on the outdoor environment;
- Aspects of use.

While specific objectives will vary between buildings, any project should include –

Table 4: Primary objectives for building renovation projects



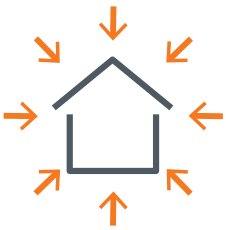
Objective 1 - Appropriate Strategy and Interventions

Provide recommendations for suitable energy upgrade of the building fabric and mechanical systems, ensuring the proposed energy efficiency measures respect the heritage significance of the building.



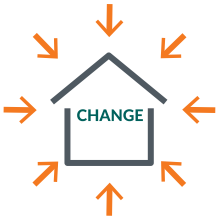
Objective 2: Energy Performance

Carry out a BER Non-Domestic Energy Assessment Procedure (NEAP), or Domestic Energy Assessment Procedure (DEAP) if applicable, and model of the building with the aim of achieving a set BER rating*, or Cost Optimal rating.



Objective 3: Environment Condition

Set quality outcomes not just on the metric of BER ratings, but also improvements in the users' environment (indoor air quality, lighting, etc.) and architectural heritage protection, through holistic project design.



Objective 4: Building Improvement Opportunities

Assess, and carry out where feasible, any opportunities for improvements that fall outside the remit of the energy upgrade of the building.

* *In most cases the goal is to achieve a B rating in line with Ireland's Long Term Renovation Strategy 2020, however, the rating may need to be reviewed and set on a case-by-case basis.*

Do not make this step overly complicated or time-consuming. The most important thing here is a mutual agreement from all the parties involved on what is important in the project.

9.2 Stage 3 Checklist

Setting Objectives

- ☐ Establish short- and long-term objectives for the project.
- ☐ Review the objectives against criteria in IS EN 16883:2017.
- ☐ The objectives are communicated within the project group and with stakeholders.



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Leinster House works in progress



→
Custom House, Dublin

10 Stage 4 – Design and Specification



Stage 4: Design and Specification

- Review opportunities and constraints in building fabric, mechanical services, etc.;
- Develop strategies for energy upgrades to building fabric and mechanical systems;
- Test solutions based on available information and technology;
- Ensure the design follows a holistic approach.

Having done all the groundwork assessing the building and setting objectives, it is now time to identify appropriate energy-efficiency improvements.

Improvements to the energy performance of a building can refer to:

- Rectifying defects and damage;
- Changes/upgrades to the building fabric;
- Changes to the services systems (mechanical and electrical);
- Changes to the energy supply and control; and
- Changes in user behaviour.

While each of these measures have an impact on the energy performance, at this stage it is necessary to address the building fabric and the services systems as the key elements for proposing energy performance upgrades. Energy supply may be difficult to address on a large enough scale to make a noticeable difference to the building performance. User behaviour has a big impact on the building's energy performance, and this will be addressed in the post-occupancy section.

It is likely to be of little or no benefit carrying out energy performance improvements to the building unless existing defects have been addressed.

First and foremost, it is likely to be of little or no benefit carrying out energy performance improvements to the building unless existing defects have been addressed. This ensures that the existing fabric is performing correctly and will not have a negative impact on proposed interventions. In the worst case scenario, if existing defects are not rectified they may result in unintended consequences and the accelerated decay of historic building fabric.

Following the rectification of defects, the next step is to address the fabric and services strategies. While it is likely that both strategies will be developed in parallel and will rely on each other, it is preferable to address the passive elements (i.e. building fabric) in the first instance followed by the services elements.

While it is acknowledged that this is not strictly a linear process, the preferred approach follows these steps:

1. Tackle Existing Defects/Issues;
2. Fabric Energy Upgrades;
3. Services Upgrades.

EN 16883:2017 Selection of Measures

Whether addressing defects or making proposals, I.S. EN 16883:2017, provides a step-by-step process to work through the options to arrive at the most appropriate solution.

The following is a summary of the steps –

- Compile a long list of measures;
- Exclude inappropriate measures;
- Assess remaining measures;
- Select packages of measures;
- Assess in relation to targets.

If the result does not correspond with the targets, then it may be necessary to review and revise either the proposals or the targets.





→
Department of Social Protection, Tuam, Co. Galway

10.1 Tackling Existing Defects

It is critical to address any defects or issues identified in the "Building Assessment" stage. Not only does rectifying existing defects or issues ensure that the proposed improvements will perform to their optimum, but it will also minimise defects being mistakenly covered up and causing unseen issues. If these issues manifest at a much later stage, they could potentially cause serious harm to the building and more costly repairs.

Major defects must be addressed as soon as they are identified, regardless of the overall works programme. There is often a critical opportunity as part of investigative works to carry out temporary repairs to halt water ingress and allow fabric to dry out.

Porous building fabric that has excessive moisture, particularly walls, might also result in increased thermal transmittance of the component.

Defect repairs typically fall under emergency repairs; however, it may be necessary to discuss the extent and detail of repairs with the local authority planning department and conservation officer prior to commencing any emergency works where the building is statutorily protected.

The rectification works may be complicated or straightforward, depending on the complexity of the defect. If a roof slate is missing, the solution is quite straightforward. However, if rising damp is identified, this may be more difficult to rectify.

It is particularly important to be aware of moisture damage. Moisture damage is one of the most common issues with historic buildings and can cause major issues. High levels of moisture can result in the deterioration of the building fabric and reduce the service life of the building components. Moisture induced damages in historic buildings include frost damage, wood rot, rising damp, mould growth, algae growth, and salt efflorescence. Porous building fabric that has excessive moisture, particularly walls, might also result in increased thermal transmittance of the component. This has the effect of increasing heat loss through the building fabric.





Example building defects

The DHLGH Advice Series – *Maintenance, A Guide to the Care of Older Buildings*, is an invaluable resource on how to maintain historic buildings, including on-going and periodic maintenance.

A list of defects will have been complied following the condition assessment to identify what issues need to be addressed. While each defect is specific to the building and situation, the following steps should be used to record in detail the defects and proposed rectification works.

Photographic documentation: It is important to create a clear and comprehensive photographic survey of the defective and/or damaged area as part of a visual assessment. It should be used to highlight materials, layer thickness (using a scale), details, etc. The photos should cover all relevant aspects of the defect - the cause and effects of the defect. For instances, if moisture damage on a wall is caused by a broken rainwater downpipe externally, it is necessary to record the broken downpipe as well as the damage to the wall.

Damage report: A damage report is carried out following identification of the defect to map as accurately as possible the damaged area. This is usually best mapped on drawings (elevations and plans) along with any other relevant information that can be gathered (such as previous repairs). The level of recording defects should reflect the complexity of the damage. Relatively straightforward defects require simple identification (such as a broken pipe note on a drawing), while other more complex defects required more detailed recording (such as a dedicated elevation identifying missing brick repairs). Based on the assessment of the damage, measures to rectify are recommended in the report.

Rectification works: The rectification works may be complicated or straightforward, depending on the complexity of the defect. If a roof slate is missing, the solution is quite straightforward. However, if rising damp is identified this may be more difficult to rectify.

In relation to moisture defects in particular, once the source is identified this should be fixed immediately and the affected area should be allowed to dry out (if necessary). The level of drying out may vary from defect to defect, for example, a 600mm solid brick and rubble wall that has been exposed to moisture for years will require an extensive drying out period, whereas moisture in timber elements in a recently defective roof will require a much shorter time to dry out. It is important to allow for correct drying out of the building fabric to occur. Introducing upgrades to insufficiently dry fabric could result in trapped moisture causing more serious harm to the building. The level of drying out may have a major impact on the programme or sequence of works and should be identified as early as possible in the project.

Introducing upgrades to insufficiently dry fabric could result in trapped moisture causing more serious harm to the building.

When proposing suitable rectification works it is helpful to follow the steps as referred to in I.S. EN 16883:2017 Selection of Measures.

10.2 Fabric Energy Upgrade Strategy

After assessing the existing condition of the building and rectifying all necessary defects and damage, the energy upgrade strategy should only then be developed. While it is important to create a retrofit strategy that includes fabric and services energy improvements working in harmony, it is preferable to address the passive elements of the upgrade in the first instance (i.e., the building fabric) before relying on mechanical and electrical systems, so as to avoid a reliance on energy intensive equipment.

When addressing the fabric energy upgrades, it is necessary to create an overall strategy that looks at the building as a whole and proposes interventions that take into account the information gathered at Stage 2 Building Assessment.

When addressing the fabric energy upgrades, it is necessary to create an overall strategy that looks at the building as a whole and proposes interventions that take into account the information gathered at Stage 2 Building Assessment. Once an overall strategy is identified the individual elements (walls, floors, roofs, etc.) can then be tested separately to determine their suitability in that particular instance. If the proposed upgrade strategies for individual elements are found to be unsuitable due to technical or heritage restrictions, then alternative materials and solutions should be tested. If this is still unsuccessful then it is necessary to re-assess the overall strategy. This process should be followed until the individual elements are determined as suitable within the overall strategy.

When deciding on the overall strategy or testing individual elements, refer to I.S. EN 16883:2017 Selection of Measures to assist in the decision-making process.

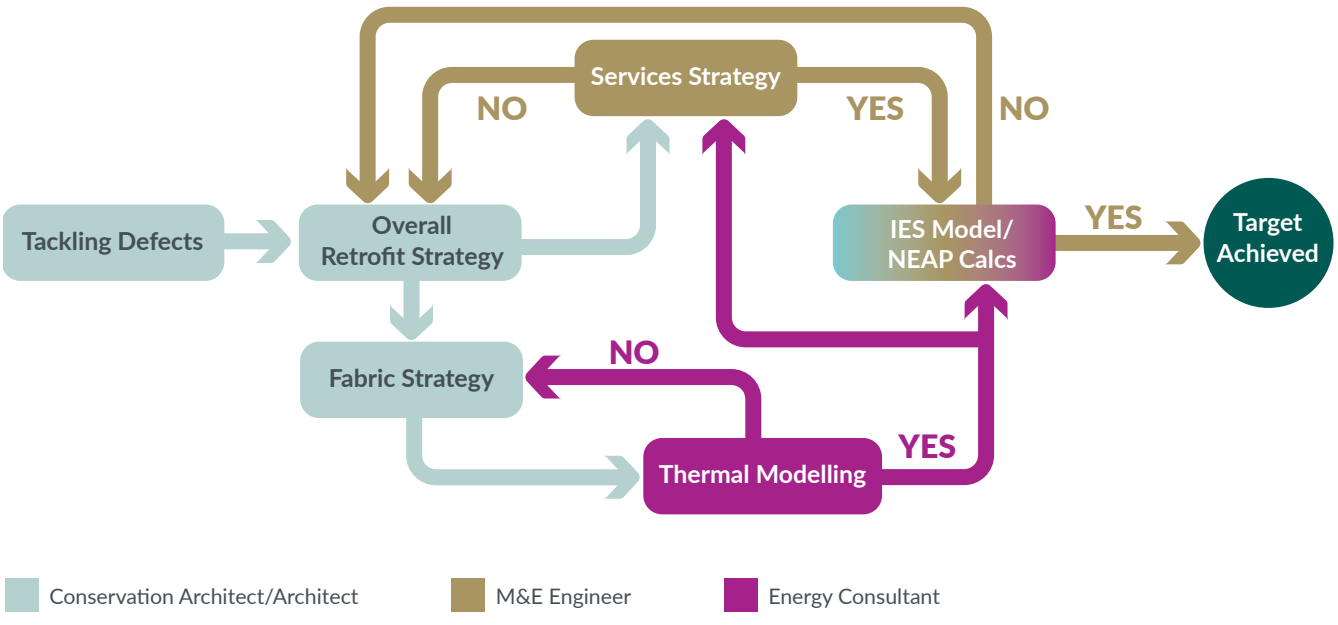


Figure 10: Stage 4 Design Process

Overall Strategy

The overall strategy is the over-arching proposal which is applied to the building fabric with the aim of achieving the objectives as set out in Stage 3. Determine at this stage the general approach to interventions for the whole building, such as, where is the best location to apply insulation, how to deal with windows/ doors, to what extent elements can be removed or need to be retained, etc.

The overall strategy should take into account all the information that has been gathered in the "Building Assessment" stage. It should be conscious of the condition survey, the heritage significance, the existing and proposed uses, the environment and context, and the existing energy performance. It also needs to consider the end user and how the building will be occupied and operated once completed.

Condition survey: The issues raised in the condition survey should have been addressed by this stage. Nevertheless, these issues could have an impact on the proposals. It is important to consider whether the original issues that caused the defect could be amplified by the proposed interventions?

Heritage significance: The heritage significance of the building will likely be the most important aspect when proposing interventions in historic properties. Understanding the heritage significance will either help identify more suitable strategies or help exclude certain proposals. However, just because a building does not have a statutory protection does not mean it has no heritage value and any proposals should be mindful of any heritage significance.



→
Derrynane House, Co. Kerry

Identifying a general conservation philosophy at this stage will assist the Design Team in the decision-making process. This would establish which elements should be preserved, which ones are acceptable to change, and the appropriate approaches and principles for alterations and interventions. Here it is important to communicate the conservation philosophy to the entire Design Team and ensure buy-in from all stakeholders.

Uses: A review of present and past uses can reveal what the building was originally intended for and how it is performing within the current use. The proposed use may have implications in terms of Building Regulations requirements and energy efficiency when carrying out the thermal analysis calculations.

In addition to this the proposed use may greatly change how a space performs. For example, if the building is upgraded and the level of air tightness is greatly improved, this will place a higher significance on the ventilation requirements. Alongside this, if certain spaces being ventilated are high humidity spaces this will place further emphasis on achieving a suitable solution that will not cause condensation and mould growth. It is therefore important to be familiar with the intended uses of both individual spaces and the building as a whole.

Environment and context: The environment and context may have the least significant impact on the direction of the overall strategy; however, it is still important to be aware of these. The climate may have an impact on issues such as access or buildability, whereas the environment may have an impact on how certain fabric elements are performing when testing proposed interventions.

Existing energy performance: A baseline model will have been produced as part of the "Building Assessment" stage showing the existing energy performance of the building. This will need to be assessed in terms of the objectives for energy performance upgrades. Consider, for example, how the existing building fabric is performing and consider whether this is a major source of heat loss. The existing energy performance model might identify that only certain elements of the building need to be upgraded. Such detail might be critical in informing the overall strategy.

Having gone through the assessment of the categories above, it should be possible to identify the optimal fabric upgrades. After completing this step, one should communicate what the overall fabric strategy is by highlighting (on drawings, schematics, etc.) the proposed upgrades to the roofs, walls, floors, windows and doors. This overall strategy will be the overarching conceptual proposal from which the individual elements will be tested. This should be presented to and agreed upon with the wider Design Team and Client.

Assigning Target Values

Once the overall fabric strategy has been established, an initial NEAP assessment of the proposals should be carried out. None of the individual elements will have been tested at this junction, so it would be necessary to assign target values on the proposed interventions. While these target values will be assumptions until the interventions are tested, there are some guidelines that can be used to give suggested values (e.g. U-values, psi-values, air tightness etc.). The target values need to be appropriate to the construction or build-up type. For instance, if the roof is to be addressed and there are minimal impacts on insulation within the attic zone, it would be possible to target a low U-value. However, if an Internal Wall Insulation was to be applied to a solid masonry wall in a sensitive location, it may only be possible to apply a thin layer of insulation. In such a case, only a higher target U-value may be possible.

Some guidance on this issue is available in:

Building Regulations TGD Part L: Although many historic buildings will be Protected Structures and therefore currently exempt from TGD Part L, this document can still be used as a guide for target values. The document gives suggested "Maximum Elemental U-value for Material Alterations" for all elements. These can be used to inform the target U-values depending on the intervention. In some instances, it may be appropriate to use the lower U-value associated with the "Area-weighted Average Elemental U-value" (such as in the case of the attic insulation above). However, in other cases it may be more appropriate to use a conservative higher U-value, therefore the "Average Elemental U-value – individual Element of Section of Element" can be a useful guide.

External Sources/Case Studies: Various research and case studies have been carried out on historic buildings that can suggest similar values as a guide. For example, *Improving Energy Efficiency in Traditional Buildings* (DHLGH, 2023), publications by the Chartered Institution of Building Services Engineers (CIBSE) and the Energy Efficiency in Traditional Buildings Advice Series all have a number of very useful case studies and guidance on historic buildings which include proposed build-ups and their U-values. However, care should be taken when relying on external information to ensure that this comes from a qualified source and has been verified.

Professional Experience: Often the Design Team will have experience from working on similar projects and can use that experience to suggest suitable target values.

When identifying the overall strategy it is useful to compile a table of the interventions, as per below, setting out the location, what the proposals are, what the impact is on the building, an assessment of the proposal, the current calculated or measured U-value and target U-value.

Table 5: Table of proposed fabric interventions

Location	Intervention	Heritage Impact	Assessment	Current U-value	Target U-value
Roof	Identify what is being proposed? *Example: Flexible insulation installed within the ceiling joist zone in attic.*	What impact does it have on the existing fabric? *Example: Minimal impact as there is currently significant space in attic. Intervention is reversible.*	Assess the proposal *Example: Intervention will have a positive impact on the energy performance with little impact on the heritage significance.*	x.xx W/m²K *Example: x.xx W/m²K*	x.xx W/m²K *Example: 0.16 W/m²K*
Walls					
Floors					
Windows					
Doors					



→ Wood fibre board insulation fitted to floor joists in interfloor zone

It is also useful to prepare schematic drawings (sections, plans, etc.) of the proposals, similar to the drawing below, while identifying the interventions. This is a useful visual tool to communicate the overall fabric strategy with the wider Design Team and Client as well as helpful means of highlighting the main interventions from which to test the individual elements.



Figure 11: Schematic drawing to communicate fabric energy upgrade strategy.



Figure 12: NEAP Guidance Document (2021), NEAP BER Publication and Survey Guide (2023), and NEAP survey form.

Initial NEAP Assessment

Once target values have been assigned to the proposed interventions, this can be tested in NEAP to identify what level of improvement is being achieved. The results can also indicate whether more or fewer interventions should be considered. An initial BER rating and primary energy usage can be identified at this stage.

Individual Assessment

With the overall fabric strategy identified and initially tested, it is now time to look at each individual fabric element and specify the proposed interventions in more detail. These interventions will be tested against a range of criteria to identify potential benefits and risks in order to arrive at the most suitable solution. Using the I.S. EN 16883:2017 Selection of Measures as a step-by-step guide, any obvious inappropriate materials or interventions should be excluded to leave a short list of possible solutions.

This short list of materials or interventions would then be assessed against the Assessment Criteria, as set out in I.S. EN 16883:2017, and Table 6 on the next page. This assessment aims to highlight any risks or benefits associated with each option, so that the short list can be compared against one another to find the most suitable solution.

The Assessment Criteria as per I.S. EN 16883:2017 lists seven categories, under which are a number of criteria (Table 6). Using the associated five-level Assessment Scale each material or intervention in the short list should be interrogated against each criteria and assigned either a risk, benefit or neutral assessment and then compared alongside one another in a simple table format. This allows an easy visual comparison between the various solutions. Below is an example of the assessment table comparing a number of different measures.

The Assessment Criteria tool is not intended to provide the definitive answer. Rather it should instead be used as a tool to facilitate a process to test each option. It should be used as a guide and can be tailored to each proposal. The Assessment Category and Criteria headings generally cover most aspects to consider, however, these can be expanded if necessary to suit particular project requirements.

Table 6: Intervention assessment template for fabric upgrades based on I.S. EN 16883:2017

Intervention 01 Assessment Criteria					
Assessment Category	Assessment Criteria	Measure 1	Measure 2	Measure 3	Measure 4
Technical Compatibility	Hygrothermal risks				
	Structural risks				
	Corrosion risks				
	Salt reaction risks				
	Biological risks				
	Buildability				
Heritage Significance	Material/constructional impact				
	Risk of visual impact				
	Risk of spatial impact				
Economic Viability	Capital cost				
	Economic savings				
Energy	Impact on energy demand				
	Life cycle energy demand				
Indoor Environmental Quality	Conditions suitable for building				
	Conditions suitable for occupants				
	Emission of harmful substances				
Impact on Outdoor Environment	Greenhouse Gas Emissions				
	Emission of harmful substances				
	Natural resources				
Aspects of use	Influence on the use of building				
	Consequence of change of use				
	Ability of users to operate system				

Assessment Scale				
High Risk		Neutral		High Benefit

Wider considerations

In addition to the Assessment Criteria, the individual assessment should consider:

- Embodied carbon of materials chosen;
- Life Cycle Assessment;
- The OPW Green Procurement Policy, including Environmental Product Declarations.

While these criteria are outside the scope of this guidance document, they are important considerations that need to be aware of.

For further information refer to ***The OPW Roadmap to Green Public Procurement and Sustainable Construction*** (forthcoming).

Individual Fabric Element Upgrades

This guide is not intended to explain in great detail how traditional buildings perform, as that information is covered in a number of other publications. For particular advice on this, refer to the *Improving Energy Efficiency in Traditional Buildings: Guidance for Specifiers and Installers* (DHLGH, 2023), Chapter 2, which explains in detail the physical properties of traditional buildings as well as specific materials and building elements (walls, floors, roofs, etc.).



→
Intelligent airtight vapour control membrane installed over outside of rafters prior to installation of rafter level insulation

Traditional buildings physics: The physical properties of traditional buildings will inevitably vary from type to type and period to period, however, there are some key criteria that area generally consistent across all traditional buildings.

- **Vapour permeability:** How "breathable" is the building? Traditional solid walls rely on the permeability of the building fabric to allow water vapour to evaporate during periods of drying out. This permeability must not be inhibited.
- **Moisture movement:** How is moisture dealt with in the building? Traditional building fabric has the ability to absorb moisture (both internally and externally) and then release it. Trapping moisture within the fabric can cause serious negative consequences.
- **Air tightness/ventilation:** How airtight is the building? Traditional buildings would often rely on natural ventilation through the fabric to maintain a stable indoor environment. This must not be confused with draughts, which are uncontrolled excessive air flow through poorly maintained or defective fabric (i.e. poorly sealed windows, gaps/cracks in fabric). Creating a more airtight fabric will require the provision of additional ventilation to be considered.

Roofs: Insulating an attic or roof is generally one of the most effective and non-intrusive measures that can be undertaken. Attic spaces in traditional buildings are typically ventilated spaces. Any intervention must maintain the level of ventilation, paying particular attention to the eaves and ridge level. This may also require introduction of slate vents and ridge vents.



→
Wood fibre rafter insulation installed over intelligent airtight vapour control membrane



→
Counter battens installed over insulation to encourage airflow

Floors: Traditional buildings were typically constructed with either a suspended timber floor or a solid ground floor. Suspended timber floors are more straightforward to insulate, whereas solid ground floors are often more difficult.

A suspended timber floor, like an attic, requires natural ventilation within the floor void to deal with any excess moisture. It is important to maintain air flow across the floor area, typically through the use of grills in external walls to allow cross ventilation. These grills must be maintained and kept free.

Insulating a solid ground floor can be very challenging. One option is to add insulation on top of the existing floor slab, however, this would have an impact on the floor to ceiling height, door head heights, skirtings, architraves, floor finishes, etc. and in most instances is likely to be impractical. Alternatively the ground floor slab would be removed and excavated to provide a new insulated floor build-up maintaining the existing floor level. This, however, could undermine the existing foundation level if the foundation is relatively shallow. A variation of this is to install insulation at the perimeter where the floor meets the external wall, reducing the extent of intervention.

Walls: Traditional walls are often solid wall construction and typically represent the most difficult areas of intervention. Solid wall construction relies on vapour permeability to control the indoor environment. Any interventions to solid walls must not inhibit the vapour permeability. Hygrothermal risk analysis of the proposed interventions must be undertaken to determine whether the proposals will have a negative impact on the fabric through increased risks of thermal bridging or moisture retention.

There are typically two options for insulating solid masonry walls – externally (External Wall Insulation, or EWI) or internally (Internal Wall Insulation, or IWI), however both present challenges.



→ Installation of a cork lime internal wall insulation with reinforcing mesh

If IWI is used, the installation can be highly disruptive and there will be an impact on the internal space — window reveals/shutter boxes, cornices, decorative mouldings, etc. may need to be removed and reinstalled and the overall floor space may be slightly reduced. It is particularly important to use vapour permeable insulation to avoid trapping moisture between the insulation and the solid wall, however the specification of vapour permeable insulation in itself does not mitigate hygrothermal risks.

If EWI is used, there will be an impact on the external appearance - streetscape, window reveals, roof eaves, window cills, location of rainwater goods, etc. With EWI, it is important to specify vapour permeable insulation to allow moisture from interior to evaporate externally, but again this does not mitigate the need for hygrothermal risk assessment.

Windows and Doors: In traditional buildings, windows are typically single glazed and timber frame. It is preferable to retain the surviving historic or original windows and doors as much as possible.



→
Example of vacuum-insulated glazing (Source AGC)

Energy Efficiency Upgrades for Windows and Doors

- **Draughtproofing:** The first step should be to install a perimeter seal to the windows and doors to improve their airtightness. In most cases, traditional doors, once in good condition only require draughtproofing.
- **Secondary Glazing:** Introducing a secondary glazing system inside the existing window can upgrade the overall performance of the window while maintaining the original fabric. This may, however, require altering existing internal joinery, such as shutterboxes.
- **Glass Replacement:** If the glass panes are not historic or the windows have been altered it may be preferable to replace the glazing with higher performing double glazed units or vacuum glazing. Care must be taken to avoid loss of sensitive historic fabric.
- **Full Replacement:** The last resort should be to replace the windows or doors in their entirety. However, where windows or doors are not historic or have been previously replaced with inferior alternatives, it may be more acceptable to conduct a full replacement.

Types of insulation: The type of insulation chosen will have a critical impact on the building fabric. In traditional buildings, a key difference between insulation types is their hygroscopic nature, or in simpler terms, how they absorb and transport water in liquid or gas states. This is often referred to as their 'breathability'. Insulation comes in two main types – vapour-tight and vapour-open. Understanding the difference between the types of insulation is important when choosing a material to apply, to avoid negatively impacting on the building fabric performance.

- **Vapour-tight:** Vapour-tight insulation prevents moist air from penetrating the insulation. This can be useful in certain instances where it is necessary to prevent moisture passing through the material and coming into contact with the building fabric, such as in a warm roof structure. Vapour-tight insulation is very popular due to its availability, relative affordability, and typically lower thermal conductivity.
- **Vapour-open:** The capillary action of vapour-open insulation allows moisture to transport through the material which assists the drying out of the full construction. Vapour-open insulation is often made from natural materials and in most cases is more compatible with traditional buildings as it allows the natural transfer of moisture vapour. Vapour-open insulation typically is more expensive, less readily available and has a higher thermal conductivity, however, this is becoming less so as more emphasis is placed on the need and/or desire for vapour-open and natural insulations.

In addition to hygrothermal attributes, a number of other factors are necessary to consider when choosing between different materials, such as the product's associated embodied carbon, global warming potential, fire rating, toxicity, and biodegradability. Once data is collected for each potential insulation from Technical Data Sheets and Environmental Product Declarations, the I.S. EN 16883:2017 Assessment Criteria table can be a useful tool to compare materials and to assist in making informed choices.

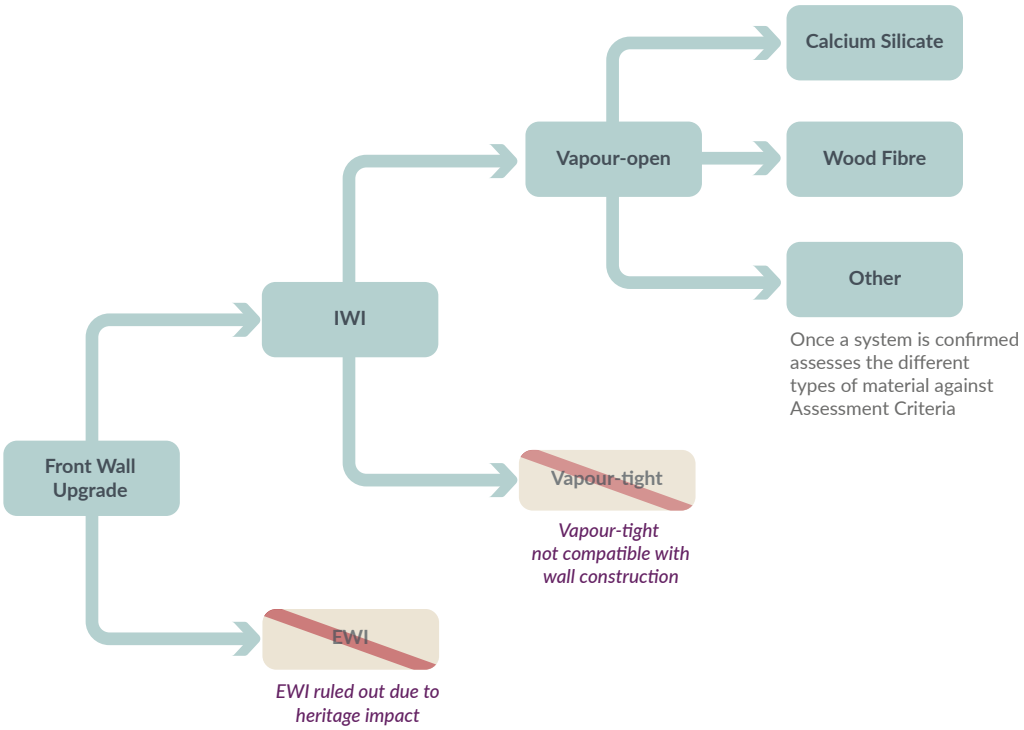


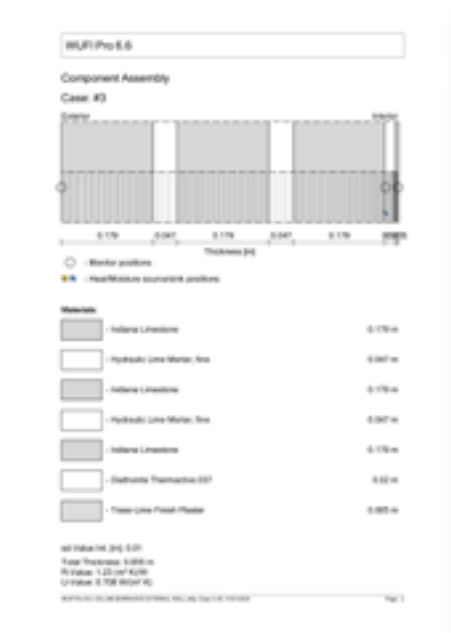
Figure 13: Example of typical process diagram to determine most suitable intervention

Detail Analysis

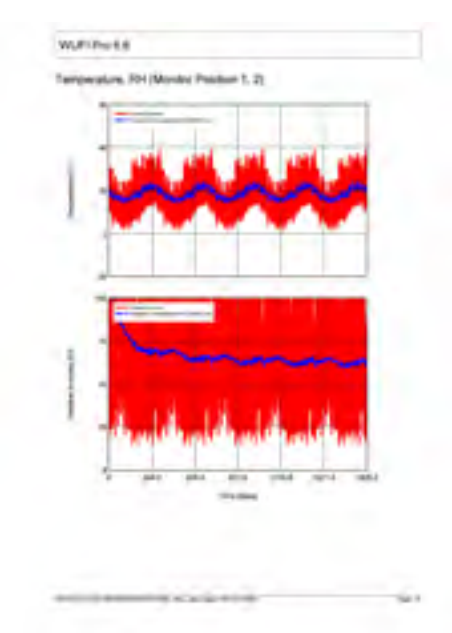
After deciding on the preferred individual system and material, it is necessary to carry out a technical analysis of each intervention to spot potential risks from surface condensation, mould growth, interstitial condensation and hygrothermal risks, while also confirming the anticipated U-value and linear thermal bridge values.

There are many different software programmes available to test the hygrothermal suitability and the surface condensation/mould growth. The choice of software will often come down to a preference by the specialists in the Design Team. Some options include PSI-THERM 2D, WUFI, Glaser Method, COND, DELPHIN, MATCH. The aim is to confirm the suitability of the proposed interventions while also calculating the proposed U-values and the linear thermal bridge values, which will feed into the NEAP model.

Hygrothermal Risk Assessment: A hygrothermal risk assessment uses proprietary software to model how moisture and heat flow will affect building materials over time based on the material properties and local weather files. The modelling software runs a simulation to determine what is likely to happen in the different construction layers and determines the estimated water content of the materials hour-by-hour. This assessment is used to identify the long-term risk of interstitial condensation. It is necessary to have carried out a Karsten tube test on the external building materials to confirm their absorption rate to input into the hygrothermal model.



Left →
WUFI model for a solid masonry wall with 20mm internal cork lime plaster



Right →
WUFI temperature and relative humidity model for a solid masonry wall with 20mm internal cork lime plaster. Note that the RH of the cork lime plaster is below the 80% risk threshold after drying out

Thermal Bridge Modelling: A separate technical assessment is carried out on key junctions to determine the risk of surface condensation and mould growth. Using proprietary software key detailed sections and plans are modelled to test the internal surface temperature and identify if the proposed interventions would create the conditions that would encourage surface condensation and/or mould growth, while also confirming the proposed U-values and linear thermal bridge values. The in-situ U-value tests are important here to provide accurate information on the existing building fabric energy performance.

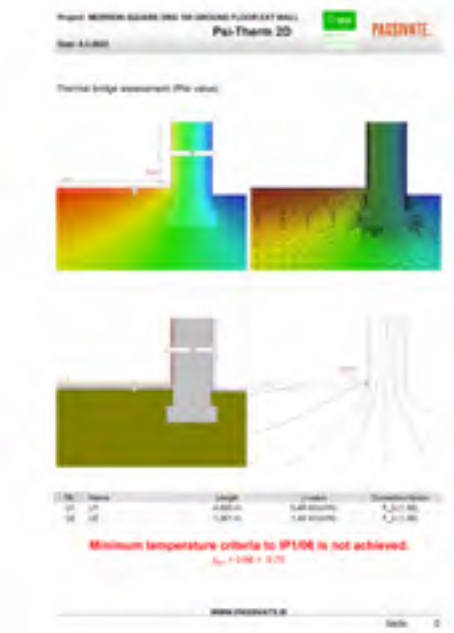
The first step is to identify the key detail junctions to be modelled. The number of junctions to be tested will be dictated by the complexity and scale of the building. Typically these would include:

- Junctions between windows/doors and external wall;
- Ground floor and external wall junction;
- Roof and external wall junction
- Junction between change in material type/thickness;
- Junctions between insulated and uninsulated areas.

Linear Thermal Bridge: Linear thermal bridge analysis is carried out in accordance with ISO 10211, with reference to BRE convention document BR497 – Linear thermal bridges and surface temperature factors – calculation methods, as referenced in TGD L. Linear thermal bridge values, or psi-values, provide a measurement in units of W/mK of the additional heat losses along the length of building junctions which are not included in any calculated U-value. The analyses are carried out in 2D or 3D, depending on the nature of the junction/detail and the construction type. For example, linear junctions which do not comprise any metal frame (SFS) construction can typically be carried out in 2D, whereas single point penetrations (e.g. screw fixings) would

Linear thermal bridge values, or psi-values, provide a measurement in units of W/mK of the additional heat losses along the length of building junctions which are not included in any calculated U-value.

typically require 3D analysis. Single point heat loss values, or chi-values, provide an estimate of the additional heat loss caused by a single point penetration which is normally not included in any calculated U-value for building elements. The NEAP methodology and most software used for assessment of Part L compliance allow for the input of linear thermal bridging values in order that these are included in the overall energy assessment and compliance assessment. However, it should be noted, that most single point chi-values cannot be individually entered into energy modelling software, and so should be included in the U-value calculation for the relevant element in a separate, external calculation, which is then inputted to the overall energy model.



→ Thermal bridge modelling report for a ground floor to external wall junction

Surface Temperature: Surface temperature factors are used to determine the potential risk of mould growth at internal surfaces in buildings. The required values for differing building types are presented in BRE information paper IP1/06. This list is, however, not exhaustive, typically covering storage areas, warehouses, dwellings, offices, schools, gyms, breweries, launderettes, and presenting the required maximum surface temperature factor, or fRsi value. The fRsi value is calculated as a ratio of the lowest internal surface temperature identified in a thermal model as a function of the overall temperature difference across the construction. A higher fRsi value indicates a higher calculated internal surface temperature, and therefore lower risk of internal surface mould growth and/or surface condensation. Analyses are normally carried out based on an assumed internal temperature of 20oC and external temperature of 0oC. The critical fRsi value, for example, of an office is 0.5 which represents an internal surface temperature of 10oC or higher being required. For dwellings, the value is 0.75, indicating the need for an internal surface temperature of 15oC or higher.

A higher fRsi value indicates a higher calculated internal surface temperature, and therefore lower risk of internal surface mould growth and/or surface condensation.

While the fRsi values described in the relevant documents referenced in TGD L can be used to determine compliance with building regulations, it is important to consider that in-use risk of mould growth or condensation are not dependent normally on the fixed steady-state boundary conditions provided in these documents. Rather, these are influenced by the actual design temperatures and relative humidity values in the spaces in the building. It is advised to discuss the design conditions with the Design Team in order to determine whether a higher risk of condensation or mould growth may exist, or whether the in-use conditions present a lower-risk environment than those described in the building regulations.

Updated NEAP Assessment Based on Individual Analysis

Once the technical assessment has been carried out on individual build-ups and junctions it is possible to identify whether the risk of the proposed intervention is acceptable or not. If the level of risk is unacceptable, it is necessary to return to that individual intervention and alter the proposal to achieve an acceptable result, by either:

- Changing the level of upgrade (e.g. the thickness of insulation);
- Looking for alternative solutions (e.g. a different insulation material); or
- Reviewing the overall strategy for fabric upgrades to look for alternative solutions.

Once it is determined that the risk of the proposed interventions is acceptable, the overall strategy table is updated with the modelled U-values and psi-values. The strategy is tested once again in the NEAP software to incorporate the updated individual results.



→ Upgraded services and insulation in the attic of Leinster House

10.3 Services Upgrade Strategy

It is likely that the development of the services strategies will happen in parallel with the fabric strategies, and in practical terms, one strategy will not be able to progress beyond certain points without the input of the other (and visa-versa). However, for the sake of clarity in this guidance document, each strategy is taken separately and it is recommended that the fabric strategy be progressed in more detail before the services strategy as an informed idea of post-renovation energy use and heat loss is required to inform the review and selection of energy systems. Many of the same processes are repeated in the services strategy as those in the fabric strategy, however, they have been included for completeness and ease of reference.

The process of creating a services strategy follows the same format as the fabric upgrades. An overall strategy is devised and tested in the NEAP software, after which the individual services elements are tested separately. If the individual elements are not achieving the required result, alternative individual elements are proposed. If the required result is still not achieved, then it is necessary to review the overall strategy for alternative solutions.

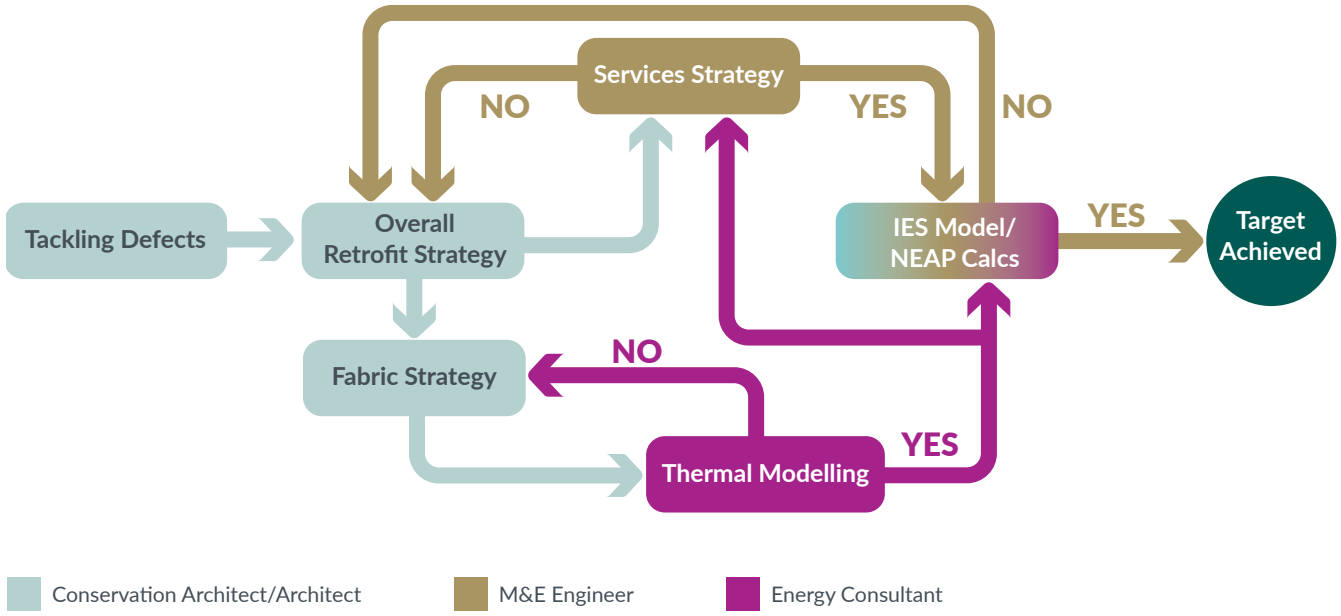


Figure 14: Stage 4 Design Process

Overall Strategy

The overall services strategy sets out in principle what the proposals are for the main mechanical and electrical systems in the building. This considers what type of heating is proposed, how the building is to be ventilated, and what the lighting system is. The overall strategy can be broken down into four main areas to consider:

- Space Heating;
- Hot Water Supply;
- Ventilation;
- Lighting

Each element will have varying degrees of challenges depending on the scale and complexity of the project. However, in general, the space heating and ventilation are likely to be the more difficult elements to address in the existing building as part of the overall strategy. This is mainly due to the impact of introducing large mechanical ductwork and pipework into the existing fabric where it previously had never existed.

Like the overall fabric strategy, the overall services strategy should consider all the information that has been gathered in the "Building Assessment" stage, and only then, assess the proposals for the overall services strategy against the same categories, namely:

- Condition survey,
- Heritage significance,
- Uses,
- Environment and context,
- Existing energy performance.

Refer to the overall fabric strategy for more information on these categories.

Having gone through the assessment of the categories above in relation to each of the upgrade elements, it is then possible to identify the preferred services improvements. After completing this stage, compile a simple table identifying the proposed upgrades for the heating, hot water, lighting systems and ventilation. This should also include any impacts on the existing building and any mitigation measures required.

Assigning Target Values

As before, it will be necessary to assign target values to the mechanical systems to test when testing the NEAP model. The main values relating to the mechanical systems that will need to be assigned at this stage are the airtightness rate and the Heat Loss Indicator (HLI).

Airtightness rate: It is a misconception that traditional buildings are inherently "leakier" than modern ones. Leaky construction in traditional buildings is more a consequence of shrinkage, settlement, alterations, and repairs. These challenges have little to do with the actual construction techniques. Traditional methods can achieve strong airtightness rates while still maintaining the required vapour permeability. However, when a traditional building is made more airtight as a result of retrofit measures – which can be expected to occur when window seals are repaired, roof and floor insulation is installed, and chimneys are blocked from use – adequate controlled ventilation must be introduced and maintained. When designing a ventilation strategy, the airtightness rate determines how much controlled ventilation is required to each area.

Traditional methods can achieve strong airtightness rates while still maintaining the required vapour permeability. However, when a traditional building is made more airtight as a result of retrofit measures.

Heat Loss Indicator: Heat Loss Indicator (HLI) value is the total heat loss per m^2 of building floor area. The HLI value is important when specifying the type of heating system to be used. A minimum HLI is recommended for certain types of heating systems (such as air-source heat pumps).

At this early stage of development of the overall services strategy, the information necessary to provide accurate values



→ Blower door airtightness test in progress. Note that the fans and red door are temporary. (©GreenBuild)

for the airtightness and the HLI will likely not be available. Therefore, assumptions will need to be made for these values. Guidance can be given by:

Building Regulations TGD Part L and F: Like the fabric strategy, it is useful to refer to TGD Part L for guidance on the rate of airtightness, even if the building is exempt.

CIBSE: The Chartered Institution of Building Services Engineers is a prime source of expertise for the building services industry. While also providing guidance on target values, CIBSE design guides also provide information to assist in determining existing or current values for airtightness and HLI.

Professional Experience: Similarly to the fabric strategy, it will be necessary to rely on the expert experience of the Design Team to propose working target values at this early stage.

Developed NEAP Assessment

As with the overall fabric strategy, carry out an initial NEAP assessment based on the developed overall services strategy to test whether the proposals are broadly in line with the objectives and targets set at Stage 3. At this stage, the individual fabric elements may be sufficiently developed to provide a more accurate assessment.

Figure 15: Building Energy Rating levels (SEAI)

At this stage, compile a simple table identifying what the upgrades are to the heating, hot water, ventilation and lighting. This should also include the impact on the existing building and any mitigation measures required.

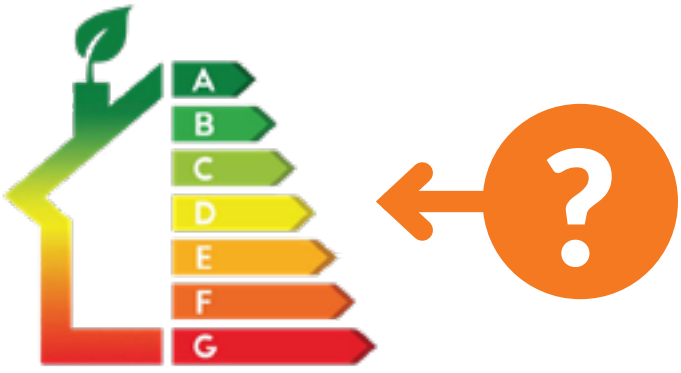


Table 7: Table of proposed service interventions

Intervention	Heritage Impact	Location	Assessment
Space Heating *Example: Heating system replaced with air-source heat pump*	What impact does it have on the existing fabric? *Example: Type of heating output to be determined. Underfloor heating may be disruptive to floor structure.*	Identify where it is being proposed *Example: External plant at basement. New heating output system throughout*	Assess the proposal *Example: Requires high level of airtightness. May require more invasive work to building fabric*
Water Heating			
Ventilation			
Lighting			

Service Input

1. Reducing the temperature difference between indoors and outdoors by adopting Adaptive Thermal Comfort principles – an indoor temperature (as far as possible).
2. Improving the building envelope.
3. Increasing the efficiency of heating and cooling equipment.

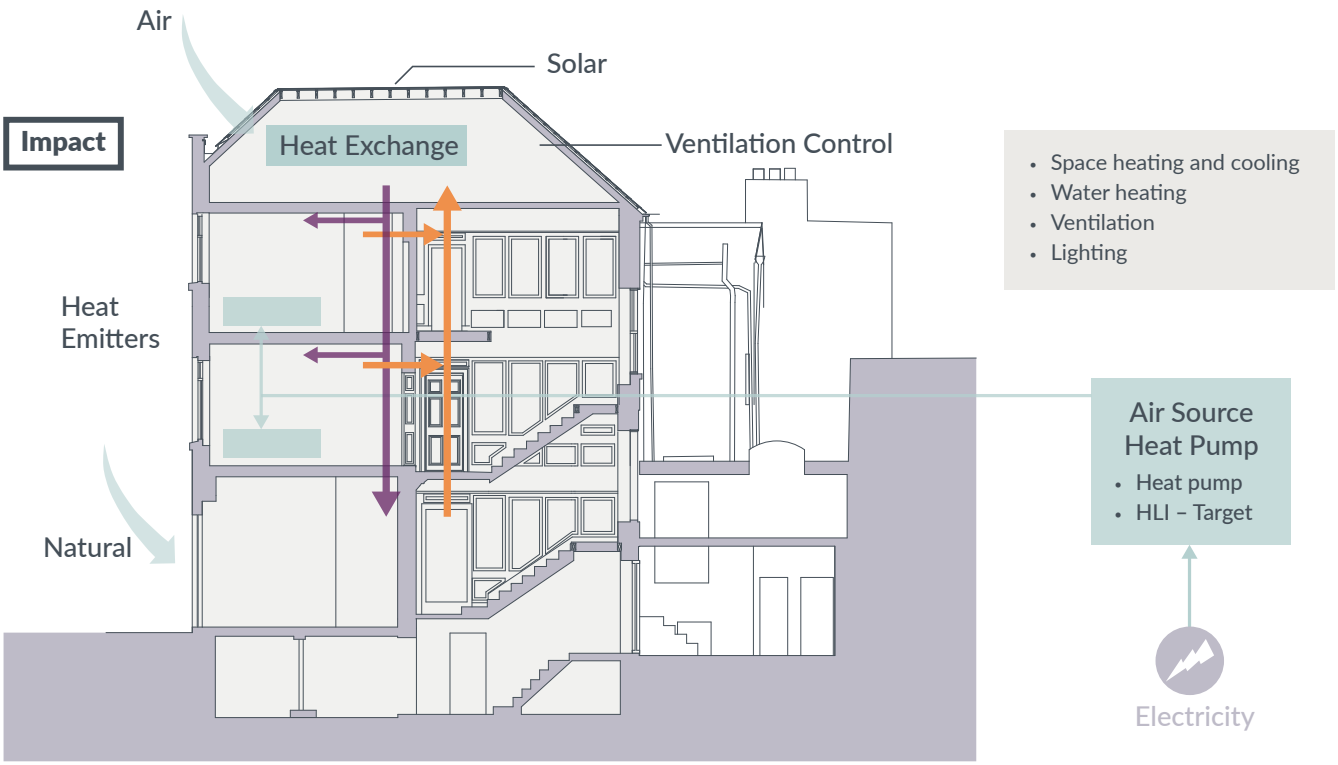


Figure 16: Schematic drawing to communicate service upgrade strategy

It is also useful to compile schematic drawings (sections, plans, etc.) of the proposals, similar to the drawing below, when identifying the interventions. This will help visualise the interventions and highlight areas of concern from which to test the individual elements.

Individual Assessment

After identifying the preferred overall strategy to improve the services systems performance, it is necessary to look at each individual system and specify the proposed improvements in more detail. These systems will then be tested for their impact on the existing building, their expected performance, and their overall economic and environmental benefit.

This follows the same format as the assessment of the individual fabric elements.

The initial long list of options for each element should be reviewed using the I.S. EN 16883:2017 Selection of Measures step-by-step guide in order to remove any obvious inappropriate measures. The shortlisted measures are then compared against one another using the Assessment Criteria, as set out in I.S. EN 16883:2017, and as indicated in Table 8. This assessment highlights any risks or benefits associated with each measure to allow for clear comparisons to be drawn between options.

As noted before, the Assessment Criteria tool is not intended to provide the definitive answer in all cases but instead to assist the decision-making process.



→
Leinster House air source heat pumps

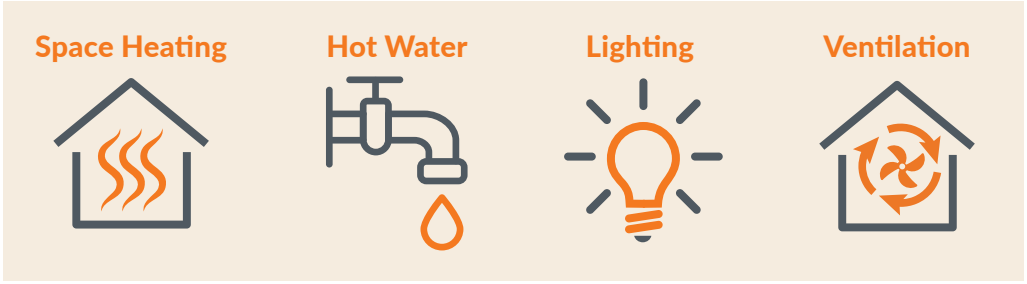
Table 8: Intervention assessment template for services based on I.S. EN 16883:2017

Intervention 01 Assessment Criteria					
Assessment Category	Assessment Criteria	Measure 1	Measure 2	Measure 3	Measure 4
Technical Compatibility	Hygrothermal risks				
	Structural risks				
	Corrosion risks				
	Salt reaction risks				
	Biological risks				
	Buildability				
Heritage Significance	Material/constructional impact				
	Risk of visual impact				
	Risk of spatial impact				
Economic Viability	Capital cost				
	Economic savings				
Energy	Impact on energy demand				
	Life cycle energy demand				
Indoor Environmental Quality	Conditions suitable for building				
	Conditions suitable for occupants				
	Emission of harmful substances				
Impact on Outdoor Environment	Greenhouse Gas Emissions				
	Emission of harmful substances				
	Natural resources				
Aspects of use	Influence on the use of building				
	Consequence of change of use				
	Ability of users to operate system				

Assessment Scale				
High Risk		Neutral		High Benefit

Individual Services Elements

Like the assessment of the building fabric upgrades, it is not intended for this general guidance documentto explore the different options for services systems upgrade in great detail. However, there are some overarching principles to consider in relation to the services systems that will likely be relevant to most projects. In general, this relates to:





Space Heating

The general position in relation to space heating is a requirement to move away from fossil fuel heating systems. While there are various renewable energy solutions available, three common solutions are:

- Biomass;
- District Heating;
- Heat Pumps

The airtightness and heat loss indicator (HLI) of the building fabric will have a major impact on the efficiency of the heating system proposed. For instance, to qualify for an SEAI domestic grant, it is recommended that heat pumps only be used where the HLI is less than or equal to 2W/m^{2}K. This is not to suggest that heat pumps cannot be used in building with a higher HLI, however, it is identifying the importance of a low HLI, and by extension a high level of airtightness, to provide an efficient mechanical system.



→
Air source heat pump installed in a protected structure

As noted earlier, there is a key difference between the 'breathability' of a building fabric and airtightness. A building's fabric can be both breathable and airtight, since airtightness is the reduction of unwanted draughts and leaks, whereas 'breathability' is the ability of the building fabric to naturally regulate excess moisture within its construction. It is therefore very important to achieve a good level of airtightness while maintaining a vapour permeable fabric. While improving airtightness relies on the correct detailing and specification, particularly around junctions, also critical is the workmanship involved in implementing those details. If the workmanship is poor, then the airtightness level will inevitably be poor as a result.

The specific details of different heating systems vary from system to system. However, it is worth noting with heat pumps, the temperature of the heating output is typically lower than in a traditional fossil fuel system. This is why heat pumps are ideally suited to underfloor heating, as they require a lower temperature to operate.

Where underfloor heating is not an option, consider either using a different heating system or a different output system, such as:

- Using fan assisted radiators – floor standing and concealed type would be more discrete,
- Increasing the number, size or type of radiators,
- Augmenting the existing radiators with additional radiators or radiant panels,
- Providing a combination of the above.

The location and type of any new radiators or radiant panels require careful consideration in order to minimise potential impacts on internal architecture.



Hot Water

In most instances the water heating will be supplied by the same heating source as the space heating system. This is likely to be the most efficient solution as the one unit is providing dual heating. In certain instances, it would be more suitable to provide a separate system, such as a dedicated under-counter electric heater for wash hand basins, particularly in situations where hot water requirements are typically low.

Running pipework for hot and cold water supply should utilise existing routes where possible, including existing notching and coring. In most instances, the routing of hot and cold water supply pipework would be more straightforward than routing other larger ductwork due to the smaller diameter pipes required.



Lighting

The general position in relation to lighting is to provide LED lighting throughout. The lighting load of traditional standard incandescent lights can have a significant impact on the primary energy usage, therefore by changing to LED this can drastically reduce the energy demand. The longer life span of LED also means a reduction in maintenance and replacements, thereby reducing the embodied

carbon of the lighting system. In only very specific instances should less efficient lighting solutions be accepted, such as where existing light fixtures cannot be upgrade or replaced for heritage reasons. Alongside the lighting fittings, installing smart controls can offer a further reduction in energy use by turning off or reducing the lighting level when areas are not in use.



Ventilation

As noted in the Space Heating section, it is very important to provide a high level of airtightness to allow for the heating system to run efficiently. However, with a higher level of airtightness there is a greater need to provide for controlled ventilation.

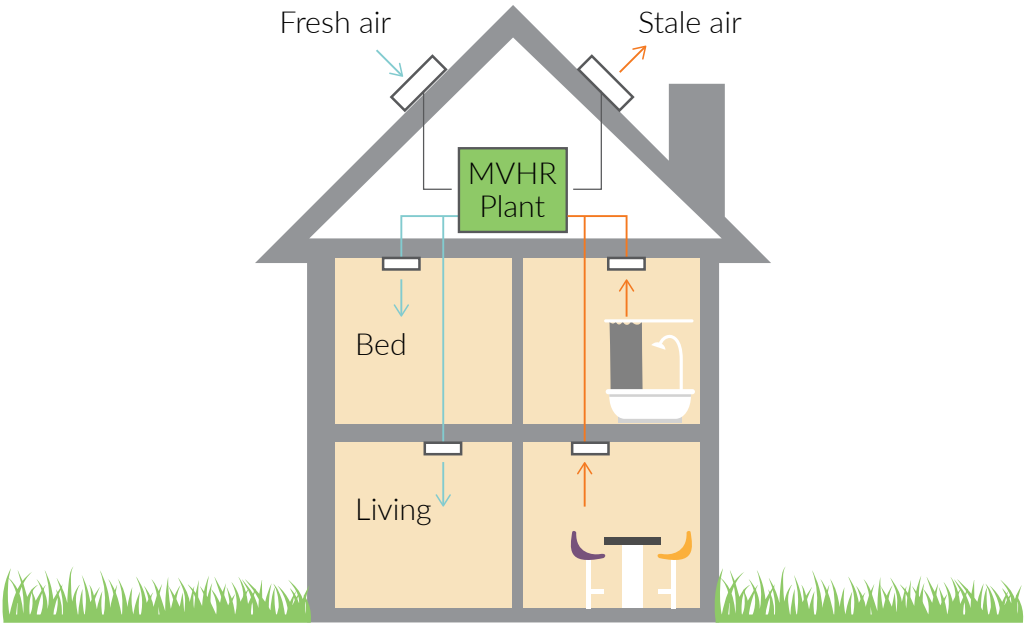
Typically, there are four approaches, each with their own advantages and disadvantages:

- Natural ventilation;
- Mechanical ventilation;
- Hybrid ventilation or mixed mode ventilation; and
- Bespoke solution.

Table 9: Typical ventilation options for historic buildings

Type of ventilation	Description
Natural	Each space is provided with a direct source of natural ventilation from outside, typically via an opening in an external wall. The movement of air is facilitated by the pressure differential between inside and outside and the location of openings to provide a cross flow of ventilation. No mechanical equipment is required so the energy use is minimised. The use of automated vents or actuators to windows that operate on humidity sensors would cut down on draughts and provide more controlled ventilation, however, these may be difficult to integrate within the existing window or may be considered unsightly and historically inappropriate. Use of existing chimneys is encouraged to reduce the number of openings in walls required. Depending on the number of rooms or spaces, this strategy may result in an excessive number of openings in external walls. Equally in some instances it may not be possible to provide for an opening in a certain external wall, such as a street facing wall in an ACA, so there may need to be extra openings provided in the rear wall to compensate. The incoming air to the building will be the same temperature as outside therefore the space heating demand will be higher in order to compensate for this. This could be significant particularly in the winter when the temperature difference between inside and outside would be greatest. This is difficult to control and can cause user discomfort from draughts on cool windy days.

Type of ventilation	Description
Mechanical	A single main supply of incoming fresh air is filtered through a mechanical unit and supplied throughout the building to all habitable rooms. All wet rooms are extracted through the same mechanical unit. The extracted air is taken through a central heat exchanger to increase the temperature of the incoming fresh air, thereby reducing the space heating demand. This provides a constant stable supply of fresh air to the whole building and avoids numerous holes in external walls. However, ductwork is required to each space, which can be very disruptive particularly in buildings with sensitive interiors and could have an unacceptable negative impact. Depending on the size of the building, the mechanical unit can also be very large. It may be possible to use multiple smaller mechanical units instead of one larger unit to create a more sensitive installation.
Hybrid	This system uses a combination of natural and mechanical systems. This could be the more suitable solution where some of the building is difficult to access with ductwork or where it would not be possible to install holes in external walls.
Bespoke Solution	The most sensitive solution may in fact be one that does not rely on the guidance given in TGD Part F, and instead relies on an engineered solution. For instance, a management solution might involve setting up a system whereby the users of the building are notified when it is necessary to introduce fresh air. This would minimise the impact on the existing building - both the external walls and the interior fabric - while still providing a managed ventilation solution. However, the occupiers of the building would need to be made aware of how the system operates to maintain its performance and a building control derogation may be required.



Mechanical heat recovery ventilation schematic.

Detail Analysis

After identifying the preferred individual solution, it is necessary to test the impact on the existing building. These tests will vary from project but will broadly correspond to the following:

Table 10: Identifying preferred service solutions

Service	Description
Space Heating 	This will typically involve calculating what the required heating output per space is. This will identify if the existing radiators, for example, are compatible with and sufficient for the proposed heating system. In most cases the original radiators were sized for a fossil fuel system. With a change to a heat pump, for example, this would likely require the radiator sizes or numbers to be increased, sometimes four-fold. It may be possible to accommodate additional radiators in a room, or more efficient less aesthetically pleasing radiators in joinery. Alternatively, radiant panels placed in discrete locations may also be acceptable.
Hot Water 	It is necessary to calculate the likely demand and test the associated energy requirements. If the demand is low, or periodical, it may be more acceptable to use a separate more energy intensive solution, such as electric heaters, than to use the space heating system, which may require a larger unit and additional water storage. For more intensive use locations, incorporate the hot water supply with the space heating system.
Lighting 	This should typically be more straightforward. However, it is still necessary to test whether there is going to be a new lighting layout or reuse of the existing electrical installation. The specifier should also consider whether this would be suitable for new light fittings. Additionally, in some very specific instances there may be a requirement to retain existing light fittings which may not be able to be retrofitted with LED fittings. A move away from uniform lighting strategy should not be ruled out. Older buildings often have ornate ceilings and only have a single lighting point, so it is often better to retain this making it a feature with a sympathetic central light fitting and using task lighting at desks or specific areas. Controls should also be used on task lamps. This will use less energy and preserve the ceiling.
Ventilation 	This will involve calculating the volume of air required for each space and sizing the ductwork or openings to suit. To identify the preferred solution, detail what the impact of each ventilation option would be on the building fabric and determine which will be more suitable. With a natural ventilation solution this would involve calculating the number, size and location of external openings. On the other hand, a mechanical ventilation solution would involve identifying where the ductwork would run throughout the building and where the plant would be located. A comparison will be required to determine which solution would be more acceptable. A combination of both natural and mechanical ventilation in certain instances may be required. Alternatively, a bespoke, engineered solution might be required. If so, early engagement with the Local Authority would be critical in deciding whether a derogation of Part F is required.

Updated NEAP Assessment based on Individual Analysis

Like the building fabric upgrades, it is possible to identify the level of risk for each proposal after testing the individual elements. If the level of risk is unacceptable, it is necessary to return to that individual intervention and look to alter the proposal. This would involve looking for alternative solutions (i.e. changing the location of ventilation duct routes). If this is still unacceptable it may be necessary to review the overall strategy to find alternative solutions, such as changing from mechanical to natural ventilation.

Once the individual interventions are deemed acceptable, the services strategy table is updated and the NEAP model is once again tested.

10.4 Testing Strategies in NEAP

There are a number of points at which to carry out testing of the NEAP model during the development of the fabric and services strategies. The process of testing the strategies in the NEAP assessment is an iterative process, and often involves trying multiple solutions and refining options before settling on the most suitable proposal. This will often happen throughout the process, and it is used to inform the final decision-making. Although the model is referred to on an ongoing basis, there are some key stages when it is useful to assess the NEAP model to confirm whether decisions made will have a positive or negative impact on the building's energy performance. These mainly coincide with:

- Identifying the overall strategy of the building fabric. Assumptions on the building fabric U-values, Y-values, etc., will need to be made at this stage and initial discussions on the overall services strategy will have been made with some assumptions required;
- Testing the building fabric key junctions and identifying the preferred individual element solutions. The overall services strategy may be finalised at this stage or may be ongoing;
- Identifying the overall services strategy. Assumptions may need to be made on the airtightness and HLI;
- Testing the individual services elements. At this stage both the fabric and services strategies will have been tested and confirmed.

At the end of the process, once the overall and individual strategies for the building fabric and services energy upgrades are tested, the NEAP assessment will identify what the BER rating is (or the kWh/m2/yr). This should be reviewed against the original project objectives and targets, and once determined these targets have been achieved, the interventions are implemented as necessary.

10.5 Other Considerations

Although this guidance document is focused on the energy upgrades in historic properties, in practical terms there will always be many other factors to consider during the course of a project. While these are separate considerations, they very often have a direct impact on the energy performance strategy, and need to be considered in any assessments, from the overall strategies to the individual material selections.

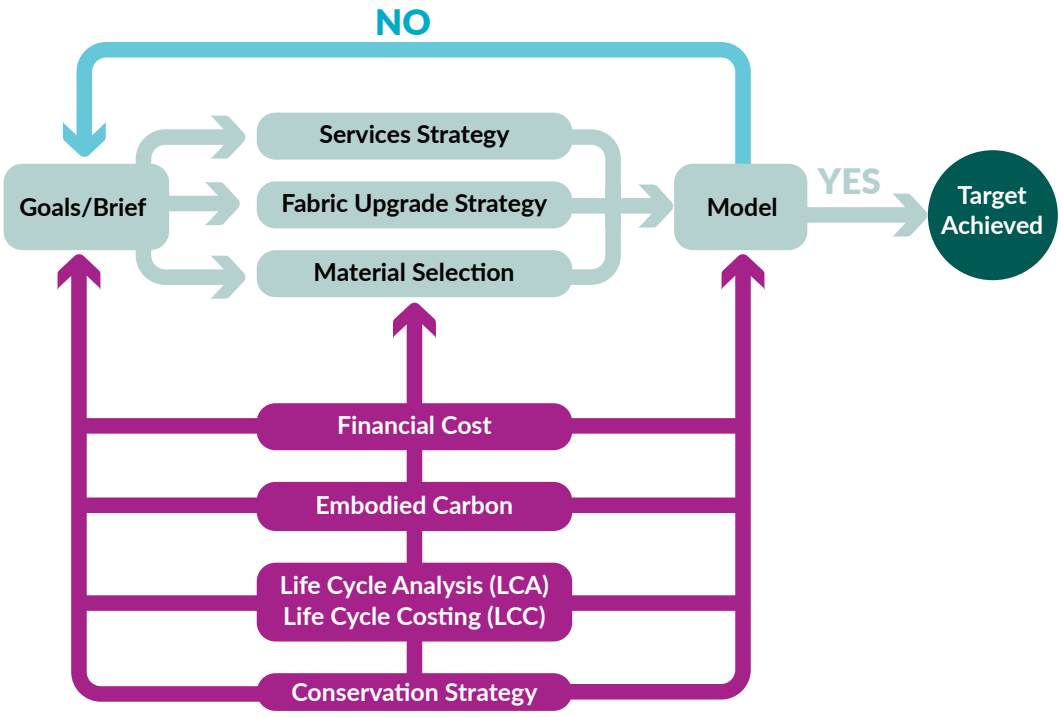


Figure 17: Other typical factors to consider during the design and decision-making process

10.6 Stage 4 Checklist

Tackling Existing Defects

- ☐ Review any previous maintenance process in the building, paying special attention if the building has been unoccupied where defects may have gone unnoticed for long periods of time.
- ☐ Ensure a full condition survey has been carried out identifying all known damage/defects.
- ☐ Accurately record all defects and damage
- ☐ Identify suitable repairs and allow for in the programme where repairs may require addressing up front or long term drying out.
- ☐ Discuss emergency repairs with the conservation/planning authorities.
- ☐ Put in place an on-going maintenance system in the short-term prior to the upgrade works and also long-term for when the upgrade works are complete.

Fabric Energy Upgrade Strategy

- ☐ Have all defects been fully addressed?
- ☐ Has a general conservation philosophy been identified?
- ☐ Has the overall fabric strategy been described on a drawing/table and communicated to the Design Team and Client?
- ☐ Carry out an initial NEAP assessment on the overall fabric strategy using assigned target values.
- ☐ Assess each of the individual fabric proposals using the Assessment Criteria tool.
- ☐ Carry out dynamic hygrothermal assessment of the building with the proposed interventions.
- ☐ Identify the key junctions and carry out surface condensation/mould growth risk analysis.
- ☐ Re-test the NEAP model with the confirmed individual element values.

Services Upgrade Strategy

- ☐ Is the overall services strategy in line with the conservation philosophy identified?
- ☐ Has the overall services strategy been described on a drawing/table and communicated to the Design Team and Client?
- ☐ Carry out an initial NEAP assessment on the overall services strategy using assigned target values
- ☐ Assess each of the individual services proposals using the Assessment Criteria tool
- ☐ Identify the impact of the individual systems on the building, particularly the routing of ductwork and pipe-work
- ☐ Re-test the NEAP model with the confirmed individual element values

11 Stage 5 - Implementation, Post-Occupancy Evaluation and Monitoring

Stage 5: Implementation, Post-Occupancy Evaluation and Monitoring

- Review design as constructed against goals and evaluate outcomes;
- Monitor post-occupancy to assess design versus actual performance.

11.1 Implementation

While this guidance is not intended to focus on the implementation of the proposals, as this is covered in other standards and guidelines, there are some key lessons to be aware of to assist in successful implementation.

Contractor proposals which deviate from the design specifications must not impact materially on the final energy strategy, and may need to be re-tested in the energy model by the Design Team to confirm compliance with energy targets.

Extra care is needed for the implementation phase on historic buildings, as the likelihood of unforeseen issues is greater in projects. Most of the qualifications and competence needed in the planning phase will still be relevant during implementation. Carrying over this expertise and personnel from the planning phase is key to ensuring continuity and transfer of knowledge. An ongoing dialogue with the statutory heritage bodies is advised, if not required, during the implementation phase.

Historic buildings will often have special planning requirements regarding documentation of the construction process and the final result. The documentation is also a method to assess the success of the project, and provides learnings that can be used in future projects. Documentation should include drawings and photos, as well as methods of construction and materials used. This should be more detailed than on a regular project.

It is important to keep in mind that the documentation itself will be a historic document. It should be useful for future users in understanding what was done and why. It is imperative to record any changes or deviations from the planned proposals to ensure the accuracy of post-occupancy evaluations. This documentation will also be necessary for the project Safety File.

During the construction stage of most projects, there will be situations where the Contractor proffers alternative proposals of the specifications. The Design Team need to be aware of the likely additional time and resources required to review and consider alternative Contractor proposals. Contractors also need to be made aware of any set criteria and constraints at tender stage, and the basis of such criteria and constraints. This information is very important to include in the tender documentation, as well as any requirements for the Contractor to carry out any testing, samples and benchmarks. Contractor proposals which deviate from the design specifications must not impact materially on the final energy strategy, and may need to be re-tested in the energy model by the Design Team to confirm compliance with energy targets. It is useful to include the energy strategy report as part of the tender documentation.

11.2 Post-occupancy Evaluation

This is generally a weak point in most projects. It is as important to have the correct management and post-occupancy monitoring strategy in place as it is to have the correct retrofit strategy. Without proper evaluation, it is not possible to assess the impact of interventions, or to know if proposals function the way they were designed. Post-occupancy evaluation provides an opportunity to have a dialogue with the people involved in the daily operation and use of the building.



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Dublin Castle, Block M

The building is unlikely to function properly if the correct management and maintenance procedures are not in place following occupancy of the retrofitted building. This can vary depending on the use and level of occupancy of the building, but will inevitably include making the users of the building aware of:

- The building services systems and strategy,
- Implementing a robust maintenance strategy,
- Monitoring any defects, and
- Carrying out repairs as required.

It would be very useful for future projects to monitor the performance of the retrofit when completed. This can provide valuable learnings and help build up a comprehensive knowledge base which can feed into future projects.

The criteria for post-occupancy evaluation and monitoring should be identified at the outset of a project and it may be appropriate to include in the Design Team scope of works.



Following occupation of the building for its new or upgraded functions, one should evaluate its performance to check if the objectives have been met in practice and whether the strategies are performing as designed. This provides important information on the project as well as highlights any shortfalls in the strategies. It also provides useful experience for future works.

The extent and depth of the evaluation should be identified by the Design Team in collaboration with the Client and end users, and should reflect the complexity of the project. The evaluation should follow the same format as Section 8.3 and cover the following criteria:

- Technical compatibility;
- Heritage significance;
- Economic viability;
- Energy;
- Indoor environmental quality;
- Impact on outdoor environment; and
- Use.

An initial evaluation should be carried out soon after occupation of the building and focus on functionality and the need for any adjustments. A second evaluation should be carried out within 1-3 years.

11.3 Monitoring

Monitoring of the building is important from a number of perspectives. Chief among these is ensuring that the retrofit plan is performing as designed, planned and calculated, and in order to understand where any performance gaps may arise. It also allows for an understanding to be developed as to where energy performance is being lost due to either issues with standard calculation methodologies or issues with the construction method ology, such as changes in materials due to availability or cost, or installation challenges, etc.

Of equal importance to energy performance of buildings is also the environments which they provide to occupants regarding thermal comfort and hygiene. The cultural focus on providing and maintaining good indoor air quality is ever growing, particularly in light of the COVID pandemic, as well as continuing evidence regarding performance, well-being and sickness rates among building occupants in well v's poorly performing environments.

Building performance monitoring can be carried out in a number of ways, with the primary three described below:

Total Building Energy Monitoring: One approach is to monitor total building energy consumption, which is used to quantify the total energy savings post-retrofit in comparison to the pre-retrofit energy use of the building. In a scenario where heating and hot water is provided by heat pumps, this is likely a purely electrical measurement. It would also be important to separately monitor electrical consumption at the heat pump directly, as well as to extract data from the heat pump interface or BMS regarding electrical consumption due to hot water and space heating distinctly. Cooling would also be included where applicable. Separate monitoring of circuits for lighting, white goods, fans, and other goods on socket circuits (e.g. computers, monitors, chargers etc.) would allow a detailed breakdown of whole building electrical consumption to be assessed.

In-situ Monitoring: With regard to the efficacy of building fabric upgrade measures, in-situ monitoring can be implemented to examine not only the energy performance of the retrofitted walls, roofs, or floors, but also to examine the hygrothermal performance of the walls. This is important, as these are typically the most complex element in the retrofit of a traditional building due to their sensitivity to moisture.

This procedure involves placing probes at various points of interest in the wall during construction or prior to building occupation, which are then connected to nodes on a data logger. This data logger then feeds the data to a central base station, from which live conditions within the wall build-up can be monitored remotely via a cloud interface.



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In-situ moisture monitoring system

A monthly report on the conditions at various interfaces and locations in the wall (or floor, roof, etc.) can then be provided. Furthermore, where hygrothermal risk assessment has been carried out on the project at the design stage, the predicted moisture levels across the building element can be compared with the actual in-situ monitored values in order to validate the process. This would be of particular importance nowadays, when the retrofit of traditional buildings is gathering pace. Limitations in the hygrothermal risk assessment process need to be better understood in order to improve confidence in the proposed retrofit methodologies for various building typologies and construction types, as well as the calculations used to support the design process. In time, this would allow the generation of standard detailing and solutions guidance documents which may address a number of element types, construction materials, as well as varying climate conditions found throughout the country.

Indoor Environment Monitoring: With regard to indoor air quality, there is a spectrum of parameters commonly used to assess the quality of air and any risks posed to occupants. A number of these risks are generated directly by occupants, including heat, moisture and CO_2, while others are produced within buildings, such as volatile organic compounds (VOC's) due to off-gassing from manufactured products, plastics etc., as well as carbon monoxide from fossil fuel burning appliances, radon penetration from ground floors etc. Others can be brought into the building via non-filtered holes in the wall vents, such as nitrous oxide (NO), nitrogen dioxide (NO_2), small particulate matter from traffic and industry (PM2.5 and PM10), and ozone (O_3). Internal humidity in naturally ventilated buildings is also intrinsically linked to external temperature and relative humidity, so there are compounding factors in that regard.

Temperature and relative humidity can be readily monitored using sensors and loggers as well as silent colour coded alarms. These encourage active user engagement with the building, opening or closing windows or turning on fans/ vents once an alarm is activated. This is also similar for CO_2 monitors, which inform occupants when excess levels are present with a call-to-action alarm.

Other IAQ (indoor air quality) parameters are less readily perceptible to occupants and are rarely monitored or analysed despite their significance in terms of potential health risk as well as well-being and performance effects on occupants. Specialist IAQ monitors with remote cloud interfaces can be installed in the building in order to provide a live view of the IAQ level and allow occupants or building managers to take action to ensure acceptable levels of multiple air quality parameters are being provided.

Once the data loggers are installed in selected locations around the building, indoor air quality specialist consultants can provide monthly, quarterly, or annual indoor air quality reports. They can also undertake review workshops with relevant stakeholders to determine where any issues are arising and discuss options to mitigate these in future in order to provide hygienic and comfortable environments for occupants. Locating these in sensitive historic interiors will require care.



Figure 18: uHoo IAQ monitor and smart phone interface

11.4 Post Completion Report

Each project should be accompanied by a Post Completion Report and should be provided to the OPW for their records and to aid future projects. The report is best produced by the Design Team with input from Contractor and Sub-Contractors, and the requirements should be clearly set out at the outset of a project and included in the Design Team scope of works and tender works requirements.

The report should be tailored to suit the complexity of the project, however, it should generally include the following information:

- Project brief;
- General information regarding the existing building;
- Heritage value and existing condition of building;
- BER rating at outset of project;
- Project specific goals;
- Proposed overall strategies, including tables/drawings/schematics of interventions;
- Testing of individual interventions;
- BER rating on completion; and
- Post-occupancy evaluation and monitoring, as necessary, to allow for inclusion of any changes to design and handover information data.

The report is not meant to simply show the positive aspects of the project. Because it is intended to provide learnings for future works, it should include any issues or deficiencies that were encountered, how these were dealt with, and what lessons were learnt in the process.

At the outset of a project, the Design Team needs to be made aware of the requirement to evaluate the building post-occupancy, to monitor the performance and to compile a Post Completion Report. This should be included in the Design Team appointments, and it is important that sufficient time and resources are allocated to this to ensure the information provided is worthwhile and beneficial for future projects.

Similarly, the Contractor needs to be made aware of the requirements post completion, and these should be included in the tender documentation. The Post Completion Report should be included as part of the handover information provided to the Client from the Contractor and Design Team.

11.5 Stage 5 Checklist

Implementation

- ☐ Ensure good communication between contractors, craftspeople and Design Team during and after implementation.
- ☐ Expect the unexpected and be prepared to adapt to discoveries in the building.
- ☐ Use qualified contractors and craftspeople with experience working with historic buildings.
- ☐ Remain engaged with statutory authorities.
- ☐ Document the implementation phase. Describe what was done and how, but also why it was done. Record any changes of deviations from the planned proposals.
- ☐ Use photos and provide enough information to describe the process. The intention is to highlight failings as well as best practice.
- ☐ Ensure contractor proposals align with energy strategy targets and any specific constraints on material selection, design details etc.

Post Completion

- ☐ Carry out an initial user evaluation soon after occupation and a second evaluation within 1-3 years.
- ☐ Identify and carry out monitoring post occupancy.
- ☐ Post Completion Report is prepared by the whole DesignTeam with Contractor input.
- ☐ Lessons learned are identified, and communicated to future projects.

Opposite page →
Four Courts, Dublin





Appendices

Appendix 1: Project Stage Checklist

The following template gives an overview of the sequence of steps to follow based on the general guidelines.

Energy Upgrade Stage Checklist			
Retrofit Stage	**Stage Task**	**Comments**	**Completed**
Stage 1 Initiating the process	Prepare Brief		
	Compile Design Team		
Stage 2 Building Assessment	Compile General Information on Building		
	Assess Heritage Value		
	Assess Uses		
	Assess Building Construction and Condition		
	Assess Environment and Context		
	Assess Energy Performance		
	Prepare Energy Baseline Model		
Stage 3 Setting Objectives	Set out Primary Goals		
	Assess Goals using Assessment Criteria		
Stage 4 Design and Specification	Tackle Existing Defects		
	Prepare Overall Fabric Upgrade Strategy		
	Assess Individual Fabric Upgrades		
	Prepare Overall Mechanical Upgrade Strategy		
	Assess Individual Mechanical Upgrades		
	Test Strategies in Energy Model		
Stage 5 Implementation, Post-Occupancy Evaluation and Monitoring	Implementation		
	Post Completion Report		
	Inform User Behaviour		
	Post-Occupancy Evaluation		
	Monitoring		

Appendix 2: Case Study Template

Introduction

This document should be used as a template for the case study write-up of all future OPW energy renovation projects. This document, along with the OPW Approaches to Improving the Energy Performance of Heritage Properties in State Care guide and existing case study, should be shared as part of the tender package and tenderers should be clearly notified that a case study report is expected prior to completion of the contract.

A recommended set of headings, sub-headings and words counts have been provided in this template, however these may not apply in all cases or may need to be revised. The objective is build up a depository of energy renovation projects while introducing tenderers to the OPW approach to energy renovations and expected project planning, building assessments and decision-making procedures around designing the building fabric and services improvements. There is also an expectation for post occupancy evaluation which should be considered at the tendering phase.

Stage 1. Initiating the Process

Project Brief (200 words)

Provide a description of the project scope and initial brief with bullet points.

Project Aims (200 words)

Provide a description of the initial project objectives and aims with bullet points.

Design Team (200 words)

List details of the full design team including OPW staff, Architects, Engineers and Energy Consultants. Whether consultants are listed by name is up to the report authors.

Stage 2. Building Assessment

General Information (200 words)

Include a description of the building and general information, such as:

- Statutory Status
- NIAH No.
- Construction date
- Current and past uses
- Proposed use
- Architectural style
- Construction type
- General condition

Heritage Value (1,000 words)

Architectural Heritage Value Assessment

This section should include a short history of the building, its context and their associated heritage value. The information in this section will be used later to inform the review of various proposed energy renovation measures and their impact on the heritage value of the building.

The Architectural Heritage Value Assessment should reference associated listings on the Record of Protected Structures, the National Inventory of Architectural Heritage (NIAH), the Architectural Heritage Protection Guidelines for Planning Authorities and should highlight any points of special interest, which may include:

- Architectural
- Historical
- Archaeological
- Artistic
- Cultural
- Scientific
- Technical, and/or
- Social

Phases of Development

It is recommended to use plans and sections to indicate various phases of development, alteration or renovation that may have occurred over the life of the building.

Description of Architectural Style

This section should provide a brief but descriptive assessment of the architectural styles and the representative period features found in the building.

Photographic Evidence

This section should include photographs of key heritage aspects of the building (e.g. decorative plasterwork, finishes, furnishings, etc.). It is recommended to correlate photographic evidence to plans, sections or ideally an axonometric section.

Use (500 words)

Past, Present and Proposed Use(s)

This section should be short and concise, describing both past and present uses, along with proposed uses of the building. Plans for each floor should be provided indicating past/present/proposed uses.

Construction and Condition (1,000 words)

The text in this section should focus on the material construction and condition of the building at present. A thorough condition assessment should be conducted at this stage to inform the analysis and text. Opening up works may be required to ascertain the build-up of the thermal envelope of the building.

Building Fabric and Construction

This section should provide details on the building materials (e.g. handmade versus machine made bricks, type of stone with likely quarry location if known, lime versus cement pointing), known or assumed build-up of the thermal envelop and notable construction techniques employed during the building's construction or subsequent alterations. It is recommended that the text is accompanied by an axonometric section.

Condition Survey

A thorough condition survey should be done at the outset of the project to identify any defects or damage that need to be rectified prior to the implementation of any energy renovation measures. Any defects/damage should be listed here and accompanied with a selection of representative photos.

Environment and Context (400 words)

This section should comment on the local environment of the building. It may include reference to local climate data files, information about the environmental context (proximity to the road, other buildings, traffic levels, orientation, etc.), historical flood events, development plans for the area, etc.

Existing Energy Performance (500 words)

Baseline Energy Model

The baseline model should establish the baseline existing conditions of the building based on DEAP or NEAP default values, in-situ measured values or calculated values for the thermal envelope building fabric. Default values should be confirmed at the outset of the project and in-situ measured and/or calculated values should be obtained as necessary and when feasible. Construction details of the thermal envelope along with the corresponding values should be provided in a table similar to Table 1 below.

Table 1: Baseline Energy Model

Building Element	Description	Default Value	Measured Value	Calculated Value
Walls	e.g. solid masonry walls	e.g. 2.43 W/m²K	e.g. 2.14 W/m²K	
Floors	e.g. uninsulated concrete floor	e.g. 2.44 W/m²K		
Roof	e.g. uninsulated attic space	e.g. 1.62 W/m²K		
Glazing	e.g. single glazing	e.g. 5.60 W/m²K		
Airtightness	e.g. leaky building	e.g. 25 m³/(h.m²)		
Thermal Bridges	e.g. high thermal bridging	e.g. 0.060 W/mK		

The baseline model should also include information on current systems including space heating, hot water, ventilation and lighting.

A baseline BER should be established first using DEAP/NEAP defaults. Once in-situ measured and/or calculated values are obtained, a second BER should be modelled. Both BERs should include calculated primary energy use and the proportion of energy use contributed to space heating, hot water, lighting and auxiliary uses. It is important to have both a BER based on defaults and a second BER based on measured/calculated values as the former will be accepted by Building Control while the latter provides a more accurate portrait of the existing building's energy use and performance.

Details of the existing building fabric and services along with the breakdown of primary energy use and resulting BER should be presented on a single page using tables, diagrams and graphics.

Stage 3. Setting Objectives

Primary Goals (300 words)

This section should briefly but clearly set out the primary goals of the energy renovation project. These should be based on the assessments carried out in Stage 2 and may be ranked in hierarchical order if relevant.

Assessment Criteria (300 words)

Following the I.S. EN 16883:2017 guidelines, the primary project goals should be reviewed at a high level filled into Table 2.

Table 2: Principle Goals Assessment Criteria

Assessment Category	Comments
Technical Compatibility	e.g. The building retains many historic features and due to its construction and exposed location, some interventions will require hygrothermal risk assessment to determine suitability.
Heritage Significance	
Economic Viability	
Energy Performance	
Indoor Environmental Quality	
Impact on Outdoor Environment	
Aspects of Use	

Stage 4. Design and Specification

Existing Defect Repair Strategy (500 words)

This section should include details of the existing defects, proposed repair strategies, level of urgency and timeline for completion. It is recommended to present information following Table 3 below.

Table 3: Defect Repair Strategy

Defect	Repair Strategy	Urgency (low medium/high)	Timeline (month)

Summary of Individual Fabric Upgrade Details (1,000 words)

This section should provide an overview of all thermal upgrades proposed for the building. Details should be presented following the format in Table 4. Additional lines should be added for different treatments of features (e.g. if different elevations, windows/doors or roofs require a different approach to insulation/ airtightness). It is recommended to also present the information in Table 4 with an axonometric drawing.

Table 4: Overall Fabric Upgrade Strategy

Existing Condition	Intervention	Heritage Impact	Technical Assessment	Existing U-value	Target U-value
Roof					
e.g. Uninsulated attic space with lime parging below slates	e.g. Wool-type insulation to be installed within and perpendicular over-top the ceiling joist zone.	e.g. Installation of insulation at loft level will not disturb any historic fabric and will not visually impact the building.	e.g. Installing insulation between joists would be relatively straightforward and low risk. Service access platform will be required.	e.g. 1.62 W/m²K	e.g. 0.16 W/m²K
Walls					
Ground Floor					
Windows					
Doors					

Details – Ground Floor/Wall Junctions (1,500 words)

Further details of the thermal upgrade strategy should be presented in the 'Details' sections according to the prescribed headings. Details should be developed for all junctions as these present the most technical risk. Details should also be provided for junctions where the insulation strategy changes or where there is a break in insulation. Each section should start with a brief summary of thermal upgrade details presented in the format of Table 5.

Table 5: Fabric Upgrade Summary

Existing Build-up	Insulation	Thickness	Thermal Conductivity	Existing U-value	Target U-value
Ground Floor					
e.g. uninsulated concrete slab (200mm)	e.g. compacted recycled foam glass aggregate	e.g. 150mm	e.g. 0.07 W/mK	e.g. 2.44 W/m²K	e.g. 0.15 W/m²K
Basement Wall					
e.g. solid calp limestone rubble and lime mortar (450mm) with internal lime plaster (30mm)	e.g. internal wall insulation (IWI) with lime cork plaster	e.g. 30mm	e.g. 0.080 W/mK	e.g. 2.10 w/m²K	e.g. 0.6 W/m²K

Text on the existing condition and proposed thermal upgrade should be accompanied by photographs and section drawings. Sections should clearly show the existing build-ups alongside the proposed alterations.

An intervention assessment should be completed for each junction detail. Assessments should follow the format of Table 5 using the risk/benefit scale shown below.

Table 6: Intervention Assessment Criteria

Assessment Category	Assessment Criteria	Comments	Scale
Technical Compatibility	Hygrothermal risks	e.g. IWI is high risk – hygrothermal risk assessment required.	
	Structural risks		
	Corrosion risks		
	Salt reaction risks		
	Biological risks		
	Buildability/Reversibility		
Heritage Significance	Material/constructional impact		
	Risk of visual impact		
	Risk of spatial impact		
Economic Viability	Capital cost		
	Economic savings		
Energy	Impact on energy demand		
	Life cycle energy demand		
Indoor Environmental Quality	Conditions suitable for building		
	Conditions suitable for occupants		
	Emission of harmful substances		
Impact on Outdoor Environment	Greenhouse Gas Emissions		
	Emission of harmful substances		
	Natural resources		
Aspects of use	Influence on the use of building		
	Consequence of change of use		
	Ability of users to operate system		

Risk/Benefit Assessment Scale				
High Risk		Neutral		High Benefit

Following the high level assessment of interventions, a material selection assessment should be carried out using Table 7 as a guide and the Risk/Benefit Assessment Scale shown above. This table should be completed for all thermal upgrade interventions for each junction (e.g. ground floor insulation and wall insulation). Insulation options have been shown in Table 7 but these should be amended according to the individual project.

Table 7: Material Selection Assessment Criteria

Assessment Category	Assessment Criteria	PIR Insulation	Calcium Silicate Board	Cork Insulated Plaster	Wood Fibre Board
Technical Compatibility	Hygrothermal risks				
	Structural risks				
	Corrosion risks				
	Salt reaction risks				
	Biological risks				
	Buildability				
Heritage Significance	Material/constructional impact				
	Risk of visual impact				
	Risk of spatial impact				
Economic Viability	Capital cost				
	Economic savings				
Energy	Impact on energy demand				
	Life cycle energy demand				
Indoor Environmental Quality	Conditions suitable for building				
	Conditions suitable for occupants				
	Emission of harmful substances				
Impact on Outdoor Environment	Greenhouse Gas Emissions				
	Emission of harmful substances				
	Natural resources				
Aspects of use	Influence on the use of building				
	Consequence of change of use				
	Ability of users to operate system				

Based on the material selection assessment process, details of the selected material should be provided in Table 8. A short paragraph summarising the decision process should accompany this table.

Table 8: Material Selection Information

Material Selection	
Type	Calcium Silicate Insulation Board
Thickness	50mm
Vapour Open	✓
Thermal Conductivity	0.059 W/mK

Details – Wall/Roof Junctions (1,500 words)

As per Details – Ground Floor/Wall Junctions.

Details – Insulation Break/Change Junctions (1,500 words)

As per Details – Ground Floor/Wall Junctions.

Details – Window/Door Reveals and Upgrades (1,500 words)

As per Details – Ground Floor/Wall Junctions.

Details – Hygrothermal Risk Analysis (1,000 words)

This section should provide details of any hygrothermal risk analysis done to confirm the suitability of any thermal upgrades. This may include both condensation risk analysis and thermal bridge modelling. Details of the software used and a summary of findings should be presented here.

Details – Airtightness Strategy (1,000 words)

This section should provide details of the airtightness strategy and results of any testing done to the building before and after upgrade works are complete. This may include a blower door test and air leakage location test.

Summary of Individual Service Upgrade Details (1,000 words)

This section should provide an overview of all service upgrades proposed for the building. Details should be presented following the format in Table 9. Additional lines should be added for different treatments (e.g. if different services are required for different parts of the building).

Table 9: Overall Services Strategy

Existing System	Intervention	Location	Heritage Impact	Technical Assessment
Space Heating				
e.g. oil fired boiler	e.g. Mechanical Heat Pump	e.g. External unit to be located at Basement courtyard area	e.g. Fossil fuel heating is no longer an acceptable solution based on Government policy so less carbon intensive alternatives need to be sought. District heating may be an option in the future where wider area-based works are undertaken. Biomass would not be suitable as there would be an impact on the air quality in the city. Therefore, a heat pump is the most sensible solution.	e.g. The heat pump requires a low Heat Loss Indicator to work efficiently. This demands a relatively high level of airtightness, i.e. 5-10m³/(h.m²). To achieve this target is likely to require invasive works to be building fabric.
Ventilation				
Water Heating				
Lighting				

Details – Space Heating (1,000 words)

Further details of the services upgrade strategy should be presented in the 'Details' sections according to the prescribed headings. Each section should start with a brief summary of services upgrade details presented in the format of Table 10. Information should be accompanied by photographs and diagrams as relevant.

Table 10: Services Upgrade Summary

Intervention	Existing Primary Energy Use (kWh/m²)	Existing CO_2eq Emissions (g per kWh)	Target Primary Energy Use (kWh/m²)	Target CO_2eq Emissions (g per kWh)
e.g. replace oil-fired boiler with air-to-water heat pump				

An intervention selection assessment should be completed for each service upgrade detail. Assessments should follow the format of Table 11 but should be catered to each service and relevant options.

Table 11: Intervention Selection Assessment Criteria – Space Heating

Assessment Category	Assessment Criteria	Cast Iron Radiators	Aluminium Radiators	Underfloor Heating
Technical Compatibility	Hygrothermal risks			
	Structural risks			
	Corrosion risks			
	Salt reaction risks			
	Biological risks			
	Buildability			
Heritage Significance	Material/constructional impact			
	Risk of visual impact			
	Risk of spatial impact			
Economic Viability	Capital cost			
	Economic savings			
Energy	Impact on energy demand			
	Life cycle energy demand			
Indoor Environmental Quality	Conditions suitable for building			
	Conditions suitable for occupants			
	Emission of harmful substances			
Impact on Outdoor Environment	Greenhouse Gas Emissions			
	Emission of harmful substances			
	Natural resources			
Aspects of use	Influence on the use of building			
	Consequence of change of use			
	Ability of users to operate system			

Risk/Benefit Assessment Scale				
High Risk		Neutral		High Benefit

Details – Water Heating (1,000 words)

As per Details – Space Heating.

Details – Ventilation (1,000 words)

As per Details – Space Heating.

Details – Lighting (1,000 words)

As per Details – Space Heating.

DEAP/NEAP Analysis of Proposed Upgrades (500 words)

Building upon the Baseline Energy Model, two DEAP/NEAP models should be prepared for the building. As before, the first should be based on default values while the second should be based on the measured/calculated values. Each sequenced energy renovation DEAP/NEAP model should then follow the same step-by-step energy renovation proposals. A suggested sequence for the energy renovation DEAP/NEAP models is provide in Table 12 below.

Table 12: Example Sequenced Energy Renovation DEAP/NEAP Model

Seq No.	DEAP/NEAP Model - Key input criteria	BER Rating	Primary Energy (kWh/m²)
1	Existing Baseline Model - Using Default Values	E1	246.88
2	Existing Model - Using Values based on Professional Experience (as per 2 above) **	D2	224.92
3	Lighting upgraded from existing incandescent bulbs to LED	C2	195.1
4	Windows upgraded (incl. new Psi) and air permeability improved to 20 m³/m².hr	C1	160.47
5	Roof upgraded (incl. new Psi) and air permeability improved to 15 m³/m².hr	B2	105.8
6	Walls upgraded (incl. new Psi) and air permeability improved to 10 m³/m².hr	B2	70.15
7	Basement floor upgraded (incl. new Psi) and air permeability improved to 5 m³/m².hr	A3	61.28
8	Heating system upgraded to Air-Source-Heat-Pump and DHW supplied by Instantaneous Water Heaters	A3	30.07

As with the baseline energy model, details of the fabric and service upgrades along with the breakdown of primary energy use and resulting BER should be presented on a single page using tables, diagrams and graphics.

Stage 5. Implementation, Post Occupancy Evaluation and Monitoring

In the following sections, results from any post-renovation/post-occupancy tests or monitoring should be presented. These should be informative but concise and the use of images, tables, graphs and diagrams is recommended.

Airtightness (500 words)

An air pressurisation test should be carried out prior to completion to confirm the air tightness level of the building following the energy upgrades. It is important that this test is carried out prior to completion so that any areas of excess heat loss can be addressed as part of the construction stage.

Indoor Air Quality (500 words)

As part of the ventilation strategy air sensor monitors are to be installed to all spaces to monitor the quality of air for the users, as well as temperature and humidity. This will monitor the air for carbon dioxide (CO2), volatile organic compounds (VOCs), etc. and give feedback to the quality of the internal space for users. It will identify when additional ventilation should be introduced by opening windows.

Energy Use Intensity (500 words)

Energy Use Intensity (EUI) is the delivered energy consumption per m2 that is required by the building over the course of year. This metric can be used to compare buildings of a similar type, to understand how well the building performs in use, as well as for comparison against the energy calculations carried out at design stage. This should be assessed against the Primary Energy rating at design stage to establish if what is built aligns with the design calculations, and if not, how, where, to what extent, and why any deviations occur.

Interstitial Moisture Monitoring (500 words)

One of the most comprehensive monitoring methods is assessing the in-situ relative humidity within the upgrade fabric. The data gathered will enable a better understanding of the hygrothermal behaviour of solid walls in response to internal and external environmental loads, and the effects of adding thermal insulation. A number of sensors, such as relative humidity, temperature, and wood block resistance sensors, are installed within the fabric during construction, (i.e. between the layer of insulation and brick wall). The sensors are connected to data loggers from which the data is downloaded remotely and collected for analysis. This provides very valuable real-time, long-term data on the performance of the fabric which can be compared to the pre-installation design assumptions.

Occupant Satisfaction Survey (500 words)

The post occupancy evaluation may also include an occupant satisfaction survey. Standard survey have been developed but the design team may also develop their own. The results of the survey should be summarised with key findings highlighted.

Lessons Learned (1,000 words)

This section is an opportunity for the design team to review the design process.

Appendix 3: Further Reading

Baker, P. (2011) Technical Paper 10: U-values and Traditional Buildings – In-Situ Measurements and their Comparisons to Calculated Values. Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=16d0f7f7-44c4-4670-a96b-a59400bcdc91.

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Department of Housing, Local Government and Heritage (2023) Improving Energy Efficiency in Traditional Buildings: Technical Guidance for Specifiers and Installers. Available at: https://www.gov.ie/en/publication/18cb9-improving-energy-efficiency-in-traditional-buildings-guidance-for-specifers-and-installers-2023/.

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Health and Safety Authority (2023) Code of Practice for Indoor Air Quality. Available at: https://www.hsa.ie/eng/publications_and_forms/publications/codes_of_practice/code_of_practice_for_indoor_air_quality.html

Hume, J. and S. Doran (2015) In-situ measurements of Wall U-values in English Housing. London: BRE. Available at: https://www.gov.uk/government/publications/in-situ-measurements-of-wall-u-values-in-english-housing.

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IGBC (2020) Introducing Building Renovation Passports: Feasibility Study. Dublin: SEAI. Available at: https://www.igbc.ie/wp-content/uploads/2020/09/Introducing-BRP-In-Ireland-Feasibility-Study.pdf.

McCaig, I, Pender, R and D. Pickles (2018) Energy Efficiency and Historic Buildings: How to Improve Energy Efficiency. London: Historic England. Available at: https://historicengland.org.uk/advice/technical-advice/energy-efficiency-and-historic-buildings/.

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Rhee-Duverne, S and P. Baker (2015) A Retrofit of a Victorian Terrace House in New Bolsover: A Whole House Thermal Performance Assessment. London: Historic England. Available at: https://historicengland.org.uk/research/results/reports/103-2015#:~:text=The%20work%20was%20carried%20out,of%20single%2Dglazed%20timber%20framed.

S.R. 54:2014 and A1:2022 Code of practice for the energy efficient retrofit of dwellings. Dublin: National Standards Authority of Ireland. Available at: https://shop.standards.ie/en-ie/standards/s-r-54-2014-a2-2022-877610_saig_nsai_nsai_3214983/.

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Weeks, C., Ward, T. and C. King (2013) Reducing thermal bridging at junctions when designing and installing solid wall insulation. London: BRE. Available at: https://www.brebookshop.com/details.jsp?id=327287.

Appendix 4: Development Team

This guidance has been developed by the OPW, with a contract team led by Shaffrey Architects with Arup Engineering and Passivate Building Energy Consulting, as follows:

Audrey Farrell (Chair)	OPW Heritage Services – Conservation
Francis Shier	OPW Heritage Services – Conservation
Caroline Engel Purcell, PhD	OPW Heritage Services – Conservation
Grainne Shaffrey	Shaffrey Architects
Jonathan Buckley	Shaffrey Architects
Eamonn Kehoe	Shaffrey Architects
Andrew Lundberg	Passivate Building Energy Consulting
Yaroslav Konchakovskyi	Passivate Building Energy Consulting
John Burgess	Arup Engineering
John Bynum	Arup Engineering
Timothy Phelan	Arup Engineering
Mark Dillon	Arup Engineering

With support from representatives across the OPW and DHLGH, as follows:

Tomás O'Connor	OPW Heritage Services – Conservation
Terri Sweeny Meade	OPW Heritage Services – Conservation
Gretta Doyle	OPW Heritage Services – Conservation
Gosia Kudyba	OPW Office of State/Principal Architect
Conor Byrne	OPW Mechanical and Electrical Engineering Services
Jacqui Donnelly	Department of Housing, Local Government and Heritage
Carl Raftery	Department of Housing, Local Government and Heritage



OPW

Oifig na
nOibreacha Poiblí
Office of Public Works