Deep Energy Renovation of Traditional Buildings

Addressing Knowledge Gaps and Skills Training in Ireland

The Sustainable Energy Authority of Ireland

The Heritage Council

Carrig Conservation International, Ltd.

ICOMOS Ireland National Scientific Committee on
Energy, Sustainability and Climate Change (NSCES+CC)

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FOREWORD

The cultural value we attribute to our historic buildings informs our identity as individuals and as a collective society and they therefore play an important contributing role in our urban and rural environments. Yet, as spaces for human inhabitation, they demand energy and as the reduction of carbon emissions becomes a forefront issue in our public policy, historic and traditional buildings will need to play a contributing role in this climate mitigation ambition.

More than one-sixth of our dwellings are traditionally-built, with solid walls and tried-and-tested materials and construction methods. They perform differently to modern construction, and in order for them to be modified effectively to use less energy, their physical properties and performance need to be taken into account. The risks of applying energy efficiency methods used for modern construction to traditionally-built buildings include damage both to the building fabric and to the health of the building occupants. It is also important to acknowledge the embodied energy that enduring elements of structures have. Properly maintained Georgian windows, for instance, have outlasted modern PVC windows produced in the mid-late 20th century multiple times over. Regrettably, we do not yet have a calculation for recognising this contribution, alongside the other forms of intrinsic value, which historic buildings have.

Ireland's fourth *National Energy Efficiency Action Plan* lays out the energy reduction targets and the means to achieve these targets across all sectors in Irish society. According to the Sustainable Energy Authority of Ireland (SEAI) assessments, by the end of 2016, Ireland had reduced energy use by less than 12% of the 2020 target of 20%.[1] The *Current Trajectory Scenario* estimates that Ireland will miss its national energy efficiency target by nearly 4%, meaning that we may incur significant EU fines. In this scenario, we, as users of the built environment, need to be more frugal with our energy use in buildings.

The Heritage Council is pleased to present this report, the result of an innovative collaboration between a State Agency, an NGO and the private sector, based on grant support from SEAI, a separate arm of the State. In itself, this is a template for the type of co-operative action involving governmental and non-governmental partners that is needed to achieve solutions to complex issues affecting our communities. In the treatment of our historic built environment, we must not lose sight of the concept of quality, so central to what 'heritage' has to offer. This partnership extends the policy-making role of the State to include those who may implement it, which further validates the effectiveness of the contribution of public funds toward solving this issue. Through the involvement of the ICOMOS Ireland National Scientific Committee on Energy, Sustainability and Climate Change (NSCES+CC), it was possible to access international good practice and the evolving expert deliberations in the EU on how regulatory regimes can best contribute to reducing energy demand without sacrificing the technical performance characteristics and aesthetic qualities of traditional buildings.

It is important to acknowledge and thank the many parties who in various ways contributed to the completion of this report. First and foremost, the principal author of the report Dr Caroline Engel Purcell has worked hard to put into order a mass of technical guidance, policy, regulation and good practice guides. Several partner non-governmental organisations have contributed to the process, including participation by Marion Jammet of the Irish Green Building Council, Kevin Sheridan, Stephen McGuinness and Pat Nestor of the Irish Building Control Institute, and representatives from the Royal Institute of the Architects of Ireland, Engineers Ireland, and the Society of Chartered Surveyors of Ireland. The Heritage Council's Architecture Officer acted as liaison with the Sustainable Energy Authority of Ireland throughout the course of the research and outreach activities of this project.

Michael Starrett

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[1] *National Energy Efficiency Action Plan for Ireland: 2017-2020* (2017). Dublin: Department of Communications, Climate Action & Environment. p 8.

EXECUTIVE SUMMARY

The primary intent of this research project is to review the current state of knowledge and risks relating to the deep energy renovation of traditional buildings, which have different hygroscopic and thermal behaviours to buildings of modern construction, and which represent approximately 16% of the total housing stock in Ireland. One of the key characteristics of traditional buildings is that they are constructed of solid masonry walls that are 'breathable', ie. the building fabric allows moisture to be absorbed and released cyclically. This form of construction relies on vapour-permeable materials and higher levels of ventilation to ensure the well-being of the building fabric and the internal environment. The term 'traditional building' is more comprehensively described in the DEHLG publication 'Energy Efficiency in Traditional Buildings'.[2]

This document provides an overview of the important issues and risks relating to the energy renovation of traditional buildings and directs readers toward credible sources for further information. Building upon the STBA *Responsible Retrofit of Traditional Buildings* gap analysis report of 2012[3], the Annotated Bibliography section of this report assembles in one place a list of the statutes, standards, technical documents, academic research and case studies relevant to the deep energy renovation of traditional buildings in Ireland. This is a fast-moving field of research and since 2012, at least 54 further technical research and guidance documents have been published or revised that examine various aspects of the hygrothermal performance of traditional buildings pre- and post-renovation. Overall, of the 475 plus resources collected during the course of this project, more than three-quarters were published after 2012. The Annotated Bibliography is designed to provide building practitioners with the resources and tools to specify deep energy renovation works appropriate to traditional buildings in Ireland and to help them span the persisting knowledge gaps in practice. Web links to the resources discussed in the text have been provided in the right-hand column of the document. Resources available for purchase are marked in **yellow**, while those available free of charge are marked in **blue**. If utilising these resources, please note the source document and authorship, and any copyright associated with that document.

Further objectives of this research are to identify technical and non-technical barriers inhibiting the effective implementation of energy renovation in Ireland; to identify knowledge gaps and areas for further research; and, based on the evidence identified, to propose future courses of action. The promotion and dissemination of this research has already helped to create co-operative cross-institutional communication between senior members of the relevant State Departments, statutory bodies, non-governmental organisations and a broad set of stakeholders in the building sector. Continued collaboration is necessary to further explore and address the identified issues in a meaningful way. Taking stock of the current state of knowledge, as this report does, is an essential first step.

In addition, the following forthcoming developments are expected to be of importance with regard to the deep energy renovation of traditional buildings in Ireland:

- The Department of Housing, Planning and Local Government and the Department of Culture, Heritage and the Gaeltacht both support the creation of a new NSAI Standard Recommendation Code of Practice for the Energy Efficient Renovation of Traditional Buildings.
- The Part L Amendment of the Irish Building Regulations and the corresponding TGD L for Dwellings are expected to go to public consultation toward the end of March 2018.
- The revised Energy Performance of Buildings Directive (EPBD) is due to be published in early 2018.
- The SEAI update of the BER system is due to be released in June 2018.
- The second edition of the Built to Last study is due to be published in 2018.

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[2] *Advice Series: Energy Efficiency in Traditional Buildings* (2010), Dublin: Department of the Environment, Heritage and Local Government. Available at: https://www.chg.gov.ie/heritage/built-heritage/architectural-heritage-advisory-service/advice-for-owners/. p 5.

[3] May, N. and Rye, C. (2012) *Responsible Retrofit of Traditional Buildings: A Report on Existing Research and Guidance with Recommendations*, London: Sustainable Traditional Buildings Alliance. Available at: http://stbauk.org/stba-guidance-research-papers.

SUMMARY OF PROPOSED FUTURE COURSES OF ACTION

Upon the completion of this research, the following courses of action are now possible and recommended:

To lobby the Building Regulations Section of the Department of Housing, Planning and Local Government for improved technical guidance on traditionally-built buildings. This could be achieved by:

a. Clarifying, illustrating and publicising their little-known document 'The application of the Building Regulations to works in existing buildings'.[4] This could be revised to reflect the concerns of protected structures and proposed protected structures in the first place, and then traditional moisture-permeable buildings in the second. It should be said that, while useful for a well-versed building professional, this document is quite opaque for a lay person. Ideally this text would be incorporated in a plain English text that sets out standard and alternative routes of compliance for existing buildings, illustrated with logic diagrams and case studies.

b. Publicising the existence of a procedure to apply for a dispensation or relaxation of the Building Regulations. This procedure is available but rarely used (Articles 4 and 5 of the Building Control Act 1990). For building professionals to begin to use this method, more clarity is needed on what would constitute a complete application relating to Part L, the methodology by which it would be judged, and the method and timeframe for appeal of judgments to An Bord Pleanála. Long decision and appeal time periods may make applying for relaxation a high-risk endeavour and may be seen by many as a significant block to engagement with alternative routes of compliance to Part L for traditionally-constructed buildings.

c. Promoting a 'managed' approach to improvements in energy performance of traditional buildings, emphasising that the performance of services, plant and equipment should be the preferred locus of improvement. A number of improvements can also be made to the fabric of the building without sacrificing heritage value. For instance, roof insulation can be increased to optimal levels, floor insulation can be installed in some cases, and sensible draft proofing measures ranging from the maintenance of windows to blocking up unused chimneys can be implemented to increase airtightness. The basic conservation principle to 'do as little as possible and as much as necessary' could inform step-by-step energy renovation plans for traditional and historic buildings and guidance on the most beneficial sequence of works could be provided through Building Renovation Passports.

d. Revising the Regulations so that the principle of 'no greater contravention' in relation to Part L applies even when a material change of use takes place.

e. Providing more information on the thermal performance of masonry walls (and other commonly recurring traditional fabric constructions) with the level of energy efficiency improvement that can reasonably be expected in the Standard Recommendations and Technical Guidance Documents for the Building Regulations.

f. Populating DEAP with a greater range of scientifically-derived default U-values measured for a range of traditional wall types of specific widths (including perhaps different floor and roof types). This may then improve the degree to which BER assessments reflect the actual performance of traditional dwellings.

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[4] *The Application of the Building Regulations to Works in Existing Buildings*, Dublin: Department of Housing, Planning and Local Government. Available at: http://www.housing.gov.ie/housing/building-standards/other/application-building-regulations-works-existing-buildings.

g. Supporting the measurement of hygrothermal properties for a range of traditional Irish building materials to inform research and underpin the day-to-day hygrothermal risk evaluation of building projects including renovations.[5]

h. Creating a set of Better Renovation Details (BRDs) to guide higher quality energy-efficient renovation works (of traditional dwellings) that are always hygrothermally low risk. Typologies should be chosen with stakeholders then submitted to hygrothermal risk assessment before details sheets and thermal modelling are developed.

i. Creating a methodology for alternative routes of compliance with Part L for the energy-efficient renovation of traditionally-built buildings. Alternative routes are in use in relation to Parts B (Fire) and M (Access and Use), but not L (Conservation of Fuel and Energy). Compliance with TGD L is 'prima facie', however various sections of TGD L (incl. 0.2.1.1, 0.2.1.2, 0.6.2, 0.6.4, 0.6.7) reflect an awareness that TGD L was not created with traditionally-built buildings in mind. Yet, alternative routes, how submissions should be structured, judged and appealed is not clear. The lack of clarity may be encouraging an inappropriate use of TGD L guidance, high risk specifications and/or non-compliant works. The resulting alternative route methodology would require review and approval by building control and professional bodies.

j. Recognising that the embodied energy of materials, and especially the components of buildings that are cyclically replaced, play a role in energy use or saving, and that the durability of historic buildings represents an energy investment by obviating the necessity to build a new building.

The Heritage Council, and the ICOMOS Ireland National Scientific Committee on Energy, Sustainability and Climate Change, request assistance from the Sustainable Energy Authority of Ireland, the Department of Communications, Climate Action and Environment, the Department of Housing, Planning and Local Government, and the Department of Culture, Heritage and the Gaeltacht to support quality energy renovation projects for traditionally-built buildings, including the following:

k. The Heritage Council, and the Sustainable Energy Authority of Ireland to fund and co-ordinate a grant scheme to support the production of good practice case studies for traditionally-built buildings, that show how expertise, a holistic approach to building energy performance, and sensitivity to historical and artistic character are possible, desirable and ultimately will actually achieve the energy-reduction outcomes required by international obligations.

l. The Heritage Council, with the Sustainable Energy Authority of Ireland and the Irish Green Building Council, to co-ordinate and support the provision of CPD for specifiers in conjunction with the RIAI, EI, SCSI (and the Institute of Building Control) to an agreed curriculum and standard that has been scoped out in this research.

m. The Heritage Council to create a panel of specifiers recognised for their competence in specifying works in the proposed energy efficient renovation grant scheme.

[5] The U-values of six walls of historic (pre-1945) Dublin dwellings were measured in Little, J., McGirl, F., Hanratty, M. and Arregi, B. (Forthcoming 2018) *Built to Last: Renovations of Historic Dublin Dwellings.* Dublin. The mass concrete walls had U-values worse (i.e higher) than DEAP's default values for solid walls, and the solid brick and rubble walls all had value significantly better (i.e. lower) than the default values. In one case the measured U-value for a rendered rubble wall was 1.09 W/m^2K whereas DEAP's default value was 2.1 W/m^2K, a 193% over-estimation of heat loss.

Contents

1 Introduction

1.1 Research Scope

This research has been undertaken as part of the Horizon 2020 European Commission Framework for Research and Innovation through the Sustainable Energy Authority of Ireland's Research, Development and Demonstration grant programme. This research project builds upon the knowledge gained and shared at a colloquium jointly organised by the Heritage Council and the ICOMOS Ireland National Scientific Committee on Energy, Sustainability and Climate Change (NSCES+CC) held in Dublin on 28 February 2017 (see Appendix 7.1). A principal outcome of the colloquium was the focussing of the research effort to support sole-practitioners and small practices in the specification of energy efficiency renovation works for traditional buildings and the development of a series of training courses to extend the usefulness of this report.

The primary intent of this report is to review the current state of knowledge and practice in the deep energy renovation of traditional buildings, which have different hygroscopic and thermal behaviours to modern cavity wall buildings, and which, according to the 2016 census, represent approximately 16% of the private residential housing stock in Ireland.[6] The overarching aim of this research is to support co-operative cross-institutional arrangements between senior members of the relevant State Departments, statutory bodies, non-governmental organisations and the building sector to further address the identified knowledge gaps and skills shortages, to support the development of fiscal incentives and to provide specifiers with a pathway to compliance with the building regulations. Researching the state of knowledge is an essential first step in this process.

The first phase of this project entailed the collection of literature, which began with the assessment of resources held in the archive of the ICOMOS Ireland NSCES+CC, and ultimately amounted to more than 475 resources in total. These were then was compiled into an online bibliography management system. The resources were drawn from sources including international, European, British and Irish standards, peer-reviewed journals, conference proceedings, relevant European research programmes, technical research and guidance published by heritage and sustainability bodies such as Historic Environment Scotland (HES), Historic England (HE), the Sustainable Traditional Building Alliance (STBA), the Society for the Protection of Ancient Buildings (SPAB) and the Building Research Establishment (BRE).

Building upon the STBA *Responsible Retrofit of Traditional Buildings* gap analysis report of 2012[7], the Annotated Bibliography assembles in one place a list of the statutes, standards, technical documents, academic research and case studies relevant to the deep energy renovation of traditional buildings in Ireland. This is a fast-moving field of research and since 2012, at least 54 further technical research and guidance documents have been published or revised that examine various aspects of the hygrothermal performance of traditional buildings pre- and post-renovation. Overall, of the 475 plus resources collected during the course of this project, more than three-quarters were published after 2012. The Annotated Bibliography is designed to provide building practitioners with the resources and tools to specify deep energy renovation works appropriate to traditional buildings in Ireland and to help them span the persisting knowledge gaps in practice. Web links to the resources discussed in the text have been provided in the right-hand column. Resources available for purchase are marked in **yellow**, while resources available free of charge are marked in **blue**. If utilising these resources, please note the source document and authorship, and any copyright associated with that document.

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[6] *E1005: Private Households in Permanent Housing Units 2011 to 2016 by Type of Private Accommodation, County and City, Period in which Built and Census Year*. Cork: Central Statistics Office. Available at: http://www.cso.ie/px/pxeirestat/Statire/SelectVarVal/Define.asp?maintable=E1005&PLanguage=0 (Accessed: 10 March 2018).

[7] May, N. and Rye, C. (2012) *Responsible Retrofit of Traditional Buildings: A Report on Existing Research and Guidance with Recommendations*, London: Sustainable Traditional Buildings Alliance. Available at: http://stbauk.org/stba-guidance-research-papers.

1.2 The Argument for Deep Energy Renovation

It is important to first address what is meant by 'deep energy renovation' or 'deep energy retrofit'. Deep energy renovation is the terminology used by the European Commission to describe measures taken to improve the energy and thermal efficiency of an existing building. According to the *Retrofit Factfile*, a shallow renovation can be achieved by installing insulation, replacing windows, filling drafts and so forth, while deep renovation takes a whole-house approach and includes all material improvements as well as the upgrading of existing heating and ventilation systems and the installation of renewable energy sources.[8] Though the terms are often used interchangeably, for consistency, 'deep energy renovation' or simply 'renovation' has been used throughout this report.

Ideally, deep energy renovation measures will be undertaken all at once to minimise inconvenience for the homeowners and to ensure that the maximum energy savings are reaped over the greatest length of time. However, in reality, costs are often prohibitive and renovation measures must be undertaken in separate phases, known as step-by-step renovations. In fact, according to the Passive House Institute, 80-90% of all energy renovation measures are undertaken on a step-by-step basis and it is therefore crucial that long-term plans are tailored to the individual buildings and their specific requirements.[9] On 19 December 2017, representatives from the European Parliament, Council and Commission came to an agreement on a series of improvements to the EPBD, including the implementation of long-term renovation strategies, such as building renovation passports (BRPs), as part of the National Renovation Strategies of Member States.[10] BRPs are designed to provide personalised long-term renovation roadmaps (spanning 15-20 years) to assist homeowners in achieving the greatest energy savings throughout the renovation process.

The European Commission estimates that buildings account for 40% of energy use and 36% of CO_2 emissions, and that 75% of Europe's buildings are currently using energy inefficiently, equating to more than 200 million buildings that are in need of energy renovation measures in order to meet the EU's 2020 targets and beyond. In the EU 27, 14% of buildings date from 1919 or earlier, which is equal to approximately 30 million dwellings, and an additional 26% of buildings were constructed between 1919-1945, equal to approximately 55 million dwellings. This means 120 million people are living in historic (but not necessarily heritage) buildings across Europe.[11] The Passive House Institute states that deep energy renovation works using Passive House technologies can result in an 80% reduction in energy use per building.[12] In this quest to reduce carbon emissions and energy use, it is also important to recognise the embodied energy and intrinsic value of existing traditional building elements that have lasted multiple spans of time in comparison to those built in the 20th and 21st centuries. It is not rational to expend energy through new building construction projects, and the preceding component manufacturing processes, when existing inherited buildings could and should be refurbished instead.

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[8] Grimshaw, H. (2016) *Retrofit Factfile: A Short Summary of Facts and Publications Relevant to Domestic Retrofit*, Manchester: URBED Ltd and the Carbon Co-op. Available at: http://urbed.coop/projects/retrofit-factfile. p 7.

[9] *EuroPHit Brochure: Implementing Deep Energy Step-by-Step Retrofits - Increasing the European Potential* (2016), Darmstadt, Germany: Passive House Institute. Available at: http://europhit.eu/sites/europhit.eu/files/EuroPHit_brochure_final_PHI.pdf. p 11-12.

[10] *Commission Welcomes Agreement on Energy Performance of Buildings* (2017). Brussels: European Commission. Available at: http://europa.eu/rapid/press-release_IP-17-5129_en.htm.

[11] Troi, A. 'Comfort and Energy Efficiency in Historic Buildings – the 3ENCULT Experience'. *Energy Efficiency and Comfort of Historic Buildings (EECHB)*, Brussels: Flanders Heritage Agency, 10-16. p 10.

[12] *EuroPHit Brochure: Implementing Deep Energy Step-by-Step Retrofits - Increasing the European Potential* (2016), Darmstadt, Germany: Passive House Institute. Available at: http://europhit.eu/sites/europhit.eu/files/EuroPHit_brochure_final_PHI.pdf.

1.3 The Irish Context

In 2009, Ireland made a commitment to improve its overall national energy efficiency by 20% and by 33% within the public sector. According to the SEAI, by the end of 2016 Ireland had reduced its energy consumption on a national level by just under 12% and reported that Ireland was projected to miss its 2020 energy use reduction target by 3.77%.[13] Economic growth in recent years has led to greenhouse gas (GHG) emissions actually increasing by 3.7% (2.1 million tonnes) in 2015 and Ireland is therefore set to exceed its annual GHG target limits each year up to and likely through 2020.[14] In April 2017, the Environmental Protection Agency (EPA) warned that Ireland was not only not on track to meet its 2020 greenhouse gas emission reduction target of 20% below the 2005 levels, but that non-Emission Trading Scheme (non-ETS) emissions were projected to only be 4-6% below the 2005 levels by 2020, and only 1-3% below the 2005 levels by 2030.[15]

In 2014, the Department of Communications, Climate Action and Environment (DCCAE) published the first National Renovation Strategy for Ireland. In Ireland, the residential sector is the second largest sources of greenhouse gas emissions after the transport sector, emitting 10.5 million tonnes of CO_2 each year and accounting for 27% of total national energy usage. Between 2008-2013, Ireland was recorded as having the sixth highest energy consumption per dwelling in Europe.[16] In addition, the Climate Change Advisory Council stated in their 2017 Annual Review that, of all EU countries, Ireland has the third highest GHG emissions per capita in the residential sector due to its over-reliance on fossil fuels like peat and coal and the minimal utilisation of renewable energy and district heating.[17] This figure may also be impacted by the size of the dwellings, as Irish dwellings have the fourth largest average floor area (104m^2) in the EU. The National Renovation Strategy for Ireland states that Ireland's poor performance on these fronts is 'partially due to a smaller gas network than is typical on the continent, but to fully account for the differential it must be assumed that our building stock is also less energy efficient than is typical in the rest of Europe'.[18] The next edition of the National Renovation Strategy is due to be published in early 2018 and should take into account recommendations made by the Irish Green Building Council (IGBC), which include the development of Technical Guidance Documents and training programme to ensure correct measures and materials are used in the energy renovation of traditional buildings.[19]

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[13] *National Energy Efficiency Action Plan for Ireland: 2017-2020* (2017). Dublin: Department of Communications, Climate Action & Environment. p 8.

[14] *Climate Change Advisory Council Annual Review* (2017), Dublin: Climate Change Advisory Council. Available at: http://www.climatecouncil.ie/councilpublications/annualreviewandreport/. p iii.

[15] *Ireland's Greenhouse Gas Emission Projections 2016-2035* (2017), Wexford: Environmental Protection Agency (EPA). Available at: http://www.epa.ie/pubs/reports/air/airemissions/ghgprojections/.

[16] Gynther, L., Lapillonne, B. and Pollier, K. (2015) *Energy Efficiency Trends and Policies in the Household and Tertiary Sectors: An Analysis Based on the ODYSSEE and MURE Databases*: Intelligent Energy Europe Programme of the European Union. Available at: http://www.odyssee-mure.eu/publications/br/energy-efficiency-trends-policies-buildings.pdf.

[17] *Climate Change Advisory Council Annual Review* (2017), Dublin: Climate Change Advisory Council. Available at: http://www.climatecouncil.ie/councilpublications/annualreviewandreport/.

[18] *Better Buildings: A National Renovation Strategy for Ireland* (2014), Ireland: Department of Communications, Energy and Natural Resources. Available at: http://www.dccae.gov.ie/en-ie/energy/topics/Energy-Efficiency/ireland%27s-national-renovation-strategy/Pages/Ireland%27s-Renovation-Strategy.aspx. p 11.

[19] *Build Upon Final Recommendations: Towards Large Scale Deep Energy Renovation - Unlocking Ireland's Potential* (2017), Dublin: Irish Green Building Council. Available at: http://buildupon.eu/dialogue/countries/ireland/.

The Irish Context

According to the 2016 census records, 9% of all private housing in Ireland was constructed prior to 1919 and 7% was constructed between 1919-1945.[20] The *Energy Efficiency in Traditional Buildings* guidance document produced in 2010 by the Department of Energy, Heritage and Local Government states that almost all housing built prior to 1940 was constructed using traditional building methods.[21] This means that at least one-sixth of the Irish housing stock is traditionally-built and energy renovation measures appropriate to that type of construction must be communicated to the broader building industry outside of the heritage conservation profession.

The SEAI estimates that of the 1.7 million homes in Ireland, more than 1 million have a BER rating of C3 or worse and that it will cost more than €35 billion to upgrade the existing housing stock to low carbon standards by 2050.[22] Many of the buildings that fall within the lower BER brackets are of traditional construction, but research has found that traditional solid masonry walls often outperform the default U-values assigned to them by the BER system. It is therefore important that the Dwelling Energy Assessment Procedure (DEAP) is populated with a greater variety of traditional building materials to accurately portray the thermal efficiency of traditional buildings. Likewise, it is important that BER Assessors themselves are trained to be able to accurately assess traditional buildings and to provide correct renovation advice to building owners.

Access to professional training, technical research and best practice guidance applicable to the Irish climate and built environment is essential to support the growth of deep energy renovation on a large scale. As Ireland begins in earnest to tackle the great challenge of renovating the large majority of our building stock, it is crucially important that governmental policies and agencies support best practices in relation to the renovation of traditional buildings, which have different hygroscopic material behaviours to modern vapour-closed construction. Methods and materials that permit the natural wetting and drying cycles to occur in traditional buildings after renovation are not only important to ensure the health of the building fabric, but also of its occupants. Regulatory deep energy renovation guidance is needed for traditional buildings to provide specifiers with a pathway to compliance with the building regulations, to ensure that building practitioners are specifying works according to best practice advice and to enable the roll-out of national deep energy renovation grant and loan programmes.

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[20] *E1005: Private Households in Permanent Housing Units 2011 to 2016 by Type of Private Accommodation, County and City, Period in which Built and Census Year*. Cork: Central Statistics Office. Available at: http://www.cso.ie/px/pxeirestat/Statire/SelectVarVal/Define.asp?maintable=E1005&PLanguage=0 (Accessed: 10 March 2018).

[21] *Advice Series: Energy Efficiency in Traditional Buildings* (2010), Dublin: Department of the Environment, Heritage and Local Government. Available at: https://www.chg.gov.ie/heritage/built-heritage/architectural-heritage-advisory-service/advice-for-owners/. p 5.

[22] *Behavioural Insights on Energy Efficiency in the Residential Sector* (2017), Dublin: Sustainable Energy Authority of Ireland. Available at: https://www.seai.ie/sustainable-solutions/behavioural-insights/. p 2.

2 Annotated Bibliography

2.1 International Energy Efficiency Protocols and Agreements

This section introduces the key international statutory and non-statutory documents that currently guide national energy efficiency policies.

2.1.1 Kyoto Protocol

Kyoto Protocol (1997)

The Kyoto Protocol is an international agreement established as part of the United Nations Framework Convention on Climate Change and is seen as an important first step toward the reduction and stabilization of greenhouse gas emissions globally. The Protocol was adopted in Kyoto, Japan on 11 December 1997 and entered into force on 16 February 2005. The rules for implementing the Protocol were adopted at COP 7 in Marrakech, Morocco in 2001, and are referred to as the "Marrakech Accords." The Protocol commits its 184 signing Parties (including Ireland) to internationally binding emission reduction targets, which during the second commitment period from 2013-2020 set the GHG reduction commitments at 18% below 1990 levels. The Parties are required to monitor their emissions and submit annual reports to the UN Climate Change Secretariat to ensure they are meeting their commitments.[23]

2.1.2 Europe 2020 Strategy

Europe 2020 Targets: Statistics and Indicators for Ireland

STBA Policy Mapping report (2017)

European Commission Report: National Reform Programme – Ireland (2017)

In 2007, the European Council adopted energy and climate change targets for 2020, which were confirmed in 2010 through the Europe 2020 Strategy. The objectives are 'to reduce greenhouse gas emissions by 20%, to increase the share of renewable energy to 20% and to reach 20% energy efficiency'.[24] The European Commission set out its long-term climate change agenda in 2011 through the Roadmap 2050, which set European-wide goals of a 25% reduction in GHG emissions by 2020, 40% reduction by 2030, 60% by 2040 and 80-95% by 2050.

By 2020, Ireland has committed to reduce greenhouse gas emissions to 20% below the 2005 levels, to increase the share of renewable energy to 16% of the overall final energy consumption, and to increase general energy efficiency by 20%.[25] As of 2014, 8.6%

[23] *Kyoto Protocol* (1997). Kyoto, Japan: The United Nations.

[24] *STBA Policy Mapping* (2017): Sustainable Traditional Buildings Alliance (STBA). Available at: http://stbauk.org/what-we-do/policy-mapping. p 4.

[25] *European Semester Reports: National Reform Programme - Ireland* (2017), Brussels: European Commission. Available at: https://ec.europa.eu/info/business-economy-euro/economic-and-fiscal-policy-coordination/eu-economic-governance-monitoring-prevention-correction/european-semester/european-semester-your-country/ireland_en.p 40.

of the gross final energy consumption in Ireland came from renewable energy sources and the 2015 White Paper, *Ireland's Transition to a Low Carbon Energy Future 2015-2030*, details the government's plans to continue this growth.[26] However, according to the Environmental Protection Agency, Ireland is on course to only reduce its non-Emission Trading Scheme (ETS) emissions by 4-6% below 2005 levels by 2020, and if things continue as they are, by 2030 non-ETS emissions will only be 1-3% below 2005 levels.[27] Details of Ireland's national 2020 energy efficiency targets and programmes designed to help meet these targets are outlined in the National Energy Efficiency Action Plan 2017-2020[28] and in a summary document created by the SEAI for policy-makers[29]. Statistics on Ireland's greenhouse gas emission levels from 1990 through 2015 can be found in a report and infographic created by the EPA.[30]

Ireland's Transition to a Low Carbon Energy Future 2015-2030 (2015)

Ireland's Greenhouse Gas Emission Projections 2016-2035 (2017)

National Energy Efficiency Action Plan for Ireland 2017-2020 (2017)

Ireland's Energy Targets: Progress, Ambition & Impacts - Summary to Policy-Makers (2016)

Ireland's Final Greenhouse Gas Emissions 1990-2015 (2015)

2.1.3 The Paris Agreement

At the 21st United Nations Conference of Parties (COP 21), held in Paris on 30 November – 12 December 2015, 195 countries signed the first legally binding global climate agreement. In doing so, all signing nations (including Ireland) committed to take the necessary measures at a national level to limit the rise of global temperatures to less than 2 degrees Celsius. In signing the Agreement, governments have also agreed to collectively set new ambitious targets every five years and to make public the progress made toward achieving their targets through a system of transparency and accountability. COP 22 in Marrakech[31] and COP 23 in Bonn[32] reaffirmed these goals, however under the Trump administration, the United States pulled out of the Paris Agreement amidst protests at COP 23, making it the only country in the world to overtly state that it does not intend to honour the landmark international deal.

The Paris Agreement 2015 – Policy & Documentation

[26] *Ireland's Transition to a Low Carbon Energy Future 2015-2030* (2015), Dublin: Department of Communications, Energy & Natural Resources. Available at: https://www.dccae.gov.ie/en-ie/energy/topics/Energy-Initiatives/energy-policy-framework/white-paper/Pages/White-Paper-on-Energy-Policy-in-Ireland-.aspx.

[27] *Ireland's Greenhouse Gas Emission Projections 2016-2035* (2017), Wexford: Environmental Protection Agency (EPA). Available at: http://www.epa.ie/pubs/reports/air/airemissions/ghgprojections/.

[28] *National Energy Efficiency Action Plan for Ireland: 2017-2020* (2017). Dublin: Department of Communications, Climate Action & Environment.

[29] *Ireland's Energy Targets: Progress, Ambition & Impacts - Summary to Policy-Makers* (2016), Dublin: Sustainable Energy Authority of Ireland (SEAI). Available at: https://www.seai.ie/resources/publications/Ireland___s-Energy-Targets-Progress-Ambition-and-Impacts.pdf.

[30] *Ireland's Final Greenhouse Gas Emissions in 2015* (2017), Wexford: Environmental Protection Agency (EPA). Available at: http://www.epa.ie/pubs/reports/air/airemissions/ghgemissions/.

[31] *Marrakech Climate Change Conference (COP 22)* (2016): United Nations Framework Convention on Climate Change. Available at: http://unfccc.int/meetings/marrakech_nov_2016/meeting/9567.php (Accessed: 31 January 2018).

[32] *UN Climate Change Conference - Bonn (COP 23)* (2017): United Nations Framework Convention on Climate Change. Available at: http://unfccc.int/meetings/bonn_nov_2017/meeting/10084.php (Accessed: 31 January 2018).

2.1.4 United Nations 2030 Agenda for Sustainable Development

The UN Sustainable Development Goals Report (2017)

On 1 January 2016, the 17 Sustainable Development Goals (SDGs) established by the United Nations to support the 2030 Agenda for Sustainable Development were officially enacted. Though these SDGs are not legally binding, they apply to all countries and national governments are expected to set up national frameworks to meet all 17 Goals by 2030.[33]

The Sustainable Development Goals that apply directly to traditional and historic buildings are:

- **SDG 11.** Make cities and human settlements inclusive, safe, resilient and sustainable
- **SDG 11.4.** Strengthen efforts to protect and safeguard the world's cultural and natural heritage

Coalition2030 was established in March 2017 in Ireland to meet the United Nations Sustainable Development Goals by 2030. It is an alliance of more than 100 Irish civil society groups and organisations and expertise range from children's rights to environmental sustainability. ICOMOS Ireland is currently petitioning to join Coalition2030.

2.1.5 New Urban Agenda

The New Urban Agenda (2017)

Following the enactment of the SDGs, the New Urban Agenda was adopted at the United Nations Conference on Housing and Sustainable Urban Development (Habitat III) on 20 October 2016 and was officially endorsed by the UN General Assembly on 23 December 2016. The New Urban Agenda provides local, regional and national governments, as well as private organisations, with standards and principles to support the planning, construction, development, management, and improvement of cities through five main areas: national urban policies, urban legislation and regulations, urban planning and design, local economy and municipal finance, and local implementation.[34]

The New Urban Agenda highlights the importance of SDG 11 on the development of sustainable cities and communities and the 197 participating nations, including Ireland, have agreed to 'ensure universal access to affordable, reliable and modern energy services by promoting energy efficiency and sustainable renewable energy and supporting subnational and local efforts to apply them in public buildings, infrastructure and facilities'. They have agreed to do this

[33] *Sustainable Development Goals: 17 Goals to Transform our World*: The United Nations. Available at: http://www.un.org/sustainabledevelopment/ (Accessed: 20 November 2017).

[34] *New Urban Agenda* (2017): The United Nations. Available at: http://habitat3.org/the-new-urban-agenda/. iv.

by fostering uptake in end-use sectors, such as residential, commercial, industry, transport, and waste management. Directly related to this study, they have also agreed to 'encourage the adoption of building performance codes and standards, renewable portfolio targets, energy-efficiency labelling, retrofitting of existing buildings and public procurement policies on energy, among other modalities as appropriate, to achieve energy-efficiency targets'.[35]

2.1.6 The Madrid Document

Approaches for the Conservation of 20th Century Architectural Heritage

The Madrid Document (2014)

The Madrid – New Delhi Document (2017)

During 2016/2017, the ICOMOS International Scientific Committee on 20th Century Heritage (ISC20C) requested input from the ICOMOS National Scientific Committees on Energy, Sustainability and Climate Change on Article 8 of the Madrid Document for its 2017 revision, which previously read:[36]

> *8.1: Care must be taken to achieve an appropriate balance between environmental sustainability and the conservation of cultural significance.*

The revision of this article (now Article 10) has been expanded to read:[37]

> *10.1: Care must be taken to achieve an appropriate balance between environmental sustainability and the introduction of energy efficiency measures with the conservation of cultural significance.*
>
> *10.2: Promote and communicate appropriate energy conservation and environmentally sustainable practices for twentieth-century heritage*

The revised 2017 Madrid – New Delhi Document takes a more supportive stance on integrating measures to improve the energy efficiency of heritage buildings as part of a conservation programme. The explanatory notes state that 20th century heritage buildings 'should function as efficiently as possible' but that 'cultural significance (function and use) should not be adversely impacted by energy conservation measures, whenever possible'. The document supports a 'balanced and practical solution' to the conservation of 20th century heritage that facilitates contemporary

[35] Ibid. p 30.

[36] *The Madrid Document: Approaches for the Conservation of Twentieth-Century Architectural Heritage* (2014), Madrid: ICOMOS International Scientific Committee on Twentieth-Century Heritage. Available at: http://www.icomos-isc20c.org/madrid-document-archives/.

[37] *The Madrid - New Delhi Document: Approaches for the Conservation of Twentieth-Century Architectural Heritage* (2017), Delhi: ICOMOS International Scientific Committee on Twentieth-Century Heritage. Available at: http://www.icomos-isc20c.org/madrid-document/.

approaches to environmental sustainability within the overall conservation approach. It states that it is first essential to understand the energy performance of the building as-is to identify appropriate energy renovation measures, and where original materials have failed, it supports the use of more energy efficient materials and systems in replacement as long as they do not negatively impact the building's significance.

2.2 European Energy Efficiency Directives and Standards

2.2.1 Directive 2010/31/EU: Energy Performance of Buildings Directive

Directive 2010/31/EU: Energy Performance of Buildings Directive

STBA Policy Mapping report (2017)

The Energy Performance Building Directive (EPBD; adopted 2002, recast 2010) is a legal instrument designed to improve the energy performance of buildings across Europe through the implementation of binding targets, which European nations are required to transpose into their national laws and building regulations. The EPBD requires that:[38]

1. Energy Performance Certificates (EPCs) must be issued for all new buildings and when existing buildings are advertised for sale or rent
2. Larger public buildings must display a Display Energy Certificate (DEC) at all times
3. Inspection schemes must be established for heating and air conditioning systems
4. All new buildings must be constructed as nearly zero energy buildings (NZEB) by 31 December 2020 (public buildings by 31 December 2018).
5. EU countries must set minimum energy performance requirements for all buildings that undergo major renovations and for the replacement or retrofit of building elements (heating and cooling systems, roofs, walls, etc.)
6. EU countries must devise national financial measures to improve the energy efficiency of buildings

In Ireland, EPCs are managed by the Sustainable Energy Authority of Ireland (SEAI) and are called Building Energy Ratings (BER). The BER levels range from A for the best performing buildings to G for the worst. BERs became mandatory for new buildings and with the sale or rent of existing buildings in January 2013, and by the end of 2015, approximately 609,000 BERs covering 30% of the building stock in Ireland had been issued.[39]

On 19 December 2017, representatives from the European Parliament, Council and Commission came to an agreement on a

[38] *STBA Policy Mapping* (2017): Sustainable Traditional Buildings Alliance (STBA). Available at: http://stbauk.org/what-we-do/policy-mapping. p 17-18.

[39] *Implementing the Energy Performance of Buildings Directive (EPBD).* (2015) Lisbon: Portuguese Energy Agency (ADENE). P 341

series of improvements to the EPBD. These improvements are designed to promote:[40]

European Commission Press Release: Commission Welcomes Agreement on Energy Performance of Buildings (2017)

a. A clear path to achieving a zero and near-zero energy building stock in Europe by 2050 using National Roadmaps;
b. The use of smart technologies to ensure building systems are operating at their optimum efficiency;
c. The implementation of long-term renovation strategies such as Building Renovation Passports;
d. Private and public investment and financing options;
e. Reduced energy bills and improved healthy living environments for those living in older buildings and facing fuel poverty.

In support, Vice President of the European Commission Maroš Šefčovič said:

> *The fight against climate change starts 'at home', given that over a third of the EU's emissions is produced by buildings. By renovating and making them smart, we are catching several birds with one stone – the energy bills, people's health, and the environment. And as technology has blurred the distinction between sectors, we are also establishing a link between buildings and e-mobility infrastructure, and helping stabilize the electricity grid. Let's stay on high gear.*

This agreement is the first of eight legislative proposals to be passed as part of the European Commission's Clean Energy for All Europeans package announced on 30 November 2016.[41] The text of the revised Directive is yet to be approved by the European Parliament and Council, but once approved, it will be published in the Official Journal of the Union. The changes will come into force 20 days after publication and EU Member States will have 18 months to transpose the new elements of the EPBD into their national legislation.

European Commission Press Release: Clean Energy for All Europeans (2016)

2.2.2 Directive 2012/27/EU: Energy Efficiency Directive

Under the 2012 Energy Efficiency Directive (EED), all European countries were required to transpose a set of binding energy reduction measures into their national laws by 5 June 2014. These measures are intended to ensure that the EU meets its energy efficiency improvement and greenhouse gas reduction targets by

Directive 2012/27/EU on Energy Efficiency

Ireland's Public Sector Energy Efficiency Strategy (2017)

[40] *Commission Welcomes Agreement on Energy Performance of Buildings* (2017). Brussels: European Commission. Available at: http://europa.eu/rapid/press-release_IP-17-5129_en.htm.
[41] *Clean Energy for All Europeans – Unlocking Europe's Growth Potential* (2016), Brussels: The European Commission. Available at: http://europa.eu/rapid/press-release_IP-16-4009_en.htm.

2020. The Energy Efficiency Directive is intended to enforce a more efficient use of energy from production through to consumption.

Under *Article 4: Building Renovation*, EU Member States are required to devise a long-term strategy to incentivise investment in the energy renovation of its public[42] and private building stock. The strategy must include:

1. An overview of the national building stock based, as appropriate, on statistical sampling
2. Identification of cost-effective approaches to renovations relevant to the building type and climatic zone
3. Policies and measures to stimulate cost-effective deep renovations of buildings, including staged deep renovations
4. A forward-looking perspective to guide investment decisions of individuals, the construction industry and financial institutions
5. An evidence-based estimate of expected energy savings and wider benefits

The European Commission first required individual National Renovation Strategies to be submitted in April 2014 and an updated report must be submitted every three years. Ireland's revision to the National Renovation Strategy was submitted to the European Commission in December 2017 and a decision on its approval is due early in 2018. After a series of stakeholder consultation sessions coordinated by the Irish Green Building Council in 2016, a series of Final Recommendations were presented to the Irish Government in February 2017 that included the recommendation that the next revision of the National Renovation Strategy address issues relating to the deep energy renovation of traditional buildings.[43]

Better Buildings: A National Renovation Strategy for Ireland (2014)

Build Upon: Co-Creating Ireland's National Renovation Strategy 2017-2020 workshop documents

National Energy Efficiency Action Plan for Ireland 2017-2020 (v 4, 2017)

The Buildings Performance Institute Europe (BPIE) published a status report in 2014 on the compliance of 10 European countries with Article 4 of the EED.[44] This report outlines and assesses the strategies these countries had implemented at the time in order to reach their energy efficiency and carbon emission reduction goals. The BPIE brief, *A Snapshot of National Renovation Strategies* provides updates on the progress that nine EU Member States have made in supporting energy renovation in the existing building stock

Renovation Strategies of Selected EU Countries (2014)

A Snapshot of National Renovation Strategies (2017)

[42] *Public Sector Energy Efficiency Strategy* (2017), Dublin: Department of Communications, Climate Action & Environment. Available at: https://www.dccae.gov.ie/en-ie/energy/topics/Energy-Efficiency/national-energy-efficiency-action-plan-(neeap)/Pages/National-Energy-Efficiency-Action-Plan-(NEEAP).aspx.

[43] *Build Upon Final Recommendations: Towards Large Scale Deep Energy Renovation - Unlocking Ireland's Potential* (2017), Dublin: Irish Green Building Council. Available at: http://buildupon.eu/dialogue/countries/ireland/.

[44] Staniaszek, D. (2014) *Renovation Strategies of Selected EU Countries. A Status Report on Compliance with Article 4 of the Energy Efficiency Directive*: Buildings Performance Institute Europe (BPIE). Available at: http://bpie.eu/publication/renovation-strategies-of-selected-eu-countries/ (Accessed: November).

and in tackling barriers to the uptake of deep energy renovation.[45] The report found that the Irish Government has taken steps to address some of the barriers identified in the 2014 version of the National Renovation Strategy, through the establishment of a Behavioural Economics Unit within the SEAI to study what drives consumers to undertake energy renovation works and by assessing the feasibility of a minimum Building Energy Rating.

2.2.3 EN 16883:2017 Conservation of Cultural Heritage

Guidelines for Improving the Energy Performance of Historic Buildings

EN 16883:2017 Conservation of Cultural Heritage – Guidelines for Improving the Energy Performance of Historic Buildings

The technical body for the Conservation of Cultural Heritage within the European Committee for Standardization (CEN) has drafted international guidelines for improving the energy performance of architecturally and culturally significant historic buildings through European Standard EN 16883:2017.[46] These guidelines are based on the national standards of the 34 European Member States.

EN 16883:2017 applies to historic buildings of all types and ages regardless of statutory heritage designation and presents 'a normative working procedure for selecting measures to improve energy performance, based on an investigation, analysis and documentation of the building including its heritage significance' and the impact of these measures on 'the character-defining elements of the building'.

The standard is designed to be used by building owners, authorities and professionals involved in the conservation and refurbishment of historic buildings. The standard aims to facilitate 'the sustainable management of historic buildings' by presenting a systematic approach or procedure to aid building professionals in choosing the most appropriate solutions for each individual case, but 'does not presuppose that all historic buildings need energy performance improvements.'

The Standard outlines four aspects of sustainability to be taken into consideration when prescribing energy improvement works to historic buildings:

[45] *A Snapshot of National Renovation Strategies - Examples from Selected EU Member States* (2017), Brussels: Building Performance Institute Europe (BPIE). Available at: http://bpie.eu/publication/a-snapshot-of-national-renovation-strategies-examples-from-selected-eu-member-states/.

[46] *EN 16883:2017 Conservation of Cultural Heritage - Guidelines for Improving the Energy Performance of Historic Buildings* (2017): European Committee for Standardization.

- **Environmental**: Environmental solutions should be based mainly on renewable resources that have the lowest possible greenhouse gas emissions and should account for all materials and energy used within the whole life cycle of a building (construction, operation, maintenance, refurbishment and demolition). Solutions should respect the special character of the existing building by discouraging the removal or replacement of materials with new materials, which requires a reinvestment of resources and energy with additional greenhouse gas emissions.
- **Economic**: All economic factors, such as market value, revenues and operating costs, should enable the long-term use of historic buildings.
- **Social**: A historic building should contribute aesthetically, functionally and culturally to its local and social context.
- **Cultural**: The management of a historic building should ensure its heritage significance is retained for present and future generations.

The standard asserts that these four values are 'complementary and mutually dependent, rather than isolated' and an appropriate balance should be sought between them. The overall intention of EN 16883:2017 is to 'achieve the best possible energy performance while retaining the heritage significance of the building'. To assess the suitability of energy efficiency measures, it is suggested that the risks and benefits be clearly defined in the following areas:

a. technical compatibility;
b. heritage significance of the building and its settings;
c. economic viability;
d. energy;
e. indoor environmental quality;
f. impact on the outdoor environment;
g. aspects of use.

To assist specifiers, EN 16883:2017 provides building assessment templates in the following areas: Building Information; Legal Information; Building Description; Defining Heritage Significance and Conservation Opportunities and Constraints; Assessment of Past and Present Use and Intended Future Use; Mapping Building's Technical Structure, Condition and Environmental Influences; Energy Performance Assessment; Indoor Environment Assessment; and Sources and Management Information.

2.2.4 EN ISO 13788:2012 Hygrothermal Performance of Building Components and Building Elements

Internal Surface Temperature to Avoid Critical Surface Humidity and Interstitial Condensation - Calculation Methods (Glaser Method)

European and International Standard EN ISO 13788:2012 provides simplified calculation methods, known as the Glaser method, for calculating the internal temperature and relative humidity at which mould growth can occur. Most condensation risk analysis software is based on the methodologies provided in EN ISO 13788:2012, and these assessments have been widely used within the building sector to certify new building products, to satisfy architects' professional indemnity insurance, and to certify that buildings comply with Local Authority Building Controls.[47] However, these methods have been shown to either over- or under-estimate the hygrothermal performance of traditional vapour-permeable building materials and therefore, the building industry is beginning to move toward a greater use of EN 15026:2007, which can account for the wetting and drying cycles of traditional walls.

EN ISO 13788:2012 Hygrothermal Performance of Building Components and Building Elements

The SPAB Research Report 3: Hygrothermal Modelling (2012)

2.2.5 EN 15026:2007 Hygrothermal Performance of Building Components and Building Elements

Assessment of Moisture Transfer by Numerical Simulation

European Standard EN 15026:2007specifies the equations to be used in hygrothermal simulation software to predict one-dimensional transient heat and moisture transfer in multi-layer building envelope components subjected to non-steady internal or external climatic conditions.[48] The SPAB Research Report 3 states that, unlike the Glaser method which only considers the steady-state conduction of heat and vapour diffusion, 'the transient models covered in this standard take account of heat and moisture storage, latent heat effects, and liquid and convective transport under realistic boundary and initial conditions'.[49] The simulation results from the EN 15026 methodology provide more detailed and accurate information on moisture risks in traditional buildings, such as surface or interstitial condensation, and therefore enable the user to select the most appropriate renovation solutions. However, EN 15026:2007 currently does not provide a standard methodology for investigating and simulating the hygrothermal performance of

EN 15026:2007 Hygrothermal Performance of Building Elements and Building Components

Hygrothermal Risk Evaluation for the Retrofit of a Typical Solid-Walled Dwelling (2016)

[47] Browne, D. (2012) *The SPAB Research Report 3: The SPAB Hygrothermal Modelling - Interim Report*: Society for the Protection Ancient Buildings. Available at: https://www.spab.org.uk/advice/research/findings. p 2-3.
[48] *EN 15026:2007 Hygrothermal Performance of Building Components and Building Elements - Assessment of Moisture Transfer by Numerical Assessment* (2007): European Committee for Standardization.
[49] Browne, D. (2012) *The SPAB Research Report 3: The SPAB Hygrothermal Modelling - Interim Report*: Society for the Protection Ancient Buildings. Available at: https://www.spab.org.uk/advice/research/findings. p 15.

additional internal or external insulation applied to the solid walls of existing buildings.[50]

Responsible Retrofit of Traditional Buildings: A Report on Existing Research and Guidance with Recommendations (2012)

The methodology provided by EN 15026:2007 is superior to that of EN 13788:2012 (Glaser method) for traditional buildings because it 'does not assume a dry building operating in a steady-state but promotes the use of dynamic modelling which is able to take into account the effects on a building, over time, of specific material properties and the local environment'.[51] The STBA *Responsible Retrofit of Traditional Buildings* report explains that by using 'a more detailed description of the characteristics of moisture behaviour within individual building materials', the EN 15026:2007 methodology is able to model the behaviour of moisture as both a liquid and a vapour, as well as the effects of wind-driven rain on the building fabric.

The drawback of EN 15026:2007 is that it requires a greater level of operator knowledge and therefore different users can produce a wide variety of results for the same building based on the validity of the climatic and building material data they entered into the simulation software. In order to produce accurate results, the software requires data from the following inputs: [52]

a. Assembly and inclination of building components
b. Hygrothermal material parameters and functions
c. Boundary conditions, surface transfer for internal and external climate
d. Initial condition, calculation period, numerical control parameters
e. site specific weather data and building orientation

Results can be output as:

1. Temperature and heat flux distributions and temporal variations
2. Water content, relative humidity and moisture flux distributions and temporal variations

2.2.6 CSN EN 15978:2011 Sustainability of Construction Works

[50] Ibid. p 5-6.
[51] May, N. and Rye, C. (2012) *Responsible Retrofit of Traditional Buildings: A Report on Existing Research and Guidance with Recommendations*, London: Sustainable Traditional Buildings Alliance. Available at: http://stbauk.org/stba-guidance-research-papers. p 24.
[52] Browne, D. (2012) *The SPAB Research Report 3: The SPAB Hygrothermal Modelling - Interim Report*: Society for the Protection Ancient Buildings. Available at: https://www.spab.org.uk/advice/research/findings. p 15.

Assessment of Environmental Performance of Buildings - Calculation Method

European Standard EN15978 specifies the calculation method used to assess the environmental performance of new, existing and renovated buildings.[53] The Life Cycle Assessment (LCA) covers all construction products, processes and services used over the life span of the building and is based on data obtained from Environmental Product Declarations (EPD), their "information modules" (prEN 15804) and other quantified environmental information. The standard also specifies standardised means for reporting the outcome of the assessment.

CSN EN 15978 Sustainability of Construction Works

CSN EN 15978:2011 provides guidance on and regulates:[54]

a. the description of the object of assessment;
b. the system boundary that applies at the building level;
c. the procedure to be used for the inventory analysis;
d. the list of indicators and procedures for the calculations of these indicators;
e. the requirements for presentation of the results in reporting and communication;
f. and the requirements for the data necessary for the calculation.

2.2.7 BS 7913:2013 Guide to the Conservation of Historic Buildings

Although BS 7913:2013 is not a European Standard, it is worth mentioning here as the first and only British Standard to address the conservation of historic buildings and for the guidance it provides on how to improve the energy efficiency of traditional buildings with historically appropriate materials and techniques.[55] BS 7913 was written for building professionals that may not be familiar with conservation theories and practice. It provides a checklist of matters to be considered when working on any historic building and clear guidance on typical building works that may be unsuitable for traditional buildings, such as the use of cement renders and mortars, chemical damp proof courses and solid wall insulation. Section 5.3.1 makes the case for good maintenance and repair as a viable way to reduce heat loss before more aggressive deep energy renovation measures are considered for traditional

BS 7913:2013 Guide to the Conservation of Historic Buildings

Why Buildling Conservation Needs BS 7913 (2015)

[53] *EN 15978:2011 Sustainability of Construction Works - Assessment of Environmental Performance of Buildings - Calculation Method* (2011): European Committee for Standardization.
[54] Ibid.
[55] *BS 7913:2013 Guide to the Conservation of Historic Buildings* (2013). London: British Standards Institution.

buildings.[56] As a whole, the Standard highlights the importance of understanding how traditional buildings work, how they were designed to be used, and how subsequent changes over the years are affecting their performance before any steps are taken to correct failures. BS 7913:2013 covers the following:

a. The conservation process and history of building conservation
b. Heritage values and significance
c. Using significance as a framework for managing the historic environment
d. Condition surveys, investigation techniques and equipment, performance assessment and pathology
e. Maintenance: assessing common defects and repair issues
f. New development and adaptation
g. Sustainability and energy efficiency
h. Heritage and project management and supervision
i. Competency and Accreditation

2.2.8 Additional Relevant Standards

- EN ISO 10456:2007 Building materials and products - Hygrothermal properties - Tabulated design values and procedures for determining declared and design thermal values
- EN 15603 Energy performance of buildings - Overall energy use and definition of energy ratings (See Section 2.3.9)
- CSN EN 16096 Conservation of cultural property - Condition survey and report of built cultural heritage
- CSN EN 16247-2 Energy audits - Part 2: Buildings
- EN ISO 13790 Energy performance of buildings - Calculation of energy use for space heating and cooling

EN ISO 10456:2007 Building Materials and Products

EN 15603:2008 Energy Performance of Buildings

CSN EN 16096:2012 Conservation of Cultural Property

CSN EN 16247:2014-2 Energy Audits – Part 2: Buildings

EN ISO 13790:2008 Energy Performance of Buildings

[56] Edwards, J. (2015) 'Why Building Conservation Needs BS 7913', *Context,* 141, pp. 45-46.

2.3 Irish Building Standards, Regulations and Policies

Building Regulations were first introduced in Ireland in draft form in 1976, were revised in 1981, and full legally binding Building Regulations came into force in 1991.[57] As the Building Regulations were written to apply to new construction, notes on how they apply to existing buildings are provided in a separate (and little known) addendum, *The Application of the Building Regulations to Works in Existing Buildings*.[58]

The Application of the Building Regulations to Works in Existing Buildings

The Department of Communications, Climate Action and the Environment (DCCAE) governs energy efficiency in buildings through its standards and regulations. The Sustainable Energy Authority of Ireland (SEAI) is a national body that oversees the application of governmental standards and regulations by promoting the development of sustainable technologies, energy structures and practices.[59] The SEAI administers governmental grants to facilitate research in these areas and also advises and develops programmes to promote the energy renovation of Ireland's building stock. To implement the requirements of the EU Energy Performance of Buildings Directive, the SEAI developed the Dwelling Energy Assessment Procedure (DEAP) to assess the Building Energy Ratings (BERs) of new and existing buildings. As pressure mounts to meet the EU 2020 targets, it is essential that all building practitioners are adequately equipped with the training and information to be able to judge the appropriateness of renovation measures for traditional buildings.

EFFESUS Deliverable D1.3: Assessment of European and National Policies Related to Energy Efficiency and Heritage Conservation

2.3.1 S.I. No. 3 of 1990 Building Control Act

The Building Control Act of 1990 was passed to establish a Building Control Authority and to facilitate the creation and management of building regulations. Of interest to this study is *Section 4. Dispensation or Relaxation of Building Regulations*, which states that a building control authority has the power to grant dispensation from, or the relaxation of, any requirement of the building regulations to any building works it deems reasonable. If

S.I. No. 3 of 1990 Building Control Act

[57] Badurek, M., Hanratty, M. and Sheldrick, B. (2014) *TABULA Building Typology Brochure Ireland: A Detailed Study on the Energy Performance of Typical Irish Dwellings*, Ireland: Intelligent Energy Europe. Available at: http://episcope.eu/fileadmin/tabula/public/docs/brochure/IE_TABULA_TypologyBrochure_EnergyAction.pdf. p 7.

[58] *The Application of the Building Regulations to Works in Existing Buildings*, Dublin: Department of Housing, Planning and Local Government. Available at: http://www.housing.gov.ie/housing/building-standards/other/application-building-regulations-works-existing-buildings.

[59] *Deliverable D1.3: Assessment of European and National Policies related to Energy Efficiency and Heritage Conservation* (2013): EFFESUS. Available at: http://www.effesus.eu/wp-content/uploads/2016/01/D-1.3_Assessment-of-European-and-national-policies-related-to-energy-efficiency-and-heritage-conservation.pdf. p 36.

the applicant is not notified within two months of the date of the application, it can be assumed that dispensation or a relaxation has been granted. The Building Control Authority may however agree upon an extension of the review period with the applicant.

Section 4 of the Building Control Act could be used as a pathway to compliance with the building regulations for traditional buildings undergoing deep energy renovation. The onus would be on the specifier/applicant to demonstrate the validity of the proposed approach; however, this report could be referenced in support. Ideally, the process would be simplified with the development of technical guidance and a NSAI Code of Practice to guide the energy renovation of traditional buildings.

2.3.2 S.I. No. 243 of 2012 European Union (Energy Performance of Buildings) Regulations

S.I. No. 243 of 2012 European Union (Energy Performance of Buildings) Regulations 2012

Statutory Instrument No. 243 of 2012 came into operation on 9 January 2013 and transposes EU Directive 2010/31/EU (EPBD) into Irish legislation. S.I. No. 243 of 2012 replaces the preceding S.I. No. 666 of 2006 European Communities (Energy Performance of Buildings) Regulations and its subsequent amendments (S.I. No. 229 of 2008 and S.I. No. 591 of 2008), which transposed Articles 5 and 7 of the EPBD Directive 2002/91/EC into Irish law.[60] S.I. No. 243 of 2012 requires that a Building Energy Rating (BER) certificate be commissioned for every property built or sold after 9 January 2013.

Certain buildings in Ireland are exempted from meeting the requirements of the S.I. No. 243 of 2012, including: National Monuments; Protected or Proposed Protected Structures; Places of Worship; temporary buildings; non-residential agricultural and industrial buildings; and buildings with a floor area under 50m^2.

2.3.3 S.I. No. 538 of 2017 Building Regulations (Part L Amendment)

S.I. 538 of 2017 Building Regulations (Part L Amendment)

S.I. No. 259 of 2011 Building Regulations (Part L Amendment)

Statutory Instrument No. 538 of 2017[61] is an amendment to S.I. No. 259 of 2011[62], which was published on 1 December 2017 and comes into force on 1 January 2019. Until then, S.I. No. 259 of 2011 regulates the conservation of fuel and energy in buildings through the Part L Amendment. Further guidance on the statutory requirements are provided in Technical Guidance Document (TGD) L: Conservation of Fuel and Energy for Dwellings and Non-Dwellings (see Section 2.3.15).

[60] *S.I. No. 243 of 2012 European Union (Energy Performance of Buildings) Regulations* (2013). Dublin: The Stationery Office.
[61] *S.I. No. 538 of 2017 Building Regulations (Part L Amendment)* (2017). Dublin: The Stationery Office.
[62] *S.I. No. 259 of 2011 Building Regulations (Part L Amendment)* (2011). Dublin: The Stationery Office.

For existing buildings, S.I. No. 259 of 2011 The Part L Amendment states that the energy efficiency and carbon emission requirements shall be met by:[63]

Technical Guidance Document L: Conservation of Fuel and Energy – Dwellings (2017)

Technical Guidance Document L: Conservation of Fuel and Energy – Buildings other than Dwellings (2008)

a. limiting heat loss and, where appropriate, maximising heat gain through the fabric of the building;
b. controlling, as appropriate, the output of the space heating and hot water systems;
c. limiting the heat loss from pipes, ducts and vessels used for the transport or storage of heated water or air;
d. providing that all oil and gas fired boilers installed as replacements in existing dwellings shall meet a minimum seasonal efficiency of 90% where practicable.

For existing buildings other than dwellings, S.I. 538 of 2017 revises and extends this list to:

a. limiting the heat loss and, where appropriate, availing of the heat gains through the fabric of the building;
b. providing energy efficient space heating and cooling systems, heating and cooling equipment, water heating systems and ventilation systems, with effective controls;
c. ensuring that the building is appropriately designed to limit need for cooling and, where air-conditioning or mechanical ventilation is installed, that installed systems are energy efficient, appropriately sized and adequately controlled;
d. limiting the heat loss from pipes, ducts and vessels used for the transport or storage of heated water or air;
e. limiting the heat gains by chilled water and refrigerant vessels, and by pipes and ducts that serve air-conditioning systems;
f. providing energy efficient artificial lighting systems and adequate control of these systems;
g. providing to the building owner sufficient information about the building fabric, the fixed building services, controls and their maintenance requirements when replaced so that the building can be operated in such a manner as to use no more fuel and energy than is reasonable; and
h. when a building undergoes major renovation, the minimum energy performance requirement of the building or the renovated part thereof is upgraded in order to meet the cost optimal level of energy performance insofar as this is technically, functionally and economically feasible.

[63] Ibid. p 4.

2.3.4 S.I. No. 46 of 2015 Climate Action and Low Carbon Development Act

Statutory Instrument No. 46 of 2015 provides plans made by the Irish Government to assist the national transition to a 'low carbon, climate resilient and environmentally sustainable economy' and it supports the establishment of an independent Climate Change Advisory Council to pursue these efforts.[64] The Climate Change Advisory Council published the first of its Annual Review reports in 2017, which assess the progress made in Ireland towards achieving the nation's energy efficiency and GHG reduction goals.[65] This Act provides legislative support to Ireland's 2014 National Policy Position on Climate Change and establishes the requirement for a National Mitigation Plan (NMP) to be updated and published on a 5-year basis.[66] Ireland's first NMP was published on 19 July 2017 and it not only proposes measures to address the 2020 targets, but it also sets out the government's plans to transition the country to a decarbonised society by 2050.[67] In accordance with Section 5 of the Climate Action and Low Carbon Development Act, a National Adaptation Framework was published in January 2018, which 'specifies the national strategy for the application of adaptation measures in different sectors and by local authorities'.[68]

S.I. No. 46 of 2015 Climate Action and Low Carbon Development Act

Climate Change Advisory Council Annual Review (2017)

European Commission Report: National Reform Programme – Ireland (2017)

National Mitigation Plan (2017)

National Adaptation Framework (2018)

2.3.5 S.I. No. 83 of 2007 Planning and Development Regulations

Statutory Instrument No. 83 of 2007 regulates micro-renewable energy technologies (ie. solar photovoltaic and thermal collector panels, ground source or air source heat pumps, combined heat and power systems, biomass boilers, etc.) in the domestic sector.[69] The purpose of S.I. No. 83 of 2007 is to provide exemptions for renewable energy sources through an amendment to Part 1 of Schedule 2 of the Planning and Development Regulations 2001. See also S.I. No. 235 of 2008 Planning and Development Regulations for

S.I. No. 83 of 2007 Planning and Development Regulations

S.I. No. 235 of 2008 Planning and Development Regulations

[64] *S.I. No. 46 of 2015 Climate Action and Low Carbon Development Act* (2015). Dublin: The Stationery Office.
[65] *Climate Change Advisory Council Annual Review* (2017), Dublin: Climate Change Advisory Council. Available at: http://www.climatecouncil.ie/councilpublications/annualreviewandreport/.
[66] *European Semester Reports: National Reform Programme - Ireland* (2017), Brussels: European Commission. Available at: https://ec.europa.eu/info/business-economy-euro/economic-and-fiscal-policy-coordination/eu-economic-governance-monitoring-prevention-correction/european-semester/european-semester-your-country/ireland_en.p 40.
[67] *National Mitigation Plan* (2017), Dublin: Department of Communicationsv Climate Action and Environment. Available at: https://www.dccae.gov.ie/en-ie/climate-action/topics/mitigation-reducing-ireland's-greenhouse-gas-emissions/national-mitigation-plan/Pages/default.aspx.
[68] *National Adaptation Framework: Planning for a Climate Resilient Ireland* (2018), Dublin: Department of Communications, Climate Action and Environment. Available at: https://www.dccae.gov.ie/en-ie/climate-action/topics/adapting-to-climate-change/national-adaptation-framework/Pages/default.aspx.
[69] *S.I. No. 83 of 2007 Planning and Development Regulations* (2007). Dublin: The Stationery Office.

regulations on the implementation of micro-renewables in the industrial, business and agricultural sectors.[70]

2.3.6 I.S. EN 16883:2017 Conservation of Cultural Heritage

Guidelines for Improving the Energy Performance of Historic Buildings

I.S. EN 16883:2017 Conservation of Cultural Heritage

EN 16883:2017 was transposed into Irish legislation on 4 June 2017 and is Ireland's only standard providing guidelines for sustainably and sensitively improving the energy performance of historic architecturally and culturally significant buildings.[71] This new standard is written for local authorities, building practitioners and building owners and provides a step-by-step guide to the conservation and refurbishment of historic buildings (see Section 2.2.3).

2.3.7 I.S. EN ISO 13788:2012 Hygrothermal Performance of Building Components and Building Elements

Internal Surface Temperature to Avoid Critical Surface Humidity and Interstitial Condensation - Calculation Methods

I.S. EN ISO 13788:2012 Hygrothermal Performance of Building Components and Building Elements

EN ISO 13788:2012 was transposed into Irish legislation on 3 December 2013 in its identical form as I.S. EN ISO 13788:2012 (see Sections 2.2.4 and 2.4.4.2).

2.3.8 I.S. EN 15026:2007 Hygrothermal Performance of Building Components and Building Elements

Assessment of Moisture Transfer by Numerical Simulation

I.S. EN 15026:2007 Hygrothermal Performance of Building Components and Building Elements

EN 15026:2007 was transposed into Irish legislation on 1 June 2007 in its identical form as I.S. EN 15026:2007 (see Sections 2.2.5 and 2.4.4.3).[72]

2.3.9 I.S. EN 15603:2008 Energy Performance of Buildings

Overall Energy use and Definition of Energy Ratings

[70] *S.I. No. 235 of 2008 Planning and Development Regulations* (2008). Dublin: The Stationery Office.

[71] *I.S. EN 16883:2017: Conservation of Cultural Heritage - Guidelines for Improving the Energy Performance of Historic Buildings* (2017). Dublin: National Standards Authority of Ireland.

[72] *I.S. EN 15026:2007 Hygrothermal Performance of Building Components and Building Elements - Assessment of Moisture Transfer by Numerical Simulation* (2007): National Standards Authority of Ireland.

I.S. EN 15603:2008 was transposed into Irish legislation on 4 April 2008 and is identical to the European Standard EN 15603. EN 15603 sets the parameters for the assessment and allocation of energy performance certificates (building energy ratings in Ireland) for new and existing buildings.

I.S. EN 15603:2008 Energy Performance of Buildings

2.3.10 I.S. EN 1745:2012 Masonry and Masonry Products

Methods for Determining Thermal Properties

Irish Standard EN 1745:2012 describes procedures for determining the thermal properties of masonry and masonry products.

I.S. EN 1745:2012 Masonry and Masonry Products

2.3.11 NSAI S.R. 54:2014 Code of Practice for the Energy Efficient Retrofit of Dwellings

Standard Recommendation 54:2014 (enacted 7 March 2014) was collaboratively developed by the Department of the Environment, Community and Local Government, the Department of Communications, Energy and Natural Resources, the Sustainable Energy Authority of Ireland (SEAI), the National Standards Authority of Ireland (NSAI) and the Building Research Establishment (BRE) to provide the code of practice for the energy efficient renovation of dwellings in Ireland.

NSAI S.R. 54:2014 Code of Practice for the Energy Efficient Retrofit of Dwellings

S.R. 54:2014 provides three case studies to guide practitioners (two modern cavity wall dwellings and one 1930s solid concrete wall dwelling), however the recommendations within these do not apply to traditional buildings. According to S.R. 54:2014: [73]

> *Solid walls are constructed of no-fines concrete, mass concrete, solid block or pre-cast concrete panels. The majority of these constructions were built between 1940 and the late 1960s. No-fines and mass concrete walls are the most common form of solid wall. The thermal performance of these types of construction is similar, and so the insulation solutions are similar.*

There is currently no mention of other traditional solid masonry walls or that traditional building materials need to 'breathe' and therefore, the information provided in S.R. 54:2014 may be guiding building practitioners toward internal and external solid wall insulation solutions that would be unsuitable for traditional buildings and may lead to unintended condensation and occupant health risks post-renovation.

[73] *Standard Recommendation 54:2014: Code of Practice for the Energy Efficient Retrofit of Dwellings* (2014), Dublin: National Standards Authority of Ireland. Available at: https://www.nsai.ie/S-R-54-2014-Code-of-Practice.aspx. p 90.

2.3.12 Technical Guidance Document C: Site Preparation and Resistance to Moisture

Technical Guidance Document C (1997 with 2004 amendments) provides guidance on preventing moisture problems in buildings.[74] The document was written for new construction and advises that not all recommendations would be suitable for existing buildings. The best practice guidance in Section 3: Resistance to Weather and Ground Moisture therefore does not apply to traditional buildings constructed of natural vapour-permeable materials.

Technical Guidance Document C: Site Preparations and Resistance to Moisture (1997)

2.3.13 Technical Guidance Document D: Materials and Workmanship

Technical Guidance Document (TGD) D provides guidance to assist building professionals with compliance in relation to the Part D Amendment of Building Regulations S.I. No. 224 of 2013. Irish Building Regulations apply to new constructions and to extensions and material alterations to existing buildings. Therefore, the regulations apply when renovation works are being undertaken on traditional buildings, but the guidance within does not correspond with the vapour-permeable performance of traditional materials and construction methods.

Technical Guidance Document D: Materials and Workmanship (2013)

As such, TGD D provides incorrect advice in terms of the required permeability of materials in traditional buildings in order for them to shed moisture during drying periods. For instance, under the section *Resistance to Moisture*, TGD D recommends:[75]

> *1.2 Where any material is likely to be adversely affected by condensation, by moisture from the ground or by airborne moisture such as rain or snow: - (a) the construction should prevent the passage of moisture to the material, or (b) the material should be treated or otherwise protected from moisture.*

In general, the guidance provided by TGD D is too simplistic and needs to be expanded to address the hygrothermal properties of traditional buildings and should provide specifiers with guidance on how to comply with the building regulations in special circumstances.

[74] *Technical Guidance Document C: Site Preparation and Resistance to Moisture* (2004), Dublin: Department of the Environment, Heritage and Local Government. Available at: http://www.housing.gov.ie/housing/building-standards/tgd-part-c-site-preparation-and-resistance-moisture/technical-guidance-0.

[75] *Technical Guidance Document D: Materials and Workmanship* (2013), Dublin: Department of the Environment, Community and Local Government. Available at: http://www.housing.gov.ie/housing/building-standards/tgd-part-d-materials-and-workmanship/technical-guidance-document-d-0.

2.3.14 Technical Guidance Document F: Ventilation

Technical Guidance Document F: Ventilation[76], together with TGD C, acts as the Irish equivalent of British Standard 5250:2011+A1:2016 Code of Practice for Control of Condensation in Buildings. TGD F provides guidance on the functions and means of achieving adequate ventilation in new and existing buildings where applicable. Adequate ventilation is required in all buildings to remove excess moisture to prevent condensation and mould growth and to limit the concentration of pollutants indoors. While the 30-page TGD F provides basic guidance, BS 5250 is much more substantial at 106 pages, and provides guidance on diagnosing dampness, calculating condensation risks, design guidance for various aspects of a building, as well as guidance for occupiers to avoid excessive moisture related problems.[77]

Technical Guidance Document F: Ventilation (2009)

BS 5250:2011+A1:2016 Code of Practice for Control of Moisture in Buildings

2.3.15 Technical Guidance Document L: Conservation of Fuel and Energy

Dwellings and Non-Dwellings

Technical Guidance Document L for Dwellings[78] and Non-Dwellings[79] are the corresponding guidance for the Part L Amendment of the Building Regulations S.I. No. 259 of 2011[80]. TGD L provides guidance on routes to compliance with the Building Regulations and should be read in conjunction with Part L of the Second Schedule to the Building Regulations 1997 (S.I. No. 497 of 1997) and its amendments S.I. No. 259 of 2011 and S.I. 538 of 2017.

The TGD L for Dwellings and Non-Dwellings integrate the European energy efficiency standards set by the EPBD Directive[81] by establishing minimum standards for heat loss, thermal bridging, air infiltration and the energy efficiency of heating and cooling systems. Protected Structures or those proposed for protection are exempt from the requirements of the Part L Amendment (Conservation of Fuel and Energy) Building Regulations when

Technical Guidance Document L: Conservation of Fuel and Energy – Dwellings (2017)

Technical Guidance Document L: Conservation of Fuel and Energy – Buildings other than Dwellings (2008)

Implementing the Energy Performance Building Directive (2016)

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[76] *Technical Guidance Document F: Ventilation* (2009), Dublin: Department of the Environment, Heritage and Local Government. Available at: http://www.housing.gov.ie/housing/building-standards/tgd-part-f-ventilation/technical-guidance-document-f-ventilation.

[77] Browne, D. (2012) *The SPAB Research Report 3: The SPAB Hygrothermal Modelling - Interim Report*: Society for the Protection Ancient Buildings. Available at: https://www.spab.org.uk/advice/research/findings. p 9.

[78] *Technical Guidance Document L: Conservation of Fuel and Energy - Dwellings* (2017), Dublin: Department of Housing, Planning and Local Government. Available at: http://www.housing.gov.ie/housing/building-standards/tgd-part-l-conservation-fuel-and-energy/technical-guidance-document-l-6.

[79] *Technical Guidance Document L: Conservation of Fuel and Energy - Buildings other than Dwellings* (2017), Dublin: Department of the Housing, Planning and Local Government. Available at: http://www.housing.gov.ie/housing/building-standards/tgd-part-l-conservation-fuel-and-energy/building-regulations-2017.

[80] *S.I. No. 259 of 2011 Building Regulations (Part L Amendment)* (2011). Dublin: The Stationery Office.

[81] *Implementing the Energy Performance of Buildings Directive (EPBD).* (2015) Lisbon: Portuguese Energy Agency (ADENE). P 341-354.

undergoing material alterations or a change of use.[82] The 2017 amended edition of TGD L for Non-Dwellings incorporates a new section on Near Zero Energy Buildings (NZEBs) to correspond with the requirement in Directive 2010/31/EU that all newly constructed buildings must be built to the NZEB standards by 31 December 2020. An updated TGD L for Dwellings is due to be released in 2018.

Advice Series: Energy Efficiency in Traditional Buildings (2010)

The STBA Policy Mapping report warns that the minimum energy efficiency standards set by the Part L Amendments within national building regulations are inappropriate for traditional buildings.[83] The current TGD L for Dwellings also makes no mention of vapour-permeable materials in the section on existing buildings. *Appendix B: Fabric Insulation of TGD L* repeatedly recommends the use of a vapour control layer (VCL) with IWI and roof insulation and states that 'In general, the insulation material must be of low vapour permeability', making no mention of the unsuitability of these recommendations to traditional buildings. However, the following clauses were added in 2010 to Approved Document L1B: Conservation of Fuel and Power in Existing Buildings of the English Building Regulations, importantly differentiating traditional buildings from the energy efficiency standards set for modern existing buildings and directing building professionals to seek technical renovation advice from Historic England:[84]

STBA Policy Mapping report (2017)

English Building Regulations - Approved Document L1B: Conservation of Fuel and Power in Existing Buildings (enacted 2010, last amended 2016)

> *Approved Document Part L1B Amendment for England:*
>
> *Historic and traditional buildings where special considerations may apply*
>
> *3.8 There are three further classes of buildings where special considerations in making reasonable provision for the conservation of fuel or power may apply:*
>
> *a) buildings which are of architectural and historical interest and which are referred to as a material consideration in a local authority's development plan or local development framework;*
>
> *b) buildings which are of architectural and historical interest within national parks, areas of outstanding natural beauty, registered historic parks and gardens, registered battlefields, the curtilages of scheduled ancient monuments, and world heritage sites;*

[82] *Advice Series: Energy Efficiency in Traditional Buildings* (2010), Dublin: Department of the Environment, Heritage and Local Government. Available at: https://www.chg.gov.ie/heritage/built-heritage/architectural-heritage-advisory-service/advice-for-owners/. p 69.

[83] *STBA Policy Mapping* (2017): Sustainable Traditional Buildings Alliance (STBA). Available at: http://stbauk.org/what-we-do/policy-mapping. p 19.

[84] *Approved Document L1B: Conservation of Fuel and Power in Existing Dwellings* (2016), London: HM Government. Available at: https://www.gov.uk/government/publications/conservation-of-fuel-and-power-approved-document-l. p 8.

c) buildings of traditional construction with permeable fabric that both absorbs and readily allows the evaporation of moisture.

3.9 When undertaking work on or in connection with a building that falls within one of the classes listed above, the aim should be to improve energy efficiency as far as is reasonably practicable. The work should not prejudice the character of the host building or increase the risk of long-term deterioration of the building fabric or fittings.

3.10 The guidance given by English Heritage [sic] should be taken into account in determining appropriate energy performance standards for building work in historic buildings.

3.11 In general, new extensions to historic or traditional dwellings should comply with the standards of energy efficiency set out in this Approved Document. The only exception would be where there is a particular need to match the external appearance or character of the extension to that of the host building (see paragraph 4.2).

3.12 Particular issues relating to work in historic buildings that warrant sympathetic and where advice from others could therefore be beneficial include:

a) restoring the historic character of a building that has been subject to previous inappropriate alteration, e.g. replacement windows, doors and rooflights;

b) rebuilding a former historic building (e.g. following a fire or filling a gap site in a terrace);

c) making provisions enabling the fabric of historic buildings to 'breathe' to control moisture and potential long-term decay problems.

3.13 In assessing reasonable provision for energy efficiency improvements for historic buildings of the sort described in paragraphs 3.7 and 3.8, it is important that the [Building Control Body] takes into account the advice of the local authority's conservation officer. The views of the conservation officer are particularly important where building work requires planning permission and/or listed building consent

Furthermore, Section 5 of the Approved Document L1B includes a section on the renovation of retained thermal elements.[85] Under this section, Table 3 sets out the (a) Threshold U-value W/m^{2}K and (b) Improved U-value W/m^{2}K for different variations of wall, floor and roof systems. The document states that where a thermal

[85] Ibid. p 17.

element is subject to renovation works, the performance of the whole thermal element should be renovated to meet or better the Improved U-value W/m^{2}K. A solid wall renovated with internal or external insulation is expected to achieve an Improved U-value of 0.30 W/m^{2}K (which is surprisingly low) but should not exceed the Threshold U-value of 0.70 W/m^{2}K. However, for instances where the Improved U-value is not achievable, article 5.9 advises:

> *5.9 If achievement of the relevant U-value set out in column (b) of Table 3 is not technically or functionally feasible or would not achieve a simple payback of 15 years or less, the element should be upgraded to the best standard that is technically and functionally feasible and which can be achieved within a single payback of no greater than 15 years. Guidance on this approach is given in Appendix A.*

This clause gives specifiers some flexibility in meeting the building regulations and also relieves homeowners from unrealistic financial commitments that may keep them from investing in thermal upgrades at all. Furthermore, Article 5.12 clarifies that homeowners are not expected to sacrifice valuable living space and possibly the resale value of their home to achieve the minimum Improved U-value, stating:[86]

> *5.12 Examples of where lesser provision than column (b) might apply are where the thickness of the additional insulation might reduce usable floor area of any room by more than 5 per cent or create difficulties with adjoining floor levels, or where the weight of the additional insulation might not be supported by the existing structural frame.*

Finally, Table A1 in *Appendix A: Work to Thermal Elements* sets out the target performance level for various building systems (i.e. pitched roofs, solid walls, dormer window, etc.) that would be considered reasonable under ordinary circumstances. The table also lists typical methods to achieve these standards and corresponding considerations to be taken into account with regard to reasonableness, practicality and cost-effectiveness. For instance, the target U-value given for a pitched roof is 0.16 W/m^{2}K, insulated with 250mm mineral or cellulose fibre laid between and across ceiling joints. The document then advises that specifiers assess condensation risks and make appropriate provisions in accordance with the requirements of the English Part C – Control of Condensation. To further assist building specifiers to demonstrate compliance with the building regulations in Ireland, a table such as this should be included in the revised TGD L for Dwellings (replacing Table 5 in the 2011 version) and should be expanded further to include additional building elements, typical construction methods

[86] Ibid. p 18.

and considerations to be assessed prior to energy renovation works.

Historic England supports the Government's aim to improve the energy efficiency of traditional and historic buildings through the statutory guidance provided by Approved Documents L1B and L2B and has subsequently published additional advisory documents to assist building practitioners in the process.[87]

EEHB Series: Application of Part L of the Building Regulations to Historic and Traditionally Constructed Buildings (2017)

2.3.16 National Energy Efficiency Action Plan for Ireland 2009-2020

The current National Energy Efficiency Action Plan (NEEAP) for Ireland is the fourth revision and lays out the energy reduction targets and means to achieve these targets across all sectors in Irish society. According to SEAI assessments, by the end of 2016, Ireland had reduced energy use across the residential, commercial, industry, public and transport sectors by 18,654 GWh on the target of 31,925 GWh, which equates to less than a 12% reduction on the national 2020 target of 20%.[88] The *Current Trajectory Scenario* estimated by the SEAI projects that Ireland will miss its national energy efficiency target by nearly 4%, meaning Ireland will likely miss all three of its 2020 targets and will incur significant EU fines as a result. Furthermore, if drastic changes are not made in the national energy policies, Ireland is on course to see renewable energy contribution fall from 13% in 2020 to 12% in 2030.[89]

National Energy Efficiency Plan for Ireland (v 4, 2017)

Ireland's Energy Projections: Progress to Targets, Challenges and Impacts (2017)

Ireland's Energy Targets: Progress, Ambitions & Impacts – Summary to Policy-Makers (2016)

Overall, Ireland has committed to increase energy efficiency and to reduce greenhouse gas emissions by 20% in respect to the 2005 levels. However, Ireland signed up to an even more ambitious target of a 33% improvement in energy efficiency for its public sector to provide 'leadership on energy efficiency for the whole of our economy and society'. The NEEAP states that energy use reductions in the public sector will contribute to the overall target. By the end of 2015, energy efficiency across the public sector had improved by 21%.

2.3.17 Better Buildings: A National Renovation Strategy for Ireland

Article 4 of the Energy Efficiency Directive (Directive 2012/27/EU) requires Member States to set out long-term plans for improving

[87] Pickles, D., Brocklebank, I. and Wood, C. (2017a) *Energy Efficiency and Historic Buildings: Application of Part L of the Building Regulations to Historic and Traditionally Constructed Buildings*, London: Historic England. Available at: https://historicengland.org.uk/images-books/publications/energy-efficiency-historic-buildings-ptl/.

[88] *National Energy Efficiency Action Plan for Ireland: 2017-2020* (2017). Dublin: Department of Communications, Climate Action & Environment.p 8.

[89] *Ireland's Energy Projections: Progress to Targets, Challenges and Impacts* (2017), Dublin: Sustainable Energy Authority of Ireland (SEAI). Available at: https://www.seai.ie/resources/publications/Irelands_Energy_Projections.pdf. p 1.

energy efficiency in the built environment and Ireland's first national renovation strategy was published by the Department of Communications, Energy and Natural Resources in 2014.[90] For the first National Renovation Strategy, resources and time were primarily devoted to evaluating the characteristics of the overall building stock in Ireland. In preparation for the required 2017 revision, the White Paper *Ireland's Transition to a Low Carbon Energy Future 2015 -2030* was prepared to set out a framework to guide policy.[91] A series of stakeholder consultation sessions were organised jointly by the Department of Communications, Climate Action and Environment and the Irish Green Building Council (IGBC) around the country throughout 2016 and 2017. The final recommendations from these sessions were published in February 2017 as part of the IGBC report series *Towards Large Scale Deep Energy Renovation: Unlocking Ireland's Potential*[92], and have informed the second edition of the *Long Term Renovation Strategy for Ireland 2017 – 2020*[93].

The 2014 National Renovation Strategy for Ireland makes no mention of how energy efficiency improvement works should be implemented in traditional or heritage buildings. The 2017 revision of the National Renovation Strategy was sent to the European Commission in December 2017 and is due to be published in early 2018.

Better Buildings: A National Renovation Strategy for Ireland (2014)

Ireland's Transition to a Low Carbon Energy Future 2015 – 2030 (2015)

Build Upon: Co-Creating Ireland's National Renovation Strategy 2017-2020 workshop documents

Final Recommendations for a Better National Renovation Strategy (2017)

Long Term Renovation Strategy for Ireland 2017 2020 (2017)

[90] *Better Buildings: A National Renovation Strategy for Ireland* (2014), Ireland: Department of Communications, Energy and Natural Resources. Available at: http://www.dccae.gov.ie/en-ie/energy/topics/Energy-Efficiency/ireland%27s-national-renovation-strategy/Pages/Ireland%27s-Renovation-Strategy.aspx.

[91] *Ireland's Transition to a Low Carbon Energy Future 2015-2030* (2015), Dublin: Department of Communications, Energy & Natural Resources. Available at: https://www.dccae.gov.ie/en-ie/energy/topics/Energy-Initiatives/energy-policy-framework/white-paper/Pages/White-Paper-on-Energy-Policy-in-Ireland-.aspx.

[92] *Build Upon Final Recommendations: Towards Large Scale Deep Energy Renovation - Unlocking Ireland's Potential* (2017), Dublin: Irish Green Building Council. Available at: http://buildupon.eu/dialogue/countries/ireland/.

[93] *Long Term Renovation Strategy for Ireland 2017-2010* (2017). Dublin: Department of Communications, Climate Action and Environment.

2.4 Understanding Traditional Buildings

2.4.1 Building Physics and Hygrothermal Behaviour

Nearly all buildings constructed in Ireland from medieval times up until 1940 were constructed using traditional methods[94], but what is a 'traditional' building? According to the 2010 DEHLG Advice Series publication *Energy Efficiency in Traditional Buildings*, traditional buildings in Ireland primarily consists of those built with solid masonry walls of brick or stone, often originally finished with a lime-based render, single-glazed timber or metal windows, and a timber-framed roof clad in slate, tiles, copper or lead. Solid masonry walls do not contain an air-filled cavity but were instead often filled with small stones or lime mortar. Brick walls were finished internally with a lime-based plaster while rubble walls were finished both internally and externally with a breathable lime-based plaster that allowed internal moisture to escape through the walls.

Advice Series: Energy Efficiency in Traditional Buildings (2010)

Advice Series: Maintenance - A Guide to the Care of Older Buildings (2007)

HES Technical Advice Note 15: External Lime Coatings on Traditional Buildings (2001)

HES Short Guide 6: Lime Mortars in Traditional Buildings (2014)

HES INFORM Guide: Lime and Cement Mortars in Traditional Buildings (2016)

Traditional buildings require sufficiently thick external walls to ensure that drying cycles occur before atmospheric moisture reaches the internal wall face. It is essential that all materials and finishes, including mortars[95] and renders[96], used on traditional walls are porous to allow this natural transfer of moisture to occur. Basic guidance on the detriment of non-porous materials like cement is provided in the HES Inform Guide *Lime and Cement Mortars in Traditional Buildings*[97]

The 2007 Conservation Advice Series publication *Maintenance: A Guide to the Care of Older Buildings* also provides a brief overview for homeowners on how old buildings work and how to deal with three common types of damp: rising, penetrating and condensation.[98]

Under the Intelligent Energy Europe TABULA Project (2009-2012), a study of common Irish residential building typologies and their typical energy and thermal properties was developed into an

[94] *Advice Series: Energy Efficiency in Traditional Buildings* (2010), Dublin: Department of the Environment, Heritage and Local Government. Available at: https://www.chg.gov.ie/heritage/built-heritage/architectural-heritage-advisory-service/advice-for-owners/. p 5.
[95] Snow, J. and Torney, C. (2014) *Short Guide 6: Lime Mortars in Traditional Buildings.* Edinburgh: Historic Environment Scotland.
[96] Newsom, S., Gibbons, P. and Brown, S. (2001) *Technical Advice Note 15: External Lime Coatings on Traditional Buildings*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=33c274be-9e98-49d5-9b24-a5c200f9c7bb.
[97] Mitchell, D. D. and Torney, D. C. (2016) *INFORM Guide: Lime and Cement Mortars in Traditional Buildings*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=9410b4db-0fbb-41e4-ba8d-a59500f5618d.
[98] Donnelly, J. (2007) *Advice Series: Maintenance - A Guide to the Care of Older Buildings*, Dublin: Department of Culture, Heritage and the Gaeltacht. Available at: https://www.chg.gov.ie/heritage/built-heritage/architectural-heritage-advisory-service/advice-for-owners/.

inventory with recommendations for energy performance improvements.[99] The energy analyses for each building typology were based on the Irish Dwelling Energy Assessment Procedure (DEAP). The study identified 34 Irish dwelling types across 10 age bands, of which the first three apply to this study: 1800-1899, 1900-1929, 1930-1949. Building typologies 1-7 are of traditional construction methods and the renovation pamphlets for these buildings provide important information on their typical construction and energy efficiency. The pamphlets recommend mineral wool for roof insulation, however their recommendations for internal and external wall insulation do not specify that the insulation chosen must be vapour-permeable.

Tabula Building Typology Brochure – Ireland: A Detailed Study on the Energy Performance of Typical Irish Dwellings (2014)

In 2007, Historic Environment Scotland published *Conversion of Traditional Buildings: Application of the Scottish Building Standards*, a 2-part advice document for practitioners, developers, local authorities and building owners on how to upgrade traditional buildings to meet the requirements set out by the 2004 building standards. [100] Part 1 includes four chapters on how traditional buildings perform, covering: traditional materials and components; hygrothermal qualities, heating and ventilation systems; structural systems; and safety systems and access issues. Part 2 covers how to apply the building standards to historic buildings. Whilst the documents are now over a decade old, they offer a good starting point for understanding how traditional buildings work.

Conversion of Traditional Buildings: Application of the Scottish Building Standards – Part 1 and 2 (2007)

From 2013 through 2017, the Building Research Establishment (BRE) was commissioned by the UK Department of Energy and Climate Change (now the Department of Business, Energy and Industrial Strategy) to undertake a series of studies on the energy performance and insulation of solid walled buildings, which were published under the report series, *Solid Wall Heat Losses and the Potential for Energy Savings*. In the Literature Review, the BRE advised that: [101]

BRE Literature Review - Solid Wall Heat Losses and the Potential for Energy Savings (2014)

> *The current premise of setting minimum acceptable performance levels when retrofitting as part of the Building Regulation requirements may need to be reassessed, if the likelihood of a mandatory standard results in the creation of unintended consequences, by requiring buildings to improve above their technical capabilities.*

[99] Badurek, M., Hanratty, M. and Sheldrick, B. (2014) *TABULA Building Typology Brochure Ireland: A Detailed Study on the Energy Performance of Typical Irish Dwellings*, Ireland: Intelligent Energy Europe. Available at: http://episcope.eu/fileadmin/tabula/public/docs/brochure/IE_TABULA_TypologyBrochure_EnergyAction.pdf.

[100] Urquhart, D. (2007) *Guide for Practitioners 6: Conversion of Traditional Buildings: Application of the Scottish Building Standards* Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=86c6c669-6415-4f0c-a421-a5bd00c39797.

[101] Gemmell, A. (2014) *Solid Wall Heat Losses and the Potential for Energy Savings: Literature Review*, Watford: Building Research Establishment Ltd. Available at: https://www.gov.uk/government/publications/solid-wall-heat-losses-and-the-potential-for-energy-savings-literature-review. p 113.

In traditional buildings, the thermal performance and hygroscopic behaviour are inseparable, and the combined effects of moisture and thermal properties are referred to as the hygrothermal performance. This means that increased moisture in the building fabric leads to a faster rate of heat loss through the walls because water is a conductor. Heat is generally lost either through the building envelope (measured in U-values) or by air flow between the interior and the exterior draughts. In traditional buildings, the highest percentage of heat is typically lost through the walls (35%), followed by the roofs (25%), floors (15%), draughts (15%) and windows (10%).[102] This explains why so much emphasis is being put on internal and external wall insulation and thus why it is so important to understand the implications of solid wall insulation.

HES Technical Paper 15: Assessing Risks in Insulation Retrofits using Hygrothermal Software Tools: Heat and Moisture Transport in Internally Insulated Stone Walls (2015)

Historic Environment Scotland Technical Paper 15 is a highly technical report written for building professionals and is one of the most extensive studies on the hygrothermal risks of internally insulating traditional solid masonry walled buildings.[103] The report first discusses in-depth the hygrothermal characteristics of traditional solid wall construction and typical building materials. The next chapter clarifies the differences between methodical and numerical assessment and simulation methods, which are used to measure the hygrothermal performance of the buildings before and after deep energy renovation. The report then concludes with a case study that tests each simulation methodology.

2.4.2 Calculating the U-Value for Traditional Building Materials

Advice Series: Energy Efficiency in Traditional Buildings (2010)

Heat naturally flows from warm areas to cool areas. It can flow through conduction or radiation in solid objects and through convection in liquids and gases. In the building industry, the transfer of heat through the thermal envelope of a building is termed thermal transmittance and expressed as a U-value. The U-value is a calculation of the rate at which heat moves through the walls, windows, doors, etc. Building components with a slow heat transfer are better insulators, which is reflected in a lower U-value. While some countries require the calculation of transient thermal transmittance, in the UK and Ireland, heat transfer through building materials is typically represented by a single value, based on steady-state conditions, that does not account for non-steady impacts produced by solar orientation or thermal mass.

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[102] *Advice Series: Energy Efficiency in Traditional Buildings* (2010), Dublin: Department of the Environment, Heritage and Local Government. Available at: https://www.chg.gov.ie/heritage/built-heritage/architectural-heritage-advisory-service/advice-for-owners/. p 16.

[103] Little, J., Ferraro, C. and Arregi, B. (2015) *Technical Paper 15: Assessing Risks in Insulation Retrofits using Hygrothermal Software Tools - Heat and Moisture Transport in Internally Insulated Stone Walls*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=8a2a7b9d-e3b2-4c7d-8c17-a59400a8387b.

Moisture is a conductor of heat and even a moderate amount of moisture in any building component will decrease its thermal performance and therefore increase its U-value. In traditional buildings, common causes of elevated moisture in the building components can be due to defects in the original render or the application of a non-moisture permeable render, the poor installation of windows, or the poor maintenance of gutters and roofs. Therefore, care must be taken to keep a traditional building protected from excessive moisture and to ensure any new materials installed are suitably vapour-permeable.

Steady-state heat loss through building components is expressed in W/m^2K (i.e. watts of heat lost per square metre per degree). The rate of heat loss in watts (Φ) is calculated by multiplying the area (A) by the U-value (U) by the difference of the internal temperature (Ti) and the external temperature (Te) of the building; or $\Phi = A \times U \times (Ti - Te)$.[104]

Responsible Retrofit of Traditional Buildings: A Report on Existing Research and Guidance with Recommendations (2012)

A variety of energy modelling software packages are used to assess the energy performance of traditional buildings. Some are more flexible and better suited to the changing hygrothermal conditions of traditional buildings, while others are easier to use can give faulty representations of the thermal performance of traditional building materials. According to the STBA *Responsible Retrofit of Traditional Buildings* report, 'it is widely acknowledged that energy models do not provide robust data concerning the performance of traditional buildings'.[105] The report cites an unpublished Historic England report *Hearth and Home Scoping Study* (Gentry et al, 2010) that estimates an uncertainty ratio of up to 50% when applying BREDEM (Building Research Establishment Domestic Energy Model) based models to traditional building types.

BRE Literature Review - Solid Wall Heat Losses and the Potential for Energy Savings (2014)

The STBA Responsible Retrofit report also highlighted a lack of publicly available data required by the numerically based simulation methods in relation to traditional and vernacular building materials common in the UK and Ireland. The accuracy of numerical based simulation models relies on the skill of the operator and the availability of verified and detailed climatic and material data. If credible data is not available for the materials being assessed, the simulations can predict greater energy savings for solid wall insulation (SWI) and other strategies than can actually be achieved.

The BRE Literature Review found this gap in expected and real energy savings to arise from three main factors:

[104] Gemmell, A. (2014) *Solid Wall Heat Losses and the Potential for Energy Savings: Literature Review*, Watford: Building Research Establishment Ltd. Available at: https://www.gov.uk/government/publications/solid-wall-heat-losses-and-the-potential-for-energy-savings-literature-review. p 18.

[105] May, N. and Rye, C. (2012) *Responsible Retrofit of Traditional Buildings: A Report on Existing Research and Guidance with Recommendations*, London: Sustainable Traditional Buildings Alliance. Available at: http://stbauk.org/stba-guidance-research-papers. p 21.

1. Inaccurate assumptions regarding the baseline performance of the building envelope and the temperatures the homes are heated to prior to installation;
2. Errors in the installation of the insulation and poor workmanship;
3. Changes in occupant energy use behaviour once the insulation has been installed.

The BRE Literature Review recommends an industry-wide shift to EN 15026:2007, given the limited ability of many standards currently in use to accurately assess the hygrothermal performance of traditional buildings, particularly EN 13788:2012 (the Glaser method).[106] This will require a greater level of accurate local weather and building materials to be made available through databases.

Historic Environment Scotland commissioned a study of the in situ U-values of traditional building materials back in 2007-2008 to assess the actual thermal performance of traditional building envelopes. The findings were published in the HES Technical Paper 2 and were intended to inform and help provide true energy performance assessments of traditional buildings.[107] The study measured the U-value of five traditional properties spread around Scotland and the findings demonstrate that the thermal performance of masonry walls can vary significantly due to the properties of the stones used. It also showed that the traditional internal wall finish (plastered on the hard, lath and plaster, or plasterboard) also has a significant impact on the thermal performance of the wall, with plaster on the hard providing the highest U-value and plasterboard providing the lowest. A table at the end of the report also demonstrates the variance of U-values that can be found in different external walls in the same property.

Historic Environment Scotland Technical Paper 10: *U-Values and Traditional Buildings: In Situ Measurements and their Comparisons to Calculated Values* carried out 67 in situ U-value assessments of primarily solid walls, but also some cavity walls and other insulated building elements to provide comparisons. [108] These measurements were then compared to the calculated values provided by energy modelling software programmes. What they found was that the

HES Technical Papers

HES Technical Paper 2: In Situ U-Value Measurements in Traditional Buildings – Preliminary Results (2008)

HES Technical Paper 10: U-values and Traditional Buildings (2011)

HES Technical Paper 4: Energy Modelling in Traditional Scottish Houses (2008)

HES Technical Paper 5: Energy Modelling of a Mid 19th Century Villa (2009)

HES Technical Paper 8: Energy Modelling of the Garden Bothy, Dumfries House (2010)

HES Technical Paper 18: Evaluating Energy Modelling for Traditionally Constructed Dwellings (2013)

[106] Gemmell, A. (2014) *Solid Wall Heat Losses and the Potential for Energy Savings: Literature Review*, Watford: Building Research Establishment Ltd. Available at: https://www.gov.uk/government/publications/solid-wall-heat-losses-and-the-potential-for-energy-savings-literature-review. p 113.

[107] Baker, P. (2008) *Technical Paper 2: In Situ U-value Measurements in Traditional Buildings - Preliminary Results*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=7fc3d5f6-5992-4106-92bf-a59400bf430c.

[108] 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.

software programmes tend to overestimate the U-values of traditional solid walls, meaning that in reality they perform better thermally (ie. they have a lower U-value than calculated). This, in turn, means that the improvement in U-values may be less than expected after the installation of solid wall insulation. Historic Environment Scotland Technical Papers 3[109], 4[110], 5[111], 8[112] and 18[113] all provide detailed technical information for professionals on the in situ U-values and thermal performance of traditional building elements in a climate similar to that of Ireland.

Furthermore, in reference to the *SPAB U-Value Research Report*, the BRE Literature Review explains that: [114]

> *Contrary to what steady-state calculations suggest, no simple generalisation can be stated about the relationship between U-value and type of material or thickness of elements. The actual construction of the element, defective areas, irregularities, ventilated cavities and the specific characteristics of the local materials could all lead to localised thermal performance variations and discrepancies between calculated and in situ thermal performance.*

A number of UK-based case studies published in recent years have tested the accuracy of energy modelling software to predict the U-values and thermal performance of traditional building elements. HES Technical Paper 3: *Energy Modelling Analysis of a Traditionally Built Scottish Tenement Flat* found four energy modelling software programmes to produce four different results due to inaccurate data or assumptions made by the software.[115] A study by the University of Salford assessed the real U-values of 16 traditional

The SPAB Research Report 1: U-Value Report (2010)

HES Technical Paper 3: Energry Modelling Analysis of a Traditionally Built Scottish Tenement Flat (2008)

Understanding Our Heritage: Monitoring of Energy and Environmental Performance of Traditional Terraced Houses of Northern England (2016)

In-Situ Measurements of Wall U-Values in English Housing (2014)

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[109] Barnham, B., Heath, N. and Pearson, G. (2008) *Technical Paper 3: Energy Modelling Analysis of a Traditionally Built Scottish Tenement Flat*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=d5b6702b-7348-49af-8e90-a59400bff38c.

[110] Jenkins, D. (2008) *Technical Paper 4: Energy Modelling in Traditional Scottish Houses*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=7ada182f-a22f-4664-8a0a-a59400e05ec7.

[111] *Technical Paper 5: Energy Modelling of a Mid 19th Century Villa - Baseline Performance and Improvement Options* (2009), Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=743262f6-684e-4098-bfdd-a59400e12231.

[112] Heath, N., Pearson, G., Barnham, B. and Atkins, R. (2010b) *Technical Paper 8: Energy Modelling of the Garden Bothy, Dumfries House*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=e763868b-385b-4227-a2bb-a59400e364e7.

[113] Ingram, V. and Jenkins, D. (2013) *Technical Paper 18: Evaluating Energy Modelling for Traditionally Constructed Dwellings*, Edinburgh: Historic Environment Scotland (9781849171274. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=1d90d4c3-f8ca-4468-8049-a59400b32e50.

[114] Gemmell, A. (2014) *Solid Wall Heat Losses and the Potential for Energy Savings: Literature Review*, Watford: Building Research Establishment Ltd. Available at: https://www.gov.uk/government/publications/solid-wall-heat-losses-and-the-potential-for-energy-savings-literature-review. p 104 - 105.

[115] Barnham, B., Heath, N. and Pearson, G. (2008) *Technical Paper 3: Energy Modelling Analysis of a Traditionally Built Scottish Tenement Flat*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=d5b6702b-7348-49af-8e90-a59400bff38c.

solid walled brick dwellings in Northern England[116] and an earlier study funded by the Department of Energy and Climate Change assessed the in situ U-values for approximately 300 English dwellings constructed in a variety of materials and styles.[117] Historic England has also published a technical Research Report on the thermal performance of traditional brick walls.[118]

HE Research Reports: Research into the Thermal Performance of Traditional Brick Walls (2013)

2.4.3 Building Energy Ratings (BER) and the Dwelling Energy Assessment Procedure (DEAP)

Irish homes are considered to be energy inefficient compared to the overall housing stock of Europe with the average thermal performance of Irish housing equating to a D rating under the Building Energy Rating (BER) scale.[119] As a requirement of Directive 2010/31/EU (EPBD), public buildings and owners or landlords of residential and non-residential buildings are required to produce a BER certificate upon completion of construction or with the sale or lease of existing properties.[120] Protected Structures or those proposed for protection are exempt in Ireland under the National Monuments Act. In Ireland, the certification of BERs is managed by the Sustainable Energy Authority of Ireland (SEAI).

Better Buildings: A National Renovation Strategy for Ireland (2014)

EFFESUS Deliverable D1.3: Assessment of European and National Policies Related to Energy Efficiency and Heritage Conservation

The Dwelling Energy Assessment Procedure (DEAP) is the official method in Ireland for calculating and rating the energy performance of dwellings (BERs), and for all other buildings, the Non-dwelling Energy Assessment Procedure (NEAP) is used. The SEAI has prepared an Introduction to DEAP for Professionals[121] and a user's manual with Appendix S providing the methodology and default data for existing buildings.[122] Building Energy Ratings display both the building's primary energy use as well as its carbon dioxide emissions, and give potential buyers and tenants a basic measure of the building's thermal performance. The energy rating is based on a number of standardised measurements, including a general

Dwelling Energy Assessment Procedure (DEAP) Manual

Introduction to DEAP for Professionals

SEAI DEAP Software and Resources

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[116] 'Understanding Our Heritage: Monitoring of Energy and Environmental Performance of Traditional Terraced Houses of Northern England', *Energy Efficiency and Comfort of Historic Buildings*, Brussels, 19-21 October: Flanders Heritage Agency, 225-233.

[117] Hulme, J. and Doran, S. (2014) *In-Situ Measurements of Wall U-values in English Housing*, Watford: BRE. Available at: https://www.gov.uk/government/publications/in-situ-measurements-of-wall-u-values-in-english-housing.

[118] Rhee-Duvern, S. and Baker, P. (2013) *Research Report Series: Research into the Thermal Performance of Traditional Brick Walls*: Historic England. Available at: https://historicengland.org.uk/images-books/publications/research-thermal-performance-traditional-brick-walls/.

[119] *Better Buildings: A National Renovation Strategy for Ireland* (2014), Ireland: Department of Communications, Energy and Natural Resources. Available at: http://www.dccae.gov.ie/en-ie/energy/topics/Energy-Efficiency/ireland%27s-national-renovation-strategy/Pages/Ireland%27s-Renovation-Strategy.aspx.

[120] *Deliverable D1.3: Assessment of European and National Policies related to Energy Efficiency and Heritage Conservation* (2013): EFFESUS. Available at: http://www.effesus.eu/wp-content/uploads/2016/01/D-1.3_Assessment-of-European-and-national-policies-related-to-energy-efficiency-and-heritage-conservation.pdf. p 39.

[121] *Introduction to DEAP for Professionals*, Dublin: Sustainable Energy Authority of Ireland (SEAI). Available at: https://www.seai.ie/resources/publications/Introduction_to_DEAP_for_Professionals.pdf.

[122] *Dwelling Energy Assessment Procedure (DEAP) Manual* (2012), Dublin: Sustainable Energy Authority of Ireland (SEAI). Available at: https://www.seai.ie/resources/publications/DEAP_Manual.pdf. p 91-111.

estimate of energy usage and a standard heating schedule, which for a typical household is assumed to be two hours of heating in the morning and six hours in the evening.[123]

Like other energy performance simulation software, the data available for traditional materials in DEAP is limited, which limits its accuracy in evaluating the thermal performance and energy efficiency of traditional buildings. DEAP includes only three U-values for two types of traditional solid walls: stone (2.1 W/m^{2}K) and solid brick 225mm-thick (2.1 W/m^{2}K) and 325mm-thick (1.64 W/m^{2}K).[124] However, stone and brick can vary in material characteristics and porosity levels and therefore each type can transport liquid and heat at different rates. The forthcoming publication *Built to Last: Renovations of Historic Dublin Dwellings* includes the physical measurements of one solid stone and three solid brick walled dwellings in Dublin, which demonstrate that traditional walls actually perform much better thermally than the conservative default U-values used in DEAP imply. For instance, the 750mm-thick solid rendered stone walls of a tenement home on Henrietta Street had a measured U-value of 1.09 W/m^{2}K (versus the default DEAP value of 2.1 W/m^{2}K) and a 365mm-thick solid brick dwelling on Mountjoy Square had a measured U-value of 1.17 W/m^{2}K (versus the default value 1.64 W/m^{2}K assigned to 325mm-thick solid brick walls). On the other hand, a solid 233mm-thick mass concrete walled dwelling had a measured U-value of 3.37 W/m^{2}K, which is much worse than the default 2.2 W/m^{2}K assigned to mass concrete walls in DEAP.

Advice Series: Energy Efficiency in Traditional Buildings (2010)

In order to produce an accurate BER and appropriate recommendations for improving the energy efficiency of traditional buildings, the following must be understood by the BER Assessor:[125]

a. How Building Regulations impact upon traditional buildings
b. The historic or cultural significance of the building
c. How to select the correct age band
d. How to identify the correct construction type
e. How to input actual rather than notional U-values
f. How to assess the condition of the building

HE EEHB: Energy Performance Certificates (2015)

HE EEHB: Advice for Domestic Energy Assessors and Green Deal Advisors (2015)

[123] *Advice Series: Energy Efficiency in Traditional Buildings* (2010), Dublin: Department of the Environment, Heritage and Local Government. Available at: https://www.chg.gov.ie/heritage/built-heritage/architectural-heritage-advisory-service/advice-for-owners/. p 24.

[124] Little, J., McGirl, F., Hanratty, M. and Arregi, B. (Forthcoming 2018) *Built to Last: Renovations of Historic Dublin Dwellings.* Dublin.

[125] Pickles, D. and Cattini, C. (2015a) *Energy Efficiency and Historic Buildings: Advice for Domestic Energy Assessors and Green Deal Advisors*: Historic England. Available at: https://historicengland.org.uk/images-books/publications/eehb-advice-domestic-energy-assessors-green-deal-advisors/. p 4.

The DEHLG Advice Series guidance *Energy Efficiency in Traditional Buildings* warns that the list of recommendations generated by the BER post-assessment advisory report is based on data from existing buildings of modern construction and may be inapplicable to traditional buildings. It is therefore crucially important that BER Assessors understand the hygrothermal behaviours of traditional buildings and are able to advise the building owners accordingly. The DEHLG guide also recommends enlisting a conservation professional before acting upon any recommendations provided by the BER advisory report.

To become qualified as BER Assessor for domestic properties, candidates must hold a Level 6 Award in construction studies or the equivalent, must complete the training course for BER Assessors and must pass the SEAI Domestic BER Examination. The Domestic BER Training Course provided by Chevron Training, for instance, is 6 days in length.[126] The process is similar for non-domestic properties, but the candidates must also be a member of a relevant professional organisation.

Improving the Performance of Buildings and Urban Areas. *Context*. (2017)

A short paper in the Green Retrofit edition of the IHBC journal, Context, detailed the discrepancy between the level of training required in Germany of its building energy assessors to that required of the same professionals in Britain under the Green Deal.[127] In Germany, accreditation is only available to architects, engineers and master craftsmen and requires the successful completion of a 240-hour course. To qualify as a 'building energy advisor for monuments' requires a further 54 hours of specialist training. By comparison, the Green Deal accreditation for building energy assessors could be completed within 3 days or 8 days if the person had no prior experience in the construction industry. In the UK, as in Ireland, no special training is required to be qualified to assign Energy Performance Certificates to traditional or historic buildings.

Studies in the Application of Building Energy Rating to Historic Buildings (2013)

A paper by Katriona Byrne published in the 2013 proceedings of the Irish Georgian Society conference *Energy Efficiency in Historic Houses* (held over 2009 and 2010) tested how traditional buildings performed in a BER assessment and how well the BER assessment methodology applied to them.[128] The paper details the assessment process and how the converted servants' quarters at Strokestown Park House (c. 1780) in Roscommon fared. Byrne notes that the BER assessment does not consider the following: 'building size, shape, exposure, orientation, construction materials, the type, area and U-values of each building element, ventilation characteristics, heating

[126] *QQI Domestic BER Course* Chevron Training and Recruitment Ltd. Available at: https://chevrontraining.ie/domestic-ber-course/#1502365832356-24e168b2-45b2 (Accessed: 10 January 2018).
[127] Hermann, C. (2017) 'Improving the Performance of Buildings and Urban Areas', *Context,* (149), pp. 20-22. p 21.
[128] Byrne, K. (2013) 'Studies in the Application of Building Energy Rating to Historic Buildings'. *Energy Efficiency in Historic Houses*, Dublin: Irish Georgian Society, 30-45.

systems, the controls and efficiency of heating systems, solar gains, the thermal mass of the building, the type of fuel used and any renewable energies used'.[129] The BER assessment rated the row houses between F and E1 and Byrne explains that inaccuracy in the results was due to the programme's inflexibility to customise values like insulation and the inadequate selection of U-value choices for walls. Though the standardised values of the Dwelling Energy Assessment Procedure (DEAP) enable comparison across the full scale of building types, the paper outlines exactly why standardised values are inappropriate and inaccurate for traditional buildings and why a true energy performance reading could only be achieved through numerical calculation methods (see Section 2.4.4.3). In substituting calculated U-values for the standardised values of the external walls, more realistic BER ratings for the row houses were achieved, ranging from D1 to C3.

The BER assessment also does not currently account for the embodied energy within existing buildings. 'Embodied energy' refers to the 'the energy that was required to extract, process, manufacture, transport and install building materials and is now deemed to be embodied in the finished building'.[130] Essentially, local materials that require little processing are low in embodied energy (lime mortar, timber, thatch), while materials that require high levels of manufacturing and transport (steel, bricks, concrete) are high in embodied energy (see Sections 2.6.5 and 3.1).

However, other sustainability assessment systems such as BREEAM[131] and LEED[132] provide credits for the renovation and re-use of existing structures. The Irish Green Building Council (IGBC) is currently participating in the 2-year Carbon Heroes Benchmark Programme, which is designed to equip construction professionals with the tools to calculate the embodied carbon in a building using Life-Cycle Assessment (LCA) software developed by Finnish LCA experts Bionova.[133] In September 2017, the IGBC also launched the Environmental Product Declaration (EPD) Programme which will provide transparent, 3rd party verified information about the environmental impact of construction products.[134] Both

Sustainable Refurbishment of Heritage Buildings – How BREEAM Helps to Deliver (2014)

LEED for Neighborhood Development and Historic Preservation (2013)

Carbon Heroes Benchmark Programme (2017)

IGBC Environmental Product Declaration Programme (2017)

[129] Ibid. p 34.

[130] *Advice Series: Energy Efficiency in Traditional Buildings* (2010), Dublin: Department of the Environment, Heritage and Local Government. Available at: https://www.chg.gov.ie/heritage/built-heritage/architectural-heritage-advisory-service/advice-for-owners/. p 7.

[131] Balson, K., Summerson, G. and Thorne, A. (2014) *Sustainable Refurbishment of Heritage Buildings – How BREEAM Helps to Deliver*, Watford: Building Research Establishment Ltd. Available at: https://tools.breeam.com/filelibrary/Brochures/Heritage-Sustainable-Refurbishment-v2.pdf.

[132] *LEED for Neighborhood Development and Historic Preservation* (2013), Washington D.C. Available at: https://www.usgbc.org/resources/leed-neighborhood-development-and-historic-preservation.

[133] *Carbon Heros Benchmark Programme* (2017). One Click LCA: Bionova Ltd. Available at: https://www.oneclicklca.com/construction/carbonheroes/ (Accessed: 10 January 2018).

[134] *Environmental Product Declaration Programme* (2017). Dublin: Irish Green Building Council (IGBC). Available at: https://www.igbc.ie/epd-home/ (Accessed: 2 January 2018).

programmes aim to provide a more accurate picture of sustainability for all buildings, including those already built.

The Dublin City Council study *Built to Last: The Sustainable Reuse of Buildings* (2004) assessed the economic, environmental and cultural cost of demolishing and replacing five existing buildings in Ireland versus the cost to refurbish them.[135] Four of the five case studies showed that it was economically and environmentally less costly to refurbish the existing building than to rebuild on a brownfield site. Where extensive refurbishment works were required in case study five, the cost was slightly higher than new build, but overall, refurbishing existing buildings was found to be more environmentally beneficial because the process requires less non-renewable resources. A separate paper in the International Journal of Life Cycle Assessment estimated the total carbon emissions from residential developments built in the Greater Dublin Area from 1997-2006 and demonstrates how new construction, low density and poor public transport systems have led to an increase in Ireland's GHG emissions, some of which could have been avoided by renovating the vacant and derelict housing stock in the city centre.[136]

Built to Last: The Sustainable Reuse of Buildings (2004)

Land Use Planning in Ireland: a Life Cycle Energy Analysis of Recent Residential Development in the Greater Dublin Area (2009)

Historic Environment Scotland Technical Paper 7 explains the methodology used to account for embodied carbon in natural Scottish building stone[137], while Technical Paper 13 *Embodied Energy Considerations for Existing Buildings* discusses the importance of using Life Cycle Assessment (LCA) to assess sustainable renovation measures for traditional and existing buildings, but points out that the consideration of 'sunk embodied energy and carbon' does not have any effect on the mitigation of energy usage and carbon emissions today.[138] Therefore, they argue that there are other credible reasons for retaining existing buildings, such as the long-life qualities of the materials and the historical and cultural value they hold for their local communities.

HES Technical Paper 7: Embodied Carbon in Natural Building Stone in Scotland (2010)

HES Technical Paper 13: Embodied Energy Considerations for Existing Buildings (2011)

In April 2018, it will become illegal to rent dwellings with an Energy Performance Certificate (EPC) rating lower than E in England and Wales. This legislation was introduced in 2011 and the associated Minimum Energy Efficiency Standards (MEES) were passed in 2015. The Country Land and Business Association (CLA) is a membership

The Retro Fit-Up: How Government Energy Policy is Failing Older Houses across the British Countryside (2017)

[135] *Built to Last: The Sustainable Reuse of Buildings* (2004), Dublin, Ireland: The Heritage Council. Available at: http://www.turas-cities.org/uploads/biblio/document/file/326/sustainable_reuse_buildings_athusaid_inbhuanaithe_foirgneamh.pdf.
[136] Duffy, A. (2009) 'Land Use Planning in Ireland: a Life Cycle Energy Analysis of Recent Residential Development in the Greater Dublin Area', *International Journal of Life Cycle Assessment,* 14(3), pp. 257-267.
[137] Chishna, N., Goodsir, D. S., Banfill, P. P. and Baker, D. K. (2010) *Technical Paper 7: Embodied Carbon in Natural Building Stone in Scotland*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=8c3ebef1-ba50-40cb-ab75-a59400e2b74b.
[138] Menzies, G. F. (2011) *Technical Paper 13: Embodied Energy Considerations for Existing Buildings*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=2de84deb-fc40-4ab0-a8cb-a59400b7112c.

organisation established in 1907 with over 33,000 current members who own or manage approximately 50% of land, property and business in rural England and Wales. While the CLA supports the objective of this policy, it criticised the government for the lack of guidance provided and the faulty measurement method of the SAP and in March 2017, it put forth 10 recommendations for it to consider before the policy took effect.[139] In October 2017, the government published guidance for landlords of privately rented domestic[140] and non-domestic[141] properties on how to meet the requirements of the Minimum Energy Efficiency Standards. The Netherlands has taken a similar stance and has implemented legislation requiring that office spaces have a minimum C energy rating from 1 January 2023 onward.

The Private Rented Property Minimum Energy Efficiency Standard – Domestic and Non-Domestic Landlord Guidance Documents (2017)

The Irish Department of Communications, Energy and Natural Resources *Strategy to Combat Energy Poverty 2016-2019* report found that people living in rented accommodation are twice as likely to live in a home that is E, F, or G rated.[142] The strategy is being implemented by the Department of Communications, Climate Action and Environment (DCCAE) and is due to hold a public consultation in 2018 to consider the implementation of a similar minimum BER standard with the intent to incentivise investment in energy efficiency renovation measures in the private rental market. However, if DEAP is not revised to accurately represent the thermal performance of traditional building materials (see Section 3.1), greater undue pressure to meet the minimum standards may lead to inappropriate renovations measures or unnecessary demolitions.

A Strategy to Combat Energy Poverty 2016-2019 (2016)

2.4.4 Hygrothermal Assessment and Simulation Methodologies

2.4.4.1 Non-Invasive Survey Tools

A number of non-invasive survey tools are available to assess the thermal performance of a building, such as thermographic surveys, electric moisture meters, Karsten tubes and ultrasonic scanning. Thermography, or thermal imaging, uses an infra-red camera to visualise the invisible heat energy passing through the building fabric and to identify potential problems like excessive damp,

[139] *The Retro Fit-Up: How Government Energy Policy is Failing Older Houses across the British Countryside* (2017): Country Land and Business Association Ltd. Available at: https://www.cla.org.uk/retrofitup.

[140] *The Domestic Private Rented Property Minimum Standard* (2017), London: Department of Business, Energy and Industrial Strategy. Available at: https://www.gov.uk/government/publications/the-private-rented-property-minimum-standard-landlord-guidance-documents.

[141] *The Non-Domestic Private Rented Property Minimum Standard* (2017), London: Department of Business, Energy & Industrial Strategy. Available at: https://www.gov.uk/government/publications/the-private-rented-property-minimum-standard-landlord-guidance-documents.

[142] *A Strategy to Combat Energy Poverty 2016-2019* (2016). Dublin: Department of Communications, Energy and Natural Resources. p 6.

cracking and voids in the walls. [143] Expertise is required to accurately interpret thermographic images and to ensure atmospheric conditions are right to produce valid readings. HES Short Guide 10 provides an introduction to infrared thermal imaging, advice on appropriate conditions, its practical applications and its limitations.[144]

Thermography for Traditional Buildings (2017)

HES Short Guide 10: Thermal Imaging in the Historic Environment (2015)

Electric moisture meters are a cheap and easily attainable tool to assess the level of moisture in the building fabric, but they can produce misleading results. Electric moisture meters are most reliable when used on timber and it is recommended that multiple readings be taken across a material's surface to find a pattern of moisture levels or localised areas of excessive damp, which may indicate ingress of rainwater.[145]

Karsten tubes require little training to use and are a low investment, non-invasive, in situ option that give a quick sense of the moisture absorption level of external wall materials, and therefore, the risk level of internally insulating a solid wall. Appendix 2 of HES Technical Paper 15 sets out in detail the procedure for using Karsten tubes.[146] The 2016 SDAR* Journal paper by Arregi & Little describes the use of Karsten tubes and compares the absorption qualities of the case study traditional solid wall dwelling to other exposed brick and stone, painted or rendered solid wall dwellings in Dublin.[147] The paper demonstrates the value of Karsten tubes to improve the accuracy of desktop assessment software. The forthcoming *Built to Last* report will also contain a graph mapping the results of approximately 35 such measurements of Dublin buildings, most of which are historic.[148]

HES Technical Paper 15: Assessing Risks in Insulation Retrofits using Hygrothermal Software Tools: Heat and Moisture Transport in Internally Insulated Stone Walls (2015)

Hygrothermal Risk Evaluation for the Retrofit of a Typical Solid-Walled Dwelling (2016)

Ultrasonic scanning is particularly useful to assess structural integrity and decay within the walls of protected historic structures. It uses high-frequency sound waves to penetrate the surface material and bounce back information about the internal

Advice Series: Energy Efficiency in Traditional Buildings (2010)

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[143] Atkinson, J. (2017) 'Thermography for Traditional Buildings', *Context,* (149), pp. 17-18.

[144] *Short Guide 10: Thermal Imaging in the Historic Environment* (2015), Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=088dab34-1194-43e6-af5e-a62801090992.

[145] *Advice Series: Energy Efficiency in Traditional Buildings* (2010), Dublin: Department of the Environment, Heritage and Local Government. Available at: https://www.chg.gov.ie/heritage/built-heritage/architectural-heritage-advisory-service/advice-for-owners/. p 23.

[146] Little, J., Ferraro, C. and Arregi, B. (2015) *Technical Paper 15: Assessing Risks in Insulation Retrofits using Hygrothermal Software Tools - Heat and Moisture Transport in Internally Insulated Stone Walls*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=8a2a7b9d-e3b2-4c7d-8c17-a59400a8387b.

[147] Arregi, B. and Little, J. (2016) 'Hygrothermal Risk Evaluation for the Retrofit of a Typical Solid-Walled Dwelling', *Sustainable Design & Applied Research in Engineering and the Built Environment (SDAR),* (6), pp. 17-26.

[148] Little, J., McGirl, F., Hanratty, M. and Arregi, B. (Forthcoming 2018) *Built to Last: Renovations of Historic Dublin Dwellings.* Dublin.

structure.[149] Professional experience is needed to carry out the readings and interpret the results.

2.4.4.2 The EN 13788:2012 (Glaser) Methodology

The Glaser method is a popular condensation risk assessment methodology that corresponds with Irish, European and International Standard I.S. EN ISO 13788:2012. The Glaser method is based on dewpoint methods dating back to the 1930s that were developed further in the 1950s to coincide with modern construction techniques and therefore, to only measure surface temperature and moisture conditions with reference to the potential for mould growth. Assessment software based on the principles of EN 13788:2012 assume that the dominant moisture load effecting the thermal envelope is initially in a vapour state from a source outside the thermal envelope. It does not take account of the following: [150]

I.S. EN ISO 13788:2012 Hygrothermal Performance of Building Components and Building Elements

a. The dependence of thermal conductivity on moisture content
b. The release and absorption of latent heat
c. The variation of material properties with moisture content
d. Capillary suction and liquid moisture transfer within materials
e. Air movement through cracks or within air spaces
f. The hygroscopic moisture capacity of materials
g. Transient climatic conditions, such rainfall, sunshine and wind
h. local conditions that can stress the building envelope, such as orientation, inclination, elevation and exposure

The Glaser method is a simple and effective tool when used to measure hygrothermal risks within a limited range of building envelope assemblies. However, the *SPAB Research Report 3: Hygrothermal Modelling* has shown that it is inappropriate for measuring hygrothermal risks in rainy climates and traditional buildings with permeable, hygroscopic materials. Furthermore, the report outlined the following reasons why simplifications in the method will lead to reporting errors: [151]

SPAB Research Report 3: Hygrothermal Modelling - Interim Report (2012)

[149] *Advice Series: Energy Efficiency in Traditional Buildings* (2010), Dublin: Department of the Environment, Heritage and Local Government. Available at: https://www.chg.gov.ie/heritage/built-heritage/architectural-heritage-advisory-service/advice-for-owners/. p 23.
[150] Browne, D. (2012) *The SPAB Research Report 3: The SPAB Hygrothermal Modelling - Interim Report*: Society for the Protection Ancient Buildings. Available at: https://www.spab.org.uk/advice/research/findings.
[151] Ibid. 12-14.

a. The thermal conductivity depends on the moisture content, and heat is released/absorbed by condensation/evaporation. This will change the temperature distribution and saturation values and affect the amount of condensation/drying.
b. The use of constant material properties is an approximation.
c. Capillary suction and liquid moisture transfer occur in many materials and this may change the moisture distribution.
d. Air movements through cracks or within air spaces may change the moisture distribution by moisture convection. Rain or melting snow may also affect the moisture conditions.
e. The real boundary conditions are not constant over a month.
f. Most materials are at least to some extent hygroscopic and can absorb water vapour.
g. One-dimensional moisture transfer is assumed.
h. The effects of solar and long-wave radiation are neglected. NOTE Due to the many sources of error, this calculation method is less suitable for certain building components and climates. Neglecting moisture transfer in the liquid phase normally results in an overestimate of the risk of interstitial condensation (BSI 2002).

BRE Literature Review - Solid Wall Heat Losses and the Potential for Energy Savings (2014)

The aforementioned BRE Literature Review supports these findings, stating that the Glaser method is generally only applicable for modern, non-hygroscopic building materials used in buildings with ventilated rainscreens, because it does not support the assessment of capillary moisture transport action, the effect of short term variations in rain and solar heat, nor the absorption capacity of individual building materials. [152] For traditional buildings, the authors instead recommend the use of hygrothermal assessment tools based on the principles of EN 15026:2007 (such as WUFI) as these are more reliable in predicting the build-up and transfer of moisture in traditional building components.

IP 5/06 Modelling Condensation and Airflow in Pitched Roofs (2006)

In addition, the BRE Information Paper 5/06 *Modelling Condensation and Airflow in Pitched Roofs* asserts that as airflow through cracks and cavities dominate the movement of moisture into cold pitch roofs (which account for 70-80% of domestic

[152] Gemmell, A. (2014) *Solid Wall Heat Losses and the Potential for Energy Savings: Literature Review*, Watford: Building Research Establishment Ltd. Available at: https://www.gov.uk/government/publications/solid-wall-heat-losses-and-the-potential-for-energy-savings-literature-review. p 103.

buildings in the UK), this invalidates assessment methods based on EN 137883.[153]

2.4.4.3 The EN 15026:2007 Methodology

I.S. EN 15026:2007 Hygrothermal Performance of Building Components and Building Elements

A number of numerical hygrothermal simulation software programmes exist that are designed to comply with the principles of EN 15026:2007, such as MOIST[154], Delphin[155], COMSOL[156] and WUFI[157]. Numerical simulation for hygrothermal assessments was developed in the 1990s, and unlike the Glaser method, it is designed to work with construction methods that allow the transfer of moisture through building materials.[158] The Glaser method was designed to measure the hygrothermal suitability of a component and as it does not account for the capillary transport of moisture, the absorption capabilities of the component or short-term environmental conditions like rain and solar radiation, it cannot be used to simulate realistic heat and moisture conditions. By comparison, simulation programmes based on the EN 15026:2007 methodology are expected to give a more realistic assessment of moisture risks because it takes into account real-time factors such as driving rain, solar heat gain, moisture storage and transport, and daily changes to conditions.[159] However, the software is complex and professionals will need to take a training course to use them.

HES Technical Paper 15: Assessing Risks in Insulation Retrofits using Hygrothermal Software Tools: Heat and Moisture Transport in Internally Insulated Stone Walls (2015)

Internal Insulation of Solid Masonry Walls: Practical Limits Due to Thermal Bridging and Moisture Performance (2013)

HES Technical Paper 15 takes an in-depth look at the difference between the steady-state condensation risk assessment methodologies used by the Glaser method and the transient hygrothermal performance analysis numerical simulations advised by EN 15026:2007. The authors stated and proved that the assessment of solid wall buildings and hygroscopic materials inherently fall within scope of the 15026 method and inherently out of the scope of the 13788 method. As EN 13788:2012 is designed to be applied only to modern construction, the use of desktop assessment tools based on 13788 for traditional buildings would be a non-compliant use of the standard, and therefore should be inadmissable. The report notes that an increasing number of UK

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[153] Sanders, C. (2006) *Information Paper 5/06: Modelling Condensation and Airflow in Pitched Roofs*: Building Research Establishment Ltd. Available at: https://www.thenbs.com/PublicationIndex/documents/details?Pub=BRE&DocID=278428.

[154] *MOIST Hygrothermal Simulation Software*: U.S. National Institute of Standards and Technology. Available at: https://www.nist.gov/programs-projects/moist (Accessed: 8 December 2017).

[155] *Delphin Hygrothermal Simulation Software*: Delphin. Available at: http://bauklimatik-dresden.de/delphin/index.php?aLa=en (Accessed: 8 December 2017).

[156] *COMSOL Multiphysics Modelling Software* (2018). Stockholm: COMSOL Inc. Available at: https://www.comsol.com/ (Accessed: 12 February 2018).

[157] *WUFI Hygrothermal Simulation Software*: Fraunhofer IBP. Available at: https://wufi.de/en/ (Accessed: 8 December 2017).

[158] Little, J., Ferraro, C. and Arregi, B. (2015) *Technical Paper 15: Assessing Risks in Insulation Retrofits using Hygrothermal Software Tools - Heat and Moisture Transport in Internally Insulated Stone Walls*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=8a2a7b9d-e3b2-4c7d-8c17-a59400a8387b. p 112.

[159] Marincioni, V., Sanders, C., May, N., Fehr, C. and Singh, U. (2013) *Internal Insulation of Solid Masonry Walls: Practical Limits due to Thermal Bridging and Moisture Performance*. Available at: http://stbauk.org/stba-guidance-research-papers. Appendix A.

universities are using numerical simulation software based on 15026 to assess the hygrothermal performance of buildings and materials and that an increasing number of construction professionals in Ireland and the UK have been trained in its use. Some large construction product manufacturers have also begun to use numerical simulation to test their new products. However, while its use is growing, the authors note that the availability of reliable hygrothermal data has not increased and that 'no existing materials from any building in Ireland or the UK have yet been subjected to the full range of hygrothermal testing'.[160] The study was also notable for its use of Karsten tubes to measure the absorptivity of the external face of the solid wall to aid a more accurate selection of materials from the Fraunhofer IBP database of materials in WUFI.

A number of case studies now exist that have used the WUFI programme to assess the energy performance of traditional buildings. WUFI Pro was developed by the Fraunhofer Institute for Building Physics (IBP) and is one of the most advanced numerical simulation software programmes commercially available.

SPAB Research Report 3: Hygrothermal Modelling (2012)

The *SPAB Hygrothermal Modelling Report* explains how to calculate the values for material properties that need to be inserted into the WUFI software to gain acceptable results. [161] The study also used the WUFI software to assess the pre- and post-refurbishment energy efficiency of an 1820s brick terrace dwelling in Abbeyforegate, Shrewsbury to determine how to improve the accuracy of input data through affordable and accessible test methods.

Internal Insulation of Solid Masonry Walls: Practical Limits Due to Thermal Bridging and Moisture Performance (2013)

Appendix A of the STBA discussion paper, *Internal Insulation of Solid Masonry Walls – Practical Limits due to Thermal Bridging and Moisture Performance*, assessed the effect of increasing the thickness of internal wall insulation on the moisture content of solid masonry walls in conditions of driving rain.[162] The report used WUFI and data from a particularly rainy year in Glasgow to simulate moisture retention in a solid brick wall insulated internally with 140mm of Pavedrentro and plaster on either side over a 6-year period. The simulation showed that in extreme rain conditions, the internal insulation applied at that thickness would lead to unacceptably high levels of relative humidity within the interstitial plaster by reducing the amount of internal heat that would reach it.

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[160] Little, J., Ferraro, C. and Arregi, B. (2015) *Technical Paper 15: Assessing Risks in Insulation Retrofits using Hygrothermal Software Tools - Heat and Moisture Transport in Internally Insulated Stone Walls*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=8a2a7b9d-e3b2-4c7d-8c17-a59400a8387b. p 12.

[161] Browne, D. (2012) *The SPAB Research Report 3: The SPAB Hygrothermal Modelling - Interim Report*: Society for the Protection Ancient Buildings. Available at: https://www.spab.org.uk/advice/research/findings. p 22.

[162] Marincioni, V., Sanders, C., May, N., Fehr, C. and Singh, U. (2013) *Internal Insulation of Solid Masonry Walls: Practical Limits due to Thermal Bridging and Moisture Performance*. Available at: http://stbauk.org/stba-guidance-research-papers. Appendix A.

Historic England also used WUFI to predict the impact that different internal wall insulation systems combined with different levels of driving rain would have on the relative humidity of the brick wall and internal insulation interface in the historic Shrewsbury Flax Mill Maltings over the course of thirty years.[163] In the long term, internal insulations with a high vapour resistance (such as PIR) or hygroscopic insulations (such as mineral wool) applied with a vapour control barrier were shown to cause an accumulation and retention of interstitial moisture. Both of these scenarios exceeded and maintained relative humidity levels above 90% from the beginning. In addition, high levels of driving rain were shown to have a significant impact on the moisture content of the brick wall and insulation interface.

HE Research Report: Hygrothermal Modelling of Shrewsbury Flax Mill Maltings (2015)

A Dublin-based case study by Joseph Little and Beñat Arregi demonstrated the superior functionality of the two-dimensional dynamic hygrothermal simulation capabilities of programmes based on EN 15026 through a brick-faced traditional dwelling.[164] The case study simulated four scenarios: the building in its original condition and three typical renovation approaches. The simulation results showed increased moisture at the base of the wall in all three renovation approaches and that renovation measures with high permeability and no vapour control membrane resulted in the lowest hygrothermal risk.

Hygrothermal Risk Evaluation for the Retrofit of a Typical Solid-Walled Dwelling (2016)

During the renovation of New Court at Trinity College, Cambridge, it was necessary to calibrate the default settings and database materials (configured for modern buildings and contemporary EU standards) to fit with the historic, irregular materials of the building. To do so, samples of brick, stone and render from New Court were sent to the Glasgow Caledonian University for an in-depth assessment of their porosity and hygrothermal properties. A great breadth of quality was found in the bricks and, to be on the safe side, it was decided to enter the data from the worst performing bricks into the simulation software.[165] The findings of the WUFI monitoring have been published in the RIBA publication *Sustainable Building Conservation: Theory and Practice of Responsive Design in the Heritage Environment*, as well as through two conference papers published in the proceedings of the second international

New Court, Trinity College, Cambridge: Continuing a Legacy of Inhabitation (2015)

Retrofit Internal Insulation at New Court, Trinity College, Cambridge: Options, Issues and Resolution through Material Sampling and Modelling (2016)

The Role of Monitoring and Feedback in the Refurbishment of Traditional Buildings: New Court, Trinity College, Cambridge (2016)

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[163] Baker, P. (2015) *Research Report Series: Hygrothermal Modelling of Shrewsbury Flax Mill Maltings*: Historic England88-2015). Available at: http://research.historicengland.org.uk/Report.aspx?i=15400&ru=%2fResults.aspx%3fp%3d1%26n%3d10%26t%3dHygrothermal%26ns%3d1.

[164] Arregi, B. and Little, J. (2016) 'Hygrothermal Risk Evaluation for the Retrofit of a Typical Solid-Walled Dwelling', *Sustainable Design & Applied Research in Engineering and the Built Environment (SDAR),* (6), pp. 17-26.

[165] Smith, O. (2015) 'New Court, Trinity College, Cambridge: Continuing a Legacy of Inhabitation', in Prizeman, O. (ed.) *Sustainable Building Conservation: Theory and Practice of Responsive Design in the Heritage Environment*. Newcastle upon Tyne: RIBA Publishing, pp. 159-191. p 175-176.

conference on the Energy Efficiency and Comfort of Historic Buildings.[166] [167]

Free trial versions of a variety of WUFI software programmes (Pro, Passive, Plus, Light) are available for download through the Oak Ridge National Laboratories/Fraunhofer Institute for Building Physics.[168]

WUFI Online Shop – Free Trial Versions

[166] Gustafsson, J., Brookes, C., Rye, C., Scott, C. and Smith, O. 'Retrofit Internal Insulation at New Court, Trinity College, Cambridge: Options, Issues and Resolution through Material Sampling and Modelling'. *Energy Efficiency and Comfort of Historic Buildings (EECHB)*, Brussels, 19-21 October: Flanders Heritage Agency, 289-295.

[167] Rye, C., Scott, C., Smith, O., Gustafsson, J. and Brookes, C. 'The Role of Monitoring and Feedback in the Refurbishment of Traditional Buildings: New Court, Trinity College, Cambridge'.Ibid., 206-216.

[168] *WUFI Online Shop - Free Versions*: Fraunhofer IBP. Available at: https://wufi.de/en/webshop/ (Accessed: 11 January 2018).

2.5 Best Practice Deep Energy Renovation Guidance

2.5.1 Technical Guidance and Advice Series

2.5.1.1 Irish Technical Guidance

NSAI S.R. 54:2014 Code of Practice for the Energy Efficient Retrofit of Dwellings

The National Standards Authority of Ireland (NSAI) works with governmental bodies, businesses and specialists at a national and international level to deliver new or to revise existing standards in Ireland. Although *Standard Recommendation 54:2014: Code of Practice for the Energy Efficient Retrofit of Dwellings* is currently not applicable to traditional buildings (see Section 2.3.11), there are a few guidance documents published in Ireland that provide supplementary advice.

Advice Series: Energy Efficiency in Traditional Buildings (2010)

Energy Efficiency in Traditional Buildings[169] is one of eleven Advice Series guidance documents produced by what is now the Department of Culture, Heritage and the Gaeltacht, and remains the sole guidance level document published in Ireland that addresses energy efficiency in historic (pre-1945) and traditional (solid wall) buildings. The document has been referenced a number of times in this paper and despite being published in 2010, a supplementary standard to accompany S.R. 54:2014 has not yet been produced to reflect the guidance within it.

Built to Last: the Sustainable Reuse of Buildings (2004)

Built to Last (2004[170]; 2nd ed. forthcoming 2018[171]) was a joint publication funded by the Heritage Council and Dublin City Council that promoted the sustainable reuse of older buildings. The forthcoming second edition*, Built to Last: Renovations of Historic Dublin Dwellings*, will be significantly more technical in nature to guide the energy renovation of traditional and historic buildings. The publication will provide guidance on various aspects of deep energy renovation, such as the upgrading the thermal efficiency of building fabric, the installation of heating and renewable energy systems, and principles and priorities to base specification decisions on. The publication will also include case studies of renovation works undertaken at 15 historic dwellings in Dublin that assess the impact of the works on the energy performance, as well as the architectural significance, of the dwelling.

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[169] *Advice Series: Energy Efficiency in Traditional Buildings* (2010), Dublin: Department of the Environment, Heritage and Local Government. Available at: https://www.chg.gov.ie/heritage/built-heritage/architectural-heritage-advisory-service/advice-for-owners/.

[170] *Built to Last: The Sustainable Reuse of Buildings* (2004), Dublin, Ireland: The Heritage Council. Available at: http://www.turas-cities.org/uploads/biblio/document/file/326/sustainable_reuse_buildings_athusaid_inbhuanaithe_foirgneamh.pdf.

[171] Little, J., McGirl, F., Hanratty, M. and Arregi, B. (Forthcoming 2018) *Built to Last: Renovations of Historic Dublin Dwellings.* Dublin.

The NSAI also issue what are known as Agrément Certificates to proprietary building products and systems that have been certified as fit for the Irish construction industry. The NSAI state that their Agrément logo provides customer confidence that the products will deliver on the manufacturer's promises, and in the case of insulation, that the products will improve the building's thermal performance and reduce heating bills to the level expected.[172]

NSAI Agrément Certification and Registered Insulation Installer Schemes

The quality of workmanship is as important as the quality of the product and the NSAI Agrément also certifies building professionals through a registered installer scheme for external and cavity wall insulation. Again, this scheme is designed to provide the building owner and the government with the necessary assurances that the work is done correctly. Unfortunately, it is not made clear on the NSAI Agrément website whether the external installation installer certification and approved insulations apply to modern or traditional solid wall buildings, or even that the two require different approaches and material properties. However, the certification structure is there and should be expanded to certify insulation materials, methods and installers with regard to traditional buildings, which is greatly needed in Ireland.

2.5.1.2 British Technical Guidance and Decision-Making Tools

Historic Environment Scotland (HES) has led the way in producing technical guidance documents for conservation and built environment professionals, and has also produced more general advice series for home and building owners. Ireland currently has a long way to go to match their output, but due to the similarities in our climates and building traditions, much of the recommended guidance in the HES documents is applicable to the Irish context.

HES Technical Papers

HES Technical Advice Notes

HES Refurbishment Case Studies

The HES Technical Papers, Technical Advice Notes and Refurbishment Case Study reports are written with the building and conservation professional in mind and therefore provide a high level of detail on complex matters. The HES Technical Papers disseminate the findings of research carried out or commissioned by HES. Twenty-three Technical Papers have been published to date, which primarily address different aspects of improving the energy efficiency of traditional buildings through papers such as *Indoor Air Quality and Energy Efficiency in Traditional Buildings*[173] and *Data Sources for Energy Performance Assessments of Historic*

[172] *NSAI Agrément Certification* (2017): National Standards Authority of Ireland (NSAI). Available at: https://www.nsai.ie/Agrement.aspx (Accessed: 18 December 2017).

[173] Halliday, S. (2009) *Technical Paper 6: Indoor Air Quality and Energy Efficiency in Traditional Buildings*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=e079f85f-4aa6-4218-b3c9-a59400e211fc.

Buildings in the United Kingdom[174]. The Refurbishment Case Study reports detail the work undertaken during HES funded refurbishment projects intended to improve the thermal efficiency of traditional buildings, twenty-five of which have been published to date. Many of these HES publications have been referenced within the appropriate section in this report and all publications are free to download from the HES website.

HE Energy Efficiency Research Reports

Historic England (HE) has published a number of energy efficiency technical reports under their Research Reports series and more general guidance notes under their Energy Efficiency and Historic Buildings (EEHB) series. The current focus of the Energy Efficiency Research Reports can be summarised in five categories:

1. thermal performance of traditional buildings;
2. moisture accumulation in building fabric due to energy efficiency measures;
3. numerical modelling of hygrothermal behaviour of building fabric as a risk assessment tool;
4. 'whole building' approach to energy saving in historic buildings; and
5. the SPAB building performance survey.

The SPAB Research Reports (2011-2017)

SPAB Research Report Series are a series of technical reports produced by the Society for the Protection of Ancient Buildings (SPAB) that compile the findings of the SPAB Building Performance Surveys. The first of the three SPAB Research Reports focuses on research relating to heat loss through traditional walls and the different results achieved by the in situ U-value assessment methods and the less accurate theoretical calculation models.[175] The second SPAB Research Report summarises the interim findings of the SPAB Building Performance Surveys, which assessed the performance of three traditional buildings before and after deep energy renovations works were completed.[176] The third SPAB Research Report reviews the application of British Standards and hygrothermal modelling methods advised by EN 15026:2007 and EN 13788:2012 to traditional buildings.[177]

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[174] Hay, S., Clark, T., Simpson, S. and Ingram, V. (2014) *Technical Paper 21: Data Sources for Energy Performance Assessments of Historic Buildings in the United Kingdom - Identifying Online Data Sources for the EFFESUS Project*, Edinburgh: Historic Environment Scotland (978 1 84917 157 1. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=8ef2d1cd-ab8c-423e-9635-a59400ab1020.

[175] Rye, C. and Scott, C. (2012) *The SPAB Research Report 1: The SPAB U-Value Report*: Society for the Protection of Ancient Buildings. Available at: https://www.spab.org.uk/advice/research/findings.

[176] Rye, C., Scott, C. and Hubbard, D. (2012) *The SPAB Research Report 2: The SPAB Building Performance Survey 2012 - Interim Report*: Society for the Protection Ancient Buildings. Available at: https://www.spab.org.uk/advice/research/findings.

[177] Browne, D. (2012) *The SPAB Research Report 3: The SPAB Hygrothermal Modelling - Interim Report*: Society for the Protection Ancient Buildings. Available at: https://www.spab.org.uk/advice/research/findings.

Best Practice Deep Energy Renovation Guidance

The Sustainable Traditional Buildings Alliance (STBA) is an independent, not-for-profit organisation that develops policy, guidance and training to limit the negative impacts on traditional buildings and maximise benefits to the building and homeowners when maintenance, repair and energy renovation works are being undertaken. Founded in 2012 it has already had an impressive impact through research, online guides, publications and white papers. The STBA has published a number of advisory papers referenced throughout this study, and their *Responsible Retrofit* guidance series has been contextualised and exemplified in partnership with Bristol City Council through the publication of *A Bristolian's Guide to Solid Wall Insulation: A Guide to the Responsible Retrofit of Traditional Homes in Bristol.*[178]

A Bristolian's Guide to Solid Wall Insulation (2015)

The *STBA Responsible Retrofit Guidance Wheel* encourages users to explore the performance attributes and potential material conflicts of over 50 renovation measures.[179] The wheel is categorised according to building elements (roof, wall, floor, etc.) with the relevant renovation measures inserted within the pie slices. Each renovation measure is colour coded to mark out technical, heritage and energy concerns ranging from minor to major (see Section 2.6.5). Once a measure is selected, a series of arrows appear to direct the user to other related measures. Finally, after the appropriate measures have been selected and added to a list, a final report can be printed that includes details of the advantages, concerns, related measures, references for further reading and suggested actions to minimise the risk of unintended outcomes.

STBA Responsible Retrofit Guidance Wheel

The Royal Institution of Chartered Surveyors has produced a Guidance Note on sustainability issues, *Improving Performance in Existing Buildings*.[180] This document provides professional guidance on the role of the surveyor in sustainability matters, how to survey a building in terms of meeting sustainability benchmarks, and the financial, legal and commercial considerations that effect the design of deep energy renovations. The Dec 2016/Jan 2017 edition of the RICS Building Surveying Journal focused entirely on energy efficiency in the built environment, which included five articles on building conservation. John Edward's article, *Back to Basics*, underscored how an understanding of how a traditional building was designed to work is a preliminary requirement to ensure the best outcomes of any energy renovation project.[181]

RICS Guidance Note: Sustainability: Improving Performance in Existing Buildings (2013)

RICS Building Conservation Journal (Dec 2016/Jan 2017)

[178] *A Bristolian's Guide to Solid Wall Insulation: A Guide to the Responsible Retrofit of Traditional Homes in Bristol* (2015), Bristol: Sustainable Traditional Buildings Alliance (STBA). Available at: https://warmupbristol.co.uk/content/solid-wall-insulation.

[179] *STBA Responsible Retrofit Guidance Wheel* (2017): The Sustainable Traditional Buildings Alliance. Available at: http://responsible-retrofit.org/wheel/ (Accessed: 5 December 2017).

[180] *RICS Guidance Note: Sustainability - Improving Performance in Existing Buildings* (2013), Coventry: Royal Institution of Chartered Surveyors (RICS) (GN 105/2013. Available at: http://www.rics.org/uk/knowledge/professional-guidance/guidance-notes/sustainability-improving-performance-in-existing-buildings-1st-edition/.

[181] Edwards, J. (2017a) 'Back to Basics', *RICS Building Conservation Journal,* (Dec 2016/Jan 2017), pp. 28-29.

2.5.1.3 European Technical Guidance and Decision-Making Tools

Building Performance Institute of Europe (BPIE)

The Building Performance Institute Europe (BPIE) is a non-profit think tank established to ensure 'the effective implementation of the 2010 EU Energy Performance of Buildings Directive (EPBD) and the 2012 Energy Efficiency Directive (EED); as well as the financing and delivery of energy efficiency retrofits to existing buildings'. This work is supported by independent analysis and knowledge dissemination and aims to support evidence-based policy-making to support improved energy efficiency in buildings.

BPIE Policy Factsheet: Building Renovation Passports - Consumer's Journey to a Better Home

Building Renovation Passports: Customised Roadmaps towards Deep Renovation and Better Homes (2016)

European Commission Press Release: Commission Welcomes Agreement on Energy Performance of Buildings (2017)

The BPIE have published a Policy Factsheet[182] and a more detailed report[183] providing an overview of Building Renovation Passports (BRPs) and three European examples already in operation in France, Flanders and Germany. BRPs are designed to provide personalised long-term (15-20 years) renovation roadmaps to assist homeowners in achieving the best results throughout their energy renovation process. The BPIE Factsheet recommended that the revised Energy Performance of Buildings Directive (EPBD) should require Member States to implement some form of guidance for step-by-step deep energy renovations, such as a Building Renovation Passport. This recommendation looks to have been taken on board and the revised EPBD text is due to be published in early 2018 after its approval by the European Parliament and Council.[184] The SEAI is also in the process of updating the BER system and by June 2018, it should provide more guidance on the preferred sequence of step-by-step renovation.

Implementing the Energy Performance of Buildings Directive (2015)

Implementing the Energy Performance Building Directive (EPBD) was published in 2015 to take stock of progress made by EU Member States in implementing the EU targets into their national frameworks.[185] In Part A of the document, experts provide technical information and recommendations for achieving the key targets of the EPBD and EED. Part B of the report provides the implementation status of all 28 EU Member States and Norway.

3ENCULT Handbook, Energy Efficient Solutions for Historic Buildings (2014)

The 3ENCULT (Efficient Energy for EU Cultural Heritage) project was funded by the EU Seventh Framework Programme from October 2010 to March 2014 with the objective to develop passive and active solutions for the energy renovation of historic and culturally significant buildings in Europe. To do so, the project brought together specialists in architecture, conservation, building physics,

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[182] *Policy Factsheet: Building Renovation Passports - Consumer's Journey to a Better Home*: Building Performance Institute Europe. Available at: http://bpie.eu/publication/building-renovation-passports-consumers-journey-to-a-better-home/.

[183] Fabbri, M., De Groote, M. and Rapf, O. (2016) *Building Renovation Passports: Customised Roadmaps towards Deep Renovation and Better Homes*: Building Performance Institute Europe (BPIE). Available at: http://bpie.eu/publication/renovation-passports/.

[184] *Commission Welcomes Agreement on Energy Performance of Buildings* (2017). Brussels: European Commission. Available at: http://europa.eu/rapid/press-release_IP-17-5129_en.htm.

[185] *Implementing the Energy Performance of Buildings Directive (EPBD).* (2015) Lisbon: Portuguese Energy Agency (ADENE).

sustainability, lighting and cybernetics to ensure the solutions were both sustainable and economically beneficial. The project culminated in the publication of the handbook, *Energy Efficient Solutions for Historic Buildings*, which includes eight case studies that demonstrate the recommended solutions in practice. The fourth case study features a 1768 Neoclassical solid brick walled warehouse turned office in Copenhagen, which has the same Marine West Coast climate as Ireland, defined by warm summers, mild winters and rain all year round. The study estimates that 180 metric tonnes of CO_2 can be saved through the energy renovation of Europe's 85 million pre-1945 buildings.[186] The 3ENCULT project produced a wealth of publicly accessible deliverables covering building analysis, energy efficient solutions, monitoring and climatic control, case studies and transferability of practice, design tools and quality assurance, and professional training and information dissemination.[187]

Section 5.8 of the 3ENCULT *Energy Efficient Solutions for Historic Buildings* handbook provides an overview of the recommended process for selecting appropriate renovation solutions for traditional and protected buildings.[188] The text suggests different simulation software and planning packages based on whether a static or dynamic calculation is required, followed by practical examples of different renovation solutions simulated in cold, mild and warm climates. A paper presented at the Energy Efficiency and Comfort of Historic Buildings (EECHB) conference in 2016 demonstrates the integrated diagnostic approach developed as part of the 3ENCULT project through a series of pre- and post-intervention diagnosis and monitoring procedures at a 15th century villa in Italy.[189]

EECHB: Integrated Diagnostic Approach for the Structural and Energetic Evaluation of Historic Buildings (2016)

EECHB: GBC Historic Building®: a new certification tool for orienting and assessing environmental sustainability and energy efficiency of historic buildings (2016)

First building certified GBC Historic Building: the stables of the Rocca di Sant'Apollinare (2018)

The Italian Green Building Council has developed a new energy rating system, *GBC Historic Building*, which is based on LEED to evaluate the sustainability of renovation works in pre-1945, traditional buildings.[190] The GBC Historic Building energy rating system introduces the new topic of Historic Value (20 points) alongside the original topics assessed through LEED, meaning the retention of historic buildings is a sustainable action in itself and therefore contributes to the overall level of sustainability (Certified: 40 to 49 points; Silver: 50 to 59 points; Gold: 60 to 79 points; or Platinum: 80 to 110 points). The new system also emphasises that

[186] Troi, A. and Bastion, Z. (eds.) (2014) *Energy Efficient Solutions for Historic Buildings: A Handbook*: Birkhäuser. p 9.
[187] *3ENCULT: Efficient Energy for EU Cultural Heritage*. Bozen, Italy: EURAC research. Available at: http://www.3encult.eu/en/project/welcome/default.html (Accessed: 31 October 2017).
[188] Troi, A. and Bastion, Z. (eds.) (2014) *Energy Efficient Solutions for Historic Buildings: A Handbook*: Birkhäuser. p 189.
[189] Colla, C. and Gabrielli, E. 'Integrated Diagnostic Approach for the Structural and Energetic Evaluation of Historic Buildings'. *Energy Efficiency and Comfort of Historic Buildings (EECHB)*, Brussels, 19-21 October: Flanders Heritage Agency, 44-51. p 44.
[190] Lucchi, E., Boarin, P. and Zuppiroli, M. 'GBC Historic Building®: a New Certification Tool for Orienting and Assessing Environmental Sustainability and Energy Efficiency of Historic Buildings'. *Energy Efficiency and Comfort of Historic Buildings*, Brussels, 19-21 October: Flanders Heritage Agency, 250-256. p 250.

the historic value of traditional buildings to the community context should not be compromised during energy renovations, but that sustainable solutions should be found to work with and enhance the performance of the buildings. In February 2018, the former stables of the 10th century Benedictine Monastery of the Rocca di Sant'Apollinare, located near Spina in the region of Perugia, were awarded the first GBC Historic Building certification, achieving a Gold standard rating.[191]

To Understand and Renovate the Old Building in Alsace: The Study-Advice of the State (2016)

EECHB: Guidance for finding a sustainable balance between energy efficiency, comfort, moisture damage and cultural heritage value in historic buildings (2016)

The French Ministry of Cultural Affairs and Ministry of Sustainable Development has developed guidance based on those first created by the National Association of Cities and Countries of Art and History to help traditional building owners find a balance between improved energy efficiency and heritage conservation. The guidance consists of two primary phases: Phase 1 includes the assessment of the existing condition, hygrothermal performance and heritage value; Phase 2 involves the selection of solutions that improve the thermal performance without damaging the historic value or hygrothermal performance. The application of the process has been documented through the *Ancient Habitat in Alsace: Energy and Heritage*.[192] The report documents are only available in French, however the associated EECHB conference paper *Guidance for Finding a Sustainable Balance between Energy Efficiency, Comfort, Moisture Damage and Cultural Heritage Value in Historic Buildings* summarises the evaluation criteria in terms of energy efficiency and heritage conservation and applies the strategy to a case study building in Strasbourg.[193]

EuroPHit Handbook: Step-by-Step Retrofits with Passive House Components (2016)

EuroPHit Brochure: Implementing Deep Energy Step-by-Step Retrofits (2016)

Criteria for the Passive House, EnerPHit and PHI Low Energy Building Standard (2016)

The Passive House Institute (PHI) has developed the EnerPHit Standard for the renovation of existing buildings. Although the level of change and likely heritage loss can make it unfeasible for traditional buildings to be renovated to meet the more onerous Passive House standard, the PHI estimates that energy consumption in traditional buildings can be reduced by 80% using the EnerPHit standard, through the application of compatible renovation measures and Passive House technologies. To guide the renovation process, the Passive House Institute has produced the *EuroPHit Step-by-Step Retrofits with Passive House Components Handbook*[194], the *EuroPHit Implementing Deep Energy Step-by-Step Retrofits*

[191] *First Building Certified GBC Historic Building: the Stables of the Rocca di Sant'Apollinare* (2018). News & Events: Green Building Council Italia. Available at: https://goo.gl/NFqCbu (Accessed: 4 March 2018).
[192] *To Understand and Renovate the Old Buildings in Alsace: the Study-Advice of the State* (2016). Studies on the Renovation of Existing Buildings. France: Ministry of Ecological and Solidarity Transition. Available at: http://www.grand-est.developpement-durable.gouv.fr/pour-comprendre-et-renover-le-bati-ancien-en-a193.html (Accessed: 4 March 2018).
[193] Héberlé, E. and Burgholzer, J. 'Guidance for Finding a Sustainable Balance between Energy Efficiency, Comfort, Moisture Damage and Cultural Heritage Value in Historic Buildings'. *Energy Efficiency and Comfort of Historic Buildings (EECHB)*, Brussels: Flanders Heritage Agency, 52-58.
[194] *EuroPHit Handbook: Step-by-Step Retrofits with Passive House Components* (2016). Available at: http://europhit.eu/sites/europhit.eu/files/EuroPHit_Handbook_final_Optimized.pdf.

Brochure[195] and the *Criteria for the Passive House, EnerPHit and PHI Low Energy Building Standard*[196]. Numerous case studies of traditional and protected historic buildings renovated to Passive House retrofit standard have also been added to the Passive House Database[197] (see Sections 2.6.5 and 2.6.7.2).

Details for Passive Houses: Renovation - A Catalogue of Ecologically Rated Constructions (2016)

Passive House Planning Package (PHPP), Version 9 (2015)

For building professionals, the extensive technical guide, *Details for Passive Houses: Renovation*, has been produced which explains the basic physics of traditional buildings, the hygrothermal risks involved with installing high levels of insulation, and other aspects to be considered during a renovation like air tightness, ventilation and the reconstruction or reinstallation of original design aspects.[198] The guide breaks the building tasks down into sections by construction date: Pre-1918, 1920-1950, 1950s-1960s, 1970s and 1980s, then the renovation tasks are further broken down by the type of construction and building materials. In addition, the *Passive House Planning Package* (PHPP) is a planning tool designed for architects and planning professionals that uses tried and tested calculations to yield a building's heating, cooling and energy demand. Version 9 (2015) includes new features useful for planning a step-by-step EnerPHit-approved renovation of an existing building.[199] The PHPP must be used to verify compliance with the Passive House or EnerPHit standards.

EFFESUS Booklet: Energy Efficiency in European Historic Urban Districts: A Practical Guidance (2016)

EFFESUS Research Reports (2016)

The EFFESUS (Energy Efficiency for EU Historic Districts' Sustainability) project, funded by the European Union's Seventh Framework Programme, was tasked with developing a methodology and criteria for selecting and prioritising energy efficiency interventions for historic buildings and districts.[200] The primary output of the project is the booklet, *Energy Efficiency in European Historic Urban Districts: A Practical Guide*[201], however, the EFFESUS research reports produced by a team of international experts are also available through the EFFESUS website. The EFFESUS guide provides technical and well-researched guidance on the following areas: Strategies for the energy assessment of historic urban districts; Energy efficiency solutions for historic buildings and

[195] *EuroPHit Brochure: Implementing Deep Energy Step-by-Step Retrofits - Increasing the European Potential* (2016), Darmstadt, Germany: Passive House Institute. Available at: http://europhit.eu/sites/europhit.eu/files/EuroPHit_brochure_final_PHI.pdf.
[196] *Criteria for the Passive House, EnerPHit and PHI Low Energy Building Standard* (2016): Passive House Institute. Available at: http://passiv.de/downloads/03_building_criteria_en.pdf.
[197] *Passive House Database*: Passivhaus Institut. Available at: http://passivehouse-database.org/index.php (Accessed: 6 November 2017).
[198] *Details for Passive Houses: Renovation - A Catalogue of Ecologically Rated Constructions.* (2016) Basel, Switzerland: Birkhäuser, p. 312.
[199] *Passive House Planning Package (PHPP) & designPH*: International Passive House Association. Available at: https://www.passivehouse-international.org/index.php?page_id=188 (Accessed: 5 December 2017).
[200] *EFFESUS Research Programme* (2012). Energy Efficiency for EU Historic Districts' Sustainability: The European Commission. Available at: http://www.effesus.eu/ (Accessed: 31 October 2017).
[201] *Energy Efficiency in European Historic Urban Districts: A Practical Guidance* (2016b), Leipzig, Germany: Fraunhofer Centre for International Management and Knowledge Economy MOEZ. Available at: http://www.effesus.eu/dissemination/booklet.

districts; EFFESUS innovations for renovating the envelope of historic buildings; Decision support for energy interventions in historic urban districts; and Overcoming non-technical barriers for energy interventions in historic urban districts.

EFFESUS Decision Support for Energy Improvements (2016)

EFFESUS DSS User's Manual (2015)

EECHB: The Potential for Implementing a Decision Support System for Energy Efficiency in the Historic District of Visby (2016)

EECHB: Facilitating Historic Districts Energy Retrofitting through a Comprehensive Multiscale Framework and its Implementation in the EFFESUS DSS (2016)

An important deliverable of the EFFESUS project was the development of a Decision Support System (DSS) for the assessment of energy renovation measures in protected historic buildings and districts.[202] The EFFESUS DSS is designed to help municipalities and state bodies responsible for the protection of the historic urban environment to guide stakeholders through the process of selecting and prioritising energy interventions, while respecting the historical significance of the buildings.[203] A number of case studies have been published that have used the EFFESUS DSS including *The Potential for Implementing a Decision Support System for Energy Efficiency in the Historic District of Visby*[204] and *Facilitating Historic Districts Energy Retrofitting through a Comprehensive Multiscale Framework and its Implementation in the EFFESUS DSS*[205]. A repository of energy efficient renovation measures and renewable energy technologies was also compiled as part of the EFFESUS project. Though the EFFESUS repository and DSS are currently unavailable at the time of writing, more information about both can be found in Chapters 2 and 4 of the EFFESUS Energy Efficiency in European Historic Urban Districts guide.[206]

EN 16883:2017 Conservation of Cultural Heritage – Guidelines for Improving the Energy Performance of Historic Buildings

Finally, EN 16883:2017 *Conservation of Cultural Heritage: Guidelines for Improving the Energy Performance of Historic Buildings* provides a procedure to identify if energy improvement measures are needed in historic or traditional buildings and which renovation measures fit the requirements of the building (see Section 2.2.3).[207] The decision-making process is guided by a flow chart, which lays out each individual step in the assessment and consideration process. Greater details of each step are provided in section 6 through 11 of the Standard, but the process itself should become second-nature for professionals working with the energy renovation of traditional or historic buildings.

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[202] Egusquiza, A., Hermann, C. and Rodwell, D. (2016) 'Decision Support for Energy Improvements', *Context,* 145, pp. 29-31.

[203] Kariotellis, P. (2015) *Deliverable D6.2: Decision Support System*: EFFESUS. Available at: http://www.effesus.eu/wp-content/uploads/2016/01/EFFESUS-Deliverable-D6-2_Update-21-01-20161.pdf.

[204] Eriksson, P., Egusquiza, A. and Broström, T. 'The Potential for Implementing a Decision Support System for Energy Efficiency in the Historic District of Visby'. *Energy Efficiency and Comfort of Historic Buildings (EECHB)*, Brussels, 19-21 October: Flanders Heritage Agency, 282-288.

[205] Egusquiza, A. and Izkara, J. L. 'Facilitating Historic Districts Energy Retrofitting through a Comprehensive Multiscale Framework and its Implementation in the EFFESUS DSS'.Ibid., 59-67.

[206] *Energy Efficiency in European Historic Urban Districts: A Practical Guidance* (2016b), Leipzig, Germany: Fraunhofer Centre for International Management and Knowledge Economy MOEZ. Available at: http://www.effesus.eu/dissemination/booklet.

[207] *EN 16883:2017 Conservation of Cultural Heritage - Guidelines for Improving the Energy Performance of Historic Buildings* (2017): European Committee for Standardization.

2.5.2 Advice for Traditional Building Owners

Energy renovation advice for home and building owners is generally much less technical in content and designed to introduce the reader to the main concepts of building energy performance and typical efficiency improvement measures. A few introductory guidance documents have been published in Ireland to advise on the conservation, repair and energy renovation of traditional buildings, such as *Maintenance: A Guide to the Care of Older Buildings*[208], *Energy Efficiency in Historic Houses*[209] and the aforementioned DEHLG Advice Series publication *Energy Efficiency in Traditional Buildings*[210].

Advice Series: Maintenance - A Guide to the Care of Older Buildings (2007)

Irish Georgian Society, Energy Efficiency in Historic Houses (2013)

Advice Series: Energy Efficiency in Traditional Buildings (2010)

Historic Environment Scotland has published a number of guidance documents intended for owners of traditional buildings or for heritage conservation enthusiasts that provide a brief overview of topics covered in their technical guidance documents. The INFORM Guides introduce building owners to best practice conservation methods for traditional building components and materials, and also provide guidance on how to rectify common issues, such as damp[211]. The INFORM Guide *Improving Energy Efficiency of Traditional Buildings* provides a non-technical overview of how traditional buildings work and where energy savings can be made.[212] The HES Short Guides bridge the gap between the INFORM Guides and the Technical Papers, and provide a more in-depth introduction to the more complex matters and technical specifications. Short Guides 1[213], 8[214], 10[215] and 11[216] deal directly

HES INFORM Guides

INFORM Guide: Damp - Causes and Solutions (2007)

INFORM Guide: Improving Energy Efficiency in Traditional Buildings (2014)

HES Short Guides

[208] Donnelly, J. (2007) *Advice Series: Maintenance - A Guide to the Care of Older Buildings*, Dublin: Department of Culture, Heritage and the Gaeltacht. Available at: https://www.chg.gov.ie/heritage/built-heritage/architectural-heritage-advisory-service/advice-for-owners/.

[209] 'Energy Efficiency in Historic Houses'. (2013), *Energy Efficiency in Historic Houses*, Dublin: Irish Georgian Society, 76.

[210] *Advice Series: Energy Efficiency in Traditional Buildings* (2010), Dublin: Department of the Environment, Heritage and Local Government. Available at: https://www.chg.gov.ie/heritage/built-heritage/architectural-heritage-advisory-service/advice-for-owners/.

[211] Curtis, R. (2007) *INFORM Guide: Damp - Causes and Solutions*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=bd396452-624b-4b87-9ae4-a59500b4dff4.

[212] Jenkins, M. and Curtis, R. (2014) *INFORM Guide: Improving Energy Efficiency in Traditional Buildings*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=246ff4ae-1483-452a-8fb3-a59500bd05d5.

[213] *Short Guide 1: Fabric Improvements for Energy Efficiency in Traditional Buildings* (2013), Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=179c1909-3679-4486-9583-a59100fa98c1.

[214] Hummelt, K. (2014) *Short Guide 8: Micro-Renewables in the Historic Environment.* Edinburgh: Historic Environment Scotland.

[215] *Short Guide 10: Thermal Imaging in the Historic Environment* (2015), Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=088dab34-1194-43e6-af5e-a62801090992.

[216] Curtis, R. and Hunnisett Snow, J. (2016) *Short Guide 11: Climate Change Adaptation for Traditional Buildings*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=a0138f5b-c173-4e09-818f-a7ac00ad04fb.

with different aspects of improving the energy efficiency and thermal performance of traditional buildings.

HE Energy Efficiency and Historic Buildings Guidance Notes

HE Guidance Notes

HE Guidance Series: Traditional Windows: Their Care, Repar and Upgrading (2017)

Historic England's Energy Efficiency and Historic Buildings (EEHB) series provides introductory guidance on conservation principles and methods, traditional materials and potential renovation risks. Sixteen EEHB guidance notes have been published to date under the following general topics: Insulating Roofs; Insulating Chimneys; Insulating Walls; Draught Proofing Windows and Doors; Insulating Floors; Assessing the Energy Efficiency of Dwellings[217] and the Energy Performance Certificate[218]. The recently revised EEHB publication *Application of Part L of the Building Regulations to Historic and Traditionally Constructed Buildings* was produced to help protect historic and traditional buildings from unnecessary or inappropriate upgrades made to comply with the energy efficiency requirements of Part L of the building regulations for England and Wales .[219] The document provides a background to Part L and explains how the legislation affects existing buildings, and includes ways to meet the Part L requirements. Unlike the English version of Part L, the Irish version makes no mention of historic or culturally significant buildings, however a document such as this EEHB guidance note should be produced to accompany Part L of the Irish Building Regulations. Historic England's general Guidance Series also introduces homeowners to methods to improve the thermal efficiency of their homes through general maintenance and repair through publications like *Traditional Windows: Their Care, Repair and Upgrading*[220].

STBA Responsible Retrofit Guidance Series

What is Whole House Retrofit? (2016)

Planning Responisble Retrofit of Traditional Buildings (2015)

STBA Responsible Retrofit Guidance Wheel

The Sustainable Traditional Buildings Alliance (STBA) have developed a set of new principles under the banner of 'responsible retrofit'. The publications produced under the Responsible Retrofit Guidance Series focus on excess moisture in buildings as the greatest threat to the British national renovation campaign and differentiate sharply between *as designed theoretical* (ADT) and *as built in service* (ABIS) performance. Their publication *What is Whole House Retrofit?*[221]introduces home and building owners to the basics of deep energy renovation, while the *Planning Responsible*

[217] Pickles, D. and Cattini, C. (2015a) *Energy Efficiency and Historic Buildings: Advice for Domestic Energy Assessors and Green Deal Advisors*: Historic England. Available at: https://historicengland.org.uk/images-books/publications/eehb-advice-domestic-energy-assessors-green-deal-advisors/.

[218] Pickles, D. and Cattini, C. (2015b) *Energy Efficiency and Historic Buildings: Energy Performance Certificates*: Historic England. Available at: https://historicengland.org.uk/images-books/publications/eehb-energy-performance-certificates/.

[219] Pickles, D., Brocklebank, I. and Wood, C. (2017a) *Energy Efficiency and Historic Buildings: Application of Part L of the Building Regulations to Historic and Traditionally Constructed Buildings*, London: Historic England. Available at: https://historicengland.org.uk/images-books/publications/energy-efficiency-historic-buildings-ptl/.

[220] Pickles, D., McCaig, I., Wood, C., Molyneux, N. and Makri, E. (2017b) *Traditional Windows: Their Care, Repair and Upgrading*. Available at: https://historicengland.org.uk/images-books/publications/traditional-windows-care-repair-upgrading/.

[221] *Responsible Retrofit Series: What is Whole House Retrofit?* (2016), London: Sustainable Traditional Buildings Alliance (STBA). Available at: http://www.sdfoundation.org.uk/downloads/What-is-Whole-House-Retrofit-Dec2016.pdf.

Retrofit of Traditional Buildings[222] publication and the *Responsible Retrofit Guidance Wheel*[223] support building owners and building professionals in designing holistic strategies and selecting resources that will result in lower moisture risks.

To accompany the *Bristolian's Guide to Solid Wall Insulation: A Guide to the Responsible Retrofit of Traditional Homes in Bristol*[224]developed by the STBA and Bristol City Council, the City Council created a short informational video and an interactive online tool, *Warmup Bristol*, to help homeowners identify the construction type of their home, the possible reason behind existing physical problems and the type of insulation that would suit their home and its immediate context.[225]

A Bristolian's Guide to Solid Wall Insulation (2015)

Warmup Bristol Solid Wall Insulation Survey (2016)

The Bath Preservation Trust and the Centre for Sustainable Energy have also published a guidance document, *Warmer Bath: A Guide to Improving the Energy Efficiency of Traditional Homes in the City of Bath*, which covers a breadth of material and maintenance considerations in traditional homes.[226]

Warmer Bath (2011)

The Cornwall Council Historic Environment Service has also published the guidance document *Improving Energy Efficiency in Historic Cornish Buildings*, which introduces readers to the main aspects of energy renovation measures for traditional buildings and provides references for further reading.[227]

Improving Energy Efficiency in Historic Cornish Buildings (2014)

Along with their technical Research Report series, the Society for the Protection of Ancient Buildings (SPAB) has also published a *SPAB Briefing on Energy Efficiency in Old Buildings* to promote sensitive energy renovation measures designed specifically for historic buildings.[228]

SPAB Briefing: Energy Efficiency in Old Buildings (2014)

The UK-based Energy Saving Trust provides information on ways to improve the energy efficiency of all types of dwellings through their

Energy Saving Trust: Home Energy Efficiency (2017)

[222] May, N. and Griffiths, N. (2015) *Planning Responsible Retrofit of Traditional Buildings*, London: Sustainable Traditional Buildings Alliance (STBA). Available at: http://stbauk.org/.
[223] *STBA Responsible Retrofit Guidance Wheel* (2017): The Sustainable Traditional Buildings Alliance. Available at: http://responsible-retrofit.org/wheel/ (Accessed: 5 December 2017).
[224] *A Bristolian's Guide to Solid Wall Insulation: A Guide to the Responsible Retrofit of Traditional Homes in Bristol* (2015), Bristol: Sustainable Traditional Buildings Alliance (STBA). Available at: https://warmupbristol.co.uk/content/solid-wall-insulation.
[225] *Warmup Bristol Solid Wall Insulation Survey* (2016). Bristol: Bristol City Council. Available at: https://warmupbristol.co.uk/content/solid-wall-insulation (Accessed: 30 October 2017).
[226] Anderson, W. and Robinson, J. (2011) *Warmer Bath: A Guide to Improving the Energy Efficiency of Traditional Homes in the City of Bath.* England: Bath Preservation Trust & the Centre for Sustainable Energy.
[227] *Improving Energy Efficiency in Historic Cornish Buildings* (2014), Cornwall: Cornwall Council Historic Environment Service. Available at: https://www.cornwall.gov.uk/environment-and-planning/conservation/technical-advice-and-guidance/energy-conservation-in-historic-buildings/.
[228] *SPAB Briefing: Energy Efficiency in Old Buildings* (2014), London: Society for the Protection of Ancient Buildings (2054-7684. Available at: http://www.spab.org.uk/briefing/.

website.[229] Under the home insulation tab, information about the benefits, challenges, costs and available grants is provided for solid walls, cavity walls, roofs and attics, floors, draught proofing, damp and condensation solutions, etc. General information is also provided on the types of renewable energy sources available and how to switch to them.

IHBC, *Context* no. 149: Green Retrofit (2017)

The topic of issue number 149 of the Institute of Historic Building Conservation (IHBC) journal Context was Green Retrofit, and the issue provides short but informative articles written by professionals on a range of associated topics, including *Understanding Dampness*[230], *Thermography for Traditional Buildings*[231], *Understanding the Performance of Solid Walls*[232], *The Retrofit Process*[233], *How to Deal with Retrofit Risks*[234] and others.

The National Trust Building Design Guides

The National Trust's energy renovation approach also featured in the Green Retrofit edition of Context.[235] The National Trust have published a series of Building Design Guides on their website, which present sustainable technology case studies designed to save energy or resources at various National Trust properties.[236] Not all of the completed Building Design Guides are featured on this webpage, but additional reports can be found using the publication search tool.

2.5.3 Material Interventions

2.5.3.1 Draught-Proofing Windows and Doors

For traditional buildings, the maintenance or repair of traditional features should be the first step to any energy renovation project and for exceptionally valuable historic buildings, may be the best way to improve thermal performance.

Historic England recommends the following schedule of renovation strategies for traditional buildings prioritised in order of providing the greatest energy savings at the lowest risk of damage or decay:[237]

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[229] *Home Energy Efficiency* (2017). United Kingdom: Energy Saving Trust. Available at: http://www.energysavingtrust.org.uk/ (Accessed: 24 January 2018).
[230] Edwards, J. and Ward, P. (2017) 'Understanding Dampness', *Context,* (149), pp. 15-16.
[231] Atkinson, J. Ibid.'Thermography for Traditional Buildings', pp. 17-18.
[232] Rye, C. and Scott, C. Ibid.'Understanding the Performance of Solid Walls', pp. 25-27.
[233] Edwards, J. Ibid.'The Retrofit Process', pp. 11-12.
[234] King, C. Ibid.'How to Deal with Retrofit Risks', pp. 23-24.
[235] Southall, P. Ibid.'Energy Efficiency for the National Trust', pp. 28-29.
[236] *Building Design Guides*. England: The National Trust. Available at: https://www.nationaltrust.org.uk/features/building-design-guides (Accessed: 12 March 2018).
[237] Gemmell, A. (2014) *Solid Wall Heat Losses and the Potential for Energy Savings: Literature Review*, Watford: Building Research Establishment Ltd. Available at: https://www.gov.uk/government/publications/solid-wall-heat-losses-and-the-potential-for-energy-savings-literature-review. p 112.

1. Draught-proofing of windows and doors
2. Roof insulation
3. Replacement of outdated services with high efficiency units and updated controls
4. Repair of shutters and fitting of curtains, with the possible installation of secondary glazing
5. Floor insulation
6. Wall insulation

While only 10-15% of heat loss occurs through the windowpanes or through gaps around the window frame, traditional windows are often the first to be replaced in the attempt to improve the thermal efficiency of a building. Historic Environment Scotland Technical Paper 1 has shown that draught-proofing measures can reduce air leakage around traditional windows by 86% and achieve air tightness higher than what is recommended for new dwellings.[238] HES Technical Papers 9[239], 20[240] and 23[241] also provide technical guidance on measures to assess and improve the thermal performance of traditional windows.

The Passive House Institute has recommended that triple-glazed windows be used in Ireland and most of Europe, but where historic windows are still intact, they recommend the installation of a hard coating to single pane windows or the replacement of the glass with slim-profile double-glazing.[242] A recent case study by Historic England has shown that methods such as these can reduce heat loss through traditional timber sash windows by 50%.[243]

However, research commissioned by Historic England has also shown that relatively simple and low-cost maintenance measures can improve the thermal performance of traditional timber sash

HES Technical Paper 1: Thermal Performance of Traditional Windows (2010)

HES Technical Paper 9: Slim-Profile Double Glazing: Thermal Performance and Embodied Energy (2010)

HES Technical Paper 20: Slim-Profile Double-Glazing in Listed Buildings (2013)

HES Technical Paper 23: Thermal Assessment of Internal Shutters and Window Film applied to Traditional Single Glazed Sash and Case Windows (2014)

Energy Efficient Solutions for Historic Buildings: A Handbook (2014)

HE Research Reports: Thermal Performance of Energy Efficiency Improvements to Timber Windows (2017)

HE Research Reports: Research into the Thermal Performance of Traditional Windows - Timber Sash Windows (2009)

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[238] Baker, P. (2010) *Technical Paper 1: Thermal Performance of Traditional Windows*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=f3e97c76-b4fa-4c76-a197-a59400be931b. p 2.

[239] Heath, N., Baker, P. and Menzies, G. (2010a) *Technical Paper 9: Slim-Profile Double Glazing - Thermal Performance and Embodied Energy*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=8c01582b-c71e-45d7-8991-a59400e44b0d.

[240] Heath, N. and Baker, P. (2013) *Technical Paper 20: Slim-Profile Double-Glazing in Listed Buildings - Re-Measuring the Thermal Performance*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=a4eee388-69ec-4da6-915f-a59400aa36d5.

[241] Currie, J., Williamson, J. B., Stinson, J. and Jonnard, M. (2014) *Technical Paper 23: Thermal Assessment of Internal Shutters and Window Film Applied to Traditional Single Glazed Sash and Case Windows*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=4a1a95dd-9e9f-4b9d-8381-a59400ac0be8.

[242] Troi, A. and Bastion, Z. (eds.) (2014) *Energy Efficient Solutions for Historic Buildings: A Handbook*: Birkhäuser. p 143-145.

[243] Rhee-Duverne, S. and McCaig, I. (2017) *Research Report Series: Thermal Performance of Energy Efficiency Improvements to Timber Windows*, Swindon: Historic England (02/2017. Available at: http://research.historicengland.org.uk/Report.aspx?i=15555.

windows significantly.[244] The Historic England Energy Efficiency and Historic Buildings (EEHB) Advice Series provides introductory information on the installation of secondary glazing for traditional windows[245], insulating dormer windows[246] and draught-proofing measures for traditional windows and doors[247]. The thermal improvement of traditional metal-framed windows[248] has been covered in their Research Report series and Historic England has also published the comprehensive technical guide, *Traditional Windows: Their Care, Repair and Upgrading*, to encourage proper maintenance and to recommend measures to sustainably upgrade the thermal performance of traditional windows.[249]

HE Energy Efficiency and Historic Buildings Advice Series

HE Guidance: Traditional Windows – Their Care, Repar and Upgrading (2017)

2.5.3.2 Insulating Attics and Roofs

Given that an estimated 25% of heat is lost through a building's roof, insulating at attic or roof level is the second most cost-effective and non-intrusive measure to improve the energy efficiency of traditional or historic buildings. In traditional buildings with a loft space, a minimum of 270mm of quilt insulation, laid between and across rafters in the form of mineral wool, sheep's wool or hemp wool is recommended.[250] Sheep's wool insulation is produced in Ireland, carbon neutral and has superior qualities in terms of moisture evaporation to mineral wool. Hemp wool is also hygroscopic and is a carbon negative product, meaning it traps and stores carbon as it grows, giving it a higher thermal mass overtime. Blown insulation in the form of recycled paper (cellulose) can also be used in attics, though special care must be taken to ensure that vents are not blocked, or it may cause moisture to build up in the roof timbers. The DEHLG supported the independent analysis of these and other natural insulation materials by the NSAI eight years ago, however it does not appear that any natural insulation

Warmer Bath: A Guide to Improving the Energy Efficiency of Traditional Homes in the City of Bath (2011)

Advice Series: Energy Efficiency in Traditional Buildings (2010)

[244] Wood, C., Bordass, B. and Baker, P. (2009) *Research Report Series: Research into the Thermal Performance of Traditional Windows - Timber Sash Windows*: Historic England. Available at: https://content.historicengland.org.uk/images-books/publications/thermal-performance-traditional-windows/thermal-performance-traditional-windows.pdf/.
[245] Pickles, D. (2016j) *Energy Efficiency and Historic Buildings: Secondary Glazing for Windows*: Historic England. Available at: https://historicengland.org.uk/images-books/publications/eehb-secondary-glazing-windows/.
[246] Pickles, D. (2016b) *Energy Efficiency and Historic Buildings: Insulating Dormer Windows*: Historic England. Available at: https://historicengland.org.uk/images-books/publications/eehb-insulating-dormer-windows/.
[247] Pickles, D. (2016a) *Energy Efficiency and Historic Buildings: Draught-Proofing Windows and Doors*: Historic England. Available at: https://historicengland.org.uk/images-books/publications/eehb-draught-proofing-windows-doors/.
[248] Baker, P. (2017) *Research Report Series: Improving the Thermal Performance of Traditional Windows - Metal-Framed Windows*, Swindon: Historic England. Available at: http://research.historicengland.org.uk/Report.aspx?i=15568.
[249] Pickles, D., McCaig, I., Wood, C., Molyneux, N. and Makri, E. (2017b) *Traditional Windows: Their Care, Repair and Upgrading*. Available at: https://historicengland.org.uk/images-books/publications/traditional-windows-care-repair-upgrading/.
[250] Anderson, W. and Robinson, J. (2011) *Warmer Bath: A Guide to Improving the Energy Efficiency of Traditional Homes in the City of Bath.* England: Bath Preservation Trust & the Centre for Sustainable Energy. p 43.

products have been certified through the NSAI Agrément programme yet.[251]

Historic England's Energy Efficiency and Historic Buildings Guidance Series provides basic information on installing roof insulation at rafter level[252], at ceiling level[253], for flat roofs[254] and even for thatched roofs[255].

HE Energy Efficiency and Historic Buildings Advice Series

The benefits of using natural insulation materials, including hemp, sheep's wool, cellulose and wood fibre, are further discussed in the Irish Georgian Society conference proceedings *Energy Efficiency in Historic Houses*[256].

The Use of Appropriate Materials in Maximising Energy Efficiency and Moisture Control in Historic Houses (2013)

HES Refurbishment Case Studies 2[257], 3[258], 5[259], 6[260], 9[261], and 11[262] also address the thermal efficiency of roof and attic spaces through insulation and material improvements.

HES Refurbishment Case Studies

A paper presented at the 2016 *Energy Efficiency and Comfort of Historic Buildings* conference introduced a new lime-based thermal mortar used to insulate the vaults of a medieval church in the Netherlands. The insulating mortar was made of slaked lime and

A Lime Based Mortar for Thermal Insulation of Medieval Church Vaults (2016)

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[251] *Advice Series: Energy Efficiency in Traditional Buildings* (2010), Dublin: Department of the Environment, Heritage and Local Government. Available at: https://www.chg.gov.ie/heritage/built-heritage/architectural-heritage-advisory-service/advice-for-owners/. p 27-28.

[252] Pickles, D. (2016e) *Energy Efficiency and Historic Buildings: Insulating Pitched Roofs at Rafter Level*: Historic England. Available at: https://historicengland.org.uk/images-books/publications/eehb-insulating-pitched-roofs-rafter-level-warm-roofs/.

[253] Pickles, D. (2016d) *Energy Efficiency and Historic Buildings: Insulating Pitched Roofs at Ceiling Level*: Historic England. Available at: https://historicengland.org.uk/images-books/publications/eehb-insulating-pitched-roofs-ceiling-level-cold-roofs/.

[254] Pickles, D. (2016c) *Energy Efficiency and Historic Buildings: Insulating Flat Roofs*: Historic England. Available at: https://historicengland.org.uk/images-books/publications/eehb-insulating-flat-roofs/.

[255] Pickles, D. (2016i) *Energy Efficiency and Historic Buildings: Insulating Thatched Roofs*: Historic England. Available at: https://historicengland.org.uk/images-books/publications/eehb-insulating-thatched-roofs/.

[256] Smith, P. (2013) 'The Use of Appropriate Materials in Maximising Energy Efficiency and Moisture Control in Historic Houses'. *Energy Efficiency in Historic Houses*, Dublin: Irish Georgian Society, 59-69. p 65-67.

[257] Curtis, R. (2012) *Refurbishment Case Study 2: Wells O' Wearie, Edinburgh - Thermal Upgrades to Walls, Roof, Floors & Glazing*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=4d0179ad-3306-42a0-87d8-a59300faac09.

[258] Jenkins, M. (2012a) *Refurbishment Case Study 3: Wee Causeway, Culross – Insulation to Walls and Roof*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=345e856a-5ef2-46e5-8315-a59300fc3995.

[259] Snow, J. (2013) *Refurbishment Case Study 5: The Pleasance, Edinburgh - Insulation of Coom Ceiling, Attic Space and Lightwell*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=1f44ca9b-a78b-4f04-8a16-a59300fe86e2.

[260] Jenkins, M. (2012c) *Refurbishment Case Study 6: Kildonan, South Uist - Insulation to Walls, Roof, Windows & Door*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=62dee846-2f4e-4674-8879-a59300ff84fa.

[261] Jenkins, M. (2014a) *Refurbishment Case Study 9: Leighton Library - Installation of Loft Insulation*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=e7737570-d16d-4d42-84f5-a59301017ed7.

[262] Snow, J. (2014) *Refurbishment Case Study 11: Newtongrange - Installation of Roof and Coom Insulation and Secondary Glazing*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=db047b98-e3b3-4af2-96f1-a59300f48ac8.

perlite grains, which are created by firing volcanic sand to 900°C. This forces the grains to expand into a highly porous silicate substance, making it lightweight. The perlite lime mortar mix was applied to the top attic-side of the vaults to a thickness of 100mm, and after being left to set for a few days, an additional 10mm of lime-based mortar reinforced with cattle hair was applied. The final assembly is vapour-permeable, has twice the thermal performance of mineral wool and can support the weight of a person to facilitate future maintenance.[263]

2.5.3.3 Insulating Ground Floors

Traditional buildings in Ireland and Britain were typically constructed with either a suspended timber floor or a solid ground floor commonly built of packed rubble and earth, tiles, bricks, flagstones, terrazzo or concrete. It is relatively easy and thermally beneficial to insulate a suspended timber ground floor, while it can be technically difficult, costly and highly disruptive to insulate a solid ground floor.

HE EEHB: Insulating Suspended Timber Floors (2016)

Traditional suspended timber floors were ventilated to the outdoors to prevent excessive moisture from rotting the floorboards, however this means that cold winter draughts can blow through the cracks between the floorboards. To prevent heat loss, moisture-permeable insulation can be installed on a breather membrane between and to the depth of the floor joists, with an air and vapour control layer affixed between the insulation and the underside of the floorboards.[264] As the room will no longer provide air paths to ventilate the sub-floor void, a survey should first indicate if higher moisture levels or rot could be present. The original levels of designed ventilation from wall vents through sleeper walls should also be checked. Where conditions allow, the floor joists could be removed entirely to create a breathable solid floor using recycled foamed glass aggregate and a limecrete slab an alternative approach. Other insulation options exist for floorboards that are historically valuable or cannot be lifted without damaging them, which are outlined in Historic England's guide on insulating suspended timber floors.

HE EEHB: Insulating Solid Ground Floors (2016)

It is possible to insulate solid ground floors, but the thermal benefit may be marginal compared to the cost, and the historic qualities of the floor may be damaged in the process. Insulating solid ground floors can also run the risk of exacerbating underlying moisture problems or of redirecting ground moisture to external walls. Historic England's guide on insulating solid ground floors discusses

[263] Larsen, P. K. and Hansen, T. K. 'A Lime Based Mortar for Thermal Insulation of Medieval Church Vaults'. *Energy Efficiency and Comfort of Historic Buildings (EECHB)*, Brussels, Belgium: Flanders Heritage Agency, 198-204. p 198.
[264] Pickles, D. (2016h) *Energy Efficiency and Historic Buildings: Insulating Suspended Timber Floors*: Historic England. Available at: https://historicengland.org.uk/images-books/publications/eehb-insulation-suspended-timber-floors/.

in detail the challenges, methods and factors to consider before undertaking works to insulate a traditional solid ground floor.[265]

2.5.3.4 Insulating Solid Walls

NSAI S.R. 54:2014 Code of Practice for the Energy Efficient Retrofit of Dwellings

In Ireland, NSAI *S.R. 54:2014 – Code of Practice for the Energy Efficient Retrofit of Dwellings* does not apply to buildings constructed prior to 1945, including solid wall dwellings. There is currently no supplementary technical guidance to inform building professionals of the physical properties, hygrothermal requirements and potential risks of insulating solid masonry walls internally or externally. This leaves specifiers to seek guidance on their own time and leaves no clear path to compliance with the building regulations.

HE EEHB: Insulating Solid Walls (2016)

In the 2012 version of Historic England's Energy Efficiency and Historic Buildings advice series, internal or external solid wall insulation was the last measure recommended to improve the energy efficiency of traditional or historic buildings due to uncertainties around condensation risks. However, given these uncertainties, solid wall insulation has been the focus of much research in recent years.[266]

BRE Literature Review - Solid Wall Heat Losses and the Potential for Energy Saving (2014)

During 2013, the UK Department of Energy and Climate Change (now the Department of Business, Energy and Industrial Strategy) commissioned the BRE to undertake a literature review of existing publications on the hygrothermal behaviour of solid wall dwellings and the implications of internal and external solid wall insulation. The study assessed the following five uncertainties: how heat loss through solid walls is measured; how much energy can be saved through the installation of solid wall insulation; how the gap between predicted and actual energy savings can be explained; what possible unintended consequences may occur post-installation; and additional factors to be considered before undertaking works on a historic building.[267] Section 5.5 of the BRE Literature Review summarised 20 energy renovation case studies conducted on heritage buildings, four of which opted to not add insulation to the walls due to the special characteristics of the walls or reversibility concerns. The section also summarised the U-value reductions achieved through ten typical wall insulation strategies applied to traditional buildings.

[265] Pickles, D. (2016f) *Energy Efficiency and Historic Buildings: Insulating Solid Ground Floors*: Historic England. Available at: https://historicengland.org.uk/images-books/publications/eehb-insulating-solid-ground-floors/.
[266] Pickles, D. (2016g) *Energy Efficiency and Historic Buildings: Insulating Solid Walls*: Historic England. Available at: https://historicengland.org.uk/images-books/publications/eehb-insulating-solid-walls/.
[267] Gemmell, A. (2014) *Solid Wall Heat Losses and the Potential for Energy Savings: Literature Review*, Watford: Building Research Establishment Ltd. Available at: https://www.gov.uk/government/publications/solid-wall-heat-losses-and-the-potential-for-energy-savings-literature-review.

The BRE published three other supporting studies as part of the research project, which include: *The Nature of Solid Walls In-Situ*[268], *Classification of Solid Walls*[269], and the *Rapid Measurement Device Test Report - Summary*[270].

BRE Report Series: Solid Wall Heat Losses and the Potential for Energy Saving (2014-2017)

It is estimated that 35% of heat loss occurs through the external walls of traditional dwellings, so the installation of internal or external insulation can significantly improve the overall thermal performance of traditional buildings. Where insulation is not practical, a thin thermal coating or thermal wallpaper can be applied to the wall, though this will yield only a minor improvement in the U-value. The installation of interior or exterior insulation is costly and disruptive, so before any works are undertaken, it is important to understand the hygrothermal properties and performance of the wall. It is also extremely important that any insulating materials or coatings applied to solid external walls are capillary active and vapour-permeable to allow any trapped moisture to evaporate during dry cycles. Damp building fabrics can be 30-40% less energy efficient than dry materials[271], meaning that a damp wall transfers heat from the interior to the exterior that much quicker.[272] If moisture is trapped and not allowed to dry out through the wall insulation and paint, it can also cause mould growth, can encourage rot within the internal wall timbers and can lead to a poor and unhealthy indoor environment. It is therefore recommended to seek the help of a professional to accurately assess and monitor the hygrothermal performance of the existing external wall materials before installing solid wall insulation.

Advice Series: Energy Efficiency in Traditional Buildings (2010)

To better understand the risks and complexities associated with solid wall insulation, Peter Smith references two diagrams in his paper published in *Energy Efficiency in Historic Houses* – one of a 'sick' building and the other of a 'healthy' building.[273] These diagrams demonstrate maintenance and material alterations that either lead to moisture accumulation and retention in external walls or assist with its evaporation. Prior to undertaking any works

The Use of Appropriate Materials in Maximising Energy Efficiency and Moisture Control in Historic Houses (2013)

[268] Hulme, J. (2016) *Solid Wall Heat Losses and the Potential for Energy Saving: The Nature of Solid Walls In-Situ*, Watford: Building Research Establishment Ltd. Available at: https://www.gov.uk/government/publications/solid-wall-heat-losses-and-the-potential-for-energy-saving.

[269] Custard, M. (2016) *Solid Wall Heat Losses and the Potential for Energy Saving: Classification of Solid Walls*, Watford: Building Research Establishment Ltd. Available at: https://www.gov.uk/government/publications/solid-wall-heat-losses-and-the-potential-for-energy-saving.

[270] *Solid Wall Heat Losses and the Potential for Energy Saving: Rapid Measurement Device Test Report - Summary* (2017), Watford: Building Research Establishment Ltd. Available at: https://www.gov.uk/government/publications/solid-wall-heat-losses-and-the-potential-for-energy-saving.

[271] Edwards, J. (2017b) 'The Retrofit Process', *Context,* (149), pp. 11-12.

[272] *Advice Series: Energy Efficiency in Traditional Buildings* (2010), Dublin: Department of the Environment, Heritage and Local Government. Available at: https://www.chg.gov.ie/heritage/built-heritage/architectural-heritage-advisory-service/advice-for-owners/. p 26.

[273] Smith, P. (2013) 'The Use of Appropriate Materials in Maximising Energy Efficiency and Moisture Control in Historic Houses'. *Energy Efficiency in Historic Houses*, Dublin: Irish Georgian Society, 59-69. p 61.

to insulate a solid external wall, it is recommended that a hygrothermal numerical simulation system, such as WUFI, be used to assess the impact of various insulating materials to the walls.[274] Existing finishes like cement render, mortar and non-vapour-permeable paints should be removed and replaced with capillary-active materials before wall insulation is applied to avoid any moisture related problems in the future.

A Bristolian's Guide to Solid Wall Insulation (2015)

On-Site Assessment of Hygrothermal Performance of Historic Wall Before and After Retrofitting with Insulation (2016)

Solid Wall Insulation: Best Practice and Innovation (2017)

Core Cities Green Deal Monitoring Project (2017)

A significant number of case studies and reports have been published recently which detail the challenges and monitor the performance of both internal and external solid wall insulation, two of which include the *Bristolian's Guide to Solid Wall Insulation*[275] and an on-site assessment of different solid wall insulation systems applied to three pre-WWII buildings in France[276]. In October 2017, a report commissioned by the UK Department of Business, Energy and Industrial Strategy (BEIS) was published, which compares the features of eight solid wall insulation materials currently on the market.[277] The research included interviews with insulation manufacturers, installers, architects and specifiers to understand current best practice and new methods for insulating solid walls.

The 2017 *Core Cities Green Deal Monitoring Project* report documents the performance of 65 deep renovation projects undertaken in Leeds between 2013-2015.[278] The study monitored the effects of internal or external solid wall insulation using a number of investigative measures, including surveys and occupant interviews, in-use monitoring, air tightness tests, co-heating and in situ U-value tests, and hygrothermal and thermal bridging modelling. The study found that more often than not, a whole house renovation approach was lacking, and that quality could not be guaranteed due to poor workmanship. At least half of the dwellings exhibited problems with damp prior to the renovations, but the study found that these were alarmingly overlooked or made worse in most cases.[279]

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[274] Ibid. p 60.

[275] *A Bristolian's Guide to Solid Wall Insulation: A Guide to the Responsible Retrofit of Traditional Homes in Bristol* (2015), Bristol: Sustainable Traditional Buildings Alliance (STBA). Available at: https://warmupbristol.co.uk/content/solid-wall-insulation.

[276] Borderon, J., Nussbaumer, P. and Burgholzer, J. 'On-Site Assessment of Hygrothermal Performance of Historic Wall Before and After Retrofitting with Insulation'. *Energy Efficiency and Comfort of Historic Buildings (EECHB)*, Brussels, 19-21 October: Flanders Heritage Agency, 234-240. p 234.

[277] Palmer, J. and Terry, N. (2017) *Solid Wall Insulation: Best Practice and Innovation*, London: University College London and Cambridge Architectural Research Ltd. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/658604/BEIS_-_SWI_Innovation_Final_Report_-_FINAL_Approved.pdf.

[278] Gorse, C. (2017) *Core Cities Green Deal Monitoring Project*: Leeds Beckett University. Available at: https://www.gov.uk/government/collections/buildings-energy-efficiency-technical-research.

[279] Ibid. p 11.

2.5.3.4.1 External Wall Insulation (EWI)

External wall insulation, commonly known as EWI, can be appropriate for traditional buildings that do not have a historically significant exterior. The installation process can be less disruptive to the homeowner, but it will require the extension of the roof eaves as well as the replacement or modification of window reveals and sills, door architraves, decorative features, gutters and downpipes, soil and vent pipes and other services.[280] EWI will also change the external appearance of the house and may be seen as aesthetically incompatible with the existing streetscape. External wall insulation will also insulate the wall from the warmth of the sun. Therefore, to maintain safe moisture levels, the wall will need to rely on heat gain from the internal heating system, the occupants, heat-generating appliances and solar gain through the windows. In short, external insulation will extend the thermal condition of an external wall, keeping it warmer or cooler for longer.

External wall insulation can be preferable to internal wall insulation because the whole of the exterior wall is evenly covered and points where 'cold bridging' may occur at floor, ceiling and window junctions and around electrical sockets are minimised. The DEHLG *Energy Efficiency and Traditional Buildings* notes other advantages including: retention of the thermal mass benefits provided by the solid masonry wall; reduced risk of interstitial condensation; building fabric remains heated and dry; and internal finishes and room sizes are kept as is.[281] In Ireland, random rubble stone walls would have traditionally been covered in a naturally vapour-permeable lime render, which protected the stone and mortar from driving rain, so external wall insulation may not change the appearance of the building as drastically as expected. The application of external wall insulation to protected buildings or those within a conservation area will most likely require planning permission and an architectural conservation officer should be consulted.

In addition to Historic England's Energy Efficiency and Historic Buildings guidance series, three external wall insulation projects in Northern England were monitored and analysed for their more technical Research Report Series.[282] The report begins with a very useful comparison of advice given by a number of reputable sources

[280] Anderson, W. and Robinson, J. (2011) *Warmer Bath: A Guide to Improving the Energy Efficiency of Traditional Homes in the City of Bath.* England: Bath Preservation Trust & the Centre for Sustainable Energy. p 46.

[281] *Advice Series: Energy Efficiency in Traditional Buildings* (2010), Dublin: Department of the Environment, Heritage and Local Government. Available at: https://www.chg.gov.ie/heritage/built-heritage/architectural-heritage-advisory-service/advice-for-owners/. p 37.

[282] *Research Report Series: External Wall Insulation in Traditional Buildings - Case Studies of Three Large-scale Projects in the North of England* (2014), London: Historic England. Available at: http://research.historicengland.org.uk/Report.aspx?i=15747&ru=%2fResults.aspx%3fp%3d1%26n%3d10%26k%3denergy%2520efficiency%26ns%3d1.

HE Research Reports: External Wall Insulation in Traditional Buildings - Case Studies of Three Large-Scale Projects in the North of England (2014)

to draw out inconsistencies and conflicting recommendations under the following topics: Advantages of EWI over IWI; Permeability and moisture movement; Thermal bridging; Materials; Detailing; and Permissions. The section concludes with an admission by the authors that even within specialist circles, uncertainties remained about the risks associated with installing solid wall insulation on traditional buildings. The three case studies also alarmingly demonstrated that those involved in the EWI installations may not have been aware of or chose to disregard current advice regarding solid wall insulation for traditional buildings, and in some instances, local planning officers recommended, with the best intentions, that certain architectural features such as ornamental dentil brickwork be left exposed, creating a thermal bridge and increased risks for condensation.[283] Poor workmanship and incorrect detailing meant that all three renovation case studies reported significant issues with damp within just a few years of completion.[284]

In one of the renovation case study projects, homeowners were offered the choice between internal or external insulation, and after the benefits and inconveniences of each were explained to them, 100% of homeowners chose to install external insulation.[285] Given the small room sizes in many UK and Irish homes, and the fact that most renovations will be undertaken in occupied homes, the disruption caused by IWI is likely to be unacceptable in most cases and will drive the demand for EWI. It is therefore extremely important that advisory bodies provide consistent and correct advice to both the building sector and the public alike to encourage take up and to ensure proper installation.

Post Installation of Cavity and External Wall Insulation (2016)

The BRE report *Post Installation of Cavity Wall and External Wall Insulation* demonstrates that serious problems can occur if EWI is not installed properly.[286] Wales has the highest percentage of pre-1919 (30.2%) buildings in the UK and 90% of these have solid masonry exterior walls. A variety of UK and Welsh government schemes have supported the installation of cavity wall and external wall insulation since the 1990s, but with the particularly high levels of wind-driven rain found in Wales, it is important that insulation is installed according to best practice guidance and is maintained in the years that follow. Of the seven properties insulated externally, the study found that all of the unintended consequences, which were primarily increased condensation and mould growth, occurred within two years of installation. However, the report does not specify the material of the walls or of the insulation, so it is difficult to know whether some of the issues were due to the incompatibility or vapour-impermeability of the EWI. Section 6 of

[283] Ibid. p 52.
[284] Ibid. p 58.
[285] Ibid. p 52.
[286] Brown, G. and King, C. (2016) *Post Installation Performance of Cavity Wall and External Wall Insulation (Wales)*: BRE Wales. Available at: http://www.cewales.org.uk/current-programme/retrofit/.

the report makes it is clear that many of the issues found in the buildings are due to poor workmanship and a lack of training held by installers and surveyors and recommends that a robust national standard be developed to guide the design, installation and aftercare of EWI systems.[287]

Understanding Best Practice in Deploying External Solid-Wall Insulation in the UK (2017)

A report published in November 2017 by the UK Department of Business, Energy and Industrial Strategy, *Understanding Best Practice in Deploying External Solid-Wall Insulation in the UK*, studied five exemplar mass deployment housing renovation schemes that used external wall insulation in five different cities across the UK.[288] The report identified the factors that made these schemes successful as well as enduring challenges that are inhibiting uptake on a broader scale.

2.5.3.4.2 Internal Wall Insulation (IWI)

Advice Series: Energy Efficiency in Traditional Buildings (2010)

In Ireland, plaster was traditionally applied straight onto the internal side of external masonry walls, or 'on-the-hard'. The addition of internal wall insulation will increase the wall depth and thus reduce the floor area a room, which may be a prohibitive factor for small dwellings. This may also affect the resale value of a home, as the living area will be slightly reduced. The installation process is disruptive and will require the reinstallation of electrical sockets, radiators and all decorative architectural features, such as cornices, baseboards and internal shutters, which will likely be unacceptable in protected structures.[289] Internal wall insulation in traditional buildings presents a greater risk of 'cold bridging' if not carefully installed around junctions where the insulation meets the floors, ceiling, windows, electrical sockets and other internal walls. However, despite these drawbacks, internal insulation may be preferable in dwellings with brick, stone or interesting external detailing that the owner may not wish to cover up or where the external appearance of the building is protected.

Internal Insulation of Solid Masonry Walls: Practical Limits due to Thermal Bridging and Moisture Performance (2013)

A technical summary published by the STBA Conventions Experts Group explains the practical limits of IWI on solid masonry walls due to material performance and thermal bridging through different modelling exercises.[290] They explained that it is the comparative coldness at junctions caused by the poor installation of insulation that creates a thermal bridge and leads to condensation and mould

[287] Ibid. p 31.

[288] *Understanding Best Practice in Deploying External Solid-Wall Insulation in the UK* (2017), London: University College London and Cambridge Architectural Research Ltd. Available at: https://www.gov.uk/government/publications/understanding-best-practice-in-deploying-external-solid-wall-insulation-and-internal-wall-insulation-in-the-uk.

[289] *Advice Series: Energy Efficiency in Traditional Buildings* (2010), Dublin: Department of the Environment, Heritage and Local Government. Available at: https://www.chg.gov.ie/heritage/built-heritage/architectural-heritage-advisory-service/advice-for-owners/. p 38.

[290] Marincioni, V., Sanders, C., May, N., Fehr, C. and Singh, U. (2013) *Internal Insulation of Solid Masonry Walls: Practical Limits due to Thermal Bridging and Moisture Performance*. Available at: http://stbauk.org/stba-guidance-research-papers.

growth where previously there may have been none when the entire wall was at the same coldness. In addition to increased risks of cold bridging, internal insulation limits the amount of internal heat that reaches through to the solid masonry wall, which means the temperature of the wall remains lower and can increase chances of interstitial condensation. A preliminary study undertaken by the STBA found that there is an increased risk to building fabric and human health when IWI limits the flow of heat through to the solid masonry wall beyond a certain degree.[291]

A Short Paper on Internal Wall Insulation (2012)

Caroline Rye and Cameron Scott state in the Green Retrofit edition of the IHBC journal Context that 'by using smaller quantities of insulation we are more likely to maintain a balance between the desire to cut heat loss through the fabric and continuing to allow sufficient heat to pass through the wall to avoid moisture accumulation'. [292] The paper demonstrates that a traditional solid brick walled dwelling with an in situ U-value of 1.48 W/m^{2}K can be improved to 0.48 W/m ^{2} K with a small quantity of internal insulation (40mm of wood fibre board), while maintaining a healthy relative humidity level within the wall.

Understanding the Performance of Solid Walls. Context, vol 149. (2017)

Hygrothermal Risk Evaluation for the Retrofit of a Typical Solid-Walled Dwelling (2016)

Supporting this stance, a 2016 study commissioned by the UK Department of Energy and Climate Change found that thin internal wall insulations (10-20mm thick) can achieve up to 57% of the energy savings of conventional thicker (50-150mm) internal wall insulations.[293] According to the study, thin IWI is also 'cheaper, simpler to apply, takes up less space and has less impact on the physics of the building fabric than conventional IWI'. Though the energy savings are lower per building, by negating the setbacks of conventional IWI, the report argues that the national net energy savings could be greater due to greater consumer uptake.

DECC – Thin Internal Wall Insulation (2016)

The journal paper *Avoidance and Diagnosis of Problems Associated with Internal Wall Insulation* showed the harm that internal insulation with a vapour control layer (VCL) can do in a very short amount of time to traditional solid walls by trapping interstitial moisture leading to mould growth.[294] Until 2016, British Standard 5250, which governs condensation control in buildings, recommended the use of VCLs, however the revised edition now advises that the addition of a VCL inside internal wall insulation on a solid wall may cause more harm than good.[295]

Avoidance and Diagnosis of Problems Associated with Internal Wall Insulation (2017)

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[291] May, N. (2012) *A Short Paper on Internal Wall Insulation*, London: Sustainable Traditional Buildings Alliance (STBA). Available at: http://stbauk.org/what-we-do/policy.

[292] Rye, C. and Scott, C. (2017) 'Understanding the Performance of Solid Walls', *Context,* (149), pp. 25-27.

[293] Cooke, D. and Jones, E. (2016) *DECC – Thin Internal Wall Insulation*, London: Department of Energy and Climate Change. Available at: https://www.gov.uk/government/publications/thin-internal-wall-insulation-modelling-study-on-energy-saving-potential.

[294] Smith, M. (2017) 'Avoidance and Diagnosis of Problems Associated with Internal Wall Insulation', *Journal of Building Survey, Appraisal & Valuation,* 6(1), pp. 11-25.

[295] *BS 5250:2011+A1:2016 Code of Practice for Control of Moisture in Buildings* (2016). London: British Standards Institution.

A paper published in the September 2016 edition of the academic journal Energy and Buildings assessed the impact of window and door reveals on the transmission heat transfer coefficient in internally insulated solid wall dwellings in the UK.[296] The study found that the insulation of reveals can deliver a greater reduction in heat transfer than increasing IWI thickness past a certain point, and concludes with a discussion of how to determine which level of IWI thickness is most effective and least likely to cause unintended harm in terms of increased condensation and mould growth. An earlier related study found that thicker IWI lowered the heat flux through the walls, but led to a higher heat flux through junctions (sills, jambs, lintels, intermediate floors and eaves).[297] The study found that, in a typical mid-terrace pre-1919 dwelling with 500mm-thick solid brick walls, 20mm of IWI with insulated junctions would achieve a similar transmission heat transfer coefficient to 140mm of IWI without insulating the junctions.

Estimating the Impact of Reveals on the Transmission Heat Transfer Coefficient of Internally Insulated Solid Wall Dwellings (2016)

Parametric Study on the Impact of Thermal Bridges on the Heat Loss of Internally Insulated Buildings (2015)

As previously mentioned, Historic Environment Scotland has undertaken a number of hygrothermal modelling studies to assess risks related to energy renovation measures such as solid wall insulation. The first HES Short Guide introduced home and buildings owners to four broad systems of installing vapour-permeable internal wall insulation: blown into the cavity behind existing wall linings (behind lath and plaster); applied to existing wall linings; applied directly to the masonry (works best for thinner materials like aerogel-based blankets or calcium silicate-based insulation board); or held in place by timber framing (works best for thicker materials like hemp board or wood fibreboard).[298] HES Refurbishment Case Study 4 studied the performance to six different walls in a traditional Glasgow tenement to show that thermal upgrades can be made while retaining a healthy level of vapour permeability.[299] (See also HES Refurbishment Case Studies 1[300], 2[301], 3[302], 6[303], 7[304], 8[305], 10[306] and 16[307]) More recently, the

HES Short Guide 1: Fabric Improvements for Energy Efficiency in Traditional Buildings (2013)

HES Refurbishment Case Study 4: Sword Street, Glasgow – Internal Wall Insulation to Six Tenement Flats (2012)

HES Refurbishment Case Studies

[296] Marincioni, V., Altamirano-Medina, H., May, N. and Sanders, C. (2016) 'Estimating the Impact of Reveals on the Transmission Heat Transfer Coefficient of Internally Insulated Solid Wall Dwellings', *Energy and Buildings,* 128, pp. 405-412.
[297] Marincioni, V., May, N. and Altamirano-Medina, H. (2015) 'Parametric Study on the Impact of Thermal Bridges on the Heat Loss of Internally Insulated Buildings', *Energy Procedia,* 78, pp. 889-894.
[298] *Short Guide 1: Fabric Improvements for Energy Efficiency in Traditional Buildings* (2013), Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=179c1909-3679-4486-9583-a59100fa98c1.
[299] Jenkins, M. (2012b) *Refurbishment Case Study 4: Sword Street, Glasgow – Internal Wall Insulation to Six Tenement Flats*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=651e6f16-087f-408b-ab3d-a59300fd971a.
[300] Jack, M. and Dudley, A. (2012) *Refurbishment Case Study 1: Five Edinburgh Tenement Flats – Wall and Window Upgrades*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=cfd327b0-395b-4c4f-9999-a59300f138bd.
[301] Curtis, R. (2012) *Refurbishment Case Study 2: Wells O' Wearie, Edinburgh - Thermal Upgrades to Walls, Roof, Floors & Glazing*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=4d0179ad-3306-42a0-87d8-a59300faac09.

extensive HES Technical Paper 15 assessed the impact of vapour-permeable and non-permeable internal insulation products on a traditional wall.[308]

HES Technical Paper 15: Assessing Risks in Insulation Retrofits using Hygrothermal Software Tools: Heat and Moisture Transport in Internally Insulated Stone Walls (2015)

The 3ENCULT Handbook recommends the use of internal wall insulation for historically significant buildings where external wall insulation is unsuitable due to historic details or physical constraints like a lack of space or an insufficient roof overhang. The guidelines were written with Europe's cultural and historic buildings in mind, though the recommended insulating materials and pre-installation assessment of the building and its environment would apply to any traditional building. In the Irish climate where driving rain is a regular occurrence, a vapour-permeable capillary-active interior insulation system is recommended to remove the risk of encouraging internally trapped condensation.[309] A new 'intelligent' interior thermal insulation has also been developed as part of the 3ENCULT European research project .[310]

3ENCULT Handbook: Energy Efficient Solutions for Historic Buildings (2014)

3ENCULT: iQ-Therm – 'Intelligent' Interior Insulation for Historic Buildings (2017)

At the 2016 Energy Efficiency and Comfort of Historic Buildings (EECHB) conference, numerous papers addressed the various challenges presented by internal wall insulation through case studies, such as the one conducted at Trinity College in

Energy Efficiency and Comfort of Historic Buildings conference proceedings (2016)

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[302] Jenkins, M. (2012a) *Refurbishment Case Study 3: Wee Causeway, Culross – Insulation to Walls and Roof*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=345e856a-5ef2-46e5-8315-a59300fc3995.

[303] Jenkins, M. (2012c) *Refurbishment Case Study 6: Kildonan, South Uist - Insulation to Walls, Roof, Windows & Door*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=62dee846-2f4e-4674-8879-a59300ff84fa.

[304] Snow, J. (2012) *Refurbishment Case Study 7: Scotstarvit Tower Cottage, Cupar - Thermal Upgrades and Installation of Radiant Heating*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=19362a7b-d95e-4959-97ee-a59301002df0.

[305] Jenkins, M. (2012d) *Refurbishment Case Study 8: Garden Bothy, Cumnock - Upgrades to Walls, Floors, Windows & Door*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=db827c9b-11b3-4f5e-a5e8-a5930100db68.

[306] Jenkins, M. (2014b) *Refurbishment Case Study 10: Rothesay - Installation of Insulation and Secondary Glazing*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=b74e19b0-5085-41b8-a572-a59300f3d0ca.

[307] Curtis, R. (2015) *Refurbishment Case Study 16: Kirkton of Coull, Aberdeenshire - Thermal Improvements to a 19th Century Farmhouse*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=524a5482-439d-467f-8dac-a59300f92260.

[308] Little, J., Ferraro, C. and Arregi, B. (2015) *Technical Paper 15: Assessing Risks in Insulation Retrofits using Hygrothermal Software Tools - Heat and Moisture Transport in Internally Insulated Stone Walls*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=8a2a7b9d-e3b2-4c7d-8c17-a59400a8387b.

[309] Troi, A. and Bastion, Z. (eds.) (2014) *Energy Efficient Solutions for Historic Buildings: A Handbook*: Birkhäuser. p 123-124.

[310] Engel, J. and Plagge, R. *iQ-Therm – 'Intelligent' Interior Insulation for Historic Buildings*: 3ENCULT: Efficient Energy for EU Cultural Heritage. Available at: http://www.3encult.eu/en/newsevents/all/NewsDetails6b6d.html?entryid=109347 (Accessed: 31 October 2017).

Cambridge.[311] A paper presented by two members of the Fraunhofer Institute for Building Physics compared a number of internal wall insulation systems that were compatible with the physical requirements of traditional buildings and could be removed without causing harm to historic materials.[312] A third paper compared the vapour-permeability of internal insulation products currently being marketed for use in traditional buildings.[313]

The Use of Appropriate Materials in Maximising Energy Efficiency and Moisture Control in Historic Houses (2013)

A variety of capillary-active wall insulation materials are available on the market, including Calcium Silicate based boards, wood fibre boards, hemp-based products, cellulose and sheep's wool. In *Energy Efficiency in Historic Houses*, Peter Smith outlines the properties and application techniques of products within these five categories that are particularly suited to traditional buildings and the Irish climate.[314] It is crucial that specifiers have access to current information about insulation products recommended for traditional buildings, and to answer this need, a number of institutions are currently in the process of establishing product databases (see Section 2.6.7.1).

Performance of a Range of Thermal Insulations in a Historic Building (2016)

A study published in the Engineers Journal tested the performance of seven internal insulations and two thermal lime plasters on a traditional solid brick walled dwelling is Dublin and found that the two insulations that provided the greatest improvement in U-value (aerogel by 61% and polyisocyanurate (PIR) board by 59%) also led to the highest relative humidity levels 20 months later (aerogel RH 69% and PIR RH 93%).[315] Alternatively, cork lime and hemp lime plaster (applied in two layers of 20mm each) improved the U-value considerably (by 45% and 37% respectively) and both showed the lowest relative humidity levels at a safe 65-66% after 20 months of all the interior insulation options tested. Hemp and cork lime plasters therefore achieved a healthy balance between energy efficiency and moisture risk and it is recommended that further research and guidance be prepared on the matter.

Lower Royd Radical Retrofi (2017)

A 'whole house' energy renovation project in Lower Royd, England tested the performance of a diathonite cork lime plaster as an internal insulation option to improve the U-value of the exterior walls to the Passive House retrofit EnerPHit standard (0.35 W/m2K).

[311] Gustafsson, J., Brookes, C., Rye, C., Scott, C. and Smith, O. 'Retrofit Internal Insulation at New Court, Trinity College, Cambridge: Options, Issues and Resolution through Material Sampling and Modelling'. *Energy Efficiency and Comfort of Historic Buildings (EECHB)*, Brussels, 19-21 October: Flanders Heritage Agency, 289-295. p 289-295.

[312] Krus, M., Kilian, R. and Pfundstein, B. 'Comparison of Different Systems for Internal Wall Insulation with Reversible Application for Historic Buildings'Ibid., 181-190. p 181-190.

[313] Vereecken, E. and Roels, S. 'Capillary Active Interior Insulation: A Discussion'Ibid., 191-197. p 191-197.

[314] Smith, P. (2013) 'The Use of Appropriate Materials in Maximising Energy Efficiency and Moisture Control in Historic Houses'. *Energy Efficiency in Historic Houses*, Dublin: Irish Georgian Society, 59-69.

[315] Walker, R. and Pavía, S. (2016) 'Performance of a Range of Thermal Insulations in a Historic Building', *Engineers Journal*.

[316] To achieve this U-value, the thermal plaster was applied in layers of 25mm at a time to a total depth of 100mm (Diathonite Evolution IWI is typically applied to a depth of only 30-60mm). The added depth of the plaster led to a prolonged drying-out period, and the high relative humidity at 85% meant the temperature stayed below 14C despite an aggressive heating regime. The RH eventually dropped to 62% as the walls dried-out, but the project brings about questions of whether the EnerPHit standard for U-values is too ambitious for traditionally-built buildings and whether it might not be safer and more broadly achievable to aim for the 'sweet spot' between the EnerPHit and the English Part L1 threshold renovation requirements (0.7 W/m2K).

The SPAB Building Performance Survey Reports (2011-2017)

The SPAB Building Performance Survey reports tracked and analysed the performance of three traditional buildings in England over the course of five years before and after energy renovation works - the first was insulated internally with wood fibre board and lime plaster, the second was fitted with internal polyisocyanurate (PIR) insulation, and the third was re-rendered with a thermal lime-based render.[317] The first dwelling had a 345mm thick solid brick wall with porous bricks and the deteriorating pointing. A south-facing test wall was internally insulated with 40mm of wood fibre board and a lime plaster finish, and despite the poor quality of the wall, this dwelling showed the lowest levels of relative and absolute humidity.

Hygrothermal Risk Evaluation for the Retrofit of a Typical Solid-Walled Dwelling (2016)

Alternatively, a study published in the SDAR* Journal, *Hygrothermal Risk Evaluation for the Retrofit of a Typical Solid-Walled Dwelling*, found that a traditional brick dwelling in Dublin performed best in its original condition compared to three internal wall and floor insulation scenarios.[318]Using WUFI to numerically simulate the four scenarios, the study concluded that the use of damp-proof or vapour-resistant membranes would result in a higher moisture content in the solid walls and ground slab, and that vapour-permeable insulation systems should be used for both in traditional buildings.

2.5.4 System Interventions

2.5.4.1 Heating and Ventilation Systems

Traditionally, open fireplaces were the main heating source in buildings, however they are an inefficient heat source with only 30% of the heat produced released into the room and have now

[316] Butcher, B. (2017) *Lower Royd Radical Retrofit: It's a Wrap!* Huddersfield: Green Building Store. Available at: https://www.greenbuildingstore.co.uk/lower-royd-radical-retrofit-its-a-wrap/ (Accessed: 20 December 2017).
[317] *The SPAB Research Report 2: The SPAB Building Performance Survey 2014 Interim Report* (2014): English Heritage. Available at: https://historicengland.org.uk/images-books/publications/spab-rr2-spab-building-performance-survey-interim-rep/.
[318] Arregi, B. and Little, J. (2016) 'Hygrothermal Risk Evaluation for the Retrofit of a Typical Solid-Walled Dwelling', *Sustainable Design & Applied Research in Engineering and the Built Environment (SDAR),* (6), pp. 17-26.

largely been replaced or supplemented by modern central heating systems. High efficiency boilers are now available that convert 95% of fuel into heat. Heating systems are typically due for replacement after 25-30 years and should be considered as part of any energy renovation project, and as of 2011, oil and gas boilers in Ireland must operate at a minimum 90% efficiency. To help homeowners and contractors select the most efficient heating product for each dwelling, the Sustainable Energy Authority of Ireland (SEAI) maintains the Home-heating Appliance Register of Performance (HARP).[319]

Advice Series: Energy Efficiency in Traditional Buildings (2010)

Building Services: Implications in Historic Houses, Energy Efficiency in Historic Houses (2013)

According to the DEHLG *Energy Efficiency in Traditional Buildings* guidance, the installation of a high efficiency boiler should be accompanied by the installation and programming of 'thermostatic radiator valves (TRVs), room thermostats, heating zones, water heating on a separate time and temperature control, a programmable timer, boiler interlock and load compensators or weather compensators' to ensure the system operates at maximum efficiency.[320] The IGS conference paper, *Building Services: Implications in Historic Houses*, outlines a number of options to improve the efficiency of building services and reduce carbon emissions in historic houses.[321]

Electric heating is generally inefficient due to energy waste in generation, distribution and in heating appliances, which will negatively impact the BER assessment for a building, however this may change if energy is increasingly produced through renewable sources like wind-power and hydro-power.[322] However, electric heating systems may be less intrusive in historic buildings than a piped-water heating system.

HES Technical Paper 14: Keeping Warm in a Cooler House (2011)

The Historic Environment Scotland Technical Paper 14 challenges modern comfort standards and suggests that energy savings can be made by lowering the internal temperature without sacrificing occupant comfort through the use of low-temperature background radiant heating. The paper recommends warming the dwelling to a constant 16 degrees Celsius (rather than the standard 18-22°C), and then to use supplementary heating where and when necessary in order to reduce fuel consumption and CO_2 emissions.[323] HES

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[319] *SEAI HARP Database*: Sustainable Energy Authority of Ireland (SEAI). Available at: https://www.seai.ie/energy-in-business/ber-assessor-support/harp-database/ (Accessed: 20 November 2017).

[320] *Advice Series: Energy Efficiency in Traditional Buildings* (2010), Dublin: Department of the Environment, Heritage and Local Government. Available at: https://www.chg.gov.ie/heritage/built-heritage/architectural-heritage-advisory-service/advice-for-owners/. p 49 – 50.

[321] Blennerhassett, E. (2013) 'Building Services: Implications in Historic Houses'. *Energy Efficiency in Historic Houses*, Dublin: Irish Georgian Society, 47-58.

[322] *Advice Series: Energy Efficiency in Traditional Buildings* (2010), Dublin: Department of the Environment, Heritage and Local Government. Available at: https://www.chg.gov.ie/heritage/built-heritage/architectural-heritage-advisory-service/advice-for-owners/. p 50.

[323] Humphreys, M., Nicol, F. and Roaf, S. (2011) *Technical Paper 14: Keeping Warm in a Cooler House: Creating Thermal Comfort with Background Heating and Local Supplementary Warmth*, Edinburgh: Historic Environment Scotland. Available at:

Refurbishment Case Study 7[324] and corresponding Technical Paper 22[325] further explored this concept through the installation of a low-energy infra-red radiant electric heating system in the 19th century Scotstarvit Tower Cottage along with other energy renovation measures. The case study has shown that radiant heating systems provide an adequate level of thermal comfort for occupants at a lower air temperature and could potentially lead to greater energy savings once the control systems are better understood. A second case study by Historic Environment Scotland showed a considerable reduction in energy use and an increase in thermal comfort at Kilmelford Church on the west coast of Scotland using a combination of radiant heat sources.[326]

HES Technical Paper 12 explores the impact of energy renovation measures on the indoor air quality of traditional buildings by looking at factors such as heating, ventilation and lighting.[327] The report suggests that rather than renovating old buildings to meet the standards of air tightness and energy efficiency for new builds, a combination of radiant heating and natural ventilation could produce a healthier and more sustainable indoor environment, and would reduce the risk of unintended consequences such as damp and mould growth.

A paper presented by the Fraunhofer Institute of Building Physics at the Energy Efficiency and Comfort of Historic Buildings conference in 2016 evaluated four different wall heating systems that were suitable for historic buildings.[328] The study found that while all provided suitable levels of comfort and prevented damp, the high-temperature Temperierung heating system used about 1.5 times more energy. Another paper evaluated the effect of conservation heating, dehumidification and adaptive ventilation over three years

HES Refurbishment Case Study 7: Scotstarvit Tower Cottage, Cupar - Thermal Upgrades and Installation of Radiant Heating (2012)

HES Technical Paper 22: Scotstarvit Tower Cottage: A Study of Infrared Electric Heating Installed in a Refurbished 19th Century Dwelling (2014)

HES Refurbishment Case Study 19: Trial Church Heating - Radiant Panels and Air Source Heat Pump at Kilmelford Church (2015)

HES Technical Paper 12: Indoor Environmental Quality in Refurbishment (2011)

Evaluation of Different Wall Heating Systems in Historic Monuments (2016)

An Evaluation of Three Different Methods for Energy Efficient Indoor Climate Control in Skokloster Castle (2016)

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https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=f2f2ebfd-ff37-4417-be92-a59400bb2665.

[324] Snow, J. (2012) *Refurbishment Case Study 7: Scotstarvit Tower Cottage, Cupar - Thermal Upgrades and Installation of Radiant Heating*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=19362a7b-d95e-4959-97ee-a59301002df0.

[325] Hubbard, D. (2014) *Technical Paper 22: Scotstarvit Tower Cottage - A Study of Infrared Electric Heating Installed in a Refurbished 19th Century Dwelling*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=7a69ec6b-1488-4a14-8560-a59400bbfc2a.

[326] *Refurbishment Case Study 19: Trial Church Heating - Radiant Panels and Air Source Heat Pump at Kilmelford Church* (2015), Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=97fe7075-3d8c-4b73-8ad5-a59300fa03e6.

[327] *Technical Paper 12: Indoor Environmental Quality in Refurbishment* (2011), Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=a753afcc-c9a9-4059-afd9-a59400b55838.

[328] Kilian, R., Bichlmair, S. and Krus, M. 'Evaluation of Different Wall Heating Systems in Historic Monuments – Aspects of Energy and Conservation', *Energy Efficiency and Comfort of Historic Buildings (EECHB)*, Brussels: Flanders Heritage Agency, 158-164. p 158-164.

at the historic Baroque Skokloster castle in Sweden, which was suffering from problems due to high indoor relative humidity.[329]

Traditional buildings were designed to use natural ventilation to reduce condensation and keep interior spaces fresh and cool during warm weather. Poor ventilation can lead to a build-up of damp in the building fabric and can create an unhealthy living environment.[330] The reinstatement of passive ventilation measures like the unblocking of ventilation grills and chimney flues should be explored in any renovation project.[331] Ventilation with heat recovery is one energy efficient option that meets both the heating and cooling needs in traditional buildings. Section 5.4 of the 3ENCULT Handbook discusses the pros and cons of different ventilation systems and lays out the main steps to choosing a compatible ventilation system from decision-making to installation.[332] Section 5.6 of the 3ENCULT Handbook explains how passive heating and cooling systems work in traditional buildings, Section 5.7 introduces a number of renewable energy sources and how to implement them, and Section 5.8 concludes with how to optimise active and passive heating/cooling systems based on the physical characteristics of the building, its use, conservation requirements and the local climate.

HES Inform Guide: Ventilation in Traditional Houses (2008)

HES Short Guide 11: Climate Change Adaptation for Traditional Buildings (2016)

3ENCULT Handbook: Energy Efficient Solutions for Historic Buildings (2014)

2.5.4.2 Renewable Energy Sources

According to a 2013 report by the SEAI, the residential sector accounted for 27% of the total energy used in Ireland and was responsible for 10.5 million tonnes of CO_2 emissions in 2011.[333] The SEAI also now maintains an online database of energy use across all sectors, which shows an overall dip in energy use coinciding with the 2008 recession, but predicts that energy use will meet and exceed the 2008 levels by 2022.[334] The statistics also predict a steady increase in the use of renewables as the primary energy source. The SEAI has reported that renewables accounted for 9.1% of the Gross National Consumption (GNC) in 2015, which avoided 3.9 million tonnes of CO_2 emissions and €426 million worth of fossil

Energy in the Residential Sector (2013)

SEAI Statistics: Energy Data (2018)

Energy in Ireland 1990 – 2015 (2016)

Directive 2009/28/EC

Ireland's National Renewable Energy Action Plan (2010)

[329] Wessberg, M., Leijonhufvud, G. and Broström, T. 'An Evaluation of Three Different Methods for Energy Efficient Indoor Climate Control in Skokloster Castle'.Ibid., 144-150. p 144-150.
[330] Curtis, R. (2008) *INFORM Guide: Ventilation in Traditional Houses*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=ff550899-9512-4eba-a823-a59800a7b97d.
[331] Curtis, R. and Hunnisett Snow, J. (2016) *Short Guide 11: Climate Change Adaptation for Traditional Buildings*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=a0138f5b-c173-4e09-818f-a7ac00ad04fb.
[332] Troi, A. and Bastion, Z. (eds.) (2014) *Energy Efficient Solutions for Historic Buildings: A Handbook*: Birkhäuser. p 153.
[333] Dennehy, E. and Howley, M. (2013) *Energy in the Residential Sector*, Dublin: Sustainable Energy Authority of Ireland. Available at: https://www.seai.ie/resources/publications/Energy-in-the-Residential-Sector-2013.pdf.
[334] *Energy Data* (2018). SEAI Statistics. Dublin: Sustainable Energy Authority of Ireland. Available at: https://www.seai.ie/resources/seai-statistics/energy-data/ (Accessed: 23 January 2018).

fuel imports.[335] However, residential energy use also increased by 5.2% from 2014 to 2015[336], and as the Irish economy recovers, it is clear that in order to meet the 2020 energy efficiency and carbon reduction targets, the use of renewables will need to increase steadily and significantly. Chapter 3 of the 2016 SEAI Energy in Ireland report outlines progress made toward achieving Ireland's renewable energy goals set by Directive 2009/28/EC[337] and the National Renewable Energy Action Plan[338].

HES Short Guide 8: Micro-renewables in the Historic Environment (2014)

Deep energy renovation is defined as a whole-house approach that includes all material improvements as well as the upgrading of existing heating and ventilation systems and the installation of renewable energy sources.[339] Renewable or infinite energy sources such as solar, wind and hydropower or renewable fuels like timber, biomass or wood pellets can be substituted for fossil fuel sources of thermal or electric energy. Historic Environment Scotland published an introductory Short Guide in 2014 on the use of micro-renewables in the historic environment.[340] HES defines 'micro-renewables' as small-scale, non-commercial renewable energy systems that provide heating, hot water and electricity using low- or zero-carbon technologies. The introduction of renewable energy systems should coincide with measures to reduce energy demand through correct building maintenance and thermal upgrades. The HES Short Guide first briefly outlines the pre-installation factors that should be considered with any renewable energy system, such as listed building consent or planning permission, local setting and climate, building use and energy requirements, and cost and financial incentives. The Guide then introduces the basic requirements of six different types of renewable energy systems, followed by guidance on how to minimise the visual and physical impact of their installation.

HES Refurbishment Case Study 12: Kincardine Castle – Installation of Biomass System (2014)

HES Refurbishment Case Study 21: Blair Castle, Perthshire – the Re-instatement of an Early Micro-Hydroelectric Plant (2016)

HES Refurbishment Case Studies have also detailed the installation of a biomass system at Kincardine Castle[341] and the reinstatement of an early micro-hydroelectric plant at Blair Castle in Perthshire[342] .

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[335] Howley, M. and Holland, M. (2016) *Energy in Ireland 1990-2015*, Dublin: Sustainable Energy Authority of Ireland. Available at: http://www.seai.ie/resources/publications/Energy-in-Ireland-1990-2015.pdf. p 4.

[336] Ibid. p 4.

[337] *Directive 2009/28/EC* (2009): The European Parliament and the Council of the European Union.

[338] *National Renewable Energy Action Plan - Ireland* (2010), Dublin: Department of Communications, Climate Action and Environment. Available at: https://www.dccae.gov.ie/en-ie/energy/topics/Renewable-Energy/irelands-national-renewable-energy-action-plan-(nreap)/Pages/Action-Plan.aspx.

[339] Grimshaw, H. (2016) *Retrofit Factfile: A Short Summary of Facts and Publications Relevant to Domestic Retrofit*, Manchester: URBED Ltd and the Carbon Co-op. Available at: http://urbed.coop/projects/retrofit-factfile. p 7.

[340] Hummelt, K. (2014) *Short Guide 8: Micro-Renewables in the Historic Environment.* Edinburgh: Historic Environment Scotland.

[341] Bradford, A. and Grant, N. (2014) *Refurbishment Case Study 12: Kincardine Castle - Installation of Biomass System*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=17f1bded-7991-413b-b5b9-a59300f58b65.

3ENCULT Handbook: Energy Efficient Solutions for Historic Buildings (2014)

The 3ENCULT project studied three sources of renewable electric energy production (photovoltaic, wind energy and hydropower) and three renewable thermal sources (solar thermal energy, biomass and geothermal energy) to assess the physical and aesthetic impact of their substitution for conventional energy sources in historic buildings.[343] Under each energy production type, the handbook outlines the basic requirements of each system (climatic, structural supports, etc.), installation, and highlights when planning permission might be required for protected structures.

EFFESUS Energy Efficiency in European Historic Urban Districts – A Practical Guidance (2016)

The long-term goal of the EFFESUS project is to turn Europe's historic buildings and districts carbon neutral. This can only be accomplished if the demand for energy is reduced through renovation solutions and if the energy provided maximises the use of renewable energy sources. The project has produced a repository of renewable energy technologies and measures available on the commercial market as well as a Decision Support System and 3D mapping software to assist with the development of efficient and effective urban renewable energy strategies (Section 2.1).[344] Section 2.2 of the EFFESUS Booklet breaks the process of integrating renewable energy of individual historic buildings and whole districts into 4 steps: 1) Energy demand analysis; 2) Reducing energy use and increasing energy efficiency; 3) Renewable energy integration at building level; and 4) Renewable energy integration at district level.[345]

The GreenFacts Initiative

The GreenFacts Initiative is a non-profit, non-advocacy, European initiative led by independent scientific specialists established to bring summaries of complex scientific consensus reports on health, the environment and sustainable development to the broader public.[346] The articles cover a great breadth of topics, such as 'Energy Technologies - Scenarios to 2050' and 'The Future of Solar Energy'. Each topic is subdivided into complexity levels, beginning with an introduction to the topic, which is further subdivided into a brief summary, a long-read summary, and then a link to the full source paper. Topics relating directly and indirectly to the deep energy renovation of the building stock can be found under the categories of Energy, Sustainable Development and Climate Change.

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[342] Curtis, R. (2016b) *Refurbishment Case Study 21: Blair Castle, Perthshire - The Re-instatement of an Early Micro-Hydroelectric Plant*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=c3253a24-acec-4829-80ba-a6ad00a00391.

[343] Troi, A. and Bastion, Z. (eds.) (2014) *Energy Efficient Solutions for Historic Buildings: A Handbook*: Birkhäuser. Section 5.7. p 179.

[344] *Energy Efficiency in European Historic Urban Districts: A Practical Guidance* (2016b), Leipzig, Germany: Fraunhofer Centre for International Management and Knowledge Economy MOEZ. Available at: http://www.effesus.eu/dissemination/booklet. Section 2.1. p 18.

[345] Ibid. Section 2.2. p 22.

[346] *The GreenFacts Initiative* (2017): The GreenFacts Scientific Board. Available at: https://www.greenfacts.org/en/solar-energy/index.htm (Accessed: 15 February 2018).

2.6 Addressing Knowledge Gaps, Barriers and Renovation Risks

2.6.1 Technical and Non-Technical Barriers

At present, a number of technical and non-technical barriers have been identified that are inhibiting the uptake of dwelling and non-dwelling deep energy renovations. A briefing document from the Build Upon Ireland stakeholder consultation process summarised the key barriers to the uptake of deep energy renovation measures in the commercial, public and residential sectors of Ireland.[347] The Retrofit Factfile has identified, in particular, a lack of renovation up-skilling in the building industry, shortages in the supply chain capacity and high delivery costs as barriers keeping whole house renovation from attaining a market-wide impact.[348] The Passive House Institute has recognised a need for greater access to suitable renovation materials, to well-trained local professionals able to meet the energy requirements, to public and private funding mechanisms, and to a greater variety of case studies that demonstrate how to achieve deep energy renovations to Passive House or EnerPHit standards. [349]

Build Upon: Co-Creating Ireland's National Renovation Strategy 2017-2020 - Briefing Document (2016)

Final Recommendations for a Better National Renovation Strategy (2017)

Retrofit Factfile: A Short Summary of Facts and Publications Relevant to Domestic Retrofit (2016)

Implementing Deep Energy Step-by-Step Retrofits: EuroPHit (2016)

Retrofit Revealed: The Retrofit for the Future Projects – Data Analysis Report (2013)

The *Retrofit Revealed Data Analysis Report* identified and offered solutions for overcoming seven common challenges experienced in the 54 *Retrofit for the Future* projects, which related to product and service availability and a lack of competition; integration, quality and skills in the supply chain; unexpected changes in the project team; unexpected setbacks on site; difficulties obtaining planning permission; conflicts with some neighbours and residents; and project delays and cost overrun.[350] Based on these findings, the report then provides some general suggestions to ensure that a whole house renovation projects run as smoothly as possible. To test the effectiveness of the energy renovation works in terms of energy savings and carbon reductions, the Energy Saving Trust and the Technology Strategy Board developed a monitoring protocol in 2009 for the Retrofit for the Future project. Using a standardised approach for both measuring and reporting results will enable the cross-comparison of different buildings, renovation measures and renewable technologies. The basics of this protocol are outlined in

[347] *Build Upon: Co-Creating Ireland's National Renovation Strategy 2017-2020 - Briefing Document* (2016), Dublin: Build Upon Europe. Available at: http://buildupon.eu/wp-content/uploads/2015/09/BriefingDocument_v.1.pdf.
[348] Grimshaw, H. (2016) *Retrofit Factfile: A Short Summary of Facts and Publications Relevant to Domestic Retrofit*, Manchester: URBED Ltd and the Carbon Co-op. Available at: http://urbed.coop/projects/retrofit-factfile. p 5.
[349] *EuroPHit Brochure: Implementing Deep Energy Step-by-Step Retrofits - Increasing the European Potential* (2016), Darmstadt, Germany: Passive House Institute. Available at: http://europhit.eu/sites/europhit.eu/files/EuroPHit_brochure_final_PHI.pdf. p 11.
[350] *Retrofit Revealed: the Retrofit for the Future Projects - Data Analysis Report* (2013), Swindon: The Technology Strategy Board. Available at: https://retrofit.innovateuk.org/. p 20.

the appendix of the Retrofit for the Future report, along with a core package of evaluation measures and additional recommended measures.[351] Although the monitoring guidance used for this project seems to no longer be available, a detailed approach to short-term and long-term monitoring can be found in the Energy Saving Trust guide *Monitoring Energy and Carbon Performance in New Homes.*[352]

Monitoring Energy and Carbon Performance in New Homes (2008)

Section 5 of the EFFESUS handbook *Energy Efficiency in European Historic Urban Districts* advises on how to overcome non-technical political, financial, cultural and societal barriers for energy interventions.[353] The EFFESUS Decision Support System (DSS) [354] is designed to help municipalities and state bodies guide stakeholders through the process of selecting and prioritising energy interventions, with respect to the historical significance of the buildings.[355]

EFFESUS Booklet: Energy Efficiency in European Historic Urban Districts (2016)

Historic England also published a research report in 2017 that assessed how policy, legislation and local authorities can be used to guide decision-making with regards to the energy renovation of traditional buildings.[356] The research tracked where policy, legislation and best practice guidance converge and conflict and suggested ways that local authorities could improve the knowledge base within the various departments to be in a better position to advise their constituency on deep energy renovation matters.

The Sustainable Use of Energy in Traditional Buildings: Using Legislation and Policy to Guide Decision-Making (2017)

At this stage, there is a great need to learn from mistakes by undertaking pre- and post-renovation Building Performance Evaluations (BPEs), as was done at the Land Sea and Islands Centre in Arisaig, Scotland.[357] The Centre is housed in a 19th century solid masonry former blacksmiths that was first renovated in 1999, which included the replacement of the windows, insulation to the ceiling and select external walls, the construction of three new extensions and the application of cement render to the whole of the exterior. The use of these vapour-closed materials led to a damp and cold indoor environment, and in 2014, the Mackintosh Environmental

Building Performance Evaluation - a Design Approach for Refurbishment of a Small Traditional Building in Scotland (2016)

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[351] *Retrofit for the Future: Reducing Energy Use in Existing Homes - A Guide to Making Retrofit Work* (2014), Swindon: Technology Strategy Board. Available at: https://retrofit.innovateuk.org/. p 54.

[352] *Monitoring Energy and Carbon Performance in New Homes* (2008), London: Energy Saving TrustCE298). Available at: https://tools.energysavingtrust.org.uk/Publications2/Housing-professionals/Monitoring.

[353] *Energy Efficiency in European Historic Urban Districts: A Practical Guidance* (2016b), Leipzig, Germany: Fraunhofer Centre for International Management and Knowledge Economy MOEZ. Available at: http://www.effesus.eu/dissemination/booklet. p 79.

[354] Egusquiza, A., Hermann, C. and Rodwell, D. (2016) 'Decision Support for Energy Improvements', *Context,* 145, pp. 29-31.

[355] Kariotellis, P. (2015) *Deliverable D6.2: Decision Support System*: EFFESUS. Available at: http://www.effesus.eu/wp-content/uploads/2016/01/EFFESUS-Deliverable-D6-2_Update-21-01-20161.pdf.

[356] *Research Report Series: The Sustainable Use of Energy in Traditional Buildings - Using Legislation and Policy to Guide Decision-Making* (2017): Historic England (2059-4453 (online). Available at: https://www.cse.org.uk/downloads/file/historic-england-2017-sustainable-use-of-energy-in-traditional-dwellings.pdf.

[357] Foster, J. A., Foster, S. A., Sharpe, T. R. and Poston, A. 'Building Performance Evaluation – a Design Approach for Refurbishment of a Small Traditional Building in Scotland'. *Energy Efficiency and Comfort of Historic Buildings (EECHB)*, Brussels, 19-21 October: Flanders Heritage Agency, 217-224. p 217.

Architectural Research Unit (MEARU) were brought in to assess the performance of the building before and after its second energy efficient renovation. BPEs are typically only used to assess new construction, but this case study has shown their value to ascertain tangible results in the energy renovation of traditional buildings, which could then be used to inform the improvement expectations of other renovation works in local buildings of a similar construction. HES Technical Paper 19 also documents the pre- and post-renovation performance of ten traditional properties in Scotland.[358]

HES Technical Paper 19: Monitoring Thermal Upgrades to Ten Traditional Buildings (2013)

This section of the Annotated Bibliography introduces areas that can present technical and non-technical barriers to the uptake of deep energy renovation for traditional buildings. Further recommendations of measures to help address these barriers are presented in Chapter 3: Recommended Next Steps.

2.6.2 Moisture Retention and Health Risks

The BRE Literature Review found that the most often cited unintended consequences of installing solid wall insulation in traditional buildings are increased moisture retention and overheating.[359] The study found that the majority of post-installation issues were due to poor workmanship or the incorrect assessment of the building and then the application of unsuitable insulation materials. Poor installation of internal or external solid wall insulation can lead to water ingress, thermal bridging, condensation and mould growth, which will create an unhealthy living environment. Chapter 4 of the BRE Literature Review details the causes and effects of these unintended consequences, considers the potential impact of climate change and lists a number of documents providing best practice guidance on how to avoid these unintended consequences.[360] The authors felt that with the abundance of technical guidance already available, it is a greater investment in training that is needed to ensure that best practice principles are applied in practice.

BRE Literature Review - Solid Wall Heat Losses and the Potential for Energy Savings (2014)

The BRE conducted a monitoring study of 88 homes renovated under the UK Community Energy Saving Programme (CESP) or the Registered Social Landlord (RSL) scheme between October 2009 through December 2012 using air tightness tests, infra-red thermography, relative humidity and temperature measurements, homeowner surveys and utility bill analysis before and after

Monitoring of the Community Energy Saving Programme (2016)

[358] Currie, J., Williamson, J. B. and Stinson, J. (2013) *Technical Paper 19: Monitoring Thermal Upgrades to Ten Traditional Properties*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=4d0a95cb-2a0c-484a-894d-a59400b3f69b.

[359] Gemmell, A. (2014) *Solid Wall Heat Losses and the Potential for Energy Savings: Literature Review*, Watford: Building Research Establishment Ltd. Available at: https://www.gov.uk/government/publications/solid-wall-heat-losses-and-the-potential-for-energy-savings-literature-review. p 3.

[360] Ibid.p 69-98.

renovation works were completed. The study found that overall, 75% of the renovation installations could be improved through better workmanship and 20% of the installed measures were deemed unacceptable.[361] Areas where workmanship generally lacked were: detailing of external wall insulation (EWI) around windows and wall joints (leading to cold bridging and condensation); draught sealing around newly installed windows; and the insulation and sealing of loft hatches and service pipes. The report recommends that future policy should promote improvements in these areas and that measures to improve air tightness and reduce draughts should be undertaken as part of any renovation project.

How to Deal with Retrofit Risks. Context. (2017)

In the journal article *How to Deal with Retrofit Risks*, Colin King warns that 'there are enough warning signs to suggest that insulating [solid] walls either externally or internally can lead to undesirable consequences' and advises that further research is needed 'before a large scale roll-out of wall insulation for heritage buildings can be recommended'.[362] While caution is necessary, a good number of studies have been published in the past few years that examine the hygrothermal behaviour of solid walls before and after the installation of solid wall insulation to better understand and avoid any unintended consequences. The recent publication *Avoidance and Diagnosis of Problems Associated with Internal Wall Insulation* details all of the conditions that need to be accounted for before installing internal wall insulation to a solid wall and explains clearly why vapour control layers are inappropriate for traditional buildings.[363]

Avoidance and Diagnosis of Problems Associated with Internal Wall Insulation (2017)

HES Technical Paper 15: Assessing Risks in Insulation Retrofits using Hygrothermal Software Tools: Heat and Moisture Transport in Internally Insulated Stone Walls (2015)

Hygrothermal Risk Evaluation for the Retrofit of a Typical Solid-Walled Dwelling (2016)

The 249-page HES Technical Paper 15 was written for building design professionals and addressed the use of hygrothermal modelling software to assess the risks of internally insulating solid stone walls.[364] The paper had three foci: the first was to introduce the basics of applied building physics; the second was to examine the building standards, the related simulation assessment methods (Glaser and numerical) and industry's use (and misuse) of both standards and methods; and the third was to demonstrate the differences between the two methods as applied to a Victorian solid masonry walled tenement in Glasgow. The wall was assessed in its original state and with a variety of insulation options to compare both the assessment tools and the renovation options.

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[361] *Monitoring of the Community Energy Saving Programme* (2016): Building Research Establishment (BRE). Available at: https://www.gov.uk/government/publications/monitoring-of-the-community-energy-saving-programme-cesp. p 4.

[362] King, C. (2017) 'How to Deal with Retrofit Risks', *Context,* (149), pp. 23-24.

[363] Smith, M. (2017) 'Avoidance and Diagnosis of Problems Associated with Internal Wall Insulation', *Journal of Building Survey, Appraisal & Valuation,* 6(1), pp. 11-25.

[364] Little, J., Ferraro, C. and Arregi, B. (2015) *Technical Paper 15: Assessing Risks in Insulation Retrofits using Hygrothermal Software Tools - Heat and Moisture Transport in Internally Insulated Stone Walls*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=8a2a7b9d-e3b2-4c7d-8c17-a59400a8387b.

Two of its authors, Joseph Little and Beñat Arregi, published a separate Dublin-based study of the hygrothermal risks associated with insulating the walls of a traditional solid wall dwelling in Dublin.[365] The case study demonstrated the superior functionality of simulation modelling programmes based on EN 15026:2007 when applied to traditional solid wall dwellings.[366] The simulation results showed that all three renovation approaches tested will lead increased moisture at the base of the wall compared to the buildings original state, but that insulation materials with high permeability and no vapour control membrane presented the lowest hygrothermal risk.

SPAB Research Report 2: Building Performance Surveys (2011-2017)

SPAB Research Report 3: Hygrothermal Modelling (2012)

Since 2011, the *SPAB Building Performance Survey* has been measuring the changes in moisture content in three different types of solid wall buildings (brick, granite and cob) in different regions of England to assess the seasonal and long term behaviour of moisture in the building fabric before and after the installation of solid wall insulation.[367] Research Report 3 of the SPAB Building Performance Survey used hygrothermal modelling software to assess the outcome of recommendations put forth by UK building standards. Concentrating on the solid brick wall case study dwelling in Shrewsbury, the findings demonstrated that the industry standard BS 13788-based solution of a inserting a vapour retarder (VCL) on the warm side of internal wall insulation within the traditional (c. 1820) dwelling would lead to the complete failure of the insulation with water content levels and relative humidity shown to constantly reach or exceed the 80% maximum threshold.[368]

Moisture in Buildings: An Integrated Approach to Risk Assessment and Guidance (2017)

In 2017, a White Paper was prepared by the STBA and published by the British Standards Institution (BSI), titled *Moisture in Buildings: An Integrated Approach to Risk Assessment and Guidance*.[369] As building standards have typically only applied to new construction, this White Paper was produced to guide the creation of new building standards or the revision of existing standards to provide best practice advice on how to insulate traditional solid wall buildings. According to its authors, 80% of building failures are due to moisture. Moisture risks (ranging from indoor air quality and health to building defects) appear to be increasing as airtightness and insulation levels increase in response to the desire for greater comfort levels and energy efficiency. It is accepted that the level of

[365] Arregi, B. and Little, J. (2016) 'Hygrothermal Risk Evaluation for the Retrofit of a Typical Solid-Walled Dwelling', *Sustainable Design & Applied Research in Engineering and the Built Environment (SDAR),* (6), pp. 17-26.
[366] Ibid.
[367] *The SPAB Research Report 2: The SPAB Building Performance Survey 2016 – Summary* (2017): Historic England. Available at: https://www.spab.org.uk/advice/research/findings.
[368] Browne, D. (2012) *The SPAB Research Report 3: The SPAB Hygrothermal Modelling - Interim Report*: Society for the Protection Ancient Buildings. Available at: https://www.spab.org.uk/advice/research/findings. p 61.
[369] May, N. and Sanders, C. (2017) *Moisture in Buildings: An Integrated Approach to Risk Assessment and Guidance*: Sustainable Traditional Building Alliance (STBA). Available at: http://shop.bsigroup.com/upload/279150/BSI-White-Paper-Moisture-In-Buildings.PDF.

unknowns in energy efficient renovation works, especially of solid-walled buildings, raise more concerns than the construction of new super low energy buildings, yet less guidance is provided for builders, specifiers and homeowners.

Moisture: Risk Assessment and Guidance (2014)

A 2014 STBA draft report, *Moisture: Risk Assessment and Guidance*, also provides more information about the behaviour of moisture in traditional buildings, the risks associated with internal and external wall insulation, the limitations of hygrothermal modelling in traditional buildings and advice on how to undertake moisture risk assessment and how to select the appropriate renovation approach.[370]

Health and Moisture in Buildings (2017)

In October 2017, the UK Centre for Moisture in Buildings (UKCMB) published the paper *Health and Moisture in Buildings*, which summarises the findings of more than 200 studies on the correlation between occupant health to moisture levels in buildings.[371] The UK has some of the highest levels of illnesses like asthma in the world, and the report warns that changes in the construction industry, building regulations, occupancy patterns and building use may lead to more hazardous moisture conditions in buildings in the coming years. Such detrimental changes and hazards include:[372]

a. The increasing air tightness of buildings, as demanded in building regulations and energy retrofit measures;
b. The fabric retrofit of existing building stock, which often leads to increased ventilation requirements and problems of cold bridging and trapped moisture;
c. The frequent failure of ventilation systems;
d. The reduction in room sizes and house volumes, making ventilation and air movement more difficult;
e. Increasing water use and consequent leaks from the ever-increasing numbers of appliances;
f. Increased moisture production in housing from lifestyle changes, thereby increasing moisture pressure;
g. Overcrowding of buildings, particularly in the rental sector, again increasing moisture levels and often reducing air movement;

[370] May, N. and Sanders, C. (2014) *Moisture: Risk Assessment and Guidance (DRAFT)*, London: Sustainable Traditional Buildings Alliance (STBA). Available at: http://stbauk.org/stba-guidance-research-papers. p 31.
[371] May, N., McGilligan, C. and Ucci, M. (2017) *Health and Moisture in Buildings: A report from the UK Centre for Moisture in Buildings about the health impact of buildings which are too dry or too damp*, London. Available at: http://www.ukcmb.org/ukcmb-news/report-on-mositure-and-health-in-buildings.
[372] Ibid. p 5.

h. The changing climate in the UK, leading possibly to increased flooding and wind driven rain, as well as an increased use of air conditioning in hot weather.

This UKCMB report discusses the complexity of moisture related issues and why moisture related health risks are not taken seriously in UK policy, medicine and law. The report concludes with recommendations to improve policy and building practice to ensure moisture risk assessment is at the fore of any new construction or renovation project. The UKCMB has also created an introductory video that explains how to achieve a balanced level of moisture in existing homes.[373]

UKCMB Video: Moisture Guidance for Existing Homeowners (2017)

The UK Centre for Moisture in Buildings was established, in emulation of the Swedish FuktCentrum (or Moisture Research Centre), to address the oversight of moisture-related risks in the UK building industry and to commission cross-institutional research. They support the adoption of the Swedish 'ByggaF' method for all UK building projects:[374]

> *The ByggaF method suggests that there is a formalized process ensuring that moisture risk assessment and strategy is carried through into moisture safe design, construction and operation. It is suggested that a Moisture Safety Expert is a key member for this and of the Planning/Assessment and Design team, whose work continues throughout the process until handover. The expert can be a trained architect, designer, technician, surveyor or engineer and not necessarily an additional member of the existing design team. In addition a Moisture Safety Officer should be a key member of the construction team, liaising with the Moisture Safety Expert and dealing with both the planned construction process as well as unforeseen design and construction issues on site. For this reason, both of these team members need to understand the principles of moisture safety, how to deal effectively with them and how to integrate them into other aims of the project (such as energy efficiency, security, acoustic insulation). This situation will be even more critical in renovation or non-standard buildings where unforeseen situations can occur more frequently.*

2.6.3 Occupant Behaviour

Chapter 3 of the BRE Literature Review focuses on occupant behaviour and highlights the correlation between increased energy

[373] *UKCMB launches a new video on moisture guidance for existing homeowners* (2017): UK Centre for Moisture in Buildings (UKCMB). Available at: http://www.ukcmb.org/ukcmb-news/moisture-guidance-for-existing-homeowners (Accessed: 4 January 2018).

[374] May, N. and Sanders, C. (2017) *Moisture in Buildings: An Integrated Approach to Risk Assessment and Guidance*: Sustainable Traditional Building Alliance (STBA). Available at: http://shop.bsigroup.com/upload/279150/BSI-White-Paper-Moisture-In-Buildings.PDF. p 14.

efficiency, raised comfort standards and fuel consumption. One might expect that increased energy efficiency would naturally lead to a more conservative use of fuel, but in fact, William Stanley Jevons first argued the opposite in 1865, stating that 'It is wholly a confusion of ideas to suppose that the economical use of fuel is equivalent to diminished consumption. The very contrary is the truth. As a rule, new modes of economy will lead to an increase of consumption...'[375] A paper published in the academic journal Energy Policy estimates the best and worst case scenarios of increased GHG emissions post-renovation due to the reallocation of household funds and increased spending on other GHG-intensive goods.[376] This sort of behaviour has been colloquially called 'the rebound effect', of which the BRE Literature Review outlines three types (direct, indirect and economy-wide) and presents methods to calculate their possible impact on energy savings.

Alternatively, a study by the Greater Manchester Low Carbon Housing Retrofit programme found that changes in occupant behaviour can lead to energy use reductions of 25-50%, and argues that it is therefore essential to educate the building users as part of any successful deep renovation project.[377] While user behaviour is an uncontrollable variable in the renovation process, the report outlines the significance of occupant behaviour, how to understand user behaviours and their decision making process, and recommends strategies to help influence people to make informed energy saving behavioural changes.

A lack of engagement from residents and with neighbours has also been noted as a barrier to the success of deep energy renovations. The Retrofit for the Future guide recommends engaging residents with the design process from the start, providing handover documents to help residents manage their renovated home efficiently and following up with residents after completion of the project to monitor the dwelling's energy performance as well as the user's behaviour.[378]

The *Soft Landings Framework* was first developed by the Usable Buildings Trust (UBT) in the mid-2000s and is a process of extended handover and professional aftercare for new and renovated buildings to help ensure that buildings operate to their optimum

BRE Literature Review - Solid Wall Heat Losses and the Potential for Energy Savings (2014)

Missing Carbon Reductions? Exploring Rebound and Backfire Effects in UK Households (2011)

The Missing Quarter: Integrating Behaviour Change in Low Carbon Housing Retrofit (2011)

Retrofit for the Future: Reducing Energy Use in Existing Homes - A Guide to Making Retrofit Work (2014)

A Community Approach to Retrofit and Potential Implications for the Fuel Poverty Agenda (2015)

Energy-led Domestic Retrofit: Impact of the Intervention Sequence (2016)

Energy Performance Certificates and Historic Buildings: A Method to Encourage User Participation and Sustainability in the Refurbishment Process (2016)

[375] Gemmell, A. (2014) *Solid Wall Heat Losses and the Potential for Energy Savings: Literature Review*, Watford: Building Research Establishment Ltd. Available at: https://www.gov.uk/government/publications/solid-wall-heat-losses-and-the-potential-for-energy-savings-literature-review. p 57.

[376] Druckman, A., Chitnis, M., Sorrell, S. and Jackson, T. (2011) 'Missing Carbon Reductions? Exploring Rebound and Backfire Effects in UK Households', *Energy Policy,* 39(6), pp. 3572–3581.

[377] *The Missing Quarter: Integrating Behaviour Change in Low Carbon Housing Retrofit* (2011), Manchester: Greater Manchester Low Carbon Economic Area Initiative - Housing Retrofit Programme. Available at: http://www.salford.ac.uk/__data/assets/pdf_file/0005/593258/Missing-Quarter-Behaviour-Change-report.pdf.

[378] *Retrofit for the Future: Reducing Energy Use in Existing Homes - A Guide to Making Retrofit Work* (2014), Swindon: Technology Strategy Board. Available at: https://retrofit.innovateuk.org/. p 39.

and intended efficiency after occupation. The framework is designed to address three main stages of any building project:[379]

1. The Procurement Process: Setting and maintaining client and design aspirations that are both ambitious and realistic, and managing them through the whole procurement process and into use
2. Initial Occupation: Providing support, detecting problems and undertaking fine-tuning;
3. Longer-Term Monitoring, Review, Post-Occupancy Evaluation (POE) and Feedback: Drawing important activities into the design and construction process that are often overlooked and disconnected

While the full Soft Landings Framework is only available for purchase, an introductory documents provides an overview and example worksheets for the five stages of the process: Stage 1: Inception and Briefing; Stage 2: Design Development and Review; Stage 3: Pre-Handover; Stage 4: Initial Aftercare; and Stage 5: Years 1-3 Extended Aftercare and POE.[380] The UK Cabinet Office Government Property Unit made it mandatory from 2016 onward for all new government buildings and major renovations to implement a modified version of the Soft Landings Framework during and after the completion of each project.

BSRIA Soft Landings Framework – Set of 5 Guides (2015)

The Soft Landings Framework for Better Briefing, Design, Handover and Building Performance in-Use (2014)

Section 7 of the English *Approved Document L1B: Conservation of Fuel and Power in Existing Dwellings*, which is the guidance document to support the English S.I. 2010 No. 7019 - the Building and Approved Inspectors (Amendment) Regulations 2010, mandates that:[381]

> *7.1 On completion of the work, in accordance with regulation 40, the owner of the dwelling should be provided with sufficient information about the building, the fixed building services and the operating and maintenance requirements so that the dwelling can be operated in such a manner as to use no more fuel and power than is reasonable in the circumstances.*

English Building Regulations - Approved Document L1B: Conservation of Fuel and Power in Existing Buildings (enacted 2010, last amended 2016)

A report by URBED and the Carbon Co-op collated qualitative insights and experiences from householders during each of the key stages of the whole house renovation process to assess potential uptake barriers and points of stress or confusion experienced by

A Community Approach to Retrofit and Potential Implications for the Fuel Poverty Agenda (2015)

[379] Way, M. and Bordass, B. (2014) *The Soft Landings Framework for Better Briefing, Design, Handover and Building Performance In-Use*, Berkshire: Usable Buildings Trust (UBT) (BSRIA BG 54/2014. Available at: https://www.bsria.co.uk/information-membership/bookshop/publication/soft-landings-framework/. p 13.

[380] Ibid.

[381] *Approved Document L1B: Conservation of Fuel and Power in Existing Dwellings* (2016), London: HM Government. Available at: https://www.gov.uk/government/publications/conservation-of-fuel-and-power-approved-document-l. p 20.

low-income homeowners in particular.[382] The report argues that the sharing of personal experiences during the renovation process will encourage greater uptake through a better understanding of the challenges and benefits of different renovation measures.

Solid Wall Insulation Study: Using the ISM Behaviour Change Model to Understand What Needs to Change to Encourage Greater Uptake among Householders (2014)

The Scottish Government commissioned an ISM (individual, social and material) behavioural study in 2014 to understand first, why a country with a high ratio of solid wall dwellings had comparatively low numbers of homeowners installing solid wall insulation and second, what was most likely to encourage them to do so.[383] The Energy Saving Trust found that cost was the greatest barrier for homeowners, but on the other hand, that the promise of increased warmth was a greater driver than energy or cost savings. The survey also found that local community groups were able to reach a certain sector of people that the established regional and national energy bodies have not, and that people place a great level of trust in their local community groups.

Energy Efficiency Uptake and Energy Savings in English Houses: A Cohort Study (2016)

A study of 168,889 English dwellings using UK energy renovation datasets from 2002-2007 has shown that certain dwelling features (type, age, size, region) impact the probability of homeowners to undertake major, fabric or heating energy renovation measures.[384] The data showed that owners of detached dwellings were most likely to undertake major energy renovation measures and flat owners were the least. Owners of older dwellings also exhibited lower levels of fabric improvement uptake than those of newer dwellings. The data showed a sharp and continuous rise in renovation measures like the installation of cavity wall and loft insulation, followed by the replacement of windows, boilers and heating systems, however, there was little or no increase in draught proofing measures or solid wall insulation. During the dataset collection period, governmental policies focused on helping low-income citizens to improve the energy efficiency of their homes and solid wall insulation was excluded from receiving funding through these schemes. As a result, there has been a lack of self-investment in home energy renovation from the middle and higher income sectors and the report recommends that future governmental policies be based on a true assessment of trigger points and barriers for these groups.

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[382] Grimshaw, H. and Atkinson, J. (2015) *A Community Approach to Retrofit and Potential Implications for the Fuel Poverty Agenda*, Manchester: URBED Ltd and the Carbon Co-op. Available at: http://urbed.coop/sites/default/files/20150923_Chesshire%20Lehmann%20final%20report_0.pdf.

[383] Prince, D. (2014) *Solid Wall Insulation Study: Using the ISM Behaviour Change Model to Understand What Needs to Change to Encourage Greater Uptake among Householders*, Scotland: Energy Saving Trust. Available at: http://webcache.googleusercontent.com/search?q=cache:O_SExH7i2q8J:www.energysavingtrust.org.uk/sites/default/files/EL%2520-%2520FINAL_Solid%2520Wall%2520Insulation%2520Study_1Aug14%2520%25281%2529.docx+&cd=1&hl=en&ct=clnk&gl=ie.

[384] Hamilton, I. G., Summerfield, A. J., Shipworth, D., Steadman, J. P., Oreszczyn, T. and Lowe, R. J. (2016) 'Energy Efficiency Uptake and Energy Savings in English Houses: A Cohort Study', *Energy and Buildings,* 118, pp. 259-276.

Interviews with homeowners have shown that improved resale market value and perceived social standing are other primary drivers that incentivise homeowners to undertake deep energy renovation works.[385] Likewise, improved Energy Performance Certificates (BERs in Ireland) have been recognised as a valuable incentive to encourage homeowners to include energy renovation measures alongside other cosmetic home upgrades they plan to make.[386]

Energy Performance Certificates and Historic Buildings: A Method to Encourage User Participation and Sustainability in the Refurbishment Process (2016)

A study published in the journal Building Research & Information demonstrated how the sequence of the renovation works undertaken could significantly impact the actual amount of energy saved, from a whole house renovation resulting in a 54% reduction in CO_2 emissions over 50 years, down to a 24-42% reduction depending on the renovation sequence.[387] The paper mapped out the timeline of five typical renovation sequences over 25 years, then calculated their overall annual energy consumption based on when the renovation works were undertaken. This study demonstrates that not only does clear advice need to be given on the most beneficial order for step-by-step renovation works to be implemented, but it highlights the need for energy renovation policies and financing models to incentivise either whole house or a step-by-step renovation sequence that guarantees the best results.

Energy-led Domestic Retrofit: Impact of the Intervention Sequence (2016)

A Policy Factsheet published by the Building Performance Institute Europe (BPIE) provides a brief overview of Building Renovation Passports (BRPs) and three European examples already in operation in France, Flanders and Germany.[388] BRPs are designed to provide personalised long-term (15-20 years) renovation roadmaps to assist homeowners in achieving the best results throughout their energy renovation process. The BPIE Factsheet recommended that the revised Energy Performance of Buildings Directive (EPBD) should require Member States to implement some form of guidance for step-by-step deep energy renovations, such as a Building Renovation Passport. This recommendation looks to have been taken on board and the revised EPBD text is due to be published in early 2018 after its approval by the European Parliament and Council.[389] The SEAI is also in the process of updating the BER

BPIE Policy Factsheet: Building Renovation Passports - Consumer's Journey to a Better Home

European Commission Press Release: Commission Welcomes Agreement on Energy Performance of Buildings (2017)

[385] Simpson, S., Banfill, P., Haines, V., Mallaband, B. and Mitchell, V. (2016) 'Energy-led Domestic Retrofit: Impact of the Intervention Sequence', *Building Research & Information,* 44(1), pp. 97-115.
[386] Berg, F. and Donarelli, A. 'Energy Performance Certificates and Historic Buildings: A Method to Encourage User Participation and Sustainability in the Refurbishment Process'. *Energy Efficiency and Comfort of Historic Buildings (EECHB)*, Brussels, 19-21 October: Flanders Heritage Agency, 264-271. p 264.
[387] Simpson, S., Banfill, P., Haines, V., Mallaband, B. and Mitchell, V. (2016) 'Energy-led Domestic Retrofit: Impact of the Intervention Sequence', *Building Research & Information,* 44(1), pp. 97-115.
[388] *Policy Factsheet: Building Renovation Passports - Consumer's Journey to a Better Home*: Building Performance Institute Europe. Available at: http://bpie.eu/publication/building-renovation-passports-consumers-journey-to-a-better-home/.
[389] *Commission Welcomes Agreement on Energy Performance of Buildings* (2017). Brussels: European Commission. Available at: http://europa.eu/rapid/press-release_IP-17-5129_en.htm.

system and by June 2018, it should provide more guidance on the preferred sequence of step-by-step renovation.

SEAI Behavioural Economics Unit (2017)

Behavioural Insights on Energy Efficiency in the Residential Sector (2017)

Unlocking the Energy Efficiency Opportunity – Summary for Policymakers (2015)

The SEAI has also recently set up a new Behavioural Economics Unit that will focus on 'encouraging measurable changes to homeowners' and businesses' energy behaviour'.[390] Corresponding with the establishment of the Unit, the SEAI has published a report that evaluates six years of research conducted on how to stimulate home energy efficiency upgrades in Ireland.[391] Using consumer surveys, focus groups, design thinking exercises, pilots, trials and data analysis, the SEAI aimed to understand the motivations, barriers and support needs of building owners wishing to undertake energy renovations. In relation to the energy efficiency renovation of the Irish housing stock, the report addresses consumer awareness and engagement; trigger points and decision-making frequency; the availability of finance and understanding consumer investment behaviour; and how to improve the attractiveness of subsidy and support programmes. This research builds upon an earlier SEAI report aimed at policymakers, *Unlocking the Energy Efficiency Opportunity*, which estimated the potential energy savings in different sectors through a variety of initiatives and measures.[392]

2.6.4 Cost and Financing Initiatives

Financing Energy Efficiency in Buildings: An International Review of Best Practice and Innovation (2013)

World Energy Council: KfW Energy Efficient Rehabilitation and Energy Efficient Construction Programmes

Current KfW Energy Efficient Refurbishment Grants for Existing Properties

According to a report commissioned by the World Energy Council[393], financial barriers to the uptake of energy renovation measures include the initial cost, high transaction costs, extensive payback times, financial risk exposure and a lack of knowledge among finance providers.[394] The report examined energy efficiency financing schemes in eight different countries to study how these and other financial barriers are addressed in different contexts. In Germany, the government-owned development bank KfW has provided financing through a variety of energy efficient rehabilitation and construction grants and loans since 2008.[395] To qualify, the projects must meet the high energy standards set by

[390] *Behavioural Insights - SEAI Behavioural Economics Unit* (2017). Dublin: Sustainable Energy Authority of Ireland. Available at: https://www.seai.ie/sustainable-solutions/behavioural-insights/ (Accessed: 15 January 2018).

[391] *Behavioural Insights on Energy Efficiency in the Residential Sector* (2017), Dublin: Sustainable Energy Authority of Ireland. Available at: https://www.seai.ie/sustainable-solutions/behavioural-insights/.

[392] *Unlocking the Energy Efficiency Opportunity - Summary for Policymakers* (2015), Dublin: Sustainable Energy Authority of Ireland (SEAI). Available at: https://www.seai.ie/resources/publications/Unlocking-the-Energy-Efficiency-Opportunity-Summary-for-Policymakers.pdf.

[393] *World Energy Council: Energy Efficiency Policies and Measures*: World Energy Council Available at: https://wec-policies.enerdata.net/ (Accessed: 24 October 2017).

[394] Guertler, P. and Royston, S. (2013) *Financing Energy Efficiency in Buildings: An International Review of Best Practice and Innovation*, London: Association for the Conservation of Energy. Available at: https://wec-policies.enerdata.net/Documents/cases-studies/Financing_energy_efficiency_buildings.pdf. p 4.

[395] *KfW Energy Efficient Refurbishment and Construction Financing for Existing Buildings*: KfW. Available at: https://www.kfw.de/inlandsfoerderung/Privatpersonen/Bestandsimmobilie/ (Accessed: 24 October 2017).

the loan or grant standards, which often require a whole house approach including the renewal of heating systems, wall and loft insulation and the upgrading of windows. The KfW Efficiency House Monuments programme was introduced in 2012 to provide funding for historic properties worthy of protection and therefore acknowledges the importance of preserving historic building fabric during a renovation project.[396]

Impact on Public Budgets of KfW Promotional Programmes in the Field of "Energy-Efficient Building and Rehabilitation" (2011)

The Buildings Performance Institute Europe (BPIE) is a not-for-profit 'think tank' that uses independent research to analyse European and national energy policies and to provide advice about improving the energy performance of buildings in Europe.[397] The estimated annual cost required to meet the 2050 European carbon reduction goals is between €60-100 billion up to 2020 and it is expected to rise after that. Many of the BPIE publications have assessed different barriers to large-scale national energy renovation programmes, including financial risk appraisals, attracting private investment, and current EU national funding models. One such report analysed the barriers that hinder deep renovation of the built environment in Bulgaria, Croatia, Germany, Romania, Serbia and Slovenia.[398] The BPIE policy factsheet *Attracting Investment in Building Renovation*[399] also briefly details four different European national funding models currently in place. All types of energy renovation projects in Ireland and across the EU are hindered by a lack of governmental funding and private investment, however research outputs like the *EEFIG Underwriting Toolkit*[400] (Energy Efficiency Financial Institutions Group) are being designed to take the uncertainty and risk out of investing in the energy efficiency sector.

BPIE Publications

Barriers that Hinder Deep Renovation in the Building Sector (2017)

EEFIG Underwriting Toolkit: Value and Risk Appraisal for Energy Efficiency Financing (2017)

BPIE Policy Factsheet: Attracting Investment in Building Renovation

The EU-funded Energy Efficient Mortgages Action Plan (EeMAP) initiative aims to overcome the consumer finance hurdle by encouraging banks to grant better mortgages and loans to consumers willing to invest in energy efficient renovations.[401] A number of publications are free to download from the EeMAP website, including an Energy Efficiency Mortgage Pilot Scheme[402], a

Energy Efficient Mortgage Action Plan Initiative (2018)

[396] Hermann, C. (2017) 'Improving the Performance of Buildings and Urban Areas', *Context,* (149), pp. 20-22. p 21.
[397] *Buildings Performance Institute Europe (BPIE)*. Available at: http://bpie.eu/ (Accessed: 24 October 2017).
[398] Bean, F., Fabbri, M. and Kontonasiou, E. (2017) *Barriers that Hinder Deep Renovation in the Building Sector*: EmBuild. Available at: http://bpie.eu/news/barriers-that-hinder-deep-renovation-in-the-building-sector/.
[399] *Attracting Investment in Building Renovation*, Brussels: Buildings Performance Institute Europe (BPIE). Available at: http://bpie.eu/publication/attracting-investment-in-building-renovation/.
[400] *EEFIG Underwriting Toolkit: Value and Risk Appraisal for Energy Efficiency Financing* (2017): Energy Efficiency Financial Institutions Group. Available at: http://bpie.eu/publication/eefig-underwriting-guide-value-and-risk-appraisal-for-energy-efficiency-financing/.
[401] *Energy Efficient Mortgages Action Plan*. Available at: http://energyefficientmortgages.eu/ (Accessed: 7 March 2018).
[402] *EeMAP Energy Efficiency Mortgage Pilot Scheme*: Energy Efficient Mortgage Action Plan. Available at: https://www.igbc.ie/wp-content/uploads/2018/02/EeMAP-Energy-Efficiency-Mortgage-Pilot-Scheme-Implementation-Guidelines-Draft-for-Consultation.pdf.

Consumer Research Insights report[403] and a Building Assessment Briefing for Ireland.[404]

Thinking Deeper: Financing Options for Home Retrofit (2011)

SEAI Better Energy Homes Grant Scheme

The *Thinking Deeper: Financing Options for Home Retrofit* report, published by the Institute of International and European Affairs in 2011, assessed the financial barriers to a nationwide deep renovation programme in Ireland.[405] At that time, the government had planned to renovate at least one million homes by 2020, but by the end of 2017, only 350,000 homes have undergone energy efficiency improvement works through the SEAI's *Better Energy Homes*[406] grants initiative. The report identified two main reasons for the lack of investment in deep energy renovation in Ireland: [407]

1. A lack of attractive renovation loan offerings available to consumers because banks and institutional investors are not comfortable funding deep residential renovation without proof of the value of these investments; and
2. Consumers are reluctant to invest in renovation works due to issues around length of tenure, lack of guidance on suitable energy saving measures, and the reluctance of Irish consumers to take out loans to finance home renovation works.

In order to encourage investment in residential deep renovation in Ireland, the report analyses the advantages and challenges of five different financing options in the Irish context and market, with examples of each in operation in other countries:[408]

1. Attaching the loan to the property (USA)
2. Financing repayment through cost savings on the energy meter (UK)
3. Establishing a green bank (Germany & India)
4. Using private savings to create a fund to finance retrofit (several)
5. Traditional financing methods (USA)

[403] Marijewycz, M., Worrall, D. S., Weimann, D. L., Parkinson, C., Hope, C. and Feldwick, H. (2018) *Creating an Energy Efficient Mortgage for Europe: Consumer Research Insights*: E.ON and Basis. Available at: https://www.igbc.ie/wp-content/uploads/2018/02/EeMAP_D2.7_E.ON_Final.pdf.
[404] *Building Assessment Briefing: Ireland* (2018), Dublin: Irish Green Building Council. Available at: http://energyefficientmortgages.eu/wp-content/uploads/2018/02/EeMAP_Building_Assessment_Briefing_IRELAND.pdf.
[405] Curtain, J. and Maguire, J. (2011) *Thinking Deeper: Financing Options for Home Retrofit*, Dublin: The Institute of International and European Affairs. Available at: https://www.iiea.com/publication/thinking-deeper-financing-options-for-home-retrofit/.
[406] *Better Energy Homes Grants* (2017). Dublin: Sustainable Energy Authority of Ireland. Available at: https://www.seai.ie/grants/home-grants/better-energy-homes/ (Accessed: 16 January 2018).
[407] Curtain, J. and Maguire, J. (2011) *Thinking Deeper: Financing Options for Home Retrofit*, Dublin: The Institute of International and European Affairs. Available at: https://www.iiea.com/publication/thinking-deeper-financing-options-for-home-retrofit/. p 4.
[408] Ibid. p 25.

When the report was written, home mortgages in Ireland were down by 97% compared to their peak in late 2006. In that context, the report suggested that the government focus on making deep energy renovation attractive to the 'innovators' and 'early adopters' (according to Everett Roger's *Theory of Technological Adoption*) to overcome inertia in the market and to build trust in deep renovation amongst consumers and financers. Given the economic upturn in recent years, a re-evaluation of the financial market is due.

Implementing Deep Energy Step-by-Step Retrofits. Chapter 5: Financing Solutions. (2016)

The Passive House EuroPHit guide *Implementing Deep Energy Step-by-Step Retrofits* includes a chapter on financial barriers and solutions.[409] The chapter provides guidance for commercial lending institutions on means to assess the financial soundness of renovation projects through energy savings in order to develop standardised technical criteria to support a financing programme. The chapter also addresses the existing barriers to releasing funding for deep renovation from a lender's perspective, existing best practice in public and private lending, ways to use quality assurance to cut financial risks, and highlights sources of public funding available across Europe.

An Introduction to Green Leases (2017)

The Society of Chartered Surveyors Ireland (SCSI) is due to include a new clause in its Business Leasing Code on green leases in late 2017 or early 2018, which could help tackle the split incentive that exists between landlords and tenants.[410] A green lease differs from a standard commercial lease by providing directions on how a building is to be occupied, operated and managed in the most sustainable way possible.[411]

SEAI Grant Schemes

Ireland's Energy Projections: Progress to Targets, Challenges and Impacts (2017)

SEAI Deep Retrofit Pilot Programme

In Ireland, the Sustainable Energy Authority Ireland (SEAI) is the national body charged with promoting sustainable energy structures, technologies and practices. As an advisory body, it developed the Dwellings Energy Assessment Procedure (DEAP) used to assess new and existing structures under the Building Energy Rating (BER) system. The SEAI also facilitates the advancement of sustainable practices through research and renovation grants.[412] Projections made by the SEAI in 2017 show that Ireland will miss its 2020 energy and CO_2 reduction targets if the private sector is not further incentivised to switch to sustainable low-carbon

[409] *EuroPHit Brochure: Implementing Deep Energy Step-by-Step Retrofits - Increasing the European Potential* (2016), Darmstadt, Germany: Passive House Institute. Available at: http://europhit.eu/sites/europhit.eu/files/EuroPHit_brochure_final_PHI.pdf. p 60-71.

[410] *A Snapshot of National Renovation Strategies - Examples from Selected EU Member States* (2017), Brussels: Building Performance Institute Europe (BPIE). Available at: http://bpie.eu/publication/a-snapshot-of-national-renovation-strategies-examples-from-selected-eu-member-states/. p 3.

[411] *An Introduction to Green Leases* (2017): Irish Green Building Council. Available at: https://www.igbc.ie/resources/introduction-green-leases/ (Accessed: 7 March 2018).

[412] *Grants*. Dublin: The Sustainable Energy Authority of Ireland (SEAI). Available at: https://www.seai.ie/grants/ (Accessed: 29 December 2017).

technologies and practices.[413] The SEAI estimates that more than €35 billion will be required to upgrade Ireland's existing housing stock to low carbon standards by 2050. The SEAI allocated €5 million in 2017 toward their Deep Retrofit Pilot Programme, which was open to organisations in possession of five or more pre-2006 dwellings and had the ability to deliver deep renovations. [414] The practical experience gained through this pilot programme will enable the SEAI to roll out a deep renovation grant scheme for individual homeowners from 2020 onward.

Irish National Mitigation Plan (2017)

SEAI Behavioural Economics Unit – Behavioural Insights (2017)

Behavioural Insights on Energy Efficiency in the Residential Sector (2017)

The Irish National Mitigation Plan states that since 2016, the DCCAE has been working to establish 'an integrated set of new measures designed, not only to support greater energy efficiency through deeper upgrade measures and fuel switching, but crucially to validate the international evidence for the multiple benefits of energy efficiency and fuel switching in the Irish context' and that the DCCAE is focused on finding out what motivates Irish home and business owners to invest in energy efficiency initiatives.[415] The new SEAI Behavioural Economics Unit[416] is designed to do just that and has published its first research report, *Behavioural Insights on Energy Efficiency in the Residential Sector* (see Section 2.6.3). Chapter 4 of the NMP focuses on the decarbonisation of the building environment and includes a table of mitigating measures currently in place in Ireland with an overview of costs to the Exchequer and potential CO_2 emission reductions.[417]

EECHB: Cornwall Council – Skills Training and Energy Saving Initiatives (2016)

A paper presented at the 2016 Energy Efficiency and Comfort of Historic Buildings conference in Brussels discussed how Cornwall Council has been using the Heritage Lottery funded Townscape Heritage Initiative grant schemes since 1998 to train local specifiers and installers in quality traditional repair methods and sympathetic, hygrothermally compatible energy saving measures through a hands-on approach.[418] As of 2016, 24 training days had been organised for local architects, contractors and college students and 40 local buildings had been renovated in the process. The aim of this training is to first teach specifiers that good quality, regular

[413] *Ireland's Energy Projections: Progress to Targets, Challenges and Impacts* (2017), Dublin: Sustainable Energy Authority of Ireland (SEAI). Available at: https://www.seai.ie/resources/publications/Irelands_Energy_Projections.pdf.
[414] *Deep Retrofit Pilot Programme*. Dublin: Sustainable Energy Authority of Ireland (SEAI). Available at: https://www.seai.ie/grants/home-grants/deep-retrofit-programme/ (Accessed: 18 January 2018).
[415] *National Mitigation Plan* (2017), Dublin: Department of Communicationsv Climate Action and Environment. Available at: https://www.dccae.gov.ie/en-ie/climate-action/topics/mitigation-reducing-ireland's-greenhouse-gas-emissions/national-mitigation-plan/Pages/default.aspx. p 60.
[416] *Behavioural Insights - SEAI Behavioural Economics Unit* (2017). Dublin: Sustainable Energy Authority of Ireland. Available at: https://www.seai.ie/sustainable-solutions/behavioural-insights/ (Accessed: 15 January 2018).
[417] *National Mitigation Plan* (2017), Dublin: Department of Communicationsv Climate Action and Environment. Available at: https://www.dccae.gov.ie/en-ie/climate-action/topics/mitigation-reducing-ireland's-greenhouse-gas-emissions/national-mitigation-plan/Pages/default.aspx. p 67-93.
[418] Richards, A., Clarke, A. and Hunt, M. 'Cornwall Council - Skills Training and Energy Saving Initiatives', *Energy Efficiency and Comfort of Historic Buildings*, Brussels: Flanders Heritage Agency, 135-142. p 135.

repairs to the original fabric can improve the thermal performance of traditional buildings, and secondly, that there are upgrade measures that can further improve the energy efficiency without negatively impacting the historic character of the building.

Retrofit for the Future: Analysis of Cost Data (2014)

Large-scale deep renovation programmes will only be feasible if renovation works are delivered at an affordable price. Consumers need to be provided with the accurate costs of different renovation measures and options for each measure. The costs of the 100 homes renovated through the Retrofit for the Future programme have been published as part of a cost analysis report .[419] The cost analysis report compiled the average costs for various renovation interventions, advised on the reasons for cost variations, how to avoid unnecessary costs, and how to prepare a renovation cost plan.

Report on the Development of Cost Optimal Calculations and Gap Analysis for Buildings in Ireland under Directive 2010/31/Eu on the Energy Performance of Buildings (Recast) - Residential Buildings (2013)

A study was commissioned by the Department of the Environment, Community and Local Government in 2012/2013 'to research and develop draft cost-optimal calculations and a gap analysis for residential buildings in accordance with Article 5 of Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast)'.[420] To renovate existing buildings to a 'cost-optimal level' means that the energy performance is improved to a standard that leads to the lowest financial cost during the estimated economic lifecycle of the building. Unfortunately, for existing buildings the report only analyses two reference construction types: cavity wall and uninsulated (concrete) hollow block. Further cost-optimal energy renovation studies are needed for traditional buildings. Part L of the TGD L Conservation of Fuel and Energy- Dwellings must also be expanded to provide component level performance standards for traditional buildings.

Domestic Cost Assumptions - What Does it Cost to Retrofit Homes? (2017)

The *Domestic Cost Assumptions* report by the Cambridge Architectural Research group collected data about the real cost of 18 energy renovation measures from wall insulation to boiler replacement.[421] The study included interviews with 52 energy renovation specifiers (large-scale renovation contractors and housing associations with an interest in energy efficiency) as well as installers, plumbers and electricians across England and Wales. The cost data was compiled into a report as well as an Excel

[419] Group, T. S. (2014) *Retrofit for the Future: Analysis of Cost Data*: Technology Strategy Group. Available at: https://retrofit.innovateuk.org/.

[420] Livingstone, M. and Ross, D. (2013) Report on the development of cost optimal calculations and gap analysis for buildings in Ireland under Directive 2010/31/EU on the energy performance of buildings (recast) - Residential Buildings, Hertfordshire: Department of the Environment, Community and Local Government. Available at: http://www.housing.gov.ie/housing/building-standards/energy-performance-buildings/report-development-cost-optimal-0.

[421] Palmer, J., Livingstone, M. and Adams, A. (2017) *Domestic Cost Assumptions - What Does it Cost to Retrofit Homes?* , London: Department of Business, Energy and Industrial Strategy. Available at: https://www.gov.uk/government/publications/domestic-cost-assumptions-what-does-it-cost-to-retrofit-homes.

spreadsheet with detailed information about the cost of each renovation measure provided by the relevant specifiers or installers. The study also undertook a literature review and found 15 publications that provide detailed renovation cost data. A summary of each source is provided in Appendix A of the report.

Reducing Energy Use in Traditional Dwellings: Analysis of Four Solid Wall Houses in Reading (2017)

The Historic England Research Report *Reducing Energy Use in Traditional Dwellings: Analysis of Four Solid Wall Houses in Reading* assessed the cost effectiveness of six energy renovation packages: low cost; medium cost; higher cost and/or longer payback; higher cost + internal wall insulation; higher cost + internal and external wall insulation; and higher cost + external wall insulation.[422] The report quantified the cost of each package and the expected payback period as applied to four typical traditional houses in England. The findings highlight the significant effect that occupant energy use profiles have on the expected economic payback of measures – shortening the payback time for high-energy users and lengthening it for low-energy users. The report also includes the installation cost for an extensive list of renovation measures for each dwelling, ranked by cost-effectiveness.

HES Technical Paper 16: Green Deal Financial Modelling of a Traditional Cottage and Tenement Flat (2012)

Historic Environment Scotland Technical Paper 16 assessed the eligibility of renovation measures applied to a traditional cottage and a tenement flat for funding through the Green Deal.[423] Although the Green Deal is no longer in operation in the UK, it is interesting that the report found that few measures suitable for traditional buildings qualified for Green Deal funding. The report also highlighted the discrepancy between the energy savings predicted by modelling software and the real post-renovation savings, which could put unrealistic pressure on homeowners to closely monitor their energy usage in order meet the predicted energy savings tied to the funding.

2.6.5 Protected Structures

Sustainable Refurbishment of Heritage Buildings – How BREEAM Helps to Deliver (2014)

LEED for Neighborhood Development and Historic Preservation (2013)

There is an inherent sustainability to older buildings. The DEHLG *Energy Efficiency in Traditional Buildings* guide argues that a traditional building has the potential to outperform a new build house over a lifetime of 100 years with relatively few, low cost upgrades such as draft proofing, loft insulation and boiler replacement. Existing buildings have what is known as 'embodied energy', which refers to the 'the energy that was required to

[422] Newman, C. (2017) *Research Report Series: Reducing Energy Use in Traditional Dwellings - Analysis of Four Solid Wall Houses in Reading*, Swindon: Historic England. Available at: http://research.historicengland.org.uk/Report.aspx?i=15562&ru=%2fResults.aspx%3fp%3d1%26n%3d10%26ry%3d2017%26t%3dReducing%2520Energy%26ns%3d1.

[423] Heath, N., Clark, T. and Pearson, G. (2012) *Technical Paper 16: Green Deal Financial Modelling of a Traditional Cottage and Tenement Flat*, Edinburgh: Historic Environment Scotland (978 1 84917 089 5. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=b32b622d-7778-4b7f-a2aa-a59400a678ae.

extract, process, manufacture, transport and install building materials and is now deemed to be embodied in the finished building' (see Section 2.4.3). [424] Sustainability assessment systems BREEAM[425] and LEED[426] both provide credits for the renovation and re-use of existing structures, and both have published guidance documents on how to overcome potential barriers in the energy renovation of listed and protected historic buildings.

Sustainable Building Conservation: Theory and Practice of Responsive Design in the Heritage Environment (2015)

The Future of the Past (2017)

While the energy renovation of heritage buildings will require special attention and expertise, the conservation and climate change agendas need not be at odds. The book, *Sustainable Building Conservation: Theory and Practice of Responsive Design in the Heritage Environment*[427] includes papers from leaders in the industry on topics such as *Retrofitting Heritage Buildings*[428], *The Energy Context of Domestic Traditional Buildings in the UK*[429], *Sustaining Heating in Places of Worship*[430] and others. In the paper, *The Future of the Past*, Neil May discusses the natural sustainability of traditional buildings and how they fit within the mainstream concepts of the sustainability movement, which he describes as 'positivist (materialist), neo-liberal and individual rights agenda underpinned by an almost utopian belief in technological progress and the power of the market'.[431] 'The challenge' he says, '[is] not how to become part of the sustainability discourse, but how to confront and challenge it so that it [is] possible for non-mainstream ideas and beliefs to be heard and valued'.

To demonstrate the mutual benefits of a sustainability-driven conservation approach, a number of heritage agencies have also focused in recent years on producing documents to guide practitioners through the energy renovation of protected historic buildings. Historic England and Historic Environment Scotland have both published documents that assess the impact climate change

[424] *Advice Series: Energy Efficiency in Traditional Buildings* (2010), Dublin: Department of the Environment, Heritage and Local Government. Available at: https://www.chg.gov.ie/heritage/built-heritage/architectural-heritage-advisory-service/advice-for-owners/. p 7.

[425] Balson, K., Summerson, G. and Thorne, A. (2014) *Sustainable Refurbishment of Heritage Buildings – How BREEAM Helps to Deliver*, Watford: Building Research Establishment Ltd. Available at: https://tools.breeam.com/filelibrary/Brochures/Heritage-Sustainable-Refurbishment-v2.pdf.

[426] *LEED for Neighborhood Development and Historic Preservation* (2013), Washington D.C. Available at: https://www.usgbc.org/resources/leed-neighborhood-development-and-historic-preservation.

[427] Prizeman, O. (ed.) (2015b) *Sustainable Building Conservation: Theory and Practice of Responsible Design in the Heritage Environment*. London: RIBA Enterprises Ltd.

[428] Cox, P. (2015) 'Retrofitting Heritage Buildings', in Prizeman, O. (ed.) *Sustainable Building Conservation: Theory and Practice of Responsive Design in the Heritage Environment*. Newcastle upon Tyne: RIBA Publishing, pp. 65-86.

[429] Lannon, S., Iorwerth, H., Li, X. and Waldron, D. Ibid.'The Energy Context of Domestic Traditional Buildings for the UK', pp. 39-64.

[430] Induni, B. Ibid.'Sustaining Heating in Places of Worship: Physical, social, organisational and commercial factors as determinants of strategic decision-making and practical outcomes', pp. 219-245.

[431] May, N. (2017) *The Future of the Past*, London: Sustainable Traditional Buildings Alliance (STBA). Available at: http://stbauk.org/news-1-1.

may have on historic buildings within England[432] and Scotland[433] and the measures that can be implemented both to avoid material damage to the buildings and to reduce carbon emissions from the historic building stock. For instance, a case study by Historic England documents the improved post-renovation thermal performance and air tightness of a Victorian end-terrace house in the Grade II listed model village of New Bolsover.[434] The performance of the building before and after renovation has been measured and a follow-up report is due to be published in 2018, which will assess the effectiveness of each renovation measure to reduce energy use and carbon emissions and the cost efficiency of each measure by calculating energy savings and payback periods.

Historic England, Climate Change and the Historic Environment (2012)

HES Short Guide 11: Climate Change Adaptation for Traditional Buildings (2016)

A Retrofit of a Victorian Terrace House in New Bolsover: A Whole House Thermal Performance Assessment (2015)

The Energy Heritage publication by Changeworks advised on how to improve energy efficiency without compromising historic characteristics and value.[435] The Irish Georgian Society conference proceedings, *Energy Efficiency in Historic Houses*, provides guidance on implementing energy efficiency works in protected historic houses in Ireland through papers on acquiring planning permission for energy improvement works to protected structures and possible financial assistance available[436], understanding the natural thermal performance of traditional buildings[437], improving heating systems and building services[438], selecting appropriate insulation materials[439], and how to apply the Building Energy Rating system to historic buildings[440]. The BRE Literature Review also includes a chapter on how to improve the thermal efficiency of solid wall historic buildings in line with conservation practice.[441]

Energy Heritage: A Guide to Improving Energy Efficiency in Traditional and Historic Homes (2008)

Energy Efficiency in Historic Houses (2013)

BRE Literature Review - Solid Wall Heat Losses and the Potential for Energy Savings (2014)

The *STBA Responsible Retrofit Guidance Wheel* (see Section 2.5.1.2) is a tool designed by the STBA to assist specifiers in identifying

[432] *Climate Change and the Historic Environment* (2012), London: Historic England. Available at: https://www.nps.gov/subjects/culturallandscapes/upload/English-Heritage-Climate-Change-and-the-Environment.pdf.
[433] Curtis, R. and Hunnisett Snow, J. (2016) *Short Guide 11: Climate Change Adaptation for Traditional Buildings*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=a0138f5b-c173-4e09-818f-a7ac00ad04fb.
[434] Rhee-Duverne, S. and Baker, P. (2015) *Research Report Series: A Retrofit of a Victorian Terrace House in New Bolsover - A Whole House Thermal Performance Assessment*, London: Historic England. Available at: https://www.historicengland.org.uk/images-books/publications/retrofit-victorian-terrace-house-new-bolsover/.
[435] *Energy Heritage: A Guide to Improving Energy Efficiency in Traditional and Historic Homes* (2008) Edinburgh: Changeworks Resources for Life Ltd. Available at: http://www.changeworks.org.uk/resources/energy-heritage-a-guide-to-improving-energy-efficiency-in-traditional-and-historic-homes.
[436] Raftery, C. (2013) 'Energy Performance in Protected Structures: Planning Implications and Grants'. *Energy Efficiency in Historic Houses*, Dublin: Irish Georgian Society, 7-18. p 7.
[437] Arnold, P. Ibid.'Thinking yourself warm: or how to approach heating traditional buildings'. 19-30. p 19.
[438] Blennerhassett, E. Ibid.'Building Services: Implications in Historic Houses'. 47-58. p 47.
[439] Smith, P. Ibid.'The Use of Appropriate Materials in Maximising Energy Efficiency and Moisture Control in Historic Houses'. 59-69. p 59.
[440] Byrne, K. Ibid.'Studies in the Application of Building Energy Rating to Historic Buildings'. 30-45. p 31.
[441] Gemmell, A. (2014) *Solid Wall Heat Losses and the Potential for Energy Savings: Literature Review*, Watford: Building Research Establishment Ltd. Available at: https://www.gov.uk/government/publications/solid-wall-heat-losses-and-the-potential-for-energy-savings-literature-review. p 100-113.

possible energy renovation measures and associated potential conflicts.[442] The first step in using this Guidance Wheel is to select the context of the building (Listed Building – Exceptional or Important; Conservation Area; Character Building; or Non Character Building). This selection will inform the level of technical, heritage and energy concern shown for each renovation measure. For instance, if 'Listed Building – Exceptional' is selected, major heritage concerns will be highlighted with regards to internal insulation, however if 'Character Building' is selected (i.e. a building with some character but not protected or in a conservation area), these heritage concern levels drop down to medium or minor. The heritage, technical and energy concerns for each individual renovation measure is explained in the tool sidebar with suggested actions before, during and after renovation works and links to associated guidance documents.

STBA Responsible Retrofit Guidance Wheel

Elsewhere in Europe, the Swedish Energy Agency (SEA) supports energy efficiency related research, innovation and development for historic and culturally valuable buildings through its Spara och Bevara (Save and Preserve) research programme. Since 2006, the SEA has granted approximately €4 million to each stage of the Save and Preserve research programme (Stage 1: 2007-2010; Stage 2: 2011-2014; Stage 3: 2014-2018). Pilot projects within Stage 1 primarily addressed indoor climate control and technical solutions to reduce energy use in monument buildings, such as churches and castles. Stage 2 broadened to include a wider range of historic buildings. The scope of Stage 3 has broadened further yet to include buildings constructed before 1945 with historic merit.[443] The Spara och Bevara (Save and Preserve) programme manages a substantial online database of articles relating to the energy renovation of historic buildings, and a great majority of the documents are published in English.[444] The Centre for Energy Efficiency in Historic Buildings (CEK) was established at the Uppsala University Campus Gotland to support the research programme and to act as a national centre for competence.

Spara och Bevara: Swedish Energy Agency's Research Program for Energy Efficiency in Culture-Historically Valuable Buildings

Spara och Bevara Database

Eight Years of Energy Efficiency in Historic Buildings (2016)

The Fraunhofer Centre for Conservation and Energy Performance of Historic Buildings moved into the historic and dilapidated 1760 Abbey of Benediktbeuern in Upper Bavaria in 2010 and over the next six years, researched and renovated the building according to conservation and energy saving concerns.[445] The building functions

The Fraunhofer Center for Conservation and Energy Performance of Historic Buildings Benediktbeuern

[442] *STBA Responsible Retrofit Guidance Wheel* (2017): The Sustainable Traditional Buildings Alliance. Available at: http://responsible-retrofit.org/wheel/ (Accessed: 5 December 2017).

[443] Claesson, M. and Bromstöm, T. 'Eight Years of Energy Efficiency in Historic Buildings', *Energy Efficiency and Comfort of Historic Buildings (EECHB)*, Brussels October: Flanders Heritage Agency, 2-9. p 4.

[444] *Spara och Bavara Database* Save and Preserve Database. Uppsala: Uppsala University Campus Gotland. Available at: http://eprints.sparaochbevara.se/view/subjects/ (Accessed: 7 February 2018).

[445] *The Fraunhofer Center for Conservation and Energy Performance of Historic Buildings Benediktbeuern*: Fraunhofer Institute for Building Physics IBP. Available at: https://www.fraunhofer.de/en/research/current-research/fraunhofer-center-for-conservation-and-energy-performance-of-historic-buildings.html (Accessed: 31 October 2017).

as test site for the appropriateness and reversibility of energy renovation measures, such as the installation of solid wall insulation that must be removable without causing damage to the original walls or building fabric. A hands-on training workshop has been created in the old caretaker's premises of the building where industry partners can train building professionals in traditional trades and demonstrate the use of different energy efficient products (see Section 2.6.6). The Fraunhofer Institute for Building Physics also developed the WUFI software programmes that calculate the movement of moisture and heat through building fabric and can be used to identify possible risks in traditional building renovation plans (see Section 2.4.4.3).

WUFI Online Shop – Free Trial Versions

The Fraunhofer Centre was one of 23 European partners that took part in the EFFESUS (Energy Efficiency for EU Historic Districts' Sustainability) project funded by the European Union's Seventh Framework Programme, which provides funding for research, technological development and demonstration programmes. The object of the EFFESUS project was to 'develop and demonstrate, through seven case studies, a methodology and criteria for selecting and prioritising energy efficiency interventions, based on existing and new, cost-effective technologies and systems compatible with heritage values, to achieve significant life cycle energy efficiency improvements in the retrofitting of historic districts'.[446] Experts working on the EFFESUS project have produced a number of research reports providing guidance on a variety of topics, including: assessing buildings for historic significance and the impact of energy efficiency measures on this significance[447], monitoring the physical effects on new building materials and products in traditional buildings[448], and the use of EFFESUS developed methodologies and Decision Support Systems during the project-planning phase[449]. Most of these reports are available for free under the dissemination section on their website, however the primary project output was the publication of the EFFESUS booklet, *Energy Efficiency in European Historic Urban Districts: A Practical Guide*.[450] The 100-page guide is divided into five chapters, providing technical and well-researched guidance in the following areas: Strategies for the energy assessment of historic urban districts; Energy efficiency solutions for historic buildings and districts; EFFESUS innovations for the envelope retrofitting of historic buildings; Decision support for energy interventions in historic

EFFESUS Publications (2016)

EFFESUS Booklet: Energy Efficiency in European Historic Urban Districts: A Practical Guidance (2016)

[446] *EFFESUS Research Programme* (2012). Energy Efficiency for EU Historic Districts' Sustainability: The European Commission. Available at: http://www.effesus.eu/ (Accessed: 31 October 2017).

[447] 'Heritage Significance Assessments to Evaluate Retrofit Impacts: from Heritage Values to Character-Defining Elements in Praxis'. *How to Assess Built Heritage? Assumptions, Methodologies, Examples of Heritage Assessment Systems*, Florence & Lublin: International Scientific Committee for Theory and Philosophy of Conservation and Restoration ICOMOS, 169-190.

[448] Hermann, C. and Rodwell, D. (2015) 'Retrofit measures for historic buildings and cities', *Context,* 142, pp. 29-31.

[449] Egusquiza, A., Hermann, C. and Rodwell, D. (2016) 'Decision Support for Energy Improvements', Ibid.145.

[450] *Energy Efficiency in European Historic Urban Districts: A Practical Guidance* (2016b), Leipzig, Germany: Fraunhofer Centre for International Management and Knowledge Economy MOEZ. Available at: http://www.effesus.eu/dissemination/booklet.

urban districts; and Overcoming non-technical barriers for energy interventions in historic urban districts.

3ENCULT Handbook: Energy Efficient Solutions for Historic Buildings (2014)

The 3ENCULT (Efficient Energy for Cultural Heritage) Project was also co-funded by the European Union Seventh Framework Programme from 2010-2014 to bridge the gap between historic building conservation and climate protection. The primary output from the research project was the 3ENCULT Handbook, *Energy Efficient Solutions for Historic Buildings*[451], however other case study reports, news updates and a collection of self-education and professional training materials can also be found on the 3ENCULT website.[452]

Energy Efficiency and Comfort of Historic Buildings (EECHB) Conference Proceedings (2016)

The conference proceedings from the second international Energy Efficiency and Comfort of Historic Buildings (EECHB) conference held in Brussels in 2016 have been made freely available to the public, providing recent research findings on a variety of energy efficiency topics that concern historic and traditional buildings.[453] A number of EECHB conference papers have been referenced in other sections of this report, however the following papers address how historic buildings and conservation areas fit within the energy efficiency agenda: *Balancing the Competing Demands of Heritage and Sustainability, the Benefits and Risks involved in Sustainable Retrofit: New Court, Trinity College, Cambridge*[454]*; Mismatch, Exclusion and Inclusion: Threats/Opportunities for Historic Buildings in the Current Energy Efficiency Paradigm*[455]; *Energy Efficiency in Traditional and Historic Buildings: Keeping It Simple*[456]; *Eight Years of Energy Efficiency in Historic Buildings*[457]; and *Guidance for Finding a Sustainable Balance between Energy Efficiency, Comfort, Moisture Damage and Cultural Heritage Value in Historic Buildings*[458]

Passive House Institute Database

Finally, the Passive House Institute has produced a number of case study reports that demonstrate how historic buildings can be upgraded to near Passive House standard without compromising the historic integrity and value of the property. The Passive House Database holds short case study reports of over 4,000 projects, which generally include a brief description of works undertaken

[451] Troi, A. and Bastion, Z. (eds.) (2014) *Energy Efficient Solutions for Historic Buildings: A Handbook*: Birkhäuser.
[452] *3ENCULT: Efficient Energy for EU Cultural Heritage*. Bozen, Italy: EURAC research. Available at: http://www.3encult.eu/en/project/welcome/default.html (Accessed: 31 October 2017).
[453] 'EECHB-2016 Conference Proceedings'. *Second International Conference on Energy Efficiency and Comfort of Historic Buildings*, Brussels: Flanders Heritage Agency, 342.
[454] Smith, O., Gustafsson, J., Rye, C. and Scott, C. 'Balancing the Competing Demands of Heritage and Sustainability, the Benefits and Risks involved in Sustainable Retrofit: New Court, Trinity College, Cambridge'. *Energy Efficiency and Comfort of Historic Buildings (EECHB)*, Brussels: Flanders Heritage Agency, 310-317. p 310.
[455] Brito, N. S. 'Mismatch, Exclusion and Inclusion: Threats/Opportunities for Historic Buildings in the Current Energy Efficiency Paradigm'.Ibid., 18-27. p 18.
[456] Curtis, R. 'Energy Efficiency in Traditional and Historic Buildings: Keeping It Simple'.Ibid., 19-21 October, 174-180. p 174.
[457] Claesson, M. and Bromstöm, T. 'Eight Years of Energy Efficiency in Historic Buildings'Ibid., Brussels October, 2-9. p 2.
[458] Héberlé, E. and Burgholzer, J. 'Guidance for Finding a Sustainable Balance between Energy Efficiency, Comfort, Moisture Damage and Cultural Heritage Value in Historic Buildings'.Ibid., Brussels, 52-58. p 52.

with technical material and mechanical information. A few of the most relevant case studies to this study include: *Low Energy Refurbishment with PH Components: 1850s Victorian Detached Dwelling, Dartmoor National Park, Devon, UK*[459]; *Low Energy Refurbishment with PH Components: c.1810 Solid Wall Cottage in Ripon, Yorkshire, UK*[460]; *Low Energy Refurbishment with PH Components: 1870s Scottish Cottage*[461], *EnerPHit retrofit of a Victorian Terrace House in Central London*[462] and *EnerPHit Retrofit of a Protected Historic Terraced House in Brooklyn, New York*[463].

2.6.6 Training, Up-skilling and Accreditation

A lack of training modules and certification systems has been acknowledged as a major barrier to the roll out of large scale energy renovation programmes for traditional buildings, however work is underway to address these shortfalls in Ireland.

Build Up Skill - Ireland: Analysis of the National Status Quo (2012)

Build Up Skills - Ireland: National Roadmap for Energy Training in Construction (2013)

The *Build Up Skills - Ireland* project, which ran from November 2011 – April 2013, found that although the skill level within the construction industry was generally of high quality, knowledge of energy efficient construction and renovation is lacking at all levels and training is not sufficiently aligned with the approaches required to achieve low and nearly zero energy standards in new and existing buildings. Many construction worker have years of experience doing things a certain way, so the challenge therefore is foster an attitude that is receptive to learning a new approach to their work. The comprehensive 2012 Build Up Skills – Ireland report, *Analysis of the National Status Quo*, assessed the capacity of the construction industry to meet the higher energy efficiency standards, identified existing skills gaps, and set out a strategy to upskill construction workers and to establish a formal qualification system.[464] *The National Qualification Roadmap* published at the completion of the project laid out a strategy and action plan to bring 'the knowledge, skills and competences of Irish construction workers to the level that will allow them to confidently produce low energy buildings

[459] *Low Energy Refurbishment with PH Components: 1850s Victorian Detached Dwelling, Dartmoor National Park, Devon, UK* (2011). Passive House Database: Passivhaus Institut. Available at: http://passivehouse-database.org/index.php?lang=en#d_5310 (Accessed: 6 November 2017).

[460] *Low Energy Refurbishment with PH Components: c.1810 Solid Wall Cottage in Ripon, Yorkshire, UK* (2017). Passive House Database: Passivhaus Institut. Available at: http://passivehouse-database.org/index.php?lang=en#d_5334 (Accessed: 6 November 2017).

[461] *Low Energy Refurbishment with PH Components: 1870s Scottish Cottage* (2014). Passive House Database: Passivhaus Institut. Available at: http://passivehouse-database.org/index.php?lang=en#d_4433 (Accessed: 6 November 2017).

[462] *EnerPHit Retrofit of a Victorian Terrace House in Central London, with New Rear Ground Floor Extension* (2013). Passive House Database: Passivhaus Institut. Available at: http://passivehouse-database.org/index.php?lang=en#d_4044 (Accessed: 6 November 2017).

[463] *EnerPHit Retrofit of a Protected Historic Terraced House in Brooklyn, New York* (2012). Passive House Database: Passivehaus Institut. Available at: http://passivehouse-database.org/index.php?lang=en#d_4364 (Accessed: 6 November 2017).

[464] *Build Up Skills - Ireland: Analysis of the National Status Quo* (2012): Intelligent Energy Europe. Available at: http://www.buildup.eu/en/skills/bus-projects/IE.

meeting the latest building regulations and, therefore, contribute significantly to Ireland's energy reduction targets'.[465]

QualiBuild Foundation Energy Skills Course

Construction Workers Skills Register

The Foundation Energy Skills 3-day training course was developed as part of the QualiBuild project to introduce the basics of systemic thinking around the deep energy renovation of a modern existing dwelling. The course was funded by the European Commission Build Up Skills Initiative (BUSI) and coordinated by Limerick Institute of Technology (LIT) in partnership with the Dublin Institute of Technology (DIT), the Institute of Technology Blanchardstown (ITB), The Irish Green Building Council (IGBC) and The Construction Industry Federation (CIF).[466] The project also facilitated the creation of the Construction Worker Skills Register where consumers or potential employers can view the energy skills training completed by construction workers before hiring them.[467] Although the course did not address the special skills or knowledge needed for the deep energy renovation of historic and traditional buildings, the basic framework and cross-institutional arrangement is there to develop a basic training course for traditional buildings. The training programme is now being run by the Waterford and Wexford Education and Training Board (WWETB).

CIF Training Modules

Engineers Ireland CPD Training

On its own, the Construction Industry Federation (CIF) of Ireland currently does not have any training modules that specifically relate to the deep energy renovation of existing buildings nor of the low energy construction of new buildings. Engineers Ireland have run a few full- or half-day Continuing Professional Development (CPD) courses on the energy renovation of existing buildings over the past few years, however these were one-off courses and at present, there are no energy renovation CPD courses planned for the first half of 2018.

DIT MSc in Building Performance (Energy Efficiency in Design)

The Dublin Institute of Technology (DIT) has developed a range of training courses for building professionals based on the Near Zero Energy Building (NZEB) energy performance standard. These courses are delivered through a Masters of Science in Building Performance (Energy Efficiency in Design) degree programme on a part-time basis over 2.5 years or as a series of individual modules over a longer period of time if necessary.[468] The degree programme is designed for professionally qualified architects, architectural technologists, engineers and building surveyors, and upon

[465] *Build Up Skills - Ireland: National Roadmap for Energy Training in Construction* (2013): Intelligent Energy Europe. Available at: http://ireland.buildupskills.eu/national-project/Ireland. Forward.

[466] *Foundation Energy Skills Course*: QualiBuild. Available at: http://www.qualibuild.ie/training/fes-training/ (Accessed: 15 January 2018).

[467] *Construction Worker Skills Register*: Limerick Institute of Technology. Available at: https://www.constructionworkerskillsregister.ie/ (Accessed: 15 January 2018).

[468] *DIT MSc in Building Performance (Energy Efficiency in Design)*. Dublin: Dublin Institute of Technology (DIT). Available at: http://www.dit.ie/studyatdit/postgraduate/taughtprogrammes/allcourses/dt9773ptbuildingperformanceenergyefficiencyindesignmsc.html (Accessed: 2 January 2018).

completion, will equip graduates with the essential knowledge needed to design new buildings and to renovate existing buildings to the NZEB standard. Courses cover building physics and performance, hygrothermal and thermal bridge risk assessment, energy modelling tools, NZEB policies and technologies, and calculating cost optimality. Degree requirements also include a NZEB design project and a building performance research project.

RIAI Environmental CPD Accreditation

The Royal Institute of the Architects of Ireland (RIAI) has coordinated three modules for architects and architectural technologists as part of the RIAI Environmental CPD Accreditation, which was launched in September 2012.[469] The first module covers sustainable fundamentals, and through it appears geared toward informing energy efficiency in new construction, a number of the topics would apply to existing buildings as well. The second module, *Designing Low-Energy Domestic Refurbs*, covers topics such as long-term planning for renovation works, air tightness in old buildings, building physics, and understanding how to choose an insulation compatible with the building. The third module covers building fabric design, pathways to compliance with TGD L and how to limit instances of thermal bridging.

Installer Power: The Key to Unlocking Low Carbon Retrofit in Private Housing (2015)

A 2015 report by the Sustainability Research Institute and the Severn Wye Energy Agency investigated the need to train micro enterprise and sole-trader building professionals in energy efficient upgrade measures and the potential to include energy efficiency improvements as part of general home repairs, maintenance and improvements (known as the RMI market).[470] The report provides recommendations on how to develop policies and systems to support this sector of the often unrepresented building trade.

Final Recommendations for a Better National Renovation Strategy (2017)

Build Upon: Co-Creating Ireland's National Renovation Strategy 2017-2020 - Briefing Document (2016)

Building upon the review of the National Renovation Strategy for Ireland[471], which included a consultation process with over 200 stakeholders between April 2016 and February 2017, the IGBC launched the ECCoPro Project in July 2017 to develop a user-friendly, holistic energy efficiency certification system for building professionals in Ireland. The final recommendations put forward to the government to improve the National Renovation Strategy acknowledged that construction professionals engage with consumers at trigger points during the renovation process and can therefore act as powerful influencers and advisors to guide consumers to undertake the most beneficial deep energy

[469] *RIAI Environmental CPD Accreditation*. Dublin: The Royal Institute of the Architects of Ireland (RIAI). Available at: http://www.riai.ie/events/detail/apply_for_riai_environmental_cpd_accreditation (Accessed: 7 February 2018).
[470] Maby, C. and Owen, A. (2015) *Installer Power: The Key to Unlocking Low Carbon Retrofit in Private Housing*, Gloucester: Sustainability Research Institute, The University of Leeds. Available at: http://ukace.org/wp-content/uploads/2015/12/Installer-Power-report-2015.pdf.
[471] *Build Upon: Co-Creating Ireland's National Renovation Strategy 2017-2020 - Briefing Document* (2016), Dublin: Build Upon Europe. Available at: http://buildupon.eu/wp-content/uploads/2015/09/BriefingDocument_v.1.pdf.

renovation steps.[472] As of February 2018, 85 organisations and individuals from Ireland's main building professional bodies had taken part in the ECCoPro consultation process and two more workshops are scheduled for early 2018. The aim of the project is to establish a trusted accreditation framework which will provide consumers with greater certainty of the abilities of building professionals and will in turn incentivise professionals to upskill in the energy efficiency market. Training would first focus on upskilling employed building professionals, but it is envisioned that accreditation would soon be rolled out through academic courses as well. Training would initially cover the basics of traditional building performance and managing moisture risks, and as the programme develops, specialist courses on the energy renovation of traditional buildings may be offered. The ECCoPro Workshop Reports 1[473] and 2[474] have been published, as has a preliminary report which assessed the energy efficiency knowledge base of construction professionals in Ireland and reviewed best practices in related training and accreditation programmes.[475]

IGBC ECCoPro Report 1: Construction Professionals' Energy Efficiency Knowledge and Upskilling - A Short Review (2017)

IGBC ECCoPro Workshop Report 1 (2017)

IGBC ECCoPro Workshop Report 2 (2017)

To ensure the great wealth of information gathered over the past decade of technical energy renovation studies of traditional buildings is shared with built environment professionals and building owners, Historic Environment Scotland has organised a series of outreach and training events from an introductory to a technical level. The details of the different strands of training provided by HES and industry partners are available as part of the *Energy Efficiency and Comfort of Historic Buildings* conference proceedings.[476] The Engine Shed in Stirling, Scotland was opened in 2017 by Historic Environment Scotland and is the UK's first education centre designed specifically to help the public and building professionals gain a better understanding of their historic built environment. The interactive and literary education resources at The Engine Shed are available to the public on a daily basis, but the centre also runs short day courses, a summer school and diploma modules in historic building conservation. The *Sustainability and Adaptation in the Historic Environment* module is taught over 33 hours of classroom lectures and a variety of site visits, and the course content focuses mainly on the energy efficient renovation of traditional and historic Scottish buildings.

HES Engine Shed Module: Sustainability and Adaptation in the Historic Environment

EECHB: Historic Scotland's Approach to Training and Education for Energy Efficiency in Traditional uildings (2016)

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[472] *Build Upon Final Recommendations: Towards Large Scale Deep Energy Renovation - Unlocking Ireland's Potential* (2017), Dublin: Irish Green Building Council. Available at: http://buildupon.eu/dialogue/countries/ireland/.

[473] *ECCoPro - Workshop 1* (2017), Dublin: Irish Green Building Council (IGBC). Available at: https://www.igbc.ie/policy-and-regulation/renovation-strategies/eccopro-environmental-certification-construction-professionals/.

[474] *ECCoPro - Workshop 2* (2017), Dublin: Irish Green Building Council (IGBC). Available at: https://www.igbc.ie/resources/environmental-certification-building-professionals-workshop-ii-report/.

[475] *ECCoPro Report 1: Construction Professionals' Energy Efficiency Knowledge and Upskilling - A Short Review* (2017), Dublin: Irish Green Building Council (IGBC). Available at: https://www.igbc.ie/wp-content/uploads/2017/09/IGBC-Report1-Final-20.09.17_Website.pdf.

[476] Jenkins, M. 'Historic Scotland's Approach to Training and Education for Energy Efficiency in Traditional Buildings', *Energy Efficiency and Comfort of Historic Buildings*, Brussels, 19-21 October: Flanders Heritage Agency, 128-134.

CITB Specialist Applied-skills Programmes: Heritage Occupations

In March 2017, Historic Environment Scotland, Historic England and the Welsh Historic Environment Service (Cadw) all signed a 'Strategic Skills Partnership Agreement' with the UK Construction Industry Training Board (CITB) with the intent to develop an action plan 'to equip the construction industry with the knowledge, understanding and skills for the continued and sustainable use of traditional building stock'.[477] The CITB currently has seven heritage related courses available for construction professionals under their Specialist Applied-skills Programmes (SAP).

CIOB training course: Understanding Building Conservation

The UK Chartered Institute of Building (CIOB) also runs training and CPD courses, and in 2018, will be running the 2-day training course *Understanding Building Conservation* in London, Stirling and Dublin.[478] The curriculum will cover conservation philosophy, but will also teach participants how to technically analyse thermal performance and how to diagnose problems, how to balance historic significance and technical changes like energy efficiency improvements, and how to manage expectation and to work with the different stakeholders.

The Retrofit Academy – Retrofit Coordinator PLUS programme (2017)

The Retrofit Academy was established in the UK in February 2016 to educate building practitioners according to current best practice advice on improving the energy efficiency of existing buildings. The Retrofit Academy offers accreditation through the Domestic Retrofit Coordination and Risk Management training course, which was developed to upskill construction professionals as retrofit coordinators. The programme is designed to equip professionals with the basic knowledge necessary to ensure quality control in deep energy retrofit projects and covers topics such as assessing a building for energy retrofit, building physics and solid wall insulation, building services retrofit, air tightness and ventilation, the business case for retrofit, and retrofit coordination and risk management. In 2017, the Retrofit Coordinator PLUS programme was added, which builds upon the basic Retrofit Coordinator programme and includes a course on the *Advanced Low Energy Retrofit of Traditional Buildings.*[479]

AECB CarbonLite Retrofit Online Training Course

The UK-based Association for Environment Conscious Building (AECB) was established in 1989 to promote environmentally conscious design in the construction industry. Since 2013, the AECB has been running CarbonLite Retrofit Online Training Course, which was developed to upskill construction professionals and specifiers

[477] *Major New Partnership to boost Construction Skills for Heritage* (2017). Press Releases: The Construction Industry Training Board (CITB). Available at: https://www.citb.co.uk/news-events/uk/2017/major-new-partnership-to-boost-construction-skills-for-heritage/# (Accessed: 9 January 2018).
[478] *Understanding Building Conservation* (2017). CIOB Academy: The Chartered Institute of Building (CIOB). Available at: https://www.ciobacademy.org/product/understanding-building-conservation/ (Accessed: 9 January 2018).
[479] *Retrofit Coordinator PLUS* (2017): The Retrofit Academy. Available at: http://www.retrofitacademy.org/programme/advanced-retrofit-coordinator/.

of deep energy renovations.[480] Students typically complete the full course load within 12 months, but full-time professionals are allowed to extend their enrolment as necessary. In general, the training is designed to equip students with an understanding of heating and moisture in buildings, knowledge of issues that can arise from energy renovation works, ways to avoid or manage unintended consequences and how to appraise financial investment in deep energy renovation. The programme also includes a series of online tutorials taught by experienced professionals, which include for 2018: The UK Housing Stock; Energy in Buildings; Moisture in Buildings; Case Studies; Building Services for Retrofit; and Retrofit Investment Appraisals and CLR Cost Modelling.

The Fraunhofer Center for Conservation and Energy Performance of Historic Buildings Benediktbeuern

The Fraunhofer Centre for Conservation and Energy Performance of Historic Buildings in Benediktbeuern, Germany opened in November 2016 as a research centre to advance understanding and demonstrate how traditional and protected historic buildings can be renovated to be more energy efficient. The six-year long energy efficient renovation of the Alte Schäfflerei was used as a training tool and testing ground to learn about various renovation measures and their suitability to historic buildings. For instance, ten different internal insulations were mounted in a single room and monitored to assess their performance. In line with general conservation practice, reversibility was a requirement for all renovation measures applied at the Alte Schäfflerei in case the renovation works led to unintended consequences or to accommodate future technical advancements in materials and methods. Since the completion of renovation works on the main building, the old caretaker's premises have been converted into a workshop where industry partners have the opportunity to test new products or run training sessions for craftsmen and building practitioners. There are also spaces for educational events and lectures.

2.6.7 Deep Energy Renovation Databases

2.6.7.1 Environmental Product Databases

In 2010, the DEHLG Advice Series document, *Energy Efficiency in Traditional Buildings*, recommended that NSAI Agrément certification be expanded to cover natural materials and that the NSAI develop and maintain a list of insulation materials suitable for traditional buildings, however this has not yet been done. In addition, we recommend at that the NSAI require that all new materials introduced into the Irish construction market must provide data for WUFI, including measurements of porosity, moisture absorbed, moisture emitted, and thermal mass. This should also be required as part of the CE mark certification process.

[480] *The AECB CarbonLite Retrofit Online Training Course* (2018): Association for Environment Conscious Building (AECB). Available at: https://www.aecb.net/carbonlite/carbonlite-retrofit-training-course/# (Accessed: 7 February 2018).

There is a need for a database of materials and products suitable for the deep energy renovation of traditional buildings, but questions remain on how this should be managed, and which governmental or quasi-governmental body should maintain it (perhaps the NSAI, SEAI or IGBC).

natureplus sustainable product certification system

Sustainable Construction Materials Forum (2017)

natureplus is an independent quality certification system established by the International Association for Sustainable Building and Living, which is based in Germany and consists of approximately 100 members across Europe. The *natureplus* quality stamp is awarded to building products that fulfil high standards in climate protection, healthy accommodation and sustainability. *natureplus* currently maintains a register of certified products under 20 overarching categories of building products, such as Insulation Materials, Adhesives and Fillers, Wall Paints, etc. [481] To help specifiers choose suitable insulation products for their building, some (but not all) products have been assigned a *μ (humid) and μ (dry) vapour diffusion resistance value*, which is a parameter used to determine the exchange of moisture through a construction material in assumed humid and dry environments. The lower the number, the easier it is for vapour to penetrate and move through the material. *natureplus* and the Irish Green Building Council (IGBC) jointly hosted the 'Sustainable Construction Materials Forum' in Dublin on 24 November 2017, during which presenters discussed how product labels can be used to assist specifiers in choosing suitable materials and products.

IGBC Environmental Product Declaration Programme (2017)

Carbon Heroes Benchmark Programme (2017)

As part of the Environmental Product Declaration (EPD) programme, the Irish Green Building Council (IGBC) has launched an online platform that allows Irish manufacturers and suppliers to declare the environmental impact of their products by providing 3rd party verified statements called EPD.[482] An EPD report is produced for each verified product, which will help specifiers to make informed decisions based on the environmental impact of each product. The IGBC is also participating in the Carbon Heroes Benchmark Programme, which is designed to help building professionals to quickly calculate the embodied carbon in a building through the One Click LCA software developed by Finnish LCA experts Bionova.[483]

Both the *natureplus* and EPD databases include materials and products suitable for traditional buildings, but to identify them requires a certain level of understanding and expertise.

[481] *natureplus*: International Association for Sustainable Building and Living. Available at: http://natureplus.org/index.php?id=57 (Accessed: 16 January 2018).
[482] *The Environmental Product Declaration Project*. Dublin: Irish Green Building Council (IGBC). Available at: https://www.igbc.ie/epd-home/ (Accessed: 2 January 2018).
[483] *Carbon Heros Benchmark Programme* (2017). One Click LCA: Bionova Ltd. Available at: https://www.oneclicklca.com/construction/carbonheroes/ (Accessed: 10 January 2018).

From 2013-2016, the European Commission ran an Environmental Footprint (EF) pilot project, which had three main objectives:[484]

European Commission Environmental Footprint Pilots (2013-2016)

1. To test the process for developing product- and sector-specific rules
2. To test different approaches to verification
3. To test communication vehicles for communicating life cycle environmental performance to business partners, consumers and other company stakeholders

To encourage SMEs to submit information on the environmental performance of construction products, the pilot project also tested the viability of different software tools. The European Commission also commissioned a study to support the development of appropriate compliance mechanisms, which aimed to:[485]

1. Review and describe existing compliance systems used for mandatory or voluntary policy tools used for products or organisations, for which embedded/indirect impacts are considered;
2. Define and characterise various options for compliance systems;
3. Assess the estimated costs of compliance of selected options and the estimated reliability rate of selected options, and
4. Provide recommendations on the most suitable option for PEF/OEF declarations.

2.6.7.2 Knowledge Databases

In Britain, the Homes Energy Efficiency Database (HEED)[486] is managed by the Energy Saving Trust and includes information on the energy performance and installation of energy renovations in England from 1993 to 2013. HEED includes data from installers, industry accreditation bodies, energy suppliers, government-funded programs, local authorities and home surveys. Information was collected at a dwelling level and includes a range of dwelling and energy efficiency details on over 16.4 million dwellings in the UK.[487]

Home Energy Efficiency Database (HEED)

[484] *The Environmental Footprint Pilots* (2017): European Commission. Available at: http://ec.europa.eu/environment/eussd/smgp/ef_pilots.htm (Accessed: 17 January 2018).
[485] Ibid.
[486] *Home Energy Efficiency Database (HEED)* (2017): Energy Saving Trust. Available at: http://www.energysavingtrust.org.uk/scotland/businesses-organisations/data-services/heed (Accessed: 24 January 2018).
[487] Hamilton, I. G., Summerfield, A. J., Shipworth, D., Steadman, J. P., Oreszczyn, T. and Lowe, R. J. (2016) 'Energy Efficiency Uptake and Energy Savings in English Houses: A Cohort Study', *Energy and Buildings,* 118, pp. 259-276.

Home Analytics Scotland[488] was designed to provide a more comprehensive profile of the Scottish housing stock than HEED, and accounts for potential bias in the underlying datasets. This data gathered in Home Analytics Scotland is available to the Scottish Government and local authorities and is meant to support the development and delivery of policies, schemes and programmes designed to alleviate fuel poverty through improved energy efficiency and the installation of renewable microgeneration technologies.

Home Analytics Scotland

The National Energy Efficiency Data-Framework (NEED) was established to gather data on energy use and energy efficiency improvement measures in domestic and non-domestic buildings in Britain. NEED compiles data collected for the Homes Energy Efficiency Database (HEED), the Green Deal, the Energy Company Obligation (ECO), the Feed-in Tariff scheme, and for the Department of Business, Energy and Industrial Strategy sub-national energy consumption statistics.[489]

UK National Energy Efficiency Data-Framework (NEED)

The European Commission has developed the EU Building Stock Observatory to monitor the energy performance and energy consumption of buildings across Europe. [490] The Observatory maintains a database, datamapper and a series of factsheets pertaining to the building stock characteristics. The database tracks energy efficiency levels in individual countries and the EU as a whole; the development of financing and certification schemes and how they are implemented; and energy poverty levels across the EU. However, the database relies on each individual country to submit information and it seems that information is lacking in many areas.

EU Building Stock Observatory Database and Datamapper

The Waag Society and Touch Software Applications developed the interactive Energy Label Atlas to visually map the energy performance of buildings in the Netherlands.[491] Individual building energy labels are based on publicly available data, such as the construction date and floor area, on information provided by the homeowner and on EPCs provided by energy assessors. The map is constantly updated as EPC ratings change and new data becomes available.

Energy Label Atlas

The previously mentioned Spara och Bevara (Save and Preserve) programme, funded by the Swedish Energy Agency, manages a

Spara och Bevara Database

[488] *Home Analytics Scotland* (2017): Energy Saving Trust. Available at: http://www.energysavingtrust.org.uk/scotland/businesses-organisations/data-services/home-analytics (Accessed: 24 January 2018).
[489] *National Energy Efficiency Data-Framework (NEED)* (2017). London: Department for Business, Energy and Industrial Strategy. Available at: https://www.gov.uk/government/collections/national-energy-efficiency-data-need-framework (Accessed: 24 July 2018).
[490] *EU Building Stock Observatory* (2017). Energy: European Commission. Available at: https://ec.europa.eu/energy/en/eubuildings (Accessed: 28 August 2017).
[491] *Energy Label Atlas*. The Netherlands: Waag Society. Available at: http://energielabelatlas.nl/#9/52.2631/5.5618 (Accessed: 30 January 2018).

substantial online database of articles relating to the energy renovation of historic buildings.[492]

Finally, the Passive House Institute maintains the Passipedia Database, which contains a large number of free articles that cover the basics of Passive House design, as well as a section with in-depth articles exclusively available to members.[493]

Passive House Institute
Passipedia Database

[492] *Spara och Bavara Database* Save and Preserve Database. Uppsala: Uppsala University Campus Gotland. Available at: http://eprints.sparaochbevara.se/view/subjects/ (Accessed: 7 February 2018).
[493] *Passipedia: The Passive House Resource* (2017): Passivehaus Institut. Available at: https://passipedia.org/start (Accessed: 6 November 2017).

3 Recommended Next Steps

3.1 Policy Review

NSAI S.R. 54:2014 – the primary standard used to guide the energy efficient renovation of dwellings – was not designed to be applied to traditional buildings and therefore makes no mention of the need for traditional solid wall buildings to breathe.[494] The authors of S.R. 54:2014 advise that the guidance provided in it 'may not be appropriate for dwellings which, although not protected structures or proposed protected structures, may be of architectural or historical interest' and that 'some traditional buildings perform and respond to the outside/inside environment differently from more modern/mid-to-late 20th Century buildings'. However, no further guidance is provided on how to approach the energy renovation of traditional buildings or where specifiers can seek advice.[495]

A parallel critique has occurred in the UK. For instance, in October 2017, Dame Helen Ghosh sent a letter to the UK Secretary of State for Business, Energy and Industrial Strategy by bodies involved with the conservation and energy renovation of traditional buildings in the UK (see Appendix 0). The letter asserted that current UK energy policy was overly simplistic and flawed in its application to traditional buildings, leading to wasted money and potential harm to the buildings and their occupants.

NSAI S.R. 54:2014 Code of Practice for the Energy Efficient Retrofit of Dwellings

Given the limited scope of S.R. 54:2014, on 13 February 2018 the Technical Steering Committee of this report recommended to the Department of Housing, Planning and Local Government that a new governmental guidance note, similar to S.R. 54 be developed for the deep energy renovation of traditional buildings. The issues raised - the lack of knowledge in the building industry about the hygrothermal properties of historic and traditional buildings - were noted and our recommendations were well received. We were informed that the Department of Communications, Climate Action and Environment plans to collaborate with the Department of Culture, Heritage and the Gaeltacht to produce a second edition to the *Energy Efficiency in Traditional Buildings* advice document produced in 2010 by the then Department of the Environment, Heritage and Local Government. It was decided that this new document should provide strategic rather than prescriptive guidance on how to avoid unintended risks related to the energy renovation of traditional buildings, such as increased moisture retention, the use of non-breathable materials and unnecessary harm to the historic and cultural characteristics of the buildings fabric. It should advocate a holistic or 'Whole House' approach, meaning energy renovation should not just focus on carbon

[494] *Standard Recommendation 54:2014: Code of Practice for the Energy Efficient Retrofit of Dwellings* (2014), Dublin: National Standards Authority of Ireland. Available at: https://www.nsai.ie/S-R-54-2014-Code-of-Practice.aspx.

[495] The forthcoming *Built to Last: Renovations of Historic Dublin Dwellings* (2018) gives a more detailed critique of NSAI S.R. 54:2014 and other regulatory guidance in Ireland.

reduction alone, but should be balanced with equal concern for occupant health and wellness, cultural and heritage values, impact on the local community, as well as the building's durability and embodied energy.[496] The Department of Housing, Planning and Local Government Official supports the creation of a new *NSAI Standard Recommendation Code of Practice for the Energy Efficient Renovation of Traditional Buildings*, which would give regulatory strength to the recommendations presented in the new guidance document.

What is Whole House Retrofit? (2016)

The supplementary guidance provided by *Technical Guidance Document (TGD) L: Conservation of Fuel and Energy*, based on S.I. No. 259 of 2011 Building Regulations Part L Amendment, was not written to address the energy renovation of traditional buildings and does not provide sufficient guidance on the important hygrothermal differences between modern and traditional buildings. S.I. No. 538 of 2017 will come into effect on 1 January 2019. This expands the list of ways existing non-dwellings are expected to meet the energy efficiency and carbon reduction targets set by the Energy Performance Building Directive 2010/31/EU. As a result, the associated TGD L for Non-Dwellings has been revised to nearly double its original length. Although it directs specifiers to consult the DEHLG *Energy Efficiency in Traditional Buildings* guidance document in relation to architecturally or historically significant buildings, it still does not provide adequate advice on how to avoid unintended post-renovation condensation within traditional buildings. For instance, in the six paragraphs under section B.4 of Appendix B, the use of a vapour control layer (VCL) is repeatedly recommended to control moisture levels in buildings, but nowhere does it mention that this could be incompatible and even detrimental to buildings of a traditional form of construction. No guidance is given on alternative routes of compliance with Part L.

S.I. No. 259 of 2011 Building Regulations (Part L Amendment)

S.I. 538 of 2017 Building Regulations (Part L Amendment)

Technical Guidance Document L: Conservation of Fuel and Energy - Dwellings (2017)

Technical Guidance Document L: Conservation of Fuel and Energy – Buildings other than Dwellings (2008)

The ICOMOS National Scientific Committee on Energy, Sustainability and Climate Change (NSCES+CC) submitted the following comments to the public consultation on the revision of TGD L for Non-Dwellings on 2 June 2017 in reference to:

Section 0.6 'Application to Buildings of Architectural or Historical Interest' and Section 2 'Existing Buildings other than Dwellings':

> *There is no mention of the advantage of working with an existing structure rather than building anew, particularly from the embodied energy point of view. The advantages that existing fabric represents in terms of embodied energy reduction, and energy savings during the construction/refurbishment stages should be acknowledged –*

[496] *Responsible Retrofit Series: What is Whole House Retrofit?* (2016), London: Sustainable Traditional Buildings Alliance (STBA). Available at: http://www.sdfoundation.org.uk/downloads/What-is-Whole-House-Retrofit-Dec2016.pdf. p 2.

perhaps a section on the conservation of fuel and energy during the construction stage itself might cover this. This could equally apply to new build construction projects and should be part of any serious energy reduction strategy in life-cycle terms.

Section 2:

The inclusion of air tightness as a parameter of efficiency is problematic for existing buildings, and particularly 'pre-industrial' ones, and attempts to achieve this often result in damage to character.

Section 2.1.3:

The imposition of 'standardised' constructional details, more applicable to new-build will enhance negative perceptions around older building stock, as 'poorly-performing' or 'non-compliant'. Recent research such as Arregi & Little (2016) Hygrothermal Risk Evaluation for the Retrofit of a Typical Solid-wall Dwelling (SDAR Journal Issue 6 December) has shown that in some cases the original construction of an existing building may outperform proposed interventions.

English Building Regulations - Approved Document L1B: Conservation of Fuel and Power in Existing Buildings (enacted 2010, last amended 2016)

These recommendations are not clearly represented in the revised 2017 version of the TGD L for Non-Dwellings. By comparison, the English Part L1B Amendment was revised in 2011 to include the following section:[497]

Historic and traditional buildings where special considerations may apply

3.8 There are three further classes of buildings where special considerations in making reasonable provision for the conservation of fuel or power may apply:

a) buildings which are of architectural and historical interest and which are referred to as a material consideration in a local authority's development plan or local development framework;

b) buildings which are of architectural and historical interest within national parks, areas of outstanding natural beauty, registered historic parks and gardens, registered battlefields, the curtilages of scheduled ancient monuments, and world heritage sites;

c) buildings of traditional construction with permeable fabric that both absorbs and readily allows the evaporation of moisture.

[497] *Approved Document L1B: Conservation of Fuel and Power in Existing Dwellings* (2016), London: HM Government. Available at: https://www.gov.uk/government/publications/conservation-of-fuel-and-power-approved-document-l. p 8.

3.9 When undertaking work on or in connection with a building that falls within one of the classes listed above, the aim should be to improve energy efficiency as far as is reasonably practicable. The work should not prejudice the character of the host building or increase the risk of long-term deterioration of the building fabric or fittings.

3.10 The guidance given by English Heritage [sic] should be taken into account in determining appropriate energy performance standards for building work in historic buildings.

3.11 In general, new extensions to historic or traditional dwellings should comply with the standards of energy efficiency set out in this Approved Document. The only exception would be where there is a particular need to match the external appearance or character of the extension to that of the host building (see paragraph 4.2).

3.12 Particular issues relating to work in historic buildings that warrant sympathetic and where advice from others could therefore be beneficial include:

a) restoring the historic character of a building that has been subject to previous inappropriate alteration, e.g. replacement windows, doors and rooflights;

b) rebuilding a former historic building (e.g. following a fire or filling a gap site in a terrace);

c) making provisions enabling the fabric of historic buildings to 'breathe' to control moisture and potential long-term decay problems.

3.13 In assessing reasonable provision for energy efficiency improvements for historic buildings of the sort described in paragraphs 3.7 and 3.8, it is important that the [Building Control Body] takes into account the advice of the local authority's conservation officer. The views of the conservation officer are particularly important where building work requires planning permission and/or listed building consent

This guidance clearly differentiates traditional buildings from modern existing buildings and recognises that it may not be possible, nor recommended, to aim to improve the thermal efficiency of traditional buildings to the standard expected of modern buildings. It directs readers to consult the technical guidance produced by Historic England for specific information on energy efficiency in traditional buildings. The recently revised EEHB publication *Application of Part L of the Building Regulations to Historic and Traditionally Constructed Buildings* was produced to help protect historic and traditional buildings from unnecessary or

inappropriate upgrades made to comply with the energy efficiency requirements of Part L[498]. Historic England supports the government's intentions to improve the energy efficiency of all buildings, and to support this effort, the document covers issues to be considered before renovation works begin on any traditional building and advises that a 'whole building approach' be taken to meet the Part L requirements and to improve the energy efficiency of the building 'as far as is reasonably practicable'.

EEHB Series: Application of Part L of the Building Regulations to Historic and Traditionally Constructed Buildings (2017)

Further to this guidance, Section 5 of the *Approved Document L1B: Conservation of Fuel and Power in Existing Buildings* includes specifications on the renovation of retained thermal elements.[499] Under this section, Table 3 sets out the (a) Threshold U-value W/m^{2}K and (b) Improved U-value W/m^{2}K for different variations of wall, floor and roof systems. The document states that where a thermal element is subject to renovation works, the performance of the whole thermal element should be renovated to meet or better the Improved U-value W/m^{2}K. A solid wall renovated with internal or external insulation is expected to achieve an Improved U-value of 0.30 W/m^{2}K (which is surprisingly low) but should not exceed the Threshold U-value of 0.70 W/m^{2}K. However, for instances where the Improved U-value is not achievable, article 5.9 advises:

English Building Regulations - Approved Document L1B: Conservation of Fuel and Power in Existing Buildings (enacted 2010, last amended 2016)

> *5.9 If achievement of the relevant U-value set out in column (b) of Table 3 is not technically or functionally feasible or would not achieve a simple payback of 15 years or less, the element should be upgraded to the best standard that is technically and functionally feasible and which can be achieved within a single payback of no greater than 15 years. Guidance on this approach is given in Appendix A.*

This clause gives building practitioners flexibility to specify solid wall insulation based on a more holistic assessment of the building's performance rather than a simple obligation to improve the U-value to a certain level. Studies have shown that solid wall insulations that offer the greatest improvement in U-values are often associated with an increased risk of moisture retention, which may ultimately lead to high relative humidity levels and unhealthy living environments (see Sections 2.5.3.4 and 2.6.2). This clause also relieves homeowners from unrealistic financial commitments that my keep them from investing in thermal upgrades at all. Furthermore, Article 5.12 clarifies that homeowners are not expected to sacrifice valuable living space and possibly decrease the

[498] Pickles, D., Brocklebank, I. and Wood, C. (2017a) *Energy Efficiency and Historic Buildings: Application of Part L of the Building Regulations to Historic and Traditionally Constructed Buildings*, London: Historic England. Available at: https://historicengland.org.uk/images-books/publications/energy-efficiency-historic-buildings-ptl/.

[499] *Approved Document L1B: Conservation of Fuel and Power in Existing Dwellings* (2016), London: HM Government. Available at: https://www.gov.uk/government/publications/conservation-of-fuel-and-power-approved-document-l. p 17.

resale value of their homes in order to achieve the minimum Improved U-value:[500]

> *5.12 Examples of where lesser provision than column (b) might apply are where the thickness of the additional insulation might reduce usable floor area of any room by more than 5 per cent or create difficulties with adjoining floor levels, or where the weight of the additional insulation might not be supported by the existing structural frame.*

Finally, Table A1 in *Appendix A: Work to Thermal Elements* of Approved Document L1B sets out the target performance level for various building systems (i.e. pitched roofs, solid walls, dormer window, etc.) that would be considered reasonable under ordinary circumstances. The table also lists typical methods to achieve these standards and corresponding considerations to be taken with regard to reasonableness, practicality and cost-effectiveness. For instance, the target U-value given for a pitched roof is 0.16 W/m^2K, insulated with 250mm mineral or cellulose fibre laid between and across ceiling joints. The document then advises that specifiers assess condensation risks and make appropriate provisions in accordance with the requirements of the English Part C – Control of Condensation.

To further assist specifiers in demonstrating compliance with the building regulations in Ireland, a table such as this should be included in the revised TGD L for Dwellings (replacing Table 5 in the 2011 version) along with considerations to be assessed prior to the prescribed energy renovation works. Table A1 within the recently revised TGD L for Non-Dwellings now lists the density and thermal conductivity of a number of common building materials.[501] However, the majority of materials included in this table are used in modern, moisture-impermeable construction, and it is recommended that the table be further populated with breathable building materials and traditional construction methods common to Ireland. More research is needed to test and verify the U-values and performance properties of traditional building materials specific to Ireland, which when available, could be used to populate the data sets used in WUFI.

The Department of Housing, Planning and Local Government are currently revising the Part L Amendment of the Irish Building Regulations and the corresponding TGD L for Dwellings, both of which are expected to go to public consultation towards the end of March 2018. Given that the TGD L for Dwellings was last updated in 2017, the DEHPLG does not expect it will be altered as significantly

[500] Ibid. p 18.

[501] *Technical Guidance Document L: Conservation of Fuel and Energy - Buildings other than Dwellings* (2017), Dublin: Department of the Housing, Planning and Local Government. Available at: http://www.housing.gov.ie/housing/building-standards/tgd-part-l-conservation-fuel-and-energy/building-regulations-2017. p 69.

as the Part L and TGD L for Non-Dwellings, and thus, the approved revisions for dwellings are intended to take effect in early 2019. It is not yet known if the revised TGD L will include more guidance on how traditional buildings are expected to comply with the Building Regulations.

Furthermore, research has shown that the sequence of step-by-step renovations could also significantly impact the actual amount of energy saved, ranging from a 24-42% reduction in CO_2 emissions over a 50-year period.[502] This highlights the need for energy renovation policies and financing models to incentivise step-by-step renovation sequences that will guarantee the best results. The Energy Performance of Buildings Directive (EPBD) is currently under revision (due to be published in early 2018), and it looks as though the revised version will require Member States to implement some form of guidance for step-by-step deep energy renovations, such as Building Renovation Passports. [503] The SEAI is currently in the process of updating the BER system and by June 2018, it should provide more guidance on the preferred sequence of step-by-step renovation.

Energy-Led Domestic Retrofit: Impact of the Intervention Sequence (2016)

European Commission Press Release: Commission Welcomes Agreement on Energy Performance of Buildings (2017)

The Final Recommendations from the Build Upon Ireland consultation process are in alignment with our findings, and the following suggestions were presented to the Irish government in February 2017:[504]

Final Recommendations for a Better National Renovation Strategy (2017)

> *All official guidance should be assessed for compliance with surface condensation risk factors.*
>
> *For traditional buildings, Technical Guidance Documents should be developed to ensure appropriate methods and materials are used. E.g. materials used in energy efficient renovations of historic buildings must be hygrothermally appropriate.*
>
> *Conservation guidelines to minimise the impact of modern renovation systems on the cultural significance of historic buildings should be introduced. The guidelines should not be prescriptive or technically specific, but they should clearly identify the main issues and consider relevant conservation principles. International guidance models already exist and ICOMOS Ireland could perhaps support the government with the development of these guidelines.*

In summary, this research has endeavoured to provide specifiers with the information necessary to responsibly renovate traditional

[502] Simpson, S., Banfill, P., Haines, V., Mallaband, B. and Mitchell, V. (2016) 'Energy-led Domestic Retrofit: Impact of the Intervention Sequence', *Building Research & Information,* 44(1), pp. 97-115.
[503] *Commission Welcomes Agreement on Energy Performance of Buildings* (2017). Brussels: European Commission. Available at: http://europa.eu/rapid/press-release_IP-17-5129_en.htm.
[504] *Build Upon Final Recommendations: Towards Large Scale Deep Energy Renovation - Unlocking Ireland's Potential* (2017), Dublin: Irish Green Building Council. Available at: http://buildupon.eu/dialogue/countries/ireland/.Section 5.3.

buildings for improved energy efficiency. To further support specifiers in this process, the Technical Steering Committee have lobbied the Department of Housing, Planning and Local Government to provide clearer pathways to compliance with Part L of the Irish Building Regulations by supporting the development of improved technical guidance for traditional buildings (which account for 16-18% of the Irish building stock) and a new NSAI Code of Practice for the Energy Efficient Renovation of Traditional Buildings.

Greater clarity on compliance with Part L could also be provided by:

a. Clarifying, illustrating and publicising their little-known document 'The application of the Building Regulations to works in existing buildings'.[505] This could be revised to reflect the concerns of protected structures and proposed protected structures in the first place, and then traditional moisture-permeable buildings in the second. It should be said that, while useful for a well-versed building professional, this document is quite opaque for a lay person. Ideally this text would be incorporated in a plain English text that sets out standard and alternative routes of compliance for existing buildings, illustrated with logic diagrams and case studies.

The Application of the Building Regulations to Works in Existing Buildings

b. Publicising the existence of a procedure to apply for a dispensation or relaxation of the Building Regulations. This procedure is available but rarely used (Articles 4 and 5 of the Building Control Act 1990). For building professionals to begin to use this method, more clarity is needed on what would constitute a complete application relating to Part L, the methodology by which it would be judged, and the method and timeframe for appeal of judgments to An Bord Pleanála. Long decision and appeal time periods may make applying for relaxation a high-risk endeavour and may be seen by many as a significant block to engagement with alternative routes of compliance to Part L for traditionally-constructed buildings.

[505] *The Application of the Building Regulations to Works in Existing Buildings*, Dublin: Department of Housing, Planning and Local Government. Available at: http://www.housing.gov.ie/housing/building-standards/other/application-building-regulations-works-existing-buildings.

c. Promoting a 'managed' approach to improvements in energy performance of traditional buildings, emphasising that the performance of services, plant and equipment should be the preferred locus of improvement. A number of improvements can also be made to the fabric of the building without sacrificing heritage value. For instance, roof insulation can be increased to optimal levels, floor insulation can be installed in some cases, and sensible draft proofing measures ranging from the maintenance of windows to blocking up unused chimneys can be implemented to increase airtightness. The basic conservation principle to 'do as little as possible and as much as necessary' could inform step-by-step energy renovation plans for traditional and historic buildings and guidance on the most beneficial sequence of works could be provided through Building Renovation Passports.

d. Revising the Regulations so that the principle of 'no greater contravention' in relation to Part L applies even when a material change of use takes place.

e. Providing more information on the thermal performance of masonry walls (and other commonly recurring traditional fabric constructions) with the level of energy efficiency improvement that can reasonably be expected in the Standard Recommendations and Technical Guidance Documents for the Building Regulations.

f. Populating DEAP with a greater range of scientifically-derived default U-values measured for a range of traditional wall types of specific widths (including perhaps different floor and roof types). This may then improve the degree to which BER assessments reflect the actual performance of traditional dwellings.

g. Supporting the measurement of hygrothermal properties for a range of traditional Irish building materials to inform research and underpin the day-to-day hygrothermal risk evaluation of building projects including renovations.[506]

h. Creating a set of Better Renovation Details (BRDs) to guide higher quality energy-efficient renovation works (of traditional dwellings) that are always hygrothermally low risk. Typologies should be chosen with stakeholders then submitted to hygrothermal risk assessment before details sheets and thermal modelling are developed.

[506] The U-values of six walls of historic (pre-1945) Dublin dwellings were measured in Little, J., McGirl, F., Hanratty, M. and Arregi, B. (Forthcoming 2018) *Built to Last: Renovations of Historic Dublin Dwellings.* Dublin. The mass concrete walls had U-values worse (i.e higher) than DEAP's default values for solid walls, and the solid brick and rubble walls all had value significantly better (i.e. lower) than the default values. In one case the measured U-value for a rendered rubble wall was 1.09 W/m^{2}K whereas DEAP's default value was 2.1 W/m^{2}K, a 193% over-estimation of heat loss.

Policy Review

i. Creating a methodology for alternative routes of compliance with Part L for the energy-efficient renovation of traditionally-built buildings. Alternative routes are in use in relation to Parts B (Fire) and M (Access and Use), but not L (Conservation of Fuel and Energy). Compliance with TGD L is 'prima facie', however various sections of TGD L (incl. 0.2.1.1, 0.2.1.2, 0.6.2, 0.6.4, 0.6.7) reflect an awareness that TGD L was not created with traditionally-built buildings in mind. Yet, alternative routes, how submissions should be structured, judged and appealed is not clear. The lack of clarity may be encouraging an inappropriate use of TGD L guidance, high risk specifications and/or non-compliant works. The resulting alternative route methodology would require review and approval by building control and professional bodies.

j. Recognising that the embodied energy of materials, and especially the components of buildings that are cyclically replaced, play a role in energy use or saving, and that the durability of historic buildings represents an energy investment by obviating the necessity to build a new building. [507]

[507] *Built to Last: The Sustainable Reuse of Buildings* (2004), Dublin, Ireland: The Heritage Council. Available at: http://www.turas-cities.org/uploads/biblio/document/file/326/sustainable_reuse_buildings_athusaid_inbhuanaithe_foirgneamh.pdf.

3.2 Improving Assessment Methodologies

Numerous studies referenced in this report have demonstrated that the pre-existing conditions and hygrothermal properties of traditional building materials must be understood before energy renovation works can be specified.[508] Being able to correctly assess a building is a key component of energy renovation. Building professionals have a range of overlapping competences in this regard, but few have all the skills needed for a holistic assessment. Conservation professionals generally have the skillsets to assess materials, construction methods and heritage value. Building surveyors are generally equipped to assess materials, construction methods, maintenance issues and building pathology. Other building professionals, including building fabric consultants, have the skills to assess thermal performance and/or hygrothermal risk and building pathology. To determine the necessary skills and to provide the foundation for education and upskilling of building professionals requires a body of focused research and case studies spanning the variety of traditional buildings found around the country.

Building Energy Rating (BER) Assessor training currently does not cover how to accurately assess traditional buildings and therefore, the recommendations and post-assessment reports given by BER Assessors may be harmful to the building and its occupants. In Germany, for instance, the basic building energy assessor accreditation programme is only open to qualified architects, engineers and master craftsmen and requires the successful completion of a 240-hour course, which is significantly more intensive than the 6-day course required in Ireland. In addition, to qualify as a 'Building Energy Advisor for Monuments' requires a further 54 hours of specialist training. As research has shown, the accuracy of BERs cannot be guaranteed if the assessor is not properly trained to evaluate the pre-existing conditions, materials or construction methods of traditional buildings.

The limited number of traditional materials and associated U-values available through the Dwelling Energy Assessment Procedure (DEAP) reduces the accuracy of the BER system when applied to traditional buildings. A simple way to improve the accuracy of the DEAP would be to populate the system with more accurate default U-values based on physical measurements of a greater variety of building materials at a range of thicknesses found in all types and ages of buildings in Ireland. DEAP version 4 is due to be released in early 2018, which the SEAI states 'will enable greater scope for

[508] Gemmell, A. (2014) *Solid Wall Heat Losses and the Potential for Energy Savings: Literature Review*, Watford: Building Research Establishment Ltd. Available at: https://www.gov.uk/government/publications/solid-wall-heat-losses-and-the-potential-for-energy-savings-literature-review. p 113.

future developments benefiting both assessors and homeowners'.[509]

While this will be an ongoing project, to begin the existing default values of traditional materials in DEAP could be amended based on the findings of the forthcoming *Built to Last*.[510] For comparison, credible data is also available through a number of UK-based studies, including Historic Environment Scotland's Technical Paper 2: *In Situ U-value Measurements in Traditional Buildings*[511] and Technical Paper 10: *U-values and Traditional Buildings*.[512] In England, a study by the University of Salford assessed the real U-values of 16 traditional solid walled brick dwellings in Northern England[513] and an earlier study funded by the Department of Energy and Climate Change assessed the in situ U-values for approximately 300 English dwellings constructed in a variety of materials and styles.[514] Historic England has also published a technical Research Report on the thermal performance of traditional brick walls.[515]

The default U-values used for existing pre-1976 dwellings in the UK Standard Assessment Procedure (SAP) have been reviewed by the Building Research Establishment in the run-up to the 2016 update of the SAP. *Consultation Paper 16* explains that the U-values were originally intended for use in designing heating solutions, so conservative values were better to ensure that heating systems would not be undersized.[516] However, for the purpose they are now being used for, median U-values would be more appropriate to avoid overestimating the energy savings expected from the installation of solid wall insulation. The BRE argued that the U-value currently used in the RdSAP was too pessimistic for solid walls, which was found to be 24% higher than the median value given in field studies. The Consultation Paper includes a list of amended U-values for the existing wall constructions used in SAP for England

HES Technical Paper 2: In Situ U-Value Measurements in Traditional Buildings – Preliminary Results (2008)

HES Technical Paper 10: U-values and Traditional Buildings (2011)

Understanding Our Heritage: Monitoring of Energy and Environmental Performance of Traditional Terraced Houses of Northern England (2016)

In-Situ Measurements of Wall U-Values in English Housing (2014)

HE Research Reports: Research into the Thermal Performance of Traditional Brick Walls (2013)

Consulation Paper 16: Review of Default U-Values for Existing Buildings in SAP (2016)

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[509] *DEAP Resources*. Ireland: Sustainable Energy Authority of Ireland. Available at: https://www.seai.ie/energy-in-business/ber-assessor-support/deap/ (Accessed: 4 November 2017).

[510] Little, J., McGirl, F., Hanratty, M. and Arregi, B. (Forthcoming 2018) *Built to Last: Renovations of Historic Dublin Dwellings.* Dublin.

[511] Baker, P. (2008) *Technical Paper 2: In Situ U-value Measurements in Traditional Buildings - Preliminary Results*, Edinburgh: Historic Environment Scotland. Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=7fc3d5f6-5992-4106-92bf-a59400bf430c.

[512] 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.

[513] 'Understanding Our Heritage: Monitoring of Energy and Environmental Performance of Traditional Terraced Houses of Northern England', *Energy Efficiency and Comfort of Historic Buildings*, Brussels, 19-21 October: Flanders Heritage Agency, 225-233.

[514] Hulme, J. and Doran, S. (2014) *In-Situ Measurements of Wall U-values in English Housing*, Watford: BRE. Available at: https://www.gov.uk/government/publications/in-situ-measurements-of-wall-u-values-in-english-housing.

[515] Rhee-Duvern, S. and Baker, P. (2013) *Research Report Series: Research into the Thermal Performance of Traditional Brick Walls*: Historic England. Available at: https://historicengland.org.uk/images-books/publications/research-thermal-performance-traditional-brick-walls/.

[516] Davidson, P. (2016) *Consultation Paper 16: Review of default U-values for existing buildings in SAP*: Building Research Establishment. Available at: https://www.bre.co.uk/sap2016/page.jsp?id=3619.

and Wales, Scotland and Northern Ireland. Testing will need to be done to confirm the median U-value of a variety of traditional solid wall constructions in Ireland, such as calp limestone, however the data from the BRE SAP consultation study could be used in the meantime to update the standardised values used in DEAP.

In addition, the building industry should be required to carry out risk assessments when necessary for each building type according to the relevant standard, and low risk renovation strategies should be implemented in every instance. For traditional buildings, risk assessment methodologies should be compliant with EN 15026. The range of cases that require formal risk assessment could be reduced through funding research projects that provide parametric guidance for the marginal cases (i.e. those between very low and high risk). A central platform to support the sharing of research and hard data collected through these risk assessments should also be explored.

Not all risk evaluation is expensive, time-consuming or specialist in nature. There would be great value in a government-funded project exploring methods that could be brought into common usage by all relevant building professionals. In some cases these methods must first be localised and/or the robustness must be tested. One example is to use Karsten tubes to measure the water absorption rate of a material surface, which is relatively simple, quick, low-cost and non-invasive.[517]. The moisture uptake through the brick or stone face of solid walls can vary by a factor of one hundred. The surface absorptivity can therefore affect the risk of moisture retention in an energy efficient renovation using internal wall insulation.

A number of decision-support tools and processes referenced throughout this report, such as the STBA Retrofit Wheel and the process advised by EN 16883:2017 Conservation of Cultural Heritage – Guidelines for Improving the Energy Performance of Historic Buildings, provide valuable and verified guidance to assist specifiers in the design of low-risk energy renovation projects for traditional buildings. There is an opportunity for the Irish government or authorised private bodies to further integrate the use of these decision-making processes into Irish renovation and construction practice. If new digital programmes were developed, they could be designed to facilitate methodical building surveys through well-structured prompts and to allow users to upload text, site images, measurement and photographic inputs and to record location and orientation. The value of an easy recording method to support more consistent surveying across a wide sector of the building industry and a supported decision-making process would be significant at survey and design stages, but also later for demonstrating compliance and for maintaining historic records of works completed. Further research is needed in this area, but the

[517] Appendix 2 of HES Technical Paper 15 provides a detailed practical guide for Karsten tube testing.

focus should be to adapt any decision-support tools to support a wide range of building activities and should certainly be developed with a view to export markets.

3.3 Deep Energy Renovation Training & Certification

While the long-term effects of energy renovation measures like internal and external solid wall insulation are still unknown, this study has shown that research has advanced significantly since 2012. For instance, a further 54 technical research and guidance documents have been published or revised since 2012 that examine various aspects of the hygrothermal performance of traditional buildings pre- and post-renovation. Overall, of the 475 plus resources collected during the course of this project, more than three-quarters have been published since 2012.

This document is designed to help building practitioners find the technical guidance they need to correctly specify the deep energy renovation of traditional buildings, but the challenge of raising awareness, incentivising the building industry to upskill in this area and of certifying practitioners' knowledge and ability remains.

The STBA Responsible Retrofit report found that there were significant knowledge gaps in the building industry relating to the performance of traditional buildings, including issues of heat loss, moisture, ventilation, indoor air quality, overheating and the effects of user behaviour.[518] The 2014 Historic England Research Report *External Wall Insulation in Traditional Buildings* revealed that there were (and likely still are) considerable gaps between the recommendations made in the best practice guidance and the actual application of external wall insulation to traditional buildings. The study found that external insulation was actually being installed in a manner that was 'in direct opposition to emerging traditional building principles (principally those relating to permeability and moisture movement)'.[519] The 2017 *Core Cities Green Deal Monitoring Project* documented the post-renovation performance of 65 projects in Leeds between 2013-2015.[520] The study found that, more often than not, a whole house renovation approach was lacking, that quality was compromised by poor workmanship, and at least half of the dwellings exhibited problems with damp.[521] More post-performance case studies of deep energy renovation

Responsible Retrofit of Traditional Buildings: A Report on Existing Research and Guidance with Recommendations (2012)

HE Research Report Series. External Wall Insulation in Traditional Buildings: Case Studies of Three Large-Scale Projects in the North of England (2014)

Core Cities Green Deal Monitoring Project (2017)

[518] May, N. and Rye, C. (2012) *Responsible Retrofit of Traditional Buildings: A Report on Existing Research and Guidance with Recommendations*, London: Sustainable Traditional Buildings Alliance. Available at: http://stbauk.org/stba-guidance-research-papers. p 70.

[519] *Research Report Series: External Wall Insulation in Traditional Buildings - Case Studies of Three Large-scale Projects in the North of England* (2014), London: Historic England. Available at: http://research.historicengland.org.uk/Report.aspx?i=15747&ru=%2fResults.aspx%3fp%3d1%26n%3d10%26k%3denergy%2520efficiency%26ns%3d1. p 57.

[520] Gorse, C. (2017) *Core Cities Green Deal Monitoring Project*: Leeds Beckett University. Available at: https://www.gov.uk/government/collections/buildings-energy-efficiency-technical-research.

[521] Ibid. p 11.

works are needed, especially in Ireland, however it can be assumed that basic knowledge of traditional buildings and appropriate renovation methods is still lacking across the entire building industry.

The NSAI has established a list of certified external and cavity wall insulation installers, however its certified EWI installers are not trained in the insulation of traditional solid wall buildings. It is therefore possible that NSAI approved installers may be recommending incorrect insulation materials and methods for traditional buildings. Industry-wide workshops are needed to provide detailed guidance and training on how IWI, EWI, and floor insulation works should be carried out and how failures can be avoided.

During a workshop held as part of this research project on 25 January 2018 (see Appendix 7.2), a small but distinguished group of stakeholders from different sectors of the built environment came to a general consensus that training in the deep energy renovation of traditional buildings was needed across all building trades. Many agreed that the existing professional bodies, such as the RIAI, EI and the SCSI, should be charged with delivering CPD training and recognising professional competency within their field. To guarantee uniformity and quality across the sectors, the individual training programmes and accreditation schemes would need to be approved and audited by a central governmental body, such as the SEAI. The workshop attendees felt it was important that all building trades were equipped with at least a basic knowledge of traditional building physics and be able to foresee intended and potential unintended consequences that energy renovation measures may have on the performance of a building. It was also proposed to empanel graduates of the anticipated CPD training programmes as potential advisors for a future energy efficiency renovation grant scheme.

Since 2016, the UK Government has made a version of the Soft Landings Framework mandatory in all new build and renovation government projects. The framework provides a defined process to engage clients and building users with the energy performance of their building from the initial commission, through the project's completion and into the occupation phase, during which a post-occupation evaluation is undertaken to assess whether the building is performing as efficiently as intended. A similar approach could be employed in Ireland as a prerequisite for governmental commissions. This could also function as a learning tool and would certainly assist Ireland in its endeavour to meet its 33% energy reduction target for public buildings by 2020. The incoming regulations imposed by S.I. No. 538 of 2017 already sets this process in motion by including a note that compliance with Part L can be met by 'providing to the building owner or occupants sufficient information about the building fabric, the fixed building services, controls and their maintenance requirements when

replaced so that the building can be operated in such a manner as to use no more fuel and energy than is reasonable'.[522]

To adequately address the risk of moisture retention in energy renovation projects, the UK Centre for Moisture in Buildings (UKCMB) has recommended the adoption of the Swedish ByggaF method, which advocates for a formalised process to ensure moisture risk assessment informs all phases of design, construction and occupation (see Section 2.6.2). Moisture risks are increased with the internal or external insulation of traditional solid wall buildings, and this must be reflected in the level of guidance and training available to building professionals.

A provisional CPD course has been drawn up as part of this research project with modules that relate to the information and resources referenced within this report (see Appendix 7.3). This is intended to support the development of training courses run by the professional bodies in collaboration, possibly, with the Heritage Council, the Irish Green Building Council, the SEAI and other higher education institutions that are showing leadership in this area, such as the Dublin Institute of Technology.

It is essential that lessons learned along the way are shared within the building industry. A government-funded campaign of research and case study projects would greatly aid awareness, provide key learning material, support lower risk renovations and higher levels of compliance.

In support, it is proposed that the Heritage Council, and the ICOMOS Ireland National Scientific Committee on Energy, Sustainability and Climate Change, request assistance from the Sustainable Energy Authority of Ireland, the Department of Communications, Climate Action and Environment, the Department of Housing, Planning and Local Government, and the Department of Culture, Heritage and the Gaeltacht to support quality energy renovation projects for traditionally-built buildings, including the following:

a. The Heritage Council, and the Sustainable Energy Authority of Ireland to fund and co-ordinate a grant scheme to support the production of good practice case studies for traditionally-built buildings, that show how expertise, a holistic approach to building energy performance, and sensitivity to historical and artistic character are possible, desirable and ultimately will actually achieve the energy-reduction outcomes required by international obligations.

[522] *S.I. No. 538 of 2017 Building Regulations (Part L Amendment)* (2017). Dublin: The Stationery Office.

b. The Heritage Council, with the Sustainable Energy Authority of Ireland and the Irish Green Building Council, to co-ordinate and support the provision of CPD for specifiers in conjunction with the RIAI, EI, SCSI (and the Institute of Building Control) to an agreed curriculum and standard that has been scoped out in this research.

c. The Heritage Council to create a panel of specifiers recognised for their competence in specifying works in the proposed energy efficient renovation grant scheme.

It is also proposed that pre- and post-renovation monitoring of energy efficiency and occupant wellness be made a requirement of any future governmental contracts or funding schemes. Ireland currently lacks a central framework under which to collect case study data and deep renovation research, however a number of deep energy renovation knowledge databases currently exist in Europe and Britain, which could be assessed for potential implementation in Ireland (see Section 2.6.7). Governmentally funded deep energy renovation projects should be viewed as training opportunities and the dissemination of successes and failures should be made a requirement of funding.

4 Case Studies

4.1 Ireland

Building Services: Implications in Historic Houses (2013)[523]

Built to Last: Renovations of Historic Dublin Dwellings (Forthcoming 2018)[524]

Built to Last: The Sustainable Reuse of Buildings (2004)[525]

Energy Performance in Protected Structures: Planning Implications and Grants (2013)[526]

Hygrothermal Risk Evaluation for the Retrofit of a Typical Solid-Walled Dwelling (2016)[527]

Performance of a Range of Thermal Insulations in a Historic Building (2016)[528]

Studies in the Application of Building Energy Rating to Historic Buildings (2013)[529]

TABULA Building Typology Brochure – Ireland: A Detailed Study on the Energy Performance of Typical Irish Dwellings (2014)[530]

The Use of Appropriate Materials in Maximising Energy Efficiency and Moisture Control in Historic Houses (2013)[531]

Thinking Yourself Warm: Or How to Approach Heating Traditional Buildings (2013)[532]

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[523] Blennerhassett, E. (2013) 'Building Services: Implications in Historic Houses'. *Energy Efficiency in Historic Houses*, Dublin: Irish Georgian Society, 47-58.

[524] Little, J., McGirl, F., Hanratty, M. and Arregi, B. (Forthcoming 2018) *Built to Last: Renovations of Historic Dublin Dwellings.* Dublin.

[525] *Built to Last: The Sustainable Reuse of Buildings* (2004), Dublin, Ireland: The Heritage Council. Available at: http://www.turas-cities.org/uploads/biblio/document/file/326/sustainable_reuse_buildings_athusaid_inbhuanaithe_foirgneamh.pdf.

[526] Raftery, C. (2013) 'Energy Performance in Protected Structures: Planning Implications and Grants'. *Energy Efficiency in Historic Houses*, Dublin: Irish Georgian Society, 7-18.

[527] Arregi, B. and Little, J. (2016) 'Hygrothermal Risk Evaluation for the Retrofit of a Typical Solid-Walled Dwelling', *Sustainable Design & Applied Research in Engineering and the Built Environment (SDAR),* (6), pp. 17-26.

[528] Walker, R. and Pavía, S. (2016) 'Performance of a Range of Thermal Insulations in a Historic Building', *Engineers Journal*.

[529] Byrne, K. (2013) 'Studies in the Application of Building Energy Rating to Historic Buildings'. *Energy Efficiency in Historic Houses*, Dublin: Irish Georgian Society, 30-45.

[530] Badurek, M., Hanratty, M. and Sheldrick, B. (2014) *TABULA Building Typology Brochure Ireland: A Detailed Study on the Energy Performance of Typical Irish Dwellings*, Ireland: Intelligent Energy Europe. Available at: http://episcope.eu/fileadmin/tabula/public/docs/brochure/IE_TABULA_TypologyBrochure_EnergyAction.pdf.

[531] Smith, P. (2013) 'The Use of Appropriate Materials in Maximising Energy Efficiency and Moisture Control in Historic Houses'. *Energy Efficiency in Historic Houses*, Dublin: Irish Georgian Society, 59-69.

[532] Arnold, P. Ibid.'Thinking yourself warm: or how to approach heating traditional buildings'. 19-30.

4.2 United Kingdom

'Four Case Studies Demonstrating the Impacts of Energy Conservation in Traditional Domestic Buildings' in Sustainable Building Conservation (2015)[533]

33rd Passive Low Energy Architecture International Conference: Comfort and Energy Efficiency in a Victorian House in the Past, Present and Future (2017)[534]

33rd Passive Low Energy Architecture International Conference: Improving the Energy Performance of Historic Timber-Framed Buildings in the UK (2017)[535]

BRE Literature Review: Section 5.5. Case Studies of Interventions on Heritage Buildings[536]

Core Cities Green Deal Monitoring Project (2017)[537]

Dartford Housing Retrofit Project – Evaluation Report (2017)[538]

EECHB Conference: Building Performance Evaluation – a Design Approach for Refurbishment of a Small Traditional Building in Scotland (2016)[539]

EECHB Conference: Retrofit Internal Insulation at New Court, Trinity College, Cambridge: Options, Issues and Resolution through Material Sampling and Modelling (2016)[540]

EECHB Conference: The Role of Monitoring and Feedback in the Refurbishment of Traditional Buildings: New Court, Trinity College, Cambridge (2016)[541]

HE Research Report Series: A Retrofit of a Victorian Terrace House in New Bolsover: A Whole House Thermal Performance Assessment (2015)[542]

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[533] Prizeman, O. (2015a) 'Four Case Studies Demonstrating the Impacts of Energy Conservation in Traditional Domestic Buildings', in Prizeman, O. (ed.) *Sustainable Building Conservation: Theory and Practice of Responsive Design in the Heritage Environment*. Newcastle upon Tyne: RIBA Publishing, pp. 193-218. Chapter 7. p 193.

[534] Singh, P. and Rodrigues, L. 'Comfort and Energy Efficiency in a Victorian House in the Past, Present and Future'. *33rd Passive Low Energy Architecture (PLEA) International Conference: Design to Thrive*, Edinburgh, 2-5 July: Network for Comfort and Energy Use in Buildings (NCEUB), 3118-3125. p 3118.

[535] Whitman, C. J., Prizeman, O., Gwilliam, J. and Walker, P. 'Improving the Energy Performance of Historic Timber-Framed Buildings in the UK'.Ibid., 3126-3133.

[536] Gemmell, A. (2014) *Solid Wall Heat Losses and the Potential for Energy Savings: Literature Review*, Watford: Building Research Establishment Ltd. Available at: https://www.gov.uk/government/publications/solid-wall-heat-losses-and-the-potential-for-energy-savings-literature-review. p 105-110.

[537] Gorse, C. (2017) *Core Cities Green Deal Monitoring Project*: Leeds Beckett University. Available at: https://www.gov.uk/government/collections/buildings-energy-efficiency-technical-research.

[538] Ho, J. and Celentano, S. (2017) *Dartford Housing Retrofit Project - Evaluation Report*, London: PRP. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/657781/Evaluation_of_the_Dartford_Housing_Retrofit_Project_2017.pdf.

[539] Foster, J. A., Foster, S. A., Sharpe, T. R. and Poston, A. 'Building Performance Evaluation – a Design Approach for Refurbishment of a Small Traditional Building in Scotland'. *Energy Efficiency and Comfort of Historic Buildings (EECHB)*, Brussels, 19-21 October: Flanders Heritage Agency, 217-224. p 217.

[540] Gustafsson, J., Brookes, C., Rye, C., Scott, C. and Smith, O. 'Retrofit Internal Insulation at New Court, Trinity College, Cambridge: Options, Issues and Resolution through Material Sampling and Modelling'.Ibid., 289-295.

[541] Rye, C., Scott, C., Smith, O., Gustafsson, J. and Brookes, C. 'The Role of Monitoring and Feedback in the Refurbishment of Traditional Buildings: New Court, Trinity College, Cambridge'.Ibid., 206-216. p 206.

United Kingdom

HE Research Report Series: External Wall Insulation in Traditional Buildings: Case Studies of Three Large-scale Projects in the North of England (2014)[543]

HE Research Report Series: Reducing Energy Use in Traditional Dwellings: Analysis of Four Solid Wall Houses in Reading (2017)[544]

HES Refurbishment Case Study 9: Leighton Library - Installation of Loft Insulation (2014)[545]

HES Refurbishment Case Study 1: Five Edinburgh Tenement Flats – Wall and Window Upgrades[546]

HES Refurbishment Case Study 10: Rothesay - Installation of Insulation and Secondary Glazing (2014)[547]

HES Refurbishment Case Study 11: Newtongrange - Installation of Roof and Coom Insulation and Secondary Glazing (2014)[548]

HES Refurbishment Case Study 12: Kincardine Castle - Installation of Biomass System (2014)[549]

HES Refurbishment Case Study 16: Kirkton of Coull, Aberdeenshire - Thermal Improvements to a 19th Century Farmhouse (2015)[550]

HES Refurbishment Case Study 19: Trial Church Heating - Radiant Panels and Air Source Heat Pump at Kilmelford Church (2015)[551]

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[542] Rhee-Duverne, S. and Baker, P. (2015) *Research Report Series: A Retrofit of a Victorian Terrace House in New Bolsover - A Whole House Thermal Performance Assessment*, London: Historic England. Available at: https://www.historicengland.org.uk/images-books/publications/retrofit-victorian-terrace-house-new-bolsover/.

[543] *Research Report Series: External Wall Insulation in Traditional Buildings - Case Studies of Three Large-scale Projects in the North of England* (2014), London: Historic England. Available at: http://research.historicengland.org.uk/Report.aspx?i=15747&ru=%2fResults.aspx%3fp%3d1%26n%3d10%26k%3denergy%2520efficiency%26ns%3d1.

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5 Terminology

Air Permeability / Air Tightness: is a physical property used to measure the air tightness of the building fabric. It is defined as air leakage in metres cubed per hour per square metre of envelope area (m3/hr/m2) at a test reference pressure difference across the building envelope of 50 Pascals (Pa). The envelope area of the building, or measured part of the building, is the total area of all floors, walls and ceilings bordering the internal volume subject to the test.[598] An air tightness test is used to determine the level of uncontrolled air flow through gaps and cracks in the envelope of the building.

Authenticity: The extent to which the identity of a *building* matches the one ascribed to it. The concept of authenticity is not to be confused with the concept of originality.[599]

BER Assessment: an assessment of the energy performance of a building by a BER assessor using procedures, calculation methodology and software, specified by the Issuing Authority for the purpose of assigning a BER

BER Assessor: a person registered by the Issuing Authority, for a designated class or classes of buildings, for the purpose of BER assessment of such class or classes of buildings

BER: a building energy rating recorded on the BER register on the basis of a BER assessment[600]

Biomass: Biodegradable fraction of products, waste and residues from agriculture (including vegetal and animal substances), forestry and related industries, as well as biodegradable fraction of industrial and municipal waste, used as a fuel or energy source[601]

Breathable: With reference to the fabric of a building, 'breathable' means it allows moisture within the fabric to evaporate. Breathability refers to the material's ability to absorb and release water as vapour following humidity changes (hygroscopicity) and as a liquid through contact (capillarity).[602]

Building Condition: physical state of a building at a particular time[603]

Building Envelope: building elements that separate the interior of the building from the outdoor environment[604]

Building Fabric: construction products that are fixed to the building in a permanent manner, so that the dismantling of the product changes the performance of the building and the dismantling or replacement of the product constitute construction operations[605]

Capillarity/Capillary Attraction: related to the form and shape of pore structures within materials; the absorption and release of water as a liquid

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[598] *Standard Recommendation 54:2014: Code of Practice for the Energy Efficient Retrofit of Dwellings* (2014), Dublin: National Standards Authority of Ireland. Available at: https://www.nsai.ie/S-R-54-2014-Code-of-Practice.aspx. p 16.

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[604] Ibid. p 6.

[605] Ibid. p 6.

Cavity Wall: A type of masonry construction comprising two leaves of masonry separated by a gap, or cavity, to prevent moisture from the outside transferring to the inside[606]

Character-Defining Elements: materials, forms, location, spatial configurations, uses and cultural associations or meanings that contribute to *the heritage significance* of a historic building, which must be preserved in order to retain its heritage significance[607]

Compatibility: The extent to which one material can be used with another material without putting heritage significance or stability at risk[608]

Conservation: measures and actions aimed at safeguarding *a historic building* while respecting its heritage significance, including its accessibility to present and future generations[609]

COP (Coefficient of Performance) Measurements: a measurement of efficiency; the higher the number, the more efficient the system is

Cost-Optimal Level: the energy performance level which leads to the lowest cost during the estimated economic lifecycle

Deep Energy Renovation: 'is a term for a renovation that captures the full economic energy efficiency potential of improvement works, with a main focus on the building shell, of existing buildings that leads to a very high-energy performance. The renovated buildings energy reductions are 75% or more compared to the status of the existing building/s before the renovation. The primary energy consumption after renovation, which includes, inter alia, energy used for heating, cooling, ventilation, hot water and lighting after the deep renovation of an existing building is less than 60 kWh/m2 /yr. (GBPN / Definition often used in Europe).'[610]

Deep Energy Retrofit: 'implies replacing existing systems in a building with similar ones that are of higher quality and performance, which leads to a better energy performance of an existing building. The primary energy consumption includes energy used for heating, cooling, ventilation, hot water, lighting, installed equipment and appliances. After the deep retrofit the buildings energy reduction is 50% or more compared to the status of the existing building/s the retrofit. (GBPN / Definition mainly used in US).'[611]

Delivered Energy: Energy supplied to a building and its systems to satisfy the relevant energy uses, for example space heating, water heating, cooling, ventilation or lighting. Delivered energy does not include renewable energy produced on site[612]

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[606] *Advice Series: Energy Efficiency in Traditional Buildings* (2010), Dublin: Department of the Environment, Heritage and Local Government. Available at: https://www.chg.gov.ie/heritage/built-heritage/architectural-heritage-advisory-service/advice-for-owners/. p 72.

[607] *EN 16883:2017 Conservation of Cultural Heritage - Guidelines for Improving the Energy Performance of Historic Buildings* (2017): European Committee for Standardization. p 7.

[608] Ibid. p 8.

[609] Ibid. p 8.

[610] Shnapp, S., Sitjà, R. and Laustsen, J. (2013) *What is a Deep Renovation Definition?* , Paris. Available at: http://www.gbpn.org/sites/default/files/08.DR_TechRep.low_.pdf. p 19.

[611] Ibid. p 19.

[612] *Advice Series: Energy Efficiency in Traditional Buildings* (2010), Dublin: Department of the Environment, Heritage and Local Government. Available at: https://www.chg.gov.ie/heritage/built-heritage/architectural-heritage-advisory-service/advice-for-owners/. p 72.

District Heating/Cooling: the distribution of thermal energy in the form of steam, hot water or chilled liquids, from a central source of production through a network to multiple buildings or sites, for the use of space or process heating or cooling[613]

Dwelling Energy Assessment Procedure (DEAP): the official Irish methodology for calculating the energy performance and associated carbon dioxide emissions for the provision of space heating, ventilation, water heating and lighting in dwellings.

Dwelling: a building, or any part of a building, which is used or suitable for use by persons as a place to live. Dwellings shall include houses, apartments, maisonettes, duplexes and other such buildings where persons would typically reside. Buildings, other than apartment complexes, that provide multi-occupancy accommodation under specific conditions such as hospitals, nursing homes, boarding schools, hotels and hostels, shall not be considered as dwellings[614]

Dynamic Thermal Simulation: uses a 3-dimensional model to simulate the thermal behaviour of a building hour-by-hour

Embodied Energy: energy that was required to extract, process, manufacture, transport and install building materials and is now deemed to be embodied in the finished building[615]

Energy Performance Improvement Measure: Action to achieve behavioural, design, economic or technical change leading to verifiable, measurable or estimable energy performance improvements[616]

Energy Performance Indicator: in relation to a BER certificate means the alpha-numeric indicator set out on the BER certificate as distinct from the quantification of the energy performance indicator expressed in terms of kilowatt hours per square metre floor area per year (kWh/m2 /yr)[617]

Energy Performance: Measurable results related to energy use and energy consumption. This definition is in line with the definition of energy performance in the Energy Performance of Buildings (EPB) standards, which describe it as the calculated or measured net delivered energy to meet the energy demand associated with the use of the building (including inter alia energy used for heating, cooling, ventilation, domestic hot water and lighting).[618]

Energy Rating: The evaluation of energy performance of a building based on the weighted sum of the calculated or measured use of energy carriers. EPB standards differentiate between measured energy rating and calculated energy rating, the latter being either a design energy rating (design building data, standard use and climate data), a standard energy rating (actual building data, standard use and climate data) or a tailored energy rating (actual building data, climate, use and indoor environment data adapted to the actual building and purpose of calculation).[619]

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[613] *S.I. No. 243 of 2012 European Union (Energy Performance of Buildings) Regulations* (2013). Dublin: The Stationery Office. p 9.
[614] Ibid. p 9.
[615] *Advice Series: Energy Efficiency in Traditional Buildings* (2010), Dublin: Department of the Environment, Heritage and Local Government. Available at: https://www.chg.gov.ie/heritage/built-heritage/architectural-heritage-advisory-service/advice-for-owners/. p 7.
[616] *EN 16883:2017 Conservation of Cultural Heritage - Guidelines for Improving the Energy Performance of Historic Buildings* (2017): European Committee for Standardization. p 11.
[617] *S.I. No. 243 of 2012 European Union (Energy Performance of Buildings) Regulations* (2013). Dublin: The Stationery Office. p 9.
[618] *EN 16883:2017 Conservation of Cultural Heritage - Guidelines for Improving the Energy Performance of Historic Buildings* (2017): European Committee for Standardization. p 11.
[619] Ibid. p 11.

Energy Savings: The reduction of energy consumption following implementation of an energy performance improvement measure[620]

Heat Pump: a machine, a device or installation that transfers heat from natural surroundings such as air, water or ground to buildings or industrial applications by reversing the natural flow of heat such that it flows from a lower to a higher temperature. For reversible heat pumps, it may also move heat from the building to the natural surroundings[621]

Heritage Significance: The combination of all the heritage values assigned to a building and its setting.[622]

Heritage Value: is the aspect of importance that individuals or society assign to a building. Heritage values can be of aesthetic, historic, scientific, cultural, social or spiritual nature. These types of heritage values include various aspects, for example: architectural, artistic, economic, symbolic, technological, use, etc. The heritage assigned value can change according to circumstance, e.g. how the judgement is made, the context and the moment in time. Value should always be indicated by its qualifying type.[623]

Hygroscopicity: how moisture from the environment around building fabric is absorbed into it during episodes of high humidity and is released during periods of low humidity[624]

Hygrothermal Performance: damp building materials are a better heat conductor than dry materials and lead to an increased heat loss of 30 per cent or more[625]

Hygrothermal: relates to the movement of heat and moisture through building fabric.

Integrity: The extent of physical or conceptual wholeness of a building[626]

Internal Air Quality: refers to the quality of air within and around buildings in terms of pollutants and in relation to the health and comfort of building occupants

Interstitial Condensation: damp that occurs inside a wall, roof or floor structure when warm, moist air penetrates through the external fabric or becomes trapped within and condenses into liquid water

Investigation: The gathering of all information necessary for a *conservation* decision-making process. This should include both qualitative and quantitative information. Investigation is frequently invasive, entailing opening up floors or roofs, the making of holes for fibre-optics, taking samples, etc., and may be locally destructive, as is archaeological excavation. Non-invasive methods include inspection, photogrammetry, remote sensing, the study of documentary and/or oral sources, etc.[627]

Irish Standard: national specification based on the consensus of an expert panel and subject to public consultation[628]

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[620] Ibid. p 11.

[621] *S.I. No. 243 of 2012 European Union (Energy Performance of Buildings) Regulations* (2013). Dublin: The Stationery Office. p 9.

[622] *EN 16883:2017 Conservation of Cultural Heritage - Guidelines for Improving the Energy Performance of Historic Buildings* (2017): European Committee for Standardization. p 9.

[623] Ibid. p 9.

[624] Edwards, J. and Ward, P. (2017) 'Understanding Dampness', *Context,* (149), pp. 15-16.

[625] Ibid.

[626] *EN 16883:2017 Conservation of Cultural Heritage - Guidelines for Improving the Energy Performance of Historic Buildings* (2017): European Committee for Standardization. p 9.

[627] Ibid. p 10.

[628] *Standard Recommendation 54:2014: Code of Practice for the Energy Efficient Retrofit of Dwellings* (2014), Dublin: National Standards Authority of Ireland. Available at: https://www.nsai.ie/S-R-54-2014-Code-of-Practice.aspx. p 2.

Life Cycle Assessment: a measurement of the environmental impact of a product through its full 'life', from raw material extraction through material processing, manufacture, distribution, use, repair and maintenance, and disposal. Also referred to as a 'cradle-to-grave' assessment.

Micro-Renewables: Technologies that produce heat and electricity at a small scale including solar panels, photovoltaic panels, domestic wind turbines, heat pumps and the like[629]

Modern Building: a building constructed with cavity walls (two separate walls that leave a space for air flow between them), most often built using concrete block or brick.

Non-Renewable Energy: Energy from a source that is depleted by extraction (e.g. fossil fuels)[630]

Photovoltaic Systems: Arrays of solar cells containing a semi-conducting material that converts solar radiation into electricity[631]

Pugging: A material such as ash, sand or shells laid between floor joists or packed within partition walls to provide sound insulation[632]

Refurbishment: modification to an existing building in order to bring it to an improved, acceptable condition. Refurbishment does not necessarily respect the construction techniques, material or heritage significance of a building and is therefore not necessarily a conservation action.[633]

Render: A mixture of a binder (such as lime or cement), an aggregate and water to form a coarse plaster that is applied to the external surfaces of walls[634]

Renewable Energy: Energy from renewable non-fossil sources, namely wind, solar, aerothermal, geothermal, hydrothermal and ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases[635]

Repointing: The replacement of mortar in the face joints of brickwork or stonework following either the erosion of the original mortar or its removal through raking out[636]

Reversibility: The extent to which an intervention can be undone without damage to the building[637]

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[629] *Advice Series: Energy Efficiency in Traditional Buildings* (2010), Dublin: Department of the Environment, Heritage and Local Government. Available at: https://www.chg.gov.ie/heritage/built-heritage/architectural-heritage-advisory-service/advice-for-owners/. p 72.

[630] *EN 16883:2017 Conservation of Cultural Heritage - Guidelines for Improving the Energy Performance of Historic Buildings* (2017): European Committee for Standardization. p 11.

[631] *Advice Series: Energy Efficiency in Traditional Buildings* (2010), Dublin: Department of the Environment, Heritage and Local Government. Available at: https://www.chg.gov.ie/heritage/built-heritage/architectural-heritage-advisory-service/advice-for-owners/. p 72.

[632] Ibid. p 72.

[633] *EN 16883:2017 Conservation of Cultural Heritage - Guidelines for Improving the Energy Performance of Historic Buildings* (2017): European Committee for Standardization. p 7.

[634] *Advice Series: Energy Efficiency in Traditional Buildings* (2010), Dublin: Department of the Environment, Heritage and Local Government. Available at: https://www.chg.gov.ie/heritage/built-heritage/architectural-heritage-advisory-service/advice-for-owners/. p 72.

[635] *S.I. No. 243 of 2012 European Union (Energy Performance of Buildings) Regulations* (2013). Dublin: The Stationery Office. p 9.

[636] *Advice Series: Energy Efficiency in Traditional Buildings* (2010), Dublin: Department of the Environment, Heritage and Local Government. Available at: https://www.chg.gov.ie/heritage/built-heritage/architectural-heritage-advisory-service/advice-for-owners/. p 72.

[637] *EN 16883:2017 Conservation of Cultural Heritage - Guidelines for Improving the Energy Performance of Historic Buildings* (2017): European Committee for Standardization. p 9.

Solar Gain: The heat absorbed by a building arising from its exposure to sunshine[638]

Solid Wall: A wall constructed of solid of masonry, traditionally built of stone, rubble, brick and mortar, which does not include an air cavity between the interior and exterior face. Before 1919, and before 1940 in Ireland, the majority of dwellings were built with solid masonry external walls.

Standard Recommendation: recommendation based on the consensus of an expert panel and subject to public consultation[639]

Sustainability: Ability of a system to be maintained for the present and future generations. In this context" system" comprises environmental, social, cultural and economic aspects.[640]

Technical Building System: technical equipment for heating, cooling, ventilation, humidity control, hot water, lighting or for a combination thereof[641]

Thermal Bridge: part of the building envelope where the otherwise uniform thermal resistance is significantly changed by full or partial penetration of the building envelope by materials with a different thermal conductivity, and/or a change in thickness of the fabric, and/or a difference between internal and external areas, such as those occurring at wall/floor/ceiling junctions.[642] Thermal bridging, also known as 'cold bridging', occurs at locations where part of an external wall, floor or roof, draws heat directly to the outside at a faster rate than surrounding materials.[643]

Thermal Conductivity (λ or k-value): quantity of heat transmitted through a unit thickness in a direction normal to a surface of unit area due to a unit temperature gradient under steady state conditions and when the heat transfer is dependent only on the temperature gradient W/mK[644]

Thermal Inertia: the process of materials such as brick and stone absorbing, retaining and then releasing heat slowly over time[645]

Thermal Mass: the ability of high-density materials such as brick and stone to absorb heat, retain it and then release it again slowly over time, helping to moderate the temperature fluctuations within a room[646]

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[638] *Advice Series: Energy Efficiency in Traditional Buildings* (2010), Dublin: Department of the Environment, Heritage and Local Government. Available at: https://www.chg.gov.ie/heritage/built-heritage/architectural-heritage-advisory-service/advice-for-owners/. p 72.

[639] *Standard Recommendation 54:2014: Code of Practice for the Energy Efficient Retrofit of Dwellings* (2014), Dublin: National Standards Authority of Ireland. Available at: https://www.nsai.ie/S-R-54-2014-Code-of-Practice.aspx. p 2.

[640] *EN 16883:2017 Conservation of Cultural Heritage - Guidelines for Improving the Energy Performance of Historic Buildings* (2017): European Committee for Standardization. p 7.

[641] Ibid. p 7.

[642] *Standard Recommendation 54:2014: Code of Practice for the Energy Efficient Retrofit of Dwellings* (2014), Dublin: National Standards Authority of Ireland. Available at: https://www.nsai.ie/S-R-54-2014-Code-of-Practice.aspx. p 19.

[643] *Advice Series: Energy Efficiency in Traditional Buildings* (2010), Dublin: Department of the Environment, Heritage and Local Government. Available at: https://www.chg.gov.ie/heritage/built-heritage/architectural-heritage-advisory-service/advice-for-owners/. p 18.

[644] *Standard Recommendation 54:2014: Code of Practice for the Energy Efficient Retrofit of Dwellings* (2014), Dublin: National Standards Authority of Ireland. Available at: https://www.nsai.ie/S-R-54-2014-Code-of-Practice.aspx. p 19.

[645] *Advice Series: Energy Efficiency in Traditional Buildings* (2010), Dublin: Department of the Environment, Heritage and Local Government. Available at: https://www.chg.gov.ie/heritage/built-heritage/architectural-heritage-advisory-service/advice-for-owners/. p 20.

[646] Ibid. p 20.

Thermal Resistance (R-value): measure of a body's ability to prevent heat from flowing through it, equal to the difference between the temperatures of opposite faces of the body divided by the rate of heat flow (m2K/W)[647]

Thermal Transmittance (U-value): relates to a building component or structure, and is a measure of the rate at which heat passes through that component or structure when unit temperature difference is maintained between the ambient air temperatures on each side. It is expressed in units of Watts per square metre per degree of air temperature difference (W/m2K)[648]

Thermography (Thermal Imaging): a non-invasive and non-destructive visual method of illustrating invisible heat energy and assessing the thermal performance of a building, usually using an infrared camera that displays temperature variations through an array of colours or shades of grey.[649] Infra-red (IR) light occurs beyond the red end of the visible light spectrum and is invisible to the naked eye. All objects that are warmer than absolute zero (-273°C) emit IR light. The warmer the object is, the more IR light it emits.[650]

Traditional Building: buildings constructed with solid masonry walls of brick, stone or mud (often with a render finish). This form of construction performs differently from modern construction in being moisture permeable and reliant on higher levels of ventilation to ensure the well-being of the building fabric.[651]

U-Value: (or thermal transmittance co-efficient) is a measure of how much heat will pass through one square metre of a structure when the temperature on either side of the structure differs by 1 degree Celsius. The lower the U-value, the better is the thermal performance of a structure. The U-value is expressed in W/m2 K.[652]

Vapour Control Layer (VCL): continuous layer of vapour-impermeable material

Vapour Permeability: the ability of building fabric to allow water vapour to diffuse through it

Whole-Life (Life Cycle) Costs: the initial capital costs that go into constructing a building (including all ancillary design and other costs), plus the cost of renovation, maintenance and day-to-day operation over the period of its useful life

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[647] *Standard Recommendation 54:2014: Code of Practice for the Energy Efficient Retrofit of Dwellings* (2014), Dublin: National Standards Authority of Ireland. Available at: https://www.nsai.ie/S-R-54-2014-Code-of-Practice.aspx. p 19.

[648] Ibid. p 19.

[649] Atkinson, J. (2017) 'Thermography for Traditional Buildings', *Context,* (149), pp. 17-18.

[650] *Advice Series: Energy Efficiency in Traditional Buildings* (2010), Dublin: Department of the Environment, Heritage and Local Government. Available at: https://www.chg.gov.ie/heritage/built-heritage/architectural-heritage-advisory-service/advice-for-owners/. p 22.

[651] *Standard Recommendation 54:2014: Code of Practice for the Energy Efficient Retrofit of Dwellings* (2014), Dublin: National Standards Authority of Ireland. Available at: https://www.nsai.ie/S-R-54-2014-Code-of-Practice.aspx. p 19.

[652] 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.

6 Acronyms

ACA: Architectural Conservation Area

BCAR: Building Control Amendment Regulations 2014 (doesn't apply to existing buildings)

BER: Building Energy Rating

BPE: Building Performance Evaluation

BPIE: Buildings Performance Institute Europe

BRE: Building Research Establishment Ltd.

BREDEM: Building Energy Rating Domestic Energy Model

BREEAM: Building Research Establishment Environmental Assessment Method

CCAC: Climate Change Advisory Council

CCS: Carbon Capture and Storage

CDP: County Development Plan

CERO: Carbon Emission Reduction Obligation

CERT: Carbon Emission Reduction Target

COP: Conference of Parties – referring to the international political response to climate change (i.e. COP21 '2015 Paris Climate Conference'

DEAP: Dwellings Energy Assessment Procedure

DEC: Display Energy Certificate

DPM: Damp-Proof Membrane

EC: European Commission

EFFESUS DSS: **E**nergy E**ff**iciency for **E**U Historic Districts' **Sus**tainability **D**ecision **S**upport **S**ystem

EFFESUS: **E**nergy E**ff**iciency for **E**U Historic Districts' **Sus**tainability

EI: Engineers Ireland

EPBD: Energy Performance of Buildings Directive

EPC: Energy Performance Certificate

EWI: External Wall Insulation

GHG: Greenhouse Gas

HC: Heritage Council (Ireland)

HE: Historic England

HES: Historic Environment Scotland

I.S.: Irish Standard

IAQ: Indoor Air Quality

ICOMOS: The International Council on Monuments and Sites

IGBC: Irish Green Building Council

IHBC: Institute of Historic Building Conservation

IHGM: Interstitial Hygrothermal Gradient Monitoring

IR: Infra-Red light

IWI: Internal Wall Insulation

LCA: Life Cycle Assessment

LEED: Leadership in Energy and Environmental Design

LZC: Low and Zero Carbon

MAC: Marginal Abatement Cost

NAC: Net Annual Cost

NIAH: National Inventory of Architectural Heritage

NMP: National Mitigation Plan

NPV: Net Present Value

NSAI: National Standards Authority of Ireland

NSCES+CC: National Scientific Committee on Energy, Sustainability and Climate Change

NZEB: Near Zero Energy Building

PV: Photovoltaic

RdSAP: Reduced Data Standard Assessment Procedure

RH: Relative Humidity

RIAI: Royal Institute of the Architects of Ireland

RICS: Royal Institute of Chartered Surveyors

RPS: Record of Protected Structures

S.R.: Standard Recommendation

SCSI: Society of Chartered Surveyors Ireland

SDGs: Sustainable Development Goals

SEAI: Sustainable Energy Authority of Ireland

SPAB: Society for the Protection of Ancient Buildings

STBA: Sustainable Traditional Building Alliance

SWI: Solid Wall Insulation

TER: Target Emissions Rate

UKCMB: UK Centre for Moisture in Buildings

VCL: Vapour Control Layer

VOCs: Volatile Organic Compounds

WC: Water Content

7 Appendix

7.1 Heritage Council/ICOMOS Ireland February 2017 Colloquium

An Chomhairle Oidhreachta
The Heritage Council

ICOMOS
Irish Committee
INTERNATIONAL COUNCIL ON MONUMENTS AND SITES
COISTE IDIRNÁISIÚNTA NA SEADCHOMHARTHAÍ IS NA LÁITHREACHA

Deep Energy Retro-Fitting of Traditional Buildings

Colloquium 28th February 2017

Main outcomes and recommendations

Overarching observations

In order to achieve the energy performance objectives which are central to many current government policies (based in turn on their international commitments at UN and EU levels), the fabric of existing traditionally-built or old buildings (10 to 25% of the current dwelling stock, a figure which excludes vacant or unoccupied housing) needs to be understood properly and dealt with differently from modern cavity block or cavity wall construction. A thorough understanding of a building is necessary before attempting retrofit. It requires a different programme of funding, with measures tailored to the needs of particular buildings, on a case-by-case basis. If not, the energy improvement measures will fail, the owner will not get the cost savings proposed, the building fabric will suffer accelerated deterioration and its public heritage value may be compromised or lost.

To avoid this requires the involvement of informed professional specifiers to tailor upgrade works to the specifics of the fabric of individual buildings. The expertise to do this is emerging, but is not fully developed yet. The experience of the Tipperary Energy Agency has been that if you advise people on the right thing to do for their building, it often encourages them to invest in the work. This underlines the importance of making available the applied knowledge of how to improve energy performance in heritage buildings to ensure that they continues to be utilised.

ICOMOS and the Heritage Council jointly intend to research good practice in this area in 2017. This needs to be followed by the dissemination of case studies of good practice for building works specifiers, for example through Continuing Professional Development courses. This study will outline what is known about the performance of the fabric of traditionally built buildings, and which interventions are the most well-established, reliable and will no damage the fabric of the buildings.

The new Building Regulations require both specifiers and builders to demonstrate that they are 'competent' to carry out the works proposed. Specification and certification of compliance are sensitive to the legislative framework for Building Control, and legal or technical uncertainty as well as the delay in the flow of information and approvals, are barriers to the undertaking of thermal upgrade works. Certifiers need clear and reliable paths to compliance with Building Control Regulations. CPD courses on this subject will help with 'know-how' methodologies and good practice.

New administrative and procedural measures, and guidance, are also needed to achieve this. The approach to each building must be specific to that building, but it is important to identify any appropriate standard solutions that can reliably be applied to typical problems found within poorly performing traditional buildings.

Context

The sustainable retrofit of our built environment needs to take a holistic view of environmental factors, but it also needs to take account of occupant health and well-being. If we set out to intervene in historic or traditional buildings for public good or specifically 'environmental' aims, why would we stop at considering only energy use and climate change? The sustainability agenda is broader and includes the embodied energy of existing serviceable structures, human health, social continuity, as well as the cultural heritage objectives of heritage conservation ('Heritage is sustainability'). But proportionate intervention is an important principle – the buildings might be achieving performance in other areas anyway (heritage, embodied energy, owner satisfaction with architecture or location, etc). The objective of a government policy on energy retrofit should be a balance between heritage, energy use and comfort.

The value and role of traditional buildings in society provides a context for their continued use as a cultural and material resource. Buildings are complex objects in themselves and need to be understood holistically. We currently do not have a sophisticated methodology for assessing the energy performance of traditional building fabric, which may be non-standard, multi-period, complex and layered. Additionally, the embodied energy in building materials, and the proven durability in use of historic buildings, has not been included in energy efficiency equations. If overall sustainability is the goal, taking into account embodied energy as well as energy-in-use, it is important to evaluate the efficiencies to be gained by continuing to make use of historic buildings and not abandon or replace them.

Interdepartmental government action is key to achieving outcomes on climate change action, and this principle could also be applied to action on improving energy performance in buildings. Cross-Departmental engagement – Housing, Heritage, Health – would demonstrate the multiple benefits of a holistic approach to the thermal improvement of our building stock. For example, the Department of Health has a 'Warmth and Wellbeing' Initiative. Cold, damp houses impact the occupant's health, eg. respiratory problems. The promise of an improved quality of life is what will bring people on board. Additionally, where the State spends money there must be assurances across all relevant dimensions of public policy that the required quality of work is being achieved. For a cross-departmental initiative to work, the government and the clients need to know that long-term value for money will be delivered.

Continuity

Regular maintenance and care, especially measures taken to keep the building dry, will improve its thermal performance. Maintenance of the existing construction should be the starting point. Incentivising investment in building maintenance achieves broader heritage aims and is the most cost-effective means of maintaining and improving thermal performance. Whilst it should be in the interests of building owners to invest in the maintenance of their properties, in truth, this is happening more infrequently than it should in contemporary Ireland.

If we take the building occupant (energy user) as the starting point, we recommend a phased approach. We need to understand the buildings we live in and how they work. People appreciate historic buildings, but they do not necessarily know how to maintain and operate them effectively.

Being aware of the humidity we generate in buildings as a result of daily tasks (boiling a kettle, having a shower in a small room, drying clothes on a radiator) is an important first step, and even knowing how to properly open sash windows can reduce internal moisture levels. Measures such as these that don't require planning permission and facilitate a gradual knowledge upskilling of owners are the simple things that are

light in impact and should be taught to building owners and occupiers first – with deep retrofit only coming after.

Change

There may still be a need to improve or 'change' the buildings through retrofit measures, but these two preceding contexts ('Continuity' and 'Context') are very important frames.

The great variety of existing buildings poses a challenge for specification, as there are no standard or 'one size fits all' solutions.

Regulations tend to demand fabric change even though traditional buildings are not carbon criminals. They embody energy in their construction (which is not well enough understood or accounted for in current policies and guidance) and have proven their durability (which is more than can be said for much of the recently-built housing stock).

The regulations that are imposed on existing buildings include the (perceived to be inflexible) Guidance Documents to the Building Regulations, and the Building Energy Rating (BER) method of assessing the thermal performance of buildings in use. Both prompt inappropriate interventions within traditional buildings.

We need to build the capacity of the specifiers and the building construction industry to address the broad challenge of conserving our built environment. This is a challenge. We cannot upskill the entire building industry. Architecture undergraduates are not being prepared to deal with the retrofit of buildings and many practicing architects are not equipped to deal with the basics of sustainable retrofit.

There is a diversity of informative papers available, but practitioners need assistance to negotiate them. Accessibility of information is a huge issue – 80-85% of architects in Ireland, for example, are sole practitioners and they lack the time and resources to wade through research papers and to keep up with the latest findings. Very simply, basic knowledge and understanding is needed before skills can be applied at the coalface. Currently, the practice is to delegate responsibility for specification to suppliers as they will certify it and fill a knowledge gap, but who do not have a holistic view of building performance for the occupant.

The energy retrofit of historic buildings should be approached scientifically, however it is sometimes necessary to act without perfect foreknowledge of the outcomes. There needs to be an acknowledgement that we don't always get it right the first time, and it is important that when things do go wrong, we learn from those mistakes through a reliable system of monitoring and feedback.

A methodical or scientific approach to energy retrofitting would consist of the following:

- Building pathology – how do we know what is going wrong with a building from the symptoms it shows?
- Typical historic building constructions and how to treat common conditions
- Material performance and hygroscopy
- Good practice procedures for evaluating risk in the specification of fabric improvements for traditional buildings
- Building physics (heat transfer - WUFI software modelling heat and moisture transport in building fabric exposed to weather)
- Building-specific approaches are required, but we also need categorisation: a typology of houses, building elements or constructions to structure guidance
- A risk evaluation strategy for traditional buildings in Ireland, and for individual buildings

- A forum for sharing specification experience, including bad experience without admission of liability
- A maintenance-first approach: do all the things we know how to do.

In addition to better knowledge about the actual performance of buildings, those who take professional responsibility for specifying works, including taking on liability in the medium- to long-term that fabric performance conforms to project objectives, need to be given 'pathways' to compliance' under the new Building Control regime. Only the latest update of 'BS 5250:2011 +A1 2016 – Code of practice for control of condensation in buildings' includes multiple compliance options. Designers and specifiers are innovators within the building sector and they deserve the scope to be able to deploy their skills confidently along multiple pathways.

Clients with portfolios of buildings (e.g. institutions like DIT at Grangegorman) need briefing information for their specifiers and architects, which would, in turn, contribute practice-based knowledge through the range of their portfolios.

Specific recommendations (and initiatives currently underway) mentioned by participants:

- We need short courses to convey 'just-in-time' knowledge, e.g. a two-day course to improve the understanding of traditional buildings for energy assessors.
- The Sustainable Energy Communities (SEC) programme might offer a formal way of engaging with SEAI on a joint project for traditionally constructed buildings.
- Service improvements can lead to better energy performance. We need innovative approaches to services where the fabric is too important to touch.
- We need a version of SR54 *'Code of practice for the energy efficient retrofit of dwellings'* that deals with heritage buildings
- IGBC is looking to develop Green Building skills for professionals and is currently working on an embodied carbon and life cycle analysis tool, the Environmental Product Declaration project (EPD Ireland).
- The Society of Chartered Surveyors Ireland (SCSI) are interested in the development of guidance notes on the relationship of Building Control Guidance and Energy Performance.
- The European Association of Building Surveyors (AEEBC) has a current research project under the EU Leonardo programme regarding energy retrofit and refurbishment. Disseminate results.
- A Construction Industry Training Board has long been identified as necessary if quality in building is to be assured.

Pat Nestor referred to a document on the website of the Department of Housing, Planning, Communities and Local Government, which gives advice on the application of the building regulations to protected structures (http://www.housing.gov.ie/housing/building-standards/other/application-building-regulations-works-existing-buildings). The document states that "Part L of the Second Schedule to the Building Regulations do not apply to works (including extensions) to an existing building which is a 'protected structure' or a 'proposed protected structure' within the meaning of the Planning and Development Act 2000 (S.I. 30 of 2000)."

The RIAI Sustainability Task Force has a 'Pathway to Sustainability' checklist for architectural design, grouped by design process stages. It is to be disseminated as a practice guide for architects.

Relevant publications mentioned:

- BS5250 regarding control of moisture in buildings – only newly includes multiple options.

- ‘Breaking the Mould’ series of five articles by Joseph Little.
- Fraunhofer Institute for Buildings Physics partner on WUFI software modelling heat and moisture transport in building fabric exposed to weather. Need for detailed info regarding characteristics of specific materials to model accurately.
- Technical Paper 15 for Historic Environment Scotland ‘*Assessing risks in insulation retrofits using hygrothermal software tools; Heat and moisture transport in internally insulated stone walls*’.
- ‘*Built to Last’*, Joseph Little is working on second publication of this series.
- STBA Responsible Retrofit, publications and tools, the Guidance Wheel, knowledge-gap study – ‘*The Responsible Retrofit of Traditional Buildings’* (2012) produced in conjunction with the UK Department of Energy and Climate Change (DECC). We need this sort of study in Ireland.
- ‘Hygrothermal Risk Evaluation for the Retrofit of a Typical Solid-Walled Dwelling’ published in *SDAR* Journal of Sustainable Design & Applied Research*: Vol. 4: Iss. 1, Article 3

Colm Murray, Architecture Officer, The Heritage Council

Peter Cox, President, National Scientific Committee on Energy, Sustainability and Climate Change, ICOMOS Ireland

24th July 2017

7.2 ICOMOS Ireland NSCES+CC January 2018 Workshop

An Chomhairle Oidhreachta
The Heritage Council

ICOMOS
Irish Committee
INTERNATIONAL COUNCIL ON MONUMENTS AND SITES
COISTE IDIRNÁISIÚNTA NA SEADCHOMHARTHAÍ IS NA LÁITHREACHA

Workshop on

'Deep Energy Renovation of Traditional Buildings: Assessing knowledge gaps and addressing skills training in Ireland'

research

ICOMOS Ireland - National Scientific Committee on Energy, Sustainability and Climate Change and

The Heritage Council

25th January 2018, 14:15 – 17:00 at the Irish Architectural Archive, 45 Merrion Square, Dublin 2

Aims:

a) Introduce the above research work to ICOMOS members and to invite comment on it (Caroline Engel),
b) Explore how to provide Continuing Professional Development training to specifiers of Energy renovation works and what a curriculum for such training would look like (Colm Murray),
c) Define the ideal of 'Pathways to Compliance with the Building Regulations', and how they might work for the specifier who is acting professionally in accordance with the Building Control Act, and to explore the 'The application of the Building Regulations to works in existing buildings', and how to use it (Pat Nestor, Dublin City Council Building Control officer)

And to seek answers to the following questions:

d) Recognising that specifiers will frequently find uncertainties (knowledge gaps), what is the ethical approach to balancing professionalism with the mission or duty to conserve historic fabric whilst improving energy performance?
e) What recognition should come from training / CPD? Who can certify the specifying skills of a professional who aims to provide the service of designing thermal improvements for historic buildings? – (Marion Jammet, IGBC).
f) Who will accredit or recognise? Is there scope for a Register of Energy Renovation Specifiers for Historic Buildings?

Colm Murray, The Heritage Council, 8th January 2018

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7.3 Provisional CPD Course - Deep Energy Renovation of Traditional Buildings

Proposed Curriculum Structure

Introduction to domestic retrofits

- Introduction to international, European and Irish governmental targets, statutory regulations and codes of practice.
- Introduction to conservation principles, energy-efficient design and service installation[653]
- Sources of regulatory, technical and good practice information. The issues of dynamically evolving good practice, and the importance of keeping up-to-date.
- Building Energy Ratings and how to use them, plus other energy efficiency in buildings performance information sources and how to interpret them.
- Identifying 'pathways to compliance' with Building Regulations and dealing with implicit guidance

Assessing dwellings for retrofits

- Typical traditional buildings in Ireland and their inevitable variation resulting from diversity of production circumstances and age
- The importance of thinking of buildings as a whole and parts of a whole
- Building condition and maintenance: How to appraise and survey a traditionally-built building focussing on characteristics that are important in terms of energy use reduction.
- How to balance the retention of historic and cultural value with energy efficiency objectives
- How to approach interventions: (a) re-arranging the usage of the building, (b) improvements to the services installed in the building, (c) fabric interventions, (d) installation of energy-generating plant.
- Introduction to decision support tools

Building-inhabitant interface

- Understanding use behaviour and trigger points
- Guiding homeowners through the most beneficial sequence of step-by-step energy renovations
- How changes in occupant behaviour may impact the expected carbon and cost savings
- Post-renovation hand-over: Instructing building users on moisture management and economic programming of heating systems

[653] New principles are needed in relation to the loose fit between function and form, respecting the energy embodied in existing structures, fabric and fittings, 'additive intervention', the heritage value of old services, the value of voids and pathways in building fabric, and accepting historic environmental features (window light, thermal massing, etc). Recognition of the impact of services on pre-existing buildings – plumbing, electrical services – and our acceptance of these historical processes in building we now think of as old despite their anachronistic features.

The business case for deep energy renovation

- Appraising costs and payback periods, public benefits, comfort improvements and/or energy bill reductions.
- How to effectively communication of these issues to building owners (reports, advice and recommendations, project management, specification and design)
- Quantifying the embodied energy and heritage value in existing traditionally-built buildings and incorporating this into the business case
- Currently available grant and financial support

Building services upgrading

- Assessing the efficiency of energy-delivering services in buildings and their integration with building fabric
- Information about the operation of building services as they impact on the comfort levels of buildings in use
- Issues about occupant interface with controls

Building pathology and moisture risks

- Introduction to moisture risks in the deep energy renovation of traditional buildings
- Building physics as it relates to heat loss, ventilation, the thermal performance of building materials, and their performance in combination and in constructional arrays
- Moisture movement in buildings: ground source, driving rain and generated from within
- Assessment methods and hygrothermal modelling

Ventilation, airtightness and maintenance

- Airtightness, porosity and vapour permeability characteristics of traditional construction, compared with codes of practice for new-build
- Health and ventilation
- Improving the airtightness of traditional windows through maintenance measures

Solid Wall Insulation

- Assessing the suitability of solid wall insulation for a particular building
- Benefits for external versus internal solid wall insulation
- Moisture risks and solid wall insulation
- Improving thermal performance by insulating wall joints

Project coordination and risk management

- Assessing the relative merits of alternative energy-saving strategies at the design stage based on scientific and multi-criteria judgments
- Tools and methods for making informed decisions

- Assessing the 'Heritage Impact Assessment' of potential energy-saving measures and how to make the case for proportional interventions against standards in regulations
- How to procure materials, equipment and skilled labour to install interventions for maximum efficacy
- Team and project co-ordination and management needed to carry out successful installation
- Certification of compliance with standards, accreditation of competent building contractors

Information sources, uncertainties and how to handle them

- Glossary of technical terms, clarifying meanings and concepts
- Information sources – academic, technical, regulatory, quality assuring
- How to use dynamically-evolving information and on-going research programmes
- How to interpret data on building performance
- How to assess the reliability of technical product information, data on materials' energy performance and durability, standard specifications for treatments, for the particularities of an individual building
- How to assess information provided by materials suppliers, on materials, products, equipment and services
- How to deal with gaps in knowledge and on-going uncertainties
- How to turn data from performance analysis into scientifically-based specifications
- Monitoring programmes that provide feedback on the effectiveness of specifications over longer periods of time
- Professional reflection to improve specifier's on-going performance and sharing experience with peers for collective learning
- Case Studies: optimum outcomes, transferability of principles, application of diligence and skill in the tailoring of advice and specifications from case to case

Colm Murray

8th November 2017

7.4 Letter sent to the UK Secretary of State for Business, Energy and Industrial Strategy

National Trust

THE CHURCH OF ENGLAND Shrinking the Footprint

STBA SUSTAINABLE TRADITIONAL BUILDINGS ALLIANCE

S·P·A·B

HHA HISTORIC HOUSES ASSOCIATION

IHBC · INSTITUTE · OF · HISTORIC · BUILDING · CONSERVATION

CLA

JCNAS JOINT COMMITTEE OF THE NATIONAL AMENITY SOCIETIES

The Rt Hon Greg Clark MP
Secretary of State for Business, Energy and Industrial Strategy
1 Victoria Street
London
SW1H 0ET

cc; The RT Hon Karen Bradley MP
Secretary of State for Digital, Culture, Media and Sport

The RT Hon Sajid Javid MP
Secretary of State for Communities and Local Government

30th October 2017

Dear Secretary of State,

Energy efficiency and traditional buildings

We are a group of leading heritage organisations who play a part in looking after the nation's older building stock. We believe that conservation of energy and conservation of buildings go hand in hand. However, we also share a common concern: that current energy conservation policy and practice are flawed in their application to traditional buildings, causing damage and creating risks from the perspectives of both heritage and human health; and we would like the opportunity to discuss this with you.

Buildings of traditional construction make up to 35% of the dwelling stock. Lack of understanding that these buildings need a different approach due to their construction has already led to a waste of money and carbon on inappropriate interventions, and their subsequent rectification. Not only do they fail to deliver the predicted savings, in some cases they make energy efficiency worse. These issues will be greatly compounded if the current approach goes unchanged. In our view, remedying this situation should be an early energy policy priority for Government.

As conservation organisations, we share the Government's concern about the risks of climate change, and we welcome the Clean Growth Strategy and agree with the need for practical policies to tackle it. Energy efficiency is a cornerstone in this, as well as dealing with fuel poverty. However, current policy to address energy efficiency in the nation's building stock is overly simplistic, having been designed from the perspective of modern construction and materials, paying insufficient attention to fundamental building physics, such as how traditional materials and structures 'breathe', resulting in inappropriate and damaging measures.

While we share the Government's concern about the serious health risks to humans resulting from dampness and poor ventilation in domestic properties, current interventions, when applied to an older property, can compound ill-effects. This is

because Government measures have overlooked the need to put buildings into good repair before applying retrofit measures, coupled with a lack of understanding of the context for retrofit works. These problems have been exacerbated by an underlying and longstanding skills shortage for traditional building repairs, compounded by the lack of people with an understanding of energy efficiency in traditional buildings. Hence there is little opportunity for meaningful correction at assessment and implementation stage.

The resulting combination of insufficient understanding, failure to repair before retrofit, inappropriate specification, and poor execution, allied with inadequate safeguards, has seriously compromised successive governments' efforts to mitigate climate change through retrofit. Urgent change is needed to put retrofit efforts on better track.

An additional concern of our organisations - some of which represent landlords of older properties- is the lack of clarity about a Listed Building exemption in the Private Rented Sector (PRS) Regulations which come into full force in less than six months' time. This has made it very difficult for landlords to understand their responsibilities or to have a clear approach to upgrading properties; and the timescales are now unfair and potentially impractical.

Since all main parties share a commitment to the Climate Change Act and the Paris Accord, we hope that it will be possible to take a long term approach and look well beyond the new Parliament to enable all concerned to explore and trial optimum solutions, whilst building skills and capacity.

Well maintained, older buildings can be the very essence of sustainability, due to their embodied energy, the durability of materials and their tolerance of sympathetic alterations. Getting maintenance and retrofit right should, therefore, be a priority to a Government facing the twin pressures of housing stock shortfall and climate change. We welcome the recognition that successive Governments have given to the historic environment: the acknowledgement of the contribution older buildings make to the character of our towns, villages, streets and rural landscapes, and the place they play in our nation's cultural identity. Supported by the right policy, older properties could both maintain their cultural significance and make a vital contribution to any sustainable building strategy and energy conservation.

Successful retrofit can only be achieved using a 'whole house' approach which integrates fabric measures, services and people's behaviour; and current policy and practice do not deliver this. We urge the Government to engage with the signatories on the issues defined and to address our concerns (kindly see the enclosed policy requests for more information). We can offer supportive experience and knowledge to find solutions.

We would appreciate a meeting with the Ministers at an early opportunity to discuss how regulatory improvements in this sensitive area can be progressed so that the nation's older buildings are safeguarded for future generations to use and enjoy, and can play their part in tackling climate change concerns in a substantive and appropriate way.

Yours sincerely,

Dame Helen Ghosh, National Trust

Becky Clark, Director, Cathedral & Church Buildings, Church of England

Nigel Griffiths, Director, STBA (Sustainable Traditional Buildings Alliance)

Matthew Slocombe, Director, SPAB (Society for Protection of Ancient Buildings)

Ben Cowell, Director General, Historic Houses Association

James Caird, Chair, IHBC (Institute of historic Building Conservation)

Ross Murray, CLA President, CLA (Country Land and Business Association)

Matthew Slocombe, Secretary, Joint Committee of the National Amenity Societies

POLICY REQUESTS – Energy efficient retrofit

The signatories argue for a whole house approach which integrates fabric measures, services and people's behaviour.

Specifically, we recommend that the Government:

1. **Reviews the Energy Performance Certificate (EPC) Register** to ensure that recommendations for traditional properties do not damage fabric or irresponsibly affect building character.

2. **Provides, as a matter of urgency**, clarification on whether listed buildings and properties in conservation areas are required to have an EPC and will therefore be expected to comply with the PRS energy efficiency regulations.

3. **Commissions research focusing on the energy efficiency of different wall types used in traditionally built properties to improve the accuracy of** the Standard Assessment Procedure (SAP) methodology. The forthcoming change to SAP (i.e. correcting the default U-value of solid walls to be closer to measured values) is welcomed, but strategically, this correction shows how urgent a wholescale review of SAP is, in order to avoid penalising unfairly not just listed buildings but our entire traditional housing stock.

4. **Funds more research** to better understand traditional buildings and the way they work. This is essential to inform decisions about appropriate interventions to sustain our older building stock.

5. **Ensures appropriate safeguards** for traditional buildings in any new energy efficiency schemes through a **joined-up approach** building on existing regulations[1].

To further all the above, supports a Task and Finish Group (in place of the Older Properties Working group, convened by DECC but subsequently discontinued), **with clear deliverables, to include disseminating and promoting the SQA qualifications for Older and Traditional Buildings[2] developed under its auspices.**

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[1] Many of the current problems could have been avoided had ECO and PAS 2030 (neither of which mentions traditional environment) been cross-referenced to the Special Consideration for breathable buildings in Part L of the Building Regulations, which has been in place since 2002.

[2] http://www.sqa.org.uk/sqa/68730.html

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