

PAS 2035:2023

Retrofitting dwellings for improved energy efficiency – Specification and guidance



Department for
Energy Security
& Net Zero

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Contents

Foreword	ii	12 Requirements for retrofit advice	25
0 Introduction.....	iv	12.1 Delivery of retrofit advice.....	25
1 Scope.....	1	12.2 Distressed replacement of a heating appliance	26
2 Normative references	2	13 Requirements for monitoring and evaluation	27
3 Terms and definitions	3	13.1 The purpose of monitoring and evaluation	27
4 Guidance about retrofit building physics.....	6	13.2 Retrofit Evaluator.....	27
4.1 General	6	13.3 Levels of monitoring and evaluation.....	27
4.2 Building pathology	6	13.4 Basic evaluation.....	27
4.3 Thermal models and calculations.....	6	13.5 Further monitoring and evaluation	28
5 Guidance about approaches to retrofit.....	8	14 Claims of compliance	29
5.1 Main Contractor and Retrofit Installer	8	14.1 General	29
5.2 Retrofit performance considerations, standards and constraints	8	14.2 Basis of claim	29
5.3 Medium-term improvement plans	8	14.3 Permitted forms of disclosure	29
5.4 Retrofit at scale	8	15 References	30
5.5 Fabric first.....	9	15.1 Retrofit framework standards.....	30
5.6 Concentrate on the interfaces.....	10	15.2 List of references (other than formal standards, for guidance only).....	32
5.7 Retrofit advice	10	Annexes	
6 Requirements for retrofit coordination	11	Annex A (normative)	
6.1 Retrofit Coordinator	11	Qualifications	33
6.2 Establishing intended outcomes	11	Annex B (normative)	
7 Requirements for whole-dwelling assessments	12	Industry Quality Assurance Schemes	36
7.1 Whole-dwelling assessments.....	12	Annex C (normative)	
7.2 Distressed replacement of heating appliances.....	12	Requirements for provision of adequate ventilation	37
7.3 Retrofit Assessor.....	12	Annex D (normative)	
7.4 Reporting the assessment and handing over assessment data.....	14	Requirements for dealing with interactions between EEMs	41
8 Requirements for retrofit designs	15	Annex E (normative)	
8.1 Improvement options evaluations and medium-term improvement plans	15	Requirements for the assessment of significance for traditional buildings	43
8.2 Retrofit designs	16	Bibliography	46
8.3 Distressed replacement of heating appliances.....	21	List of tables	
9 Requirements for installation of retrofit designs.....	22	Table E.1 – Key values of significance	43
10 Requirements for testing and commissioning	23	Table E.2 – PAS 2035 significance survey checklist	45
10.1 Requirements for testing.....	23	List of figures	
10.2 Requirements for commissioning.....	23	Figure 1 – The domestic retrofit process required by PAS 2035 and PAS 2030	v
10.3 Test certificates and commissioning records.....	23	Figure 2 – Domestic retrofit process that users are expected to follow in order to meet the requirements of PAS 2035	vi
11 Requirements for handover	24	Figure D.1 – The measures interaction matrix.....	42
11.1 Specification of handover requirements	24		
11.2 Handover recipients.....	24		

Foreword

Publishing information

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Supersession

PAS 2035:2023 supersedes PAS 2035:2019+A1:2022 which remains current and will be withdrawn on 30 March 2025.

Information about this document

This is a full revision of the document and introduces the following principal changes.

- PAS 2035 guidance clauses have been updated to:
 - a) reflect national policy; and
 - b) emphasize the role of PAS 2035 in protecting the consumer.
- Clauses have been included to facilitate scale retrofit by allowing retrofit design to commence based on assessments of archetypes.
- The BEIS retrofit technical guides have been included as references.
- The risk assessment process has been simplified to avoid unintended complexities.
- Change of emphasis from measures-based retrofit to whole dwelling retrofit by including more reference to a Main Contractor.
- Clarification of the role of the Retrofit Coordinator, including site visits and recording of non-compliance.
- Contents of a Medium-Term Improvement Plan is now a requirement rather than guidance.
- Requirements to produce an airtightness strategy for projects, which can include setting of an airtightness target and air leakage testing.

- Clarification of what happens in the PAS 2035 process if historic significance is identified. A new Annex E is included.
- Annex C has been simplified where possible and brought in line with the new Approved Document F
- Further Monitoring and Evaluation references the new BS 40101 Building Performance Evaluation, and Monitoring and Evaluation is now considered from inception through to completion.
- A process has been included whereby distressed replacement of heating appliances can retrospectively comply with PAS 2035.
- The guidance and requirements for climate resilience and adaptation in retrofit has been strengthened.
- The requirements and qualifications for independent inspection of the pre-installation building inspection (PIBI) in some PAS 2030 annexes have been strengthened.
- Requirements and guidance around moisture in buildings has been brought in line with language in BS 5250.

This publication can be withdrawn, revised, partially superseded or superseded. Information regarding the status of this publication can be found in the Standards Catalogue on the BSI website at [bsigroup.com/standards](https://www.bsigroup.com/standards), or by contacting the Customer Services team.

PAS 2035:2023 is published with the expectation that users intending to claim compliance with it, will commence adoption of its provisions immediately following publication with a view to fully meeting its requirements and claiming compliance with PAS 2030:2023 and therefore also PAS 2035:2023, by 30 March 2025. During this period, PAS 2035:2019+A1:2022 will remain available for use where required but will be withdrawn on 30 March 2025.

Where websites and webpages have been cited, they are provided for ease of reference and are correct at the time of publication. The location of a webpage or website, or its contents, cannot be guaranteed.

Relationship with other publications

PAS 2035:2023 is intended to be read and used in conjunction with PAS 2030:2023.

Presentation conventions

The provisions of this document are presented in roman (i.e. upright) type. Its requirements are expressed in sentences in which the principal auxiliary verb is "shall".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Where words have alternative spellings, the preferred spelling of the *Shorter Oxford English Dictionary* is used (e.g. "organization" rather than "organisation").

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0 Introduction

Statutory national targets for the reduction of greenhouse gas emissions in response to the threat of climate change imply that very significant improvements need to be made in the energy efficiency of the UK's building stock, including nearly all its 27 million domestic buildings. The Climate Change Committee sets "carbon budgets" under the Climate Change Act 2008 [1], and the Government's Net Zero Strategy [2] includes a commitment to improvements in Energy Performance Certificate (EPC) scores in existing dwellings.

This PAS supports work towards those objectives by promoting and defining technically robust and responsible "whole-dwelling" domestic retrofit work, i.e. high-quality work that supports:

- a) improved functionality, usability and durability of buildings;
- b) improved comfort, health and wellbeing of building occupants and visitors;
- c) improved energy efficiency, leading to reduced fuel use, fuel costs and pollution (especially greenhouse gas emissions associated with energy use);
- d) reduced environmental impacts of buildings;
- e) protection and enhancement of the architectural and cultural heritage as represented by the building stock;
- f) avoidance of unintended consequences related to any of the above;
- g) minimization of the "performance gap" that occurs when reductions in fuel use, fuel cost and carbon dioxide emissions are not as large as intended or predicted; and
- h) protection of the general public and the client in relation to retrofit work.

The requirements and guidance presented in this PAS are intended to apply to improvement measures in the context of a whole-dwelling approach to retrofit that takes the points listed above into account. The whole-dwelling approach considers the building as a system of elements, interfaces and occupants that interact, and not as a set of elements that are independent of each other or of occupants' practices and lifestyle.

This PAS is intended to support both the one-off installation of improvement measures and a staged approach in which improvement measures are implemented over time. It is compatible with current national and EU schemes, including the Building

Performance Institute Europe scheme¹⁾ and *Building Renovation Passports* [3]. This PAS has a role in protecting the client by reducing the risk of unintended consequences and through effective communication and advice via the individuals involved in a retrofit project that are defined in this PAS. A key role in the PAS is the Retrofit Coordinator, who is both client facing and responsible for retrofit works being compliant with PAS 2035.

Health and safety in construction projects, which include retrofit projects following this PAS, is particularly important because the industry is prone to hazardous situations and can be dangerous at times. Good health and safety processes help protect both the construction workers and the general public, which in retrofit situations often includes the occupants of the dwelling.

NOTE 1 *The Construction (Design & Management) Regulations (CDM 2015) are the main set of regulations for managing the health, safety and welfare of construction projects. CDM applies to all building and construction work and includes new build, demolition, refurbishment, extensions, conversions, repair and maintenance. Following these regulations, as well as the Building Regulations of England, Scotland, Ireland and Wales is implicit for the majority of the projects that follow this PAS.*

In 2015, the UK Government commissioned the *Each Home Counts* review [4] (originally known as the "Bonfield Review") to determine ways of improving the confidence of both Government and clients in the domestic retrofit industry and improving the quality and effectiveness of retrofit work. The report of the review published in December 2016 contains 27 recommendations, including the establishment of a quality mark for domestic retrofit supported by an industry Code of Conduct, a Consumer Charter and a framework of technical standards for retrofit. The quality mark has subsequently been established as the TrustMark quality scheme.

PAS 2035 is the overarching document in the retrofit standards framework. All the other standards referred to in this PAS are part of the retrofit standards framework (see Clause 15). This PAS and the retrofit standards framework can be applied to all domestic retrofit activity.

¹⁾ Available at see <https://www.bpie.eu/>.

Designs for the installation of retrofit measures in domestic buildings that are prepared in accordance with PAS 2035 are required to be installed, commissioned and handed over in accordance with PAS 2030, or in some cases in accordance with the Microgeneration Certification Scheme (MCS) standards ([N1], [N2]).

Requirements for the installation, commissioning and handover of retrofit measures are provided in PAS 2030, or in some cases in the MCS standards ([N1], [N2]).

Users of PAS 2030 are required to work to designs that conform to this PAS.

For domestic retrofit projects, PAS 2035 and PAS 2030 are effectively intended to be used in conjunction with each other, because one standard cannot be used without the other. The only exception is installation of some measures in accordance with the MCS standards ([N1], [N2]), rather than PAS 2030, where specified.

Figure 1 illustrates the overall process that users of PAS 2035 are expected to follow in order to comply with its requirements.

Figure 1 – The domestic retrofit process required by PAS 2035 and PAS 2030

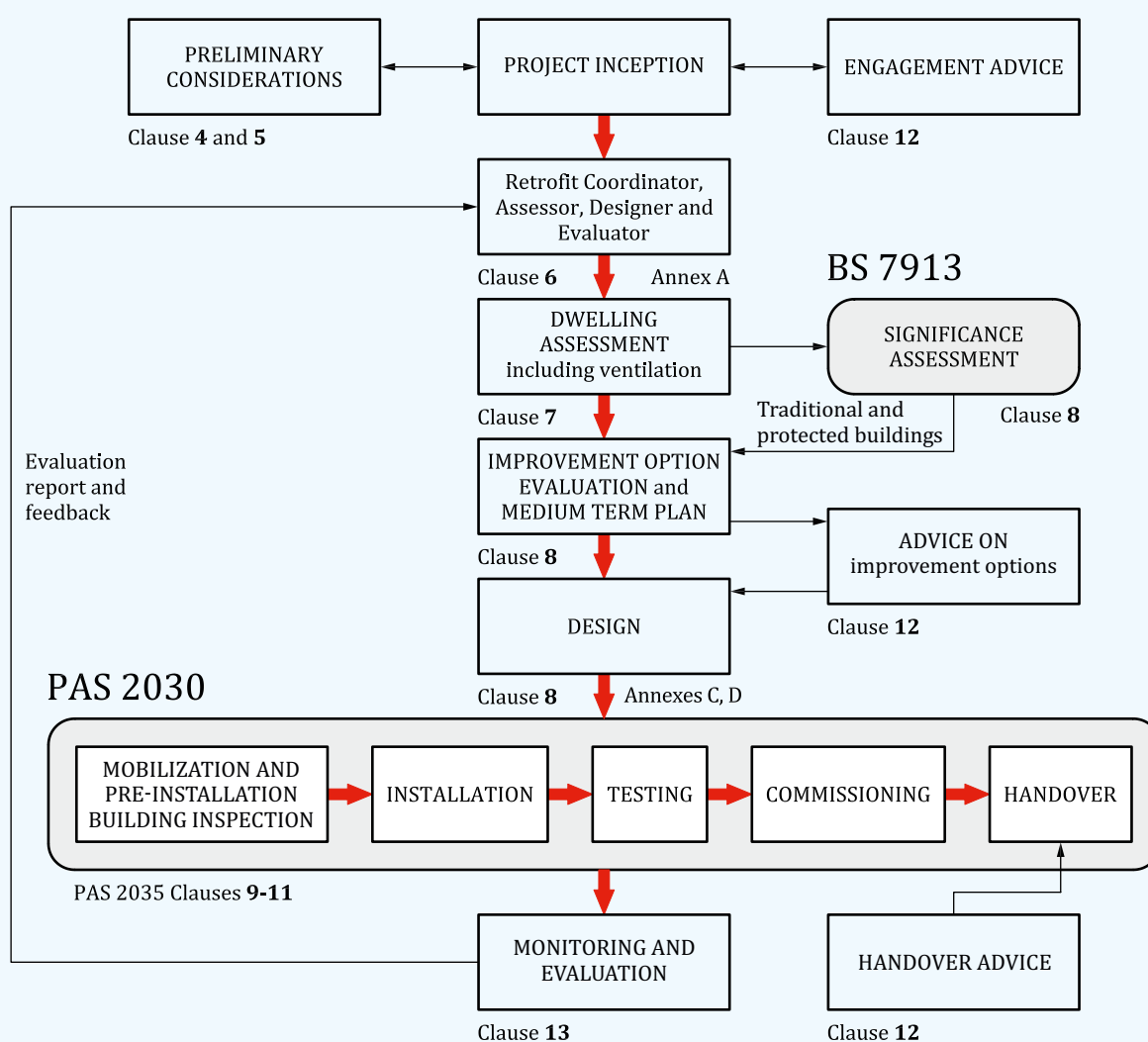
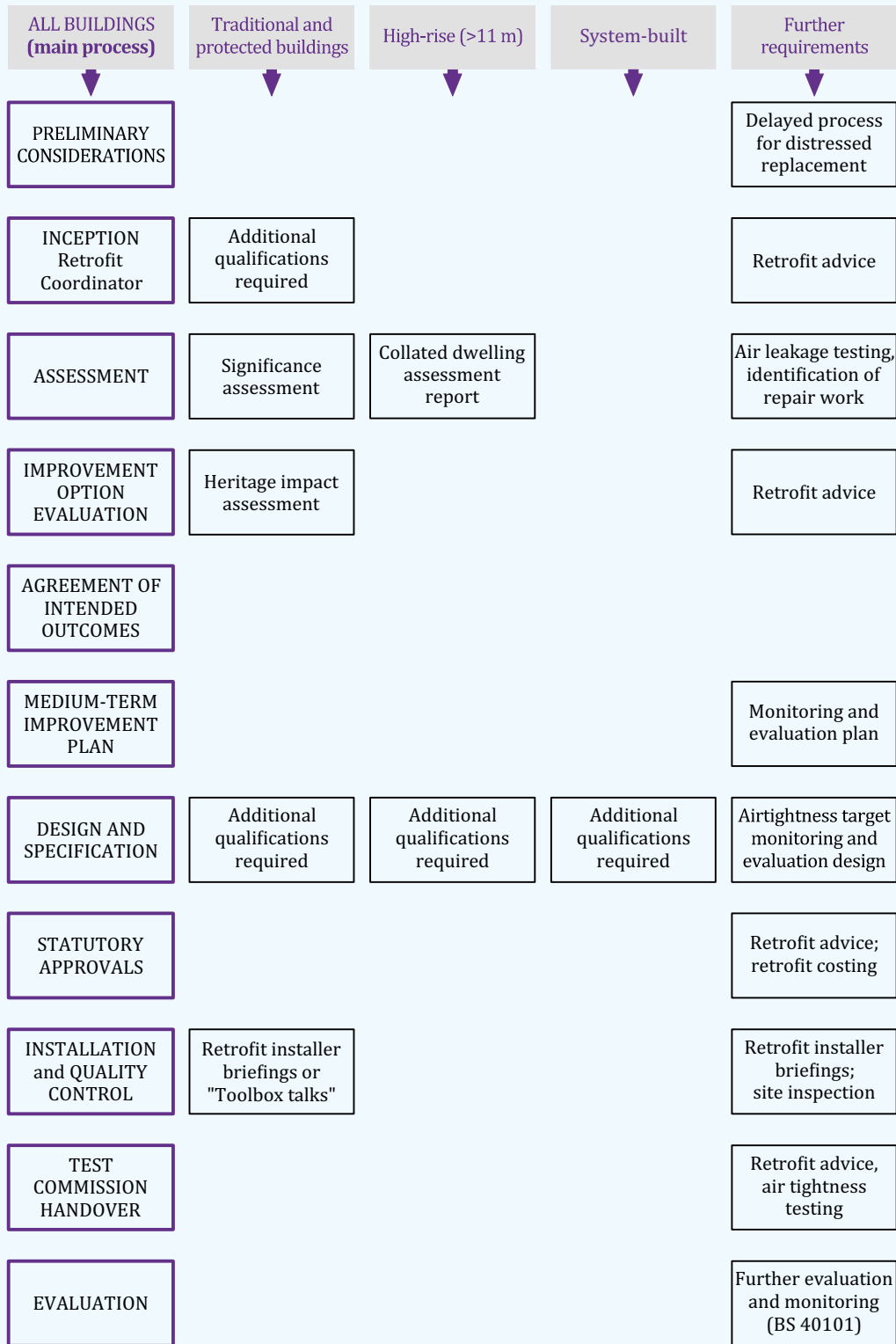


Figure 2 illustrates in more detail the process for different types of projects that users of PAS 2035 are expected to follow in order to comply with its requirements.

Figure 2 – Domestic retrofit process that users are expected to follow in order to meet the requirements of PAS 2035



NOTE 2 Figure 2 reflects only the requirements of PAS 2035. Other requirements might be part of the retrofit process as defined by UK building regulations or other statutory obligations.

1 Scope

This PAS specifies requirements for retrofit of dwellings, including:

- a) assessment of dwellings for retrofit;
- b) identification and evaluation of improvement options (energy efficiency measures, or EEMs);
- c) design and specification of EEMs (whether individual measures or packages of multiple measures); and
- d) monitoring and evaluation of retrofit projects.

This PAS covers EEMs that are intended to:

- 1) improve the insulation of the elements of the building fabric (external walls, roofs, floors, windows and doors) and reduce thermal bridging;
- 2) improve the airtightness of the building envelope;
- 3) establish a safe dynamic moisture equilibrium through each element of the building fabric;
- 4) improve the resilience of the building envelope in order to maintain the thermal properties of the building fabric and the capability of the building envelope to manage moisture in a manner suited to its construction;
- 5) reduce heat loss from ventilation with the use of high efficiency heat exchangers in a fully ducted ventilation system;
- 6) minimize the risks associated with vapour or other products, for example volatile organic compounds (VOCs), released within buildings subsequent to their airtightness being improved;
- 7) minimize the risks associated with overheating;
- 8) provide efficient heating and cooling systems with responsive, intelligent or “smart” controls, including systems that use low or zero carbon (LZC) technologies;
- 9) provide efficient water heating systems with responsive controls, including systems that use LZC technologies;
- 10) provide efficient fixed lighting, appliances and equipment with appropriate controls;
- 11) reduce electricity use and minimize internal heat gains, including systems that use LZC technologies;
- 12) provide on-site energy storage to improve the usefulness of energy generated by LZC technologies; and
- 13) reduce the impact of climate change on the building and the occupant.

Alongside the installation of EEMs to achieve some of the intended outcomes above, this PAS also covers the installation of:

- ventilation to achieve good internal air quality and minimize the risk of condensation;
- metering and monitoring systems to promote the efficient use of energy; and
- climate change adaptations needed to improve the resilience of the building to existing and/or future risk from climate change.

In addition to setting out requirements for the commissioning and handover of all of the above, this PAS specifies requirements for advising building occupants about improvement options appropriate to their homes, and the efficient and appropriate use and maintenance of their retrofitted homes, as well as for monitoring and evaluating retrofit projects when appropriate, and feeding back lessons learned to all parts of the supply chain, including the building occupants.

While the PAS 2035 process includes maintenance and repair, works that consist exclusively of maintenance and repair do not necessarily need to follow the full PAS 2035 process. This PAS does not apply to maintenance or repair of any element of an existing dwelling, or system installed in it, which does not involve improvement of the energy performance or ventilation of the dwelling, or a reduction of the carbon dioxide emissions associated with energy use in the dwelling. Nor does this PAS apply to “like for like” replacement of damaged or worn-out elements or systems that do not involve improvement of the energy performance or ventilation of the dwelling, or a reduction of the carbon dioxide emissions associated with energy use in the dwelling. This PAS does, however, apply to the distressed replacement of heating appliances, for which a specific process is outlined throughout.

***NOTE** Appropriate repair and maintenance of the building fabric can improve energy efficiency and is always the first step in energy efficiency improvements, even though it is not covered in this PAS. Otherwise, an unacceptable level of risk to the future condition of the building might be introduced.*

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes provisions, or limits the application, of this document²⁾. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Standards publications

BS 5250, *Management of moisture in buildings – Code of practice*

BS 7913, *Guide to the conservation of historic buildings*

BS 40101, *Building performance evaluation of occupied and operational buildings (using data gathered from tests, measurements, observation and user experience) – Specification*

BS EN 13141-1, *Ventilation for buildings – Performance testing of components/products for residential ventilation – Part 1: Externally and internally mounted air transfer devices*

BS EN 13141-4, *Ventilation for buildings – Performance testing of components/products for residential ventilation – Part 4: Aerodynamic, electrical power and acoustic performance of unidirectional ventilation units*

BS EN 13141-6, *Ventilation for buildings – Performance testing of components/products for residential ventilation – Part 6: Exhaust ventilation system packages used in a single dwelling*

BS EN 13141-7, *Ventilation for buildings – Performance testing of components/products for residential ventilation – Part 7: Performance testing of ducted mechanical supply and exhaust ventilation units (including heat recovery)*

BS EN 13141-8, *Ventilation for buildings – Performance testing of components/products for residential ventilation – Part 8: Performance testing of un-ducted mechanical supply and exhaust ventilation units (including heat recovery)*

BS EN ISO 14021, *Environmental labels and declarations – Self-declared environmental claims (Type II environmental labelling)*

PAS 2030, *Installation of energy efficiency measures (EEM) in existing dwellings – Specification*

Other publications

[N1] MICROGENERATION CERTIFICATION SCHEME (MCS). *Product standards*.³⁾

[N2] MICROGENERATION CERTIFICATION SCHEME (MCS). *Installer standards*.⁴⁾

[N3] HM GOVERNMENT. *The Building Regulations 2010 – Approved Document F: Ventilation – Volume 1: Dwellings*. London. 2021.

[N4] WELSH GOVERNMENT. *The Building Regulations 2010 – Approved Document F: Ventilation – Volume 1: Dwellings*. 2022 (for use in Wales).

[N5] SCOTTISH GOVERNMENT. *Building Standards Technical Handbook 2023: Domestic buildings*.⁵⁾

[N6] BUILDING CONTROL NORTHERN IRELAND. *Building Regulations (Northern Ireland) 2012 Guidance: Technical Booklet K: Ventilation*. Building Control NI, 2012.

[N7] BUILDING SERVICES RESEARCH AND INFORMATION ASSOCIATION. *Domestic ventilation systems*. Guide 46/2022. Bracknell: BSRIA, 2022.

[N8] BUILDING RESEARCH ESTABLISHMENT. *Assessing the effects of thermal bridging at junctions and around openings*. IP1/06. Bracknell: BRE, 2006.

[N9] CHARTERED INSTITUTION OF BUILDING SERVICES. *Design methodology for the assessment of overheating risk in homes*. TM59. London: CIBSE, 2017.

[N10] UK CLIMATE IMPACTS PROGRAMME (UKCIP).

[N11] BRITISH BLIND AND SHUTTER ASSOCIATION. *Guide to low energy shading*. Suffolk: BBSA, 2015.

[N12] CHARTERED INSTITUTE OF BUILDING SERVICES ENGINEERS. *Testing buildings for air leakage*. TM23. London: CIBSE, 2022.

[N13] BUILDING SERVICES RESEARCH AND INFORMATION ASSOCIATION. *Flexible ductwork*. BG 43/2013 Bracknell: BSRIA, 2006.

²⁾ Documents that are referred to solely in an informative manner are listed in the Bibliography.

³⁾ Available online at <https://www.microgenerationcertification.org/mcs-standards/product-standards>.

⁴⁾ Available online at <https://www.microgenerationcertification.org/mcs-standards/installer-standards>.

⁵⁾ Available online at <https://www.gov.scot/publications/building-standards-technical-handbook-2023-domestic/>.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1 client

property owner, householder, landlord and/or tenant of a dwelling that is subject to retrofit

NOTE 1 Sometimes also includes the funding body.

NOTE 2 In this PAS, the term “client” refers to the recipient of domestic retrofit work.

NOTE 3 There might be more than one client to consider as part of this PAS process.

3.2 climate change adaptation

process of adjustment to actual or expected climate and its effects in order to moderate harm or exploit beneficial opportunities

3.3 commissioning

activities that ensure that an installed retrofit measure, or a package of measures that form a retrofit design, operates within the boundaries and conditions of the design specification

3.4 conservation area

area of special architectural or historic interest, the character or appearance of which it is desirable to preserve or enhance.

3.5 conventional (construction)

masonry cavity wall construction (brick and/or block) with or without render, tile hanging or other external cladding

3.6 distressed replacement

fast-paced installation of an EEM

NOTE This is typically the replacement of heating and hot water in winter months, without which the living standards of the occupant are severely impacted.

3.7 dwelling

self-contained unit of accommodation, such as a house, flat or park home used by one household as a home

3.8 dwelling assessment

process of assessing the characteristics of an existing dwelling, including its local context, fabric, form, services, condition, heritage significance, ventilation, energy efficiency and occupancy, in order to provide information for the preparation of a retrofit design

3.9 energy efficiency measure (EEM)

planned work undertaken to improve the energy performance of a building by saving or generating energy

3.10 energy efficiency measure (EEM) product

item intended for installation in existing buildings, for the purpose of enhancing the energy efficiency of those buildings, that is not made available as an EEM system

3.11 energy efficiency measure (EEM) proprietary system

combination of products and materials together with any related installation method, design detailing, equipment requirements and performance objectives, placed on the market exclusively by a specific supplier, for installation in existing buildings for the purpose of enhancing the energy efficiency of those buildings

3.12 high-rise building

a building higher than 11 m or over four storeys in height above the ground

3.13 installation

location, placement and/or fixing of an EEM in, or connected to, an existing building, excluding any related work to enable the installation of the measure

3.14 installation location

building or group of buildings that are the subject of EEM installation(s)

3.15 installation method statement

definition of sequence of actions to be undertaken in installing one or more EEM products or systems in accordance with their specification, in a safe manner at a building

NOTE An installation method statement can be a single document prepared specifically for this purpose or could consist of a collection of documents, in the sequence of required application, contributing to the complete definition of the intended method.

3.16 Main Contractor

lead organization managing the retrofit delivery of EEMs to dwelling(s) or project(s), typically on multi-EEM or large-scale retrofits

3.17 Measures Interaction Matrix

chart that illustrates the ways in which measures interact in a domestic building and indicates action to be taken by the Retrofit Designer when developing the retrofit design

3.18 monitoring and evaluation

process by which the effectiveness of a retrofit project is measured and evaluated with reference to the intended and actual outcomes, in order to identify and correct problems and provide feedback to improve subsequent projects

3.19 operative

person employed by the Main Contractor or Retrofit Installer, either directly or under a subcontract arrangement, to undertake installation tasks on an EEM in accordance with the relevant installation method statement

NOTE Related requirements are given in PAS 2030.

3.20 pre-installation building inspection

inspection undertaken by or on behalf of, the Main Contractor or Retrofit Installer prior to commencement of installation to confirm that the EEM design provided by the Retrofit Designer is complete and can be fulfilled at the location specified

NOTE 1 Requirements on carrying out this inspection are given in PAS 2030.

NOTE 2 The inspection can show that the proposed installation does not result in non-compliance with statutory requirements and/or generally accepted industry good practice.

3.21 professional qualification

recognition of building-related knowledge and capability involving registration by a professional body, based on training and/or academic study to at least degree level

NOTE Such professional bodies include the Architects Registration Board (ARB), the Chartered Institute of Architectural Technologists (CIAT), the Royal Institution of Chartered Surveyors (RICS), the Chartered Institution of Building Services Engineers (CIBSE) and the Chartered Institute of Building (CIOB).

3.22 project

planned installation of EEMs in one or more dwellings following the complete PAS 2035 process with usually one Retrofit Coordinator and with a defined duration and budget

NOTE Some large-scale, multi-estate projects may have more than one Retrofit Coordinator.

3.23 protected building

building that is listed as of special architectural or historic interest, or located in a designated conservation area

3.24 Recognition of Prior Experience and Learning (RPEL)

process by which prior experience and learning is assessed against relevant criteria to provide evidence for credit towards a vocational qualification

3.25 Register of Regulated Qualifications

register of nationally accredited professional and vocational qualifications

NOTE This is maintained by Ofqual in England and by its equivalents in the devolved nations.

3.26 retrofit advice

advice given to a client or householder about retrofit process, the evaluation of improvement options, the selection of EEM's, the retrofit design, the operation and maintenance of installed measures, or how to operate a home in an energy efficient way after retrofit

3.27 retrofit assessment

survey, inspection and assessment of a building to collate information for a retrofit design

3.28 Retrofit Assessor

person qualified to carry out a retrofit assessment

NOTE See A.1 for details on the qualifications needed for this role.

3.29 Retrofit Coordinator

person qualified as a specialist retrofit project manager, taking overall responsibility for overseeing the assessment of dwellings, the identification, specification, inspection and evaluation of EEMs for installation at a given dwelling as a single project, and their subsequent monitoring and evaluation

NOTE See Clause 6 and A.2 for details on the qualifications needed for this role.

3.30 retrofit design

package of information prepared by a Retrofit Designer that determines the unique combination of EEM systems, products, and materials to be installed in a building, as well as their interrelationships, in order to achieve specified energy efficiency and other outcomes for that building

3.31 Retrofit Designer

person qualified to prepare a retrofit design

NOTE See A.3 for details on the qualifications needed for this role.

3.32 Retrofit Evaluator

person qualified to monitor and evaluate the effectiveness of a retrofit project and provide feedback to the client and/or the project team

NOTE See A.4 for details on the qualifications needed for this role.

3.33 Retrofit Installer

person or organization undertaking the physical placement of one or more EEM(s) in an existing building

NOTE 1 See PAS 2030 for further details.

NOTE 2 The Retrofit Installer is usually experienced in the installation of one or more EEMs and can be registered with the relevant certification body for each of those EEMs.

3.34 stage-by-stage

retrofit process where the whole-dwelling retrofit plan is not being implemented in one go

3.35 system-built dwelling

building of frame (timber, steel or concrete) and pre-fabricated panel (concrete or timber, or a combination) construction, or timber-framed construction with brick or stone external cladding

3.36 thermal bridge

area of the building envelope where the insulation is:

- a) discontinuous, thinner or has higher thermal conductivity than the adjacent insulation; or
- b) has reduced effectiveness due to the building geometry;

leading to locally increased heat loss and therefore locally reduced internal surface temperature, or in the summer months, a locally increased heat gain

3.37 thermal by-pass

unintended penetration or circulation of external air on the warm side of the insulation layer in a construction, rendering the insulation ineffective

3.38 toolbox talk

meeting of the Retrofit Coordinator with the Main Contractor or Retrofit Installer and installation operatives to explain the design intent and draw attention to key points

3.39 traditional construction

building with solid brick, stone or earth external walls, constructed with moisture-permeable materials and usually built prior to 1919, or pre-1919 timber-frame external walls with any infill

3.40 ventilation assessment

assessment of the adequacy of an existing ventilation system in a building that is to be retrofitted

NOTE See Annex C for the requirements on providing adequate ventilation.

3.41 ventilation upgrade

replacement or improvement of an existing ventilation system as part of a retrofit process

NOTE See Annex C for the requirements on providing adequate ventilation.

4 Guidance about retrofit building physics

4.1 General

4.1.1 Persons involved in domestic retrofit projects, including Retrofit Assessors, Retrofit Coordinators, Retrofit Designers and Retrofit Evaluators, should have working knowledge of building physics (also known as “building science”), appropriate to the nature and scale of the retrofit project(s) on which they work, and the types of buildings, with emphasis on the movement of heat, moisture and air through dwellings.

4.1.2 Occupants’ comfort, health and safety depend on control and management of the flows of heat, moisture and air through their homes, in order to maintain appropriate dynamic thermal and moisture equilibriums. The dynamic heat balance of a dwelling (i.e. the way in which heat losses are satisfied by heat inputs) is an important element of its energy efficiency. The moisture balance of a home is important to the maintenance of healthy internal conditions and the avoidance of fabric decay.

4.2 Building pathology

4.2.1 Building pathology is the process by which the history and condition of a building, and its suitability for improvement, are analysed systematically as part of its assessment for retrofit.

4.2.2 This type of analysis helps to establish the condition of the building and to identify defects and performance failures. It also establishes how defects have arisen and identifies the work that should be carried out not only to repair them and restore performance, prior to retrofit, but also to prevent them from recurring.

4.2.3 It is important when a dwelling is assessed for retrofit, and when improvement options are evaluated, that the dwelling is treated as a system comprising the building envelope (or building fabric), the building services (ventilation, heating, hot water, lights and appliances), any LZC technologies or “renewable energy systems”, and the occupants.

4.2.4 The occupants are key elements of the system because they:

- a) require certain conditions for comfort;
- b) operate energy-using lights and appliances;
- c) give off heat;
- d) produce moisture and carbon dioxide through respiration; and
- e) produce moisture through activities such as cooking, bathing and drying clothes.

4.2.5 Internal temperature and humidity are critical to comfort, and to managing the risk of internal surface condensation and mould growth. Managing the dynamic moisture equilibrium within and through the building envelope is critical both to maintaining internal air quality (IAQ) and to protecting the building fabric against moisture accumulation, rot, mould growth and decay.

4.2.6 Retrofit work designed to reduce heat loss from a dwelling, and/or reduce air infiltration and air leakage, in order to improve energy efficiency, might have unintended consequences for IAQ and for the movement of moisture through the building fabric, particularly in traditionally constructed buildings, and in non-traditional buildings constructed in the 1960s and 1970s.

4.3 Thermal models and calculations

4.3.1 Energy assessment models such as the Standard Assessment Procedure (SAP) and the Passive House Planning Package (PHPP) attempt to simulate whole-dwelling thermal performance, but most versions do not deal with moisture. Such models provide estimates of the energy performance of dwellings, based on limited amounts of data from surveys and assessments, but they inevitably involve a compromise between accuracy and functionality. More detailed and accurate predictions of energy performance require more complex simulation models that use large amounts of data sometimes measured from site, therefore these models should be considered for use on high-value and/or large-scale retrofit projects, or for projects that include bespoke and/or non-standard construction details, where a higher degree of certainty is required.

4.3.2 Retrofit Assessors, Retrofit Designers and Retrofit Coordinators should be familiar with the use of full SAP or PHPP software to support their work. Reduced Data SAP (RdSAP) software might be useful where detailed data are not available, and Retrofit Assessors are trained in its use, but users should be aware that RdSAP makes default assumptions about some aspects of existing dwellings. If RdSAP is used to support a retrofit assessment, then the data should be reviewed carefully, and preferably exported to Full SAP software.

4.3.3 Mathematical techniques are available for:

- calculating the thermal transmittances (U values) of building elements (e.g. floors, walls and roofs) from data on the thermal conductivities (λ values) of building materials when these are known;
 - assessing the risk of interstitial condensation within the construction of a building element;
- NOTE 1 In order to conform to BS 5250, the assessment of interstitial condensation (i.e. to BS EN ISO 13788) might not be sufficient as the basis for a moisture risk assessment for certain types of walls, e.g. solid walls with internal wall insulation (IWI) proposed in exposed locations.*
- calculating linear thermal transmittances (ψ values) and critical temperature factors (f_{Rsi}) at the corners, junctions and edges of building envelopes that are identified as “thermal bridges”, i.e. places where the envelope of insulation is either thinner or discontinuous;
 - calculating the component of a building’s overall thermal transmittance that is due to thermal bridging (γ value);
 - calculating overall heat losses from a dwelling due to conduction, convection (i.e. air leakage), radiation, deliberate ventilation and the inefficiency of heating system(s);
 - calculating overall heat gains in a dwelling from occupants, cooking, hot water, lighting, the use of appliances and solar gains through glazed openings;
 - calculating the whole-dwelling ventilation rate required to maintain good IAQ and minimize the risk of condensation and mould growth;
 - assessing the risk of surface condensation and mould growth using temperature factors and data on internal and external temperature and relative humidity to calculate vapour pressure differentials;
 - assessing the long-term performance of moisture, in both liquid and vapour forms, through a building element; and

NOTE 2 Confidence in such assessments can be improved through the measurement of site-specific material properties and/or monitored performance data.

- calculating internal daylight levels from data about the sizes, locations and orientations of windows, and any local shading, and assessing requirements for artificial lighting.

4.3.4 Testing and investigation techniques are available for:

- a) measuring heat losses through individual building elements;
- b) measuring heat loss through the whole building envelope;
- c) assessing the airtightness (or “air permeability”) of a building envelope;
- d) identifying air infiltration and air leakage points;
- e) measuring the moisture profiles of building fabric; and
- f) assessing heat loss through building elements through thermography, including the identification of thermal bridges and insulation discontinuities.

4.3.5 There are also techniques for:

- a) monitoring overall energy use in dwellings, from utility meters;
- b) monitoring the energy use of individual systems, using sub-meters;
- c) monitoring internal temperatures, using sensors and loggers;
- d) monitoring internal relative humidity, using sensors and loggers;
- e) monitoring interstitial temperature, relative humidity and/or material moisture content, using sensors and loggers; and
- f) monitoring and sampling IAQ using sensors and loggers (e.g. carbon dioxide concentrations, VOCs).

4.3.6 Retrofit Assessors, Retrofit Designers, Retrofit Coordinators and Retrofit Evaluators should be familiar with the relevant techniques described or listed in 4.3.3. Retrofit Coordinators and Retrofit Evaluators should be able to apply the techniques listed in 4.3.4 and 4.3.5, as appropriate, and should keep themselves updated about new and emerging monitoring techniques.

4.3.7 Many academic, vocational training and Continuing Professional Development (CPD) courses deal with thermal aspects of building physics. More detailed explanations of aspects of retrofit building physics are provided in the following:

- a) The National Standards Authority of Ireland’s *Code of practice for the energy efficient retrofit of dwellings*; and
- b) BSI’s *Moisture in buildings: An integrated approach to risk assessment and guidance* [5].

5 Guidance about approaches to retrofit

5.1 Main Contractor and Retrofit Installer

The term Main Contractor is defined in 3.16 and Retrofit Installer in 3.33. Not all projects compliant with this PAS will have a Main Contractor, but all projects should have a Retrofit Installer who complies with PAS 2030. In some projects, the Main Contractor and the Retrofit Installer might be the same organization. Compliance with this PAS is the responsibility of the PAS Certification holder, who might be the Main Contractor. However, where there is no Main Contractor, this responsibility falls to the Retrofit Installer.

5.2 Retrofit performance considerations, standards and constraints

5.2.1 Domestic retrofit projects range from the installation of single improvement measures to whole-dwelling projects involving multiple measures installed at the same time. Both types of project should be seen in the context of national emissions reduction targets: by 2050 (and 2045 in Scotland), it is necessary to reduce the average greenhouse gas (principally carbon dioxide) emissions associated with energy use in our homes by 100% compared with current emissions, through a combination of improved efficiency and low- or zero-carbon energy supply. The Climate Change Committee sets “carbon budgets” under the Climate Change Act 2008 [1], and the Government’s Net Zero Strategy [2] includes a commitment to improvements in Energy Performance Certificate (EPC) scores in homes (where reasonably practicable) and to support new green skilled jobs.

5.2.2 It is not appropriate to attempt to achieve the same level of emissions reduction for every domestic building, because the same target applied to every dwelling might result in significant damage to some buildings, rendering them unhealthy to live in or possibly even uninhabitable, and potentially damaging our architectural heritage. An average emissions reduction target might be appropriate, but greater reductions need to be made where they are technically feasible and safe, in order to compensate for the constraints on improvements to traditional buildings. In each case, protecting and improving occupants’ health, well-being and comfort should be prioritized, then energy use and emissions should be minimized within the constraints of protecting the building and its heritage values.

5.3 Medium-term improvement plans

5.3.1 For any dwelling that is proposed for retrofit, the scope for improving energy efficiency and reducing emissions should be taken into account, bearing in mind the need for significant emissions reduction. The overall scope for improvement should be identified, even if only limited improvements can be undertaken in the short term. One way of doing this is to prepare a “medium-term improvement plan” for every dwelling (or in the case of managed housing, for every dwelling type) for implementation over a period of time.

5.3.2 The purpose of a medium-term improvement plan is to guide the staged or phased improvement of a dwelling by identifying the improvements that are needed and an appropriate order for their implementation, and by highlighting critical interactions between them. Such plans should be updated to respond to changes in standards or the availability of new technologies, and to record improvements as they are made.

5.3.3 The preparation of a medium-term improvement plan should be the responsibility of the Retrofit Coordinator (see 8.1), working in collaboration with the Retrofit Designer and the client for the project.

5.4 Retrofit at scale

5.4.1 Large-scale retrofit programmes are likely to become more common and are often driven by the objective of alleviating fuel poverty, as well as improving energy efficiency and reducing emissions. There are two types:

- a) programmes that seek to install a single improvement measure in more than one dwelling, irrespective of their locations, to make incremental improvements in performance across the housing stock because of time and budget constraints, the scope for adequate assessment of dwellings prior to improvement is often reduced, so there might be a risk of technically or architecturally inappropriate measures being installed. Risk assessment and management techniques should be carried out in accordance with BS EN IEC 31010; and

- b) programmes that seek to install more than one measure in more than one dwelling in defined areas, or blocks, to make more significant improvements in performance. Areas of focus might be estates owned by housing organizations, local authority areas where there is fuel poverty, or whole cities. Assessments, improvement options evaluation and medium-term improvement plans can be focused on dwelling types, rather than on individual dwellings, in order to identify generic solutions and economies of scale. This allows retrofit design based on dwelling types to commence before all assessments are complete. Improvement options evaluation and medium-term improvement plans for dwelling types can be modified for individual dwellings, because very few homes are exactly the same, even those of superficially similar appearance. PAS 2035 requires that every dwelling has an individual retrofit assessment, improvement options evaluation and medium-term improvement plan prior to the completion of the retrofit design package. Where there are traditional buildings in this type of large-scale retrofit, using the “dwelling type” approach to advance the retrofit design is less useful since there is likely to be more variation between dwellings.

NOTE The Social Housing Decarbonisation Fund (SHDF) is an example of this type.

5.4.2 Retrofit of multiple dwellings within the same building have their own challenges, especially when there are multiple owners. CWA 17382 gives guidance on sustainable energy retrofit process management for multi-occupancy residential buildings with owner communities. Where blocks of multiple dwellings are undergoing a fabric improvement, this might require a whole-block assessment and a whole-block retrofit design, as well as individual dwelling assessment and designs which make up the complete design package.

5.4.3 There is a risk of complacency in the specification, design and installation of EEMs in multiple similar dwellings, which can lead to poorly designed and executed works being repeated across many dwellings. Dwelling-specific checks might need to be put in place to verify that the retrofit designs are suitable for each dwelling and that the installation of the details meets the desired quality standards.

5.5 Fabric first

5.5.1 Whatever the scale of retrofit, a technically sound and usually cost-effective approach is the one known as “fabric first”, which should always be considered when a retrofit plan is formulated. This approach prioritizes improvements in five stages.

- a) Bring the building fabric into good repair by dealing with defects that inhibit energy efficiency and compromise improvement measures. Deal with water penetration and damp (so that the building fabric is properly dried out) and with structural defects (e.g. cracks) and poor pointing of masonry.
- b) Implement “low hanging fruit” measures that are low cost and easy to install, e.g. energy efficient lighting, basic heating controls, better control settings.
- c) Improve the building fabric by means of insulation and airtightness measures, and by minimizing thermal bridging, to reduce heat losses and reduce the demand for heat and the required capacity of the heating system. When the insulation and airtightness of the building fabric are improved, adequate ventilation should be maintained.
- d) Satisfy the remaining heat demand as efficiently as possible using efficient heating technology and responsive, intelligent or smart controls.
- e) Use LZC “renewable” energy technologies to reduce emissions further and “top up” the performance of the dwelling to the target level.

5.5.2 The existing building fabric should be as energy efficient as possible before spending resources on other measures. Subsequently, because insulation measures are generally among the most cost-effective and long-lasting, and thus the best investment, insulation is usually the most appropriate next step. Insulating the fabric first also reduces the required capacity and cost of the heating system. The heating system usually has a shorter life than the improved building fabric (typically 15 years compared with possibly 60 years), so a dwelling might have four heating systems during the life of the installed insulation. LZC systems, such as solar water heating (also known as “solar thermal”) and solar photovoltaic systems are the final step because they are relatively expensive (often requiring subsidy), and their capacity is often limited by available space (e.g. on the roof). Most UK dwellings cannot be heated exclusively by renewable energy systems unless they are first insulated and the building services efficiency is improved to reduce the remaining energy demand so that LZCs can make a significant contribution.

5.5.3 Although “fabric first” is often a cost-effective approach, sometimes other issues dictate different priorities. For example, a worn-out boiler should be replaced, even if insulation cannot be afforded (but note that when the insulation is eventually installed the boiler will be over-sized).

5.5.4 Existing homes should make use of low-carbon heating. These technologies should be considered when the current heating system needs replacement and/or after fabric upgrades.

5.5.5 Often, architectural heritage considerations limit or rule out many insulation options, some of which are irreversible, leaving scope only for using measures that can be reversed, improving the building services or installing LZCs. In the case of older, traditionally constructed or protected buildings, a risk-based approach to the selection of improvement options is usually appropriate.

5.6 Concentrate on the interfaces

5.6.1 “Concentrate on the interfaces” is a way of approaching retrofit that complements and enhances “fabric first”. It acknowledges that retrofit projects often go wrong because of poor attention to the corners, junctions and edges of building elements (where insulation and air barriers should be continuous) and the interfaces between the building fabric, the building services and the occupants. For example, heating output should be matched to heat loss, ventilation should be matched to the air permeability of the building fabric, and occupants should be able to make efficient use of systems installed in their homes.

5.6.2 “Concentrate on the interfaces” is an approach that focuses the attention of Retrofit Designers and Main Contractors or Retrofit Installers on critical factors. It is the basis of much of the guidance and some of the requirements specified in this PAS.

5.7 Retrofit advice

5.7.1 Domestic retrofit projects should always include the delivery of retrofit advice to the occupants of the dwelling(s), at appropriate times, by a qualified Retrofit Assessor, Retrofit Coordinator, Retrofit Designer, Main Contractor or Retrofit Installer. There is evidence that where retrofit projects do not include advice, the intended outcomes are often only partially achieved, particularly with respect to fuel cost savings and reductions in the carbon dioxide emissions associated with energy use.

5.7.2 Retrofit advice should be delivered at several stages of a retrofit project, and the topics covered by advice should be appropriate to the scope of the improvement work and the stage at which it is delivered. Retrofit advice should be delivered in accordance with the requirements in Clause 12.

5.7.3 In scale- or area-based local retrofit, appropriate retrofit advice can also be delivered through peer learning through web forums, open homes events and community meetings.

6 Requirements for retrofit coordination

6.1 Retrofit Coordinator

6.1.1 Every domestic retrofit project shall be coordinated by a Retrofit Coordinator.

6.1.2 A Retrofit Coordinator shall be a person qualified in accordance with Annex A.

***NOTE** Retrofit Coordinators are qualified to provide end-to-end project coordination (i.e. from the inception of a retrofit project to handover and beyond, including undertaking basic evaluation work), and to identify, assess and manage the technical and process risks associated with domestic retrofit projects.*

6.1.3 The role of the Retrofit Coordinator shall be to identify, protect and document both the client's interest and the public interest. The Retrofit Coordinator shall be responsible for overseeing the project from inception to completion; this includes the dwelling assessment (Clause 7), the retrofit design (Clause 8), installation (in accordance with PAS 2030), through to post-completion evaluation (Clause 13).

***NOTE** There might be more than one client to consider. In cases where this leads to conflict of interest, the Retrofit Coordinator should state which takes precedence and why. A separate Retrofit Coordinator is not required for each client.*

6.1.4 The Retrofit Coordinator might be employed by the client or by an organization commissioned to undertake assessment, design, installation, commissioning or monitoring and evaluation work (or a combination of these). Where a Retrofit Coordinator is employed by an organization commissioned to undertake assessment, design, installation, commissioning or monitoring and evaluation, this shall be declared to the client. The client shall also be made aware of the Retrofit Coordinator's role to act in their interests.

6.1.5 A Retrofit Coordinator shall be involved in a retrofit project from inception (prior to the assessment) through all stages outlined in this PAS. For the distressed replacement of a heating appliance, the Retrofit Coordinator shall be involved as soon as possible in the process.

6.2 Establishing intended outcomes

6.2.1 At the outset of the project (or later, in the case of the distressed replacement of a heating appliance), the Retrofit Coordinator shall consult the client and agree and record the intended outcomes of the project. Intended outcomes shall take into account the initial condition of the building(s) and be expressed in terms of one or more of the following:

- a) reductions in energy use;
- b) reductions in energy costs and/or alleviation of fuel poverty;
- c) reductions in emissions associated with energy use;
- d) improvement in internal comfort;
- e) improvement of IAQ;
- f) elimination of condensation, damp and mould;
- g) reducing the risk of overheating;
- h) improvement in energy rating (e.g. SAP);
- i) meeting a performance standard (e.g. Nearly- Zero Emission Buildings (NZEB) or Passive House EnerPHit);
- j) improving the usefulness or sustainability of the building;
- k) protecting the building against decay or deterioration;
- l) improving the management of moisture within the building;
- m) improving resilience against flood risk;
- n) improving the resilience of dwellings to existing and/or future risks from climate change;
- o) protection or enhancement of architectural heritage; and
- p) integration of energy efficiency measures with other improvements, e.g. extension, loft conversion or general refurbishment.

***NOTE 1** A non-exhaustive list could include the public, employers' and clients' interests.*

***NOTE 2** When establishing intended outcomes, the Retrofit Coordinator should consider how these might be verified during the monitoring and evaluation phase, and whether pre-retrofit testing is required to establish the starting point, and the timescales that might be required in order to do this. To be most effective, intended outcomes should ideally be specific, measurable, achievable, relevant and time-bound.*

7 Requirements for whole-dwelling assessments

7.1 Whole-dwelling assessments

7.1.1 The Retrofit Coordinator shall confirm that every dwelling that is to be subjected to energy retrofit work is first assessed by a Retrofit Assessor, to provide information about the dwelling for use by a Retrofit Designer (see Clause 8).

NOTE Retrofit Coordinators should advise on Retrofit Assessors with the appropriate qualifications (at a minimum, as per Annex A) and experience for the type and complexity of the building to be assessed.

7.2 Distressed replacement of heating appliances

7.2.1 For a distressed replacement of a heating appliance, the whole-dwelling retrofit assessment to identify further measures shall be completed as soon as possible during or after the retrofit process.

7.3 Retrofit Assessor

7.3.1 A Retrofit Assessor shall be a person trained and qualified in accordance with Annex A.

7.3.2 The assessment shall include:

- a) location, orientation, and a description of the attachment of the dwelling to other dwellings or buildings;
- b) an appraisal of the dwelling's heritage, architectural features, structure, construction and condition, and the installed building services (ventilation, heating, hot water and lighting), in sufficient detail to establish the suitability of the dwelling for improvement;
- c) identification of any constraints imposed by the local planning authority (e.g. requirements for planning permission, listing of a building as being of special architectural or historic interest, conservation area constraints, tree preservation orders);
- d) identification of the location and severity of any existing construction defects or structural defects or leaks, and of any condensation and/or mould growth in the dwelling;

NOTE 1 This might require the use of test equipment or invasive assessments, including opening up of the building fabric.

NOTE 2 A small amount of condensation in bathrooms around sinks or showers, or around the edge of windows in extreme weather conditions, is normal.

NOTE 3 Guidance for assessment of traditional buildings is given in Investigation of moisture and its effects in traditional buildings [6].

NOTE 4 Guidance for diagnosis of dampness problems in existing buildings is given in BS 5250:2021, Annex C.

- e) identification of any EEM already installed or proposed;
- f) an inspection and review of the existing ventilation following the checklist provided in Table C.1. In addition:
 - 1) record the position and type of any fans (e.g. intermittent, continuous mechanical extract ventilation (MEV) – centralized or de-centralized, mechanical ventilation heat recovery (MVHR), single room heat recovery ventilators (srHRV), positive input ventilation (PIV)), along with make and model reference, where possible. If not possible, the reasons for this shall be included in the record;
 - 2) record the size and location of all background ventilators where present;
 - 3) any functional testing shall follow the process provided in the relevant devolved nation ventilation standards ([N3], [N4], [N5], [N6]) using procedures specified in BSRIA guidance [N10] for fan measurements. Air flow rates measured to be less than the minimum requirements set out in the relevant devolved nation ventilation standards ([N3], [N4], [N5], [N6]) shall be reported as part of the assessment.
- g) an appraisal of the dwelling's construction in sufficient detail to establish the main materials, thermal transmittances (U -values) and moisture properties of the main building elements (exposed floors, walls and roofs) and the suitability of the dwelling for improvement;

NOTE 5 Any intermittent or continuous extract ventilation fans should be checked in accordance with BSRIA guidance [N7] so that they are providing adequate air movement, and any incidence of inadequate air movement should be reported as part of the assessment.

NOTE 6 This might require the use of test equipment or invasive assessments, including opening up of the building fabric.

NOTE 7 In the case of a building containing multiple dwellings (e.g. a high-rise residential block), it might be sufficient to test a sample of the dwellings, including an example of each dwelling type, in the building.

NOTE 8 For traditionally constructed buildings, it might not be appropriate to accept the default U-values offered by RdSAP software; instead, it might be necessary to establish details of the construction in order to calculate or measure U-values.

- h) a measured survey to establish the overall dimensions of the dwelling's heat loss envelope (including any basements and attics), the dimensions of all building elements (exposed floors, external walls, roofs, etc.), the dimensions of all window and door openings, and to show the relationship of elements of the thermal envelope to one another at corners, junctions and within openings;

NOTE 9 For example, the position of a window within a wall is important, as this governs the thermal bridging around the window and impacts on the retrofit design if it includes wall insulation.

- i) identification of constraints imposed by the site, e.g. elevation and exposure (to sun, wind and rain, major roads and industrial activity), access, party walls, rights of light, consideration of adjoining properties;
- j) identification of the installed building services (ventilation, heating, hot water and lighting systems and their controls), the age and service history (where available), the locations of the equipment, the areas served; and confirmation that the systems are working correctly (or otherwise);
- k) an appraisal of occupancy, including the number of occupants and any special considerations such as the presence of vulnerable persons, e.g. children, elderly people or people with disabilities; and
- l) additional information that might have an impact on the retrofit project now and in the future, including but not limited to environmental risks, such as noise, air pollution or flooding, and climate change-induced environmental risks, such as increased flooding, extreme weather conditions, overheating and increased relative humidity.

NOTE 10 If it has been identified that the property is in a flood risk area, then an assessment by a property flood resilience surveyor should be included to identify what measures are suitable for the property, and whether any mitigation measures are required.

NOTE 11 Where invasive tests (e.g. pull-out tests to establish suitability for proposed fixings) are appropriate, then the retrofit design can specify that they be undertaken.

NOTE 12 For some buildings, particularly where the installation of EEMs is likely to be constrained, the Retrofit Coordinator might find it beneficial to undertake an initial air leakage assessment to focus on areas of improvement in airtightness as part of the retrofit design.

NOTE 13 If the Retrofit Coordinator chooses to undertake additional pre-retrofit monitoring, this should be in accordance with BS 40101 for Preliminary Evaluation (or Light building performance evaluation (BPE) or Standard BPE) to inform the retrofit design. For clarity, the requirements of BS 40101 Preliminary Evaluation are predominately satisfied by the process outlined in 7.3.2. Additionally, an occupancy survey would need to be distributed to residents, collection of 12 months' historic energy consumption data on individual properties, or a 10% sample of a portfolio of properties.

NOTE 14 Where further monitoring and evaluation is conducted under this standard (following retrofit), it is beneficial to compare post-retrofit energy consumption and occupant survey results to those obtained during the retrofit assessment. This process is beneficial to identify:

- a) specific elements of the retrofit that are performing satisfactorily;
- b) specific elements of the retrofit that are under-performing; and
- c) other objectives for further retrofit work (including any updates to the medium-term improvement plan).

7.3.3 The data collected in accordance with 7.3.2 shall be used to estimate annual fuel use, fuel costs and carbon dioxide emissions, under actual occupancy (where data is available) or standard occupancy. The Retrofit Assessor, Retrofit Coordinator or Retrofit Designer shall use a recognized domestic energy model, such as RdSAP, SAP or PHPP.

7.3.4 If the dwelling to be assessed is of traditional construction, an assessment of significance shall also be carried out in accordance with BS 7913.

NOTE A simplified version of the BS 7913 significance assessment is given in Annex E.

If the dwelling to be assessed is a protected building, or forms part of a protected building, the assessment shall also be carried out in accordance with BS 7913 and shall include:

- a) an assessment of the significance of the building as defined in BS 7913; and
- b) at the Retrofit Coordinator's discretion, where the suitability of proposed improvement measures are outside of their competence, they should seek outside professionals such as a structural engineer, building surveyor or architect with historic building and retrofit experience to report on the recommendations.

7.4 Reporting the assessment and handing over assessment data

7.4.1 The whole-dwelling assessment, including the ventilation assessment, shall be recorded and reported to the Retrofit Designer, including any RdSAP, SAP or PHPP data file and a photographic record of all the recorded features of the building and of any identified defects.

7.4.2 Where the assessment has identified construction defects or structural defects or leaks, or condensation and/or mould growth in any dwelling(s), the report shall include identification of such defects in two categories:

- a) defects that need to be repaired before any retrofit work can proceed; and
- b) defects that are recommended but not an essential prerequisite to retrofit.

7.4.3 The Retrofit Coordinator shall confirm with the Retrofit Designer that the information included in the assessment report is sufficient for the preparation of a retrofit design in accordance with Clause 8.

7.4.4 If the information in the assessment is not sufficient to provide the basis of a retrofit design, the Retrofit Designer shall identify any missing information, which the Retrofit Coordinator shall arrange for the Retrofit Assessor to collate and include in an updated assessment report.

***NOTE** If required by the certification body, the Retrofit Assessor can upload the final assessment report, the RdSAP, SAP or PHPP data file and photographic records of the assessment to the TrustMark "data warehouse" for quality assurance purposes.*

7.4.5 For large-scale retrofit projects (see 5.4), an assessment of every dwelling shall be undertaken and handed over to the Retrofit Designer prior to the completion of the retrofit design package.

***NOTE** Although a retrofit assessment is required for every dwelling, it may be collated into a single document for dwellings of the same archetype with reporting by exception for any differences in assessment on individual dwellings.*

8 Requirements for retrofit designs

NOTE 1 For guidance on retrofit designs at scale, see 5.4.

NOTE 2 The document Guidance on extending the roof line on domestic properties to ensure sufficient overhang to accommodate external wall insulation [7] contains design information that may be useful to the Retrofit Designer for external wall insulation projects.

8.1 Improvement options evaluations and medium-term improvement plans

8.1.1 For every dwelling or dwelling type (see 8.1.2) included in a retrofit assessment, before the retrofit design is started, the Retrofit Coordinator shall carry out an improvement options evaluation to identify an appropriate package of EEMs. The evaluation shall make use of the RdSAP, SAP or PHPP data file(s) provided as part of the dwelling assessment(s), and shall include calculation of:

- a) the simple payback period of the capital cost of each candidate EEM in fuel cost savings to occupants if installed on its own;

NOTE 1 Simple pay-back (in years) is the capital cost of the EEM or package of EEMs divided by the estimated annual fuel cost savings. It is acknowledged that any person or organization incurring the capital cost might be different from those benefitting from the fuel cost savings.

- b) the carbon cost-effectiveness of each candidate EEM if installed on its own; and

NOTE 2 Carbon cost-effectiveness is the lifetime cost of the EEM or package of EEMs (i.e. capital cost less annual savings over the estimated life of the EEMs in years) divided by the lifetime reduction of carbon dioxide emissions (i.e. annual reduction multiplied by estimated life in years).

- c) the simple payback and carbon cost-effectiveness of any suggested or proposed package of EEMs.

8.1.2 For large-scale retrofit projects (see 5.4), while improvement options evaluations of dwelling types are required before the retrofit design is started (8.1.1), an improvement options evaluation for every dwelling shall be undertaken prior to the completion of the retrofit design package.

8.1.3 When calculating the simple payback and carbon cost-effectiveness of improvement measures and packages of measures for the improvement options evaluation, the Retrofit Coordinator shall:

- a) use capital cost rates for measures that are approved or recommended by an independent body, such as the Energy Saving Trust, and apply them to the relevant areas of the dwelling(s) for which they are being evaluated (taken from the current version of SAP or PHPP assessment data) in order to establish capital costs;
- b) use the actual fuel costs (i.e. tariffs) applicable to the dwelling, if available; otherwise, use the national rolling average fuel costs embedded in the current version SAP energy rating;
- c) use the carbon dioxide emissions factors embedded in the current version SAP energy rating, or in the PHPP; and

NOTE 1 The SAP energy rating and the PHPP carbon dioxide emissions factors should not be mixed.

- d) adjust the calculation to allow for the pattern(s) of occupancy of the dwelling(s) (e.g. by entering actual occupancy data into the software), unless the occupancy pattern(s) are unknown, in which case the current version SAP standard occupancy is assumed.

NOTE 2 Capital costs used in the improvement option evaluation should be dwelling specific. Typical "per dwelling" capital costs of improvement measures should not be used, even if they are differentiated by dwelling type. Deemed savings associated with measures and dwelling types should not be used.

8.1.4 The Retrofit Coordinator shall prepare a tabular summary report of the improvement options evaluation and identify a recommended package of appropriate EEMs to form the basis of a medium-term improvement plan for every dwelling in accordance with 8.1.5 and 8.1.7.

NOTE If a medium-term improvement plan already exists for the property, then the Retrofit Coordinator should review and update this plan.

8.1.5 The whole-dwelling scope for improvement in energy efficiency for each dwelling shall be identified, even if only limited improvements can be undertaken in the short term. A medium-term improvement plan shall be prepared for every dwelling.

8.1.6 The Retrofit Coordinator shall prepare a monitoring and evaluation plan that is appropriate for all proposed measures in the medium-term improvement plan. At a minimum, this shall include an outline of the basic evaluation to be undertaken at the end of each stage of the retrofit.

NOTE Further guidance on monitoring and evaluation is given in BS 40101.

8.1.7 A medium-term improvement plan shall:

- a) identify constraints imposed by the history, construction, architectural character and setting of the building, and by its pattern of use;
- b) identify the set of improvement measures necessary (including EEM and enabling works) to achieve an appropriate target improvement in energy efficiency and reduction of the emissions associated with energy use, without compromising the comfort and health and safety of the occupants, or the integrity of the building;
- c) identify potential interactions between measures to ensure a whole-dwelling approach is followed, and avoid thermal bridging and other unintended consequences;
- d) identify an appropriate order in which the identified measures are to be installed;

NOTE Bearing in mind that some measures are best installed together, and that the installation of some measures might preclude the later installation of other measures (or make subsequent installation more difficult).

- e) include a monitoring and evaluation plan, as outlined in 8.1.6; and
- f) be presented in a format that allows it to be updated as work proceeds, and revised as new knowledge and new materials, products or technologies for energy efficiency become available.

8.1.8 The Retrofit Coordinator shall review the report of the improvement options evaluation, the recommended package(s) of EEMs, and the medium-term improvement plan(s) with the client(s) for the project and agree the scope of the project, the intended outcomes and appropriate energy performance target(s) for the improved dwelling(s), and the budget.

8.2 Retrofit designs

8.2.1 The Retrofit Coordinator shall verify that the EEMs to be included in each domestic retrofit project are included in the design and specification (hereafter referred to as the "retrofit design") prepared by a Retrofit Designer.

8.2.2 A Retrofit Designer shall be trained and/or qualified in accordance with Annex A.

8.2.3 Prior to undertaking the design and specification of retrofit work, the Retrofit Designer shall verify that they are in possession of a retrofit assessment conforming to Clause 7 for the relevant dwelling or dwelling type, prepared by a Retrofit Assessor, on the basis of which the retrofit design shall be prepared.

8.2.4 The Retrofit Designer shall review the assessments(s) to confirm that the information included in the assessment report is sufficient for a retrofit design, conforming to Clause 8, to be prepared.

8.2.5 If the information in the assessment(s) is not sufficient to provide the basis of a retrofit design, the Retrofit Designer shall identify any missing information and report to the Retrofit Coordinator, who shall arrange for the Retrofit Assessor to collate the required information and include it in an updated assessment report in accordance with Clause 7.

8.2.6 The Retrofit Designer shall review the report of the improvement options evaluation, the medium-term improvement plan and the technically appropriate measures with the client(s), and agree the measures to be applied to each dwelling included in the project.

8.2.7 The Retrofit Coordinator shall advise the client on the need for any statutory, health and safety or ecological approvals for the proposed retrofit work, and shall then either:

- a) make applications for any necessary statutory approvals, and negotiate them with the appropriate authorities, on behalf of the client; or
- b) cooperate with the client or any other persons (e.g. a planning consultant, an architect or the Main Contractor or Retrofit Installer) appointed to make applications for and negotiate statutory approvals, including providing information about the retrofit assessment and the retrofit design to support the applications.

NOTE Attention is drawn to planning approval, listed building consent, party wall notices or approval under the Building Regulations [8]

8.2.8 The Retrofit Designer shall prepare design and specification information about the EEM or package of EEMs proposed for the dwelling(s), including materials, products, processes and standards, as appropriate, and in sufficient detail for contractors and installers to work from, taking into account:

- a) the condition of the existing building, including the need to repair any structural defects and address causes of damp or water ingress into building fabric prior to the installation of retrofit measures;

- b) the agreed scope of the project, the intended outcomes and any agreed performance targets for the dwelling(s), and the budget;
- c) the information in the report(s) of the assessment(s) of the dwelling(s);
- d) any conditions imposed by the local planning authority or the building control body as part of a statutory approval; and

NOTE Conditions imposed by the local planning authority, or the building control body might not be known for some weeks after the applications described in 8.2.7 are made.

- e) the assessment of any existing ventilation and any consequent requirement to upgrade it.

8.2.9 The Retrofit Designer shall confirm that the specified materials and products are compatible with the building(s) and with each other. The design and specification shall be consistent with any relevant product manufacturers' installation instructions and with any relevant British or European standards or normative documents of any product or system.

8.2.10 The retrofit design shall include provision for the management of moisture within the construction, in line with BS 5250.

NOTE The materials specified should match the moisture strategy of the existing building. This might mean maintaining a dynamic moisture equilibrium within the construction for which vapor permeable and capillary active materials are most suited.

8.2.11 If any building fabric insulation measures or replacement windows and external doors are included in the package of specified improvement measures, then the airtightness measures are deemed also to be applied, because they are intrinsic in the included measures.

8.2.12 An appropriate air barrier shall be specified and designed in accordance with **8.2.15** and **8.2.16**.

NOTE 1 Proprietary airtightness products are available, such as tapes, membranes, grommets, adhesives and paints that have undergone accelerated laboratory testing, which indicates the products will maintain airtightness for over 60 years if applied correctly, following manufacturers' instructions.

NOTE 2 Air barriers can be vapour permeable or impermeable depending on the need to maintain moisture movement through an element. In some constructions, this function might be performed by wet finishes, such as lime renders or plasters that are both airtight and vapour permeable.

8.2.13 If the package of specified and existing EEMs falls into;

- a) category B or C as defined in Diagram 3.1 and Table 3.1 in Approved Document F [N3]; or
- b) there is evidence of condensation and/or mould growth in the dwelling in the retrofit assessment;

the Retrofit Designer shall confirm the adequacy of the existing ventilation (if any) of the dwellings(s) as revealed by the dwelling assessment report and, if necessary, include in the design a specification for upgrading the ventilation of the dwelling(s). Upgrading of ventilation shall be managed in accordance with Annex C.

NOTE 1 This might create more dwelling sub-types if a dwelling type(s) has already been identified.

NOTE 2 Existing EEMs include any measures that have been fitted since the original dwelling was constructed. They should be included in the categorization process as well as proposed EEMs, since they will impact on the airtightness of the dwelling.

8.2.14 The retrofit design shall also include provisions for managing the interactions between EEMs installed in the same building. The Measures Interaction Matrix provided in Annex D (Figure D.1) identifies four types of combinations of EEMs:

- a) those that do not interact (shown in green);
- b) those that might connect or interact physically (shown in yellow);
- c) those that interact in other ways (shown in orange); and
- d) those that are incompatible and should not be combined (shown in red).

8.2.15 Where the retrofit design includes any EEMs for the improvement of the building fabric (e.g. insulation, airtightness, replacement windows), it shall also include construction details, relevant to the measure, for the corners, junctions and edges of all affected building elements, and for all junctions with other building elements (whether those other elements have been improved or not); this includes all "yellow" combinations on the Measures Interaction Matrix (see Figure D.1).

8.2.16 Construction details shall be configured to maintain the continuity of the three-dimensional insulated envelope and the integrity of any airtightness barrier in order to eliminate thermal by-pass (i.e. the uncontrolled penetration of cold air to the warm side of any insulation layer), minimize thermal bridging, and maintain an appropriate or specified standard of airtightness. Construction details published as part of industry good practice guidance can be used; alternatively, if other details are used, it shall be shown by calculating it in accordance with *IP1/06* [N8] that the temperature factor (f_{Rsi}) of each detail is not less than 0.75.

8.2.17 If a stage-by-stage approach to insulation is chosen, the Retrofit Design shall include provisions for mitigating the risks relating to cold surfaces, including condensation and mould, including the use of heating and continuous ventilation, or other appropriate measures.

8.2.18 The insulation of the elements that are being treated shall be done in such a way that does not inhibit the insulation of other elements in due course, including provision for appropriate construction details that minimize thermal bridges at the junctions as outlined in **8.2.16**.

NOTE The insulation of adjacent elements is prioritized in the next stage of the medium-term improvement plan.

8.2.19 Where the retrofit design includes EEMs that do not physically connect but which might interact in other ways (i.e. “orange” combinations on the Measures Interaction Matrix), the EEM specifications shall take account of the interaction. For example, the capacity of any new heating system (appliances or emitters) shall take account of the heat loss of the dwelling as affected by any improvements to insulation, windows and doors and airtightness; and the design of any new ventilation system shall take account of the air permeability of the building envelope as affected by any improvements to insulation and airtightness.

8.2.20 The retrofit design shall not include any combinations of measures that are identified as incompatible (i.e. shown “red”) in Figure D.1.

8.2.21 The retrofit design shall also:

- a) make provisions for ventilation for the purpose of the safe operation of all combustion appliances, in accordance with the manufacturers’ instructions and the relevant British Standards;
- b) provide for resilience against rainwater ingress (including ingress due to the failure of any critical element or construction detail);

- c) provide for resilience of the installed EEM against flood;
- d) provide resilience of the installed EEM for increased future rainfall;
- e) verify that the fire safety of the building is not compromised by the installation of EEMs, and if necessary include an updated fire safety strategy; and
- f) specify any maintenance requirements necessary to verify the long-term integrity of the installation.

NOTE 1 In providing for resilience against flood, the design should be consistent with BS 85500.

NOTE 2 Attention is drawn to the guidance relating to fire safety in Approved Document B of the Building Regulations [9]. In developing or updating fire safety strategy, BS 7974 should be followed.

8.2.22 If any EEMs in the retrofit design are LZC technologies or “renewable energy systems” covered by the MCS, the retrofit design shall specify that those systems comply with the relevant MCS standards ([N1], [N2]).

8.2.23 The retrofit design shall identify the relevant technical standards for EEMs from those listed in Clause 15, and specify their application to the work that is the subject of the design.

NOTE Omission from the retrofit design of reference to a relevant standard identified in this PAS does not indicate that it does not apply.

8.2.24 The retrofit design shall also specify the sequence of installation of the EEMs, especially where incorrect sequencing adversely affects the resilience of the EEMs, the integrity of the building, its heritage significance, or its energy performance.

8.2.25 The Retrofit Coordinator shall provide the complete retrofit design to the Main Contractor or Retrofit Installer in writing for the purpose of costing the work and for subsequent installation of the EEMs. The design documentation shall include:

- a) identification of the address and precise location of the building(s) in which the EEM(s) are to be installed;
- b) identification of any access constraints and access instructions provided by the client or the occupants;
- c) identification of any repairs or maintenance required prior to implementation of the EEMs;
- d) any assumptions on which the design is based, including assumptions that underpin the assessment of the dwelling(s);
- e) confirmation of the compliance of the design with the relevant standards;

- f) specifications of the materials, products and systems to be used, and of where and how they are to be installed, whether within the building or on its exterior;
- g) construction details for all corners, junctions and edges of the building envelope (whether prepared by the Retrofit Designer or obtained from a system designer), or clear identification of any standard details that are to be used, and where;
- h) installation instructions for all new systems and equipment;
- i) testing requirements, including testing of any new gas systems and electrical installations (see Clause 10);
- j) commissioning requirements (see Clause 10);
- k) handover requirements (see Clause 11);
- l) maintenance instructions (see Clause 11);
- m) a list of measures requiring an appropriate guarantee or warranty (see Clause 11); and
- n) identification of any information required to be supplied by the Contractor or Installer to any applicable quality assurance scheme.

8.2.26 The Retrofit Coordinator shall also provide the Main Contractor or Retrofit Installer with copies of the retrofit assessment(s) for the dwelling(s).

8.2.27 The Retrofit Coordinator shall request confirmation from the Main Contractor or Retrofit Installer that the information included in the retrofit design is sufficient for costing and installation work to proceed.

***NOTE** The Main Contractor or Retrofit Installer might not be able to provide confirmation until the pre-installation building inspection required by PAS 2030 has been completed.*

8.2.28 If the information in the retrofit design is not considered sufficient for the costing and installation work to proceed, the Main Contractor or Retrofit Installer is required by PAS 2030 to identify any missing information, which the Retrofit Coordinator shall arrange for the Retrofit Designer to collate and include in an updated design.

8.2.29 If the cost of installing the EEMs in accordance with the retrofit design, as reported by the Main Contractor or Retrofit Installer, exceeds the agreed budget or funding available, the Retrofit Coordinator shall agree appropriate amendments with the client, arrange for the Retrofit Designer to revise the design accordingly, and re-submit the retrofit design to the Main Contractor or Retrofit Installer. The requirements of this PAS shall apply to the revised design.

***NOTE** If the cost of EEMs significantly changes, then the outputs of the improvement options evaluation should be updated to reflect this.*

8.2.30 Where advice in respect of a retrofit project undertaken in accordance with this PAS is to be provided to the client, the Retrofit Coordinator shall verify that the advice is provided in accordance with Clause 12. Where such advice is to be provided by other parties, the Retrofit Coordinator shall confirm that the client is aware of the potential benefit of advice being provided in accordance with Clause 12.

8.2.31 The retrofit design shall include measures to inhibit overheating of the dwelling during the installed life of the EEMs. In identifying these measures, the Retrofit Designer shall identify and record these measures in accordance with:

- a) *Design methodology for the assessment of overheating risk in homes* [N9] to assess overheating risk;
- b) the guidance and tools published by the UK Climate Impacts Programme (UKCIP) [N10] to assess future climate vulnerability and identify adaptation options; and
- c) the *Guide to low energy shading* [N11].

8.2.32 The measures to be considered for inclusion in the retrofit design to inhibit overheating shall include but not be limited to:

- a) reduction of internal heat loads through the installation of energy efficient lighting (e.g. LED lamps), energy efficient domestic appliances (e.g. appliances with high energy efficiency ratings) and energy efficient building services (particularly hot water);
- b) smoothing of internal heat loads by separation of spaces with high heat gains (e.g. kitchens) from spaces with solar gains (e.g. those with south-facing glazing);
- c) reduction of solar gains by external shading of south-facing and west-facing glazed openings, or the provision of shutters;
- d) provision of facilities for secure ventilation of the dwelling at night, during warm weather;
- e) moderation of internal temperature by exposing high thermal capacity building fabric (e.g. masonry or concrete) to the internal air (inside the insulated envelope) so that heat is absorbed from warm air and re-radiated later when the air is cooler;

- f) reduction of internal solar gains by reducing glazing area or using glazing, or retrofitted coatings, with a relatively low transmissivity; and allowance for sufficient purge ventilation and cross-ventilation (where noise, security and privacy allow); and
- g) as a last resort, install active cooling, with preference for low or zero carbon cooling where possible.

NOTE Reducing solar gains with low transmissivity glazing apply in the winter as well as the summer. Therefore, the contribution of passive solar energy to the space heating demand is reduced and the heating system is compensated.

8.2.33 If the dwelling to be improved is traditionally constructed and/or of significance, the identification of applicable EEMs shall also be consistent with BS 7913. Where an assessment identifies that a traditional building is of significance, particularly with regard to the appearance and form of the building and its relationship with its surroundings (architectural and aesthetic value) and with significant fabric (evidential value), the Retrofit Designer and Retrofit Co-ordinator shall take this into account when selecting and designing retrofit measures. Once measures have been identified, if a proposed measure might have an impact on an aspect of a building identified as significant, a heritage impact assessment following BS 7913 shall be carried out as part of the options appraisal.

NOTE Any opportunities for enhancing significance should also be considered.

8.2.34 If the dwelling to be improved is a protected building, or forms part of a protected building, the identification of applicable EEMs shall be carried out in accordance with BS 7913 and shall take account of the significance of the building as defined in the BS 7913 assessment.

8.2.35 Where the retrofit design includes any EEMs for the improvement of the building fabric (e.g. insulation, airtightness, replacement windows), the Retrofit Designer or Retrofit Coordinator shall develop an airtightness and air leakage testing strategy as part of the retrofit design.

NOTE 1 The strategy should consider the impact of EEMs on the airtightness of the building and should:

- a) explain the benefits of air leakage testing and the risks of not doing so;
- b) include the airtightness target(s) should one be set for the dwelling(s), especially where a whole-house retrofit is undertaken or if required to specify the correct ventilation system (see Annex C); and

- c) recommend any other airtightness or air leakage testing required before, during or after installation of the EEMs.

NOTE 2 An air leakage test verifies that there are no major air leaks through the installed EEMs. Ideally, a test before and after any major insulation project should be undertaken to verify that air leakage has been reduced through the building external envelope. This is to protect the building structure from moisture problems and reduce heat loss. Air leakage testing requires fan pressurization and/or depressurization to allow time for leakage checking.

NOTE 3 An airtightness target can be beneficial for the project to improve quality control and workmanship during the construction stage. Verification of the airtightness standard is different from the air leakage testing as described in NOTE 1.

8.2.36 Where an airtightness target is set as part of the strategy under 8.2.35, the retrofit design shall also include a requirement for the Main Contractor or Retrofit Installer to demonstrate compliance with the airtightness standard by means of an approved test for every dwelling, following CIBSE guidance [N12].

NOTE In the case of a building containing multiple dwellings (e.g. a high-rise residential block), it may be sufficient to test a sample of the dwellings, including an example of each dwelling type in the building. A dwelling type for airtightness testing should be selected based on the make-up of the external envelope, so the minimum number of flats to be tested might be a top-floor, mid-floor and ground-floor flat. However, if the external wall, roof or floor construction or application of EEMs varies around the block, there might be additional airtightness types. In a small block of flats or maisonettes, it might be more practicable to pressurize the whole block, because treating each flat individually might require multiple sets of equipment to pressurize adjacent units and avoid a misleading test result.

8.2.37 Before any work to install EEMs in the dwelling(s) begins, the Retrofit Coordinator shall, on request, provide the Main Contractor and/or Retrofit Installer(s) with briefings (or "toolbox talks") to explain the design intent and draw attention to key points, including the intended installation sequence(s). Such briefings shall always be provided if:

- a) the retrofit design includes new or unusual materials, products or systems with which the Retrofit Installers are not familiar; or
- b) the project includes any building fabric insulation measures or replacement windows on a high-rise or system-built dwelling; or

- c) the building to be improved (or any part of it) is traditionally constructed, and the proposed EEMs are likely to have an impact on the heritage significance and/or building fabric of the building; or
- d) the Retrofit Installers(s) have not installed the specified EEMs before; or
- e) the design is intended to achieve particularly challenging performance standards (e.g. with respect to airtightness).

8.2.38 At the end of the design process, the Retrofit Coordinator shall update the improvement options evaluation and medium-term improvement plan in accordance with the retrofit design.

NOTE If required by the TrustMark quality scheme, the Retrofit Coordinator should upload the tabular summary of the improvement option evaluation(s), medium-term low-carbon improvement plan(s) and the retrofit design(s) for the dwelling(s) to the TrustMark "data warehouse".

8.3 Distressed replacement of heating appliances

COMMENTARY ON 8.3

In the case of the design of the distressed replacement of heating appliances, it is accepted that a whole-dwelling assessment, as outlined in Clause 8, might not have been undertaken prior to the retrofit design and that it might not be possible to involve a Retrofit Coordinator during the design process.

8.3.1 The distressed replacement of heating appliances shall be carried out in accordance with **8.2.1**, **8.2.2**, **8.2.7**, **8.2.9**, **8.2.19** and **8.2.20**.

8.3.2 Once a Retrofit Coordinator has been employed in the process (during or after the distressed replacement of a heating appliance) and a whole-dwelling assessment has been undertaken, all of Clause 8 shall apply. If no further EEMs are to be installed as part of the current project, then the minimum output of the retrofit design process shall be the improvement options evaluation as outlined in **8.1.1** and the medium-term improvement plan as outlined in **8.1.4**.

9 Requirements for installation of retrofit designs

9.1 The installation of the EEMs specified in the retrofit design shall be carried out in accordance with PAS 2030. Where LZC technologies or renewable energy systems are specified, including any associated components and/or controls that are within the scope of the MCS, the installation of those systems shall be carried out in accordance with the applicable MCS standards ([N1], [N2]), instead of with PAS 2030.

9.2 The Retrofit Coordinator shall collect evidence to satisfy themselves that the requirements of PAS 2035 have been met during the installation. This shall require in-person or virtual/ remote site inspections during construction. The number of site inspections shall be set by the Retrofit Coordinator and agreed with the client(s), and shall be appropriate for the complexity and size of the project.

If an in-person site inspection is not possible, the Retrofit Coordinator shall collect digital evidence from a third party for the following measures only:

- a) hot water cylinder insulation;
- b) primary pipework insulation;
- c) draught-proofing measures;
- d) single new or replacement windows;
- e) single new or replacement external doors;
- f) replacement of electric storage heaters;
- g) heating and hot water controls;
- h) boiler replacement;
- i) radiator reflector panels;
- j) district/communal heating heat meters;
- k) district/communal heating connection;
- l) energy efficient lighting;
- m) energy efficient appliances;
- n) solar PV;
- o) solar water heating;
- p) cavity wall insulation;
- q) party cavity wall insulation;
- r) loft insulation; and
- s) solid floor insulation.

If any of the above measures connects to or penetrates another fabric EEM being installed or already installed, an in-person site inspection shall be required. Any EEMs not listed shall require an in-person site inspection.

NOTE 1 *The Retrofit Coordinator may visit the site at any stage during construction, but in order to verify compliance with PAS 2035, it is beneficial to attend when they can view the interaction of EEMs, the installation of the air barrier, the installation of thermal bridge details, and airtightness or air leakage testing, and verify that the correct products are being installed in line with the retrofit design.*

NOTE 2 *As an example, loft insulation photographic evidence should include: completed installation with ventilation safeguarded in all loft areas; post-installation loft depth, insulated tanks and pipes; access wallboards fitted as required; storage area maintained if necessary; air tightness vapour control layer (AVCL) installation; insulated and airtight loft hatch, downlighters and high-power cables safeguarded; and documentation fixed in loft.*

9.3.1 The Retrofit Coordinator shall make a written record of quality and progress from all inspections, whether in-person or from a third party. These records shall also include photographic evidence.

9.3.2 If the Retrofit Coordinator discovers any non-compliance of work on site, either with the retrofit design or with the requirements of PAS 2035, this shall be included in the record as described in 9.3 and reported in writing to the Main Contractor or Retrofit Installer, and the client. If the non-compliance is not rectified within a time scale and to a level of quality agreed between the Retrofit Coordinator and the Main Contractor or Retrofit Installer, the non-compliance shall be escalated to the applicable quality assurance regime.

NOTE 1 *Responsibility for demonstrating and claiming compliance of installation processes and the competence or qualifications of installation operatives with PAS 2030 and/or the MCS standards rests with the Retrofit Installer. Evidence of compliance should be supplied to the Retrofit Coordinator.*

NOTE 2 *An applicable quality assurance regime is TrustMark.*

10 Requirements for testing and commissioning

10.1 Requirements for testing

10.1.1 The retrofit design shall specify any requirements for testing of the improved dwelling (e.g. airtightness testing) before, during or after installation of the EEMs, and for testing of individual building systems (whether new or existing).

10.1.2 The testing of EEMs as specified in the retrofit design shall be carried out in accordance with the requirements of PAS 2030. Where LZC technologies or “renewable energy systems” that are within the scope of the MCS are specified, they shall be tested in accordance with the applicable MCS standards ([N1], [N2]).

10.2 Requirements for commissioning

10.2.1 The retrofit design shall specify requirements for commissioning of any EEMs that are building services systems (e.g. ventilation, heating and hot water systems) and of any EEMs that are part of the building fabric but include moving parts (e.g. windows, air inlets).

10.2.2 Where there are multiple EEMs requiring commissioning, the retrofit design shall specify that all building services systems are to be finally commissioned at the same time, not separately.

NOTE *This does not preclude pre-commissioning of individual measures by the Main Contractor or Retrofit Installer.*

10.2.3 The commissioning of the EEMs as specified in the retrofit design shall be carried out in accordance with the requirements of PAS 2030. Where LZC technologies or “renewable energy systems” that are within the scope of the MCS are specified, they shall be commissioned in accordance with the relevant requirements of the MCS standards ([N1], [N2]).

10.3 Test certificates and commissioning records

10.3.1 The retrofit design shall identify the test certificates and commissioning records that are to be supplied to the client via the Retrofit Coordinator.

11 Requirements for handover

11.1 Specification of handover requirements

11.1.1 The retrofit design shall specify requirements for the handover of the completed installation of energy efficiency measures, consistent with PAS 2030. Where LZC technologies or “renewable energy systems” that are within the scope of the MCS are specified, the handover shall also be carried out in accordance with the relevant requirements of the MCS standards ([N1], [N2]).

11.1.2 The specified requirements for handover shall include:

- a) physical inspection of the installed measures and an explanation of their function and operation, including demonstrations of the operation of components, devices and controls;
- b) information about the safe operation of the installed measure, including operable components (e.g. windows, including any restrictor hardware), electrical equipment, mechanical equipment and associated control devices (e.g. boilers and heating controls);
- c) information about care of the installed measure to avoid detrimental effects (e.g. avoidance of penetrating air barriers by inserting fixings into internally insulated walls, regular cleaning and replacement of air filters in mechanical ventilation systems);
- d) information about regular maintenance of the installation in order for it to operate safely, efficiently and effectively, in accordance with the requirements of any guarantees or warranties provided by the manufacturer or supplier;
- e) information about the efficient operation of the installation to facilitate the delivery of any intended reduction in energy use;
- f) a visual check that the person receiving the handover is able to operate components and controls;
- g) information about the importance of ventilation in maintaining indoor air quality and controlling overheating in the summer, and the implications or potential consequences of switching off or disabling any installed ventilation system; and
- h) provision of documentation, including test certificates and commissioning records, operation and maintenance instructions and manuals for all installed products, and systems, warranty and guarantee certificates, and other relevant documentation.

NOTE *Simplified user manuals should be provided whenever possible.*

11.1.3 The Retrofit Coordinator shall retain copies of test certificates and commissioning records, operation and maintenance instructions and manuals for all installed products, and systems, warranty and guarantee certificates, and other relevant documentation which is necessary for the safe, efficient and effective care, operation and maintenance of the installed measures. This documentation shall be kept for a period of six years or for the length of the warranties (whichever is longer). Copies of all of these documents shall be provided to the client.

11.1.4 After the retrofit work has been handed over, the Retrofit Coordinator shall recommend to the client that a new or updated EPC is prepared for the dwelling(s). If the recommendation is accepted, the Retrofit Coordinator shall arrange for the EPC to be prepared or updated by a domestic energy assessor.

NOTE *If the client is a social landlord, a new or updated EPC might be necessary for updating the client's housing stock data; if the dwelling(s) are to be re-let or sold after improvement, new or updated EPC(s) might be a legal requirement of the sale or letting process.*

11.1.5 Whenever any stage of the retrofit has been completed, as per the improvement plan, the Retrofit Coordinator shall provide the client with a new or updated medium-term improvement plan (see 5.3) that incorporates any changes as a result of the retrofit works.

11.2 Handover recipients

11.2.1 The Retrofit Coordinator shall verify that handover is to the occupants of the dwelling(s). If the occupants are not the clients for the retrofit project, then the Retrofit Coordinator shall include the landlord(s) and clients in the handover process.

NOTE *If tenants refuse to receive handover information, it is sufficient to hand over only to the client, which is usually the landlord or social housing association.*

12 Requirements for retrofit advice

12.1 Delivery of retrofit advice

12.1.1 The Retrofit Coordinator shall verify that retrofit advice is delivered as part of every domestic retrofit project. All retrofit advice delivered in connection with domestic retrofit projects shall be overseen by the Retrofit Coordinator.

12.1.2 Retrofit advice shall be delivered to the occupants of the dwelling that is subject to retrofit, irrespective of the type of tenure. However, where the occupants are tenants, the same advice shall also be offered to their landlord.

12.1.3 All retrofit advice shall be delivered in a form that can be understood by the occupants, i.e. taking account of language, the age of the occupants, any hearing or sight difficulties, etc.

NOTE Those delivering retrofit advice may use the guidance in Supporting the delivery of energy efficiency advice to consumers during smart meter installations [10].

12.1.4 Retrofit advice shall be provided to householders at the following points in the retrofit process:

- a) on initial engagement of a household and inception of a retrofit project;
- b) on completion of the improvement option evaluation;
- c) on completion of the retrofit design; and
- d) at the time of or shortly after handover of the completed installation.

12.1.5 Retrofit advice delivered at the inception of a retrofit project shall be customized to the householders' needs and include the following topics:

- a) behavioural issues, including:
 - 1) use of ventilation, heating and hot water systems, lights and appliances and their controls;
 - 2) minimization of overheating;
 - 3) health and safety risks related to fuel poverty, damp and mould, cold and hypothermia;
- b) the need to maintain buildings properly;
- c) reducing energy costs by reviewing and changing energy tariff or supplier;

NOTE 1 Independent client information about changing energy supplier is available from Ofgem.⁶⁾

- d) retrofit technologies, including building fabric measures, building services improvements, LZC and "renewable" energy systems, typical capital costs and fuel cost savings, and sources of funding;
- e) retrofit considerations, including the PAS 2035 retrofit process, any applicable quality assurance regime, finding and selecting Retrofit Coordinators, Retrofit Assessors, Retrofit Designers, or Main Contractors or Retrofit Installers, and how to complain about poor service; and

NOTE 2 An example of an applicable quality assurance regime is TrustMark, including the Consumer Charter.

- f) data considerations, including the need for data about the performance of the home and how that data is used in monitoring and evaluation.

NOTE 3 Each Home Counts [4] recommends the setting-up of an advice hub; such retrofit advice can currently be obtained from DESNZ⁷⁾ or the Energy Saving Trust⁸⁾, while an appropriate source of retrofit advice is established.

12.1.6 Retrofit advice delivered after completion of the improvement option evaluation shall be delivered by the Retrofit Coordinator who carried out the improvement option evaluation. It shall cover:

- a) any consultations that have taken place with the local authority's planning department regarding the retrofit options and their impact on external appearance, particularly where external EEMs are being considered or where conservation area or listed building constraints apply;
- b) an explanation of the improvement options considered, their compatibilities and incompatibilities, and any other associated opportunities or constraints;
- c) the estimated capital costs and fuel cost savings associated with the options considered, and their cost-effectiveness (including their carbon cost-effectiveness);
- d) identification of the recommended options and priorities included in the medium-term improvement plan; and

⁶⁾ Available at <https://www.ofgem.gov.uk/consumers/household-gas-and-electricity-guide/how-switch-energy-supplier-and-shop-better-deal>.

⁷⁾ Available at <https://helpforhouseholds.campaign.gov.uk/energy-saving-advice>.

⁸⁾ Available at <https://energysavingtrust.org.uk/about-us/contact-us>.

- e) recommendation of the EEMs to be included in the immediate retrofit project.

NOTE Where advice includes estimated fuel cost savings arising from improvement measures, the savings should be those calculated using a full SAP or PHPP assessment. Capital costs of measures should be dwelling specific, derived from rates obtained from sources independent of the manufacturer, supplier or installer of the EEMs (see Clause 8.1).

12.1.7 On completion of the retrofit design, retrofit advice shall be delivered by the Retrofit Designer who prepared the design or by the Retrofit Coordinator. The retrofit advice shall cover the key features of the design, including all the proposed EEMs, and a brief explanation of the installation process.

12.1.8 Retrofit advice delivered at the handover of a retrofit project shall be customized to the householders' needs and cover the following topics:

- a) the installed EEMs, their operation and protection (including avoiding damage to any installed airtightness layer) and their intended effect on the energy performance of the dwelling(s) and the level(s) of comfort provided;
- b) behavioural issues, including the use of any installed ventilation, heating and hot water systems, lights, appliances and their controls, how to minimize overheating, how to get the best performance from them, and the potential consequences of switching off or disabling ventilation;
- c) how repair and maintenance of the building and the installed EEMs can help sustain the building and contribute to its energy efficiency; and
- d) any applicable quality assurance regime and audit and inspection processes that might apply, the guarantees and warranties attached to the installed EEMs, and the procedures for claiming.

NOTE 1 The delivery of retrofit advice at handover is the responsibility of the Main Contractor or Retrofit Installer, but still subject to the oversight of the PAS 2035 Retrofit Coordinator.

NOTE 2 An example of an applicable quality assurance regime is TrustMark.

12.2 Distressed replacement of a heating appliance

NOTE In the case of distressed replacement of a heating appliance, it is recognized that it may not be possible to deliver retrofit advice at inception and on completion of the design.

12.2.1 Retrofit advice shall be delivered on handover as described in Clause 12.1.8. Retrofit advice on inception, as described in Clause 12.1.5, shall be delivered at the first possible opportunity, given its use to the householder.

12.2.2 Once a Retrofit Coordinator is engaged and the whole-dwelling assessment and improvement option evaluation has been completed, retrofit advice as described in 12.1.6 shall be delivered. If further EEMs are identified for the current retrofit project, then retrofit advice on completion of the retrofit design shall be delivered in accordance with 12.1.7.

13 Requirements for monitoring and evaluation

13.1 The purpose of monitoring and evaluation

The Retrofit Coordinator shall evaluate every retrofit project to:

- a) determine whether the intended outcomes (as detailed in 6.2) have been realized; and
- b) identify and learn from any project-specific or systematic problems with the retrofit risk assessment, the dwelling assessment, the retrofit design, the installation of EEMs or the testing, commissioning or handover of EEMs.

13.2 Retrofit Evaluator

13.2.1 Monitoring and evaluation shall be carried out by a Retrofit Evaluator.

13.2.2 A Retrofit Evaluator shall be a person trained and/or qualified in accordance with Annex A.

13.3 Levels of monitoring and evaluation

13.3.1 Two levels of monitoring and evaluation shall be carried out.

- a) Basic evaluation is the minimum level of evaluation that shall be applied to every completed domestic retrofit project.
- b) Further monitoring and evaluation shall be applied to projects for which:
 - 1) basic evaluation indicates that the outcomes are significantly different from those originally agreed and intended; or
 - 2) there are suspected unintended consequences of the retrofit work; or
 - 3) the monitoring and evaluation plan as per clause 8.1.6 stipulates that it is required for the EEMs being installed in this project; or
 - 4) the Retrofit Evaluator, Retrofit Coordinator or client request more detailed performance measurement on specific properties.

NOTE 1 The Retrofit Evaluator or the Retrofit Coordinator can obtain a more detailed performance measurement on agreement with the client.

NOTE 2 The decision on whether further monitoring is needed may be prompted by the client, the Retrofit Coordinator or the Retrofit Evaluator.

13.3.2 Where further monitoring and evaluation is proposed, the Retrofit Evaluator shall obtain consent from the client(s) and occupant(s) before it is undertaken.

13.4 Basic evaluation

13.4.1 Basic evaluation shall include a measure-specific questionnaire distributed to the client and the occupant(s) (if different) of the dwellings that have been retrofitted to establish:

- a) whether the agreed intended outcomes of the project (see 6.2) have been achieved;
- b) whether there have been any unintended or unexpected consequences of the work;
- c) whether the client and occupant(s) are satisfied with the outcomes;
- d) whether the client and occupant(s) are satisfied with the process of assessment, design, installation, testing, commissioning and handover of retrofit measures;
- e) the identification of any specific points of dissatisfaction;
- f) the identification of any elements of the installation that are not working as expected; and
- g) whether any comments have been provided by the client or occupant(s).

13.4.2 The Retrofit Evaluator shall collate the information provided by the client and the occupant(s) and circulate the following to the client, the Retrofit Coordinator, the Retrofit Assessor, the Retrofit Designer and the Main Contractor or Retrofit Installer:

- a) a summary of the information;
- b) recommendations for any remedial actions required;
- c) any changes required to the retrofit process; and
- d) recommendations for further monitoring and evaluation.

NOTE Not all clients and occupants might complete and return the basic evaluation questionnaire. The Retrofit Evaluator's report can only cover dwellings for which questionnaires have been completed and returned. Dwellings for which completed questionnaires are not returned should be excluded from the analysis and noted in the report.

13.4.3 Basic evaluation shall be completed and reported within three months after handover of the retrofit project.

13.5 Further monitoring and evaluation

13.5.1 Where it has been determined that further monitoring and evaluation is required (**13.3.1**), the Retrofit Evaluator shall design a further monitoring and evaluation plan (if one does not exist already) with a defined duration, in accordance with BS 40101 for Preliminary Evaluation, Light BPE, or Standard BPE (including Investigative BPE elements) which shall:

- a) establish why there was any discrepancy between predicted performance and outcome performance, or explain any unintended consequences;
- b) identify and specify any necessary remedial work; and
- c) identify areas of learning to avoid the same problem occurring in other projects.

13.5.2 The Retrofit Evaluator shall collate the information obtained during the further monitoring and evaluation process and circulate the following to the client, the Retrofit Coordinator, the Retrofit Assessor, the Retrofit Designer and the Main Contractor or Retrofit Installer:

- a) a summary of the information;
- b) recommendations for any remedial actions required;
- c) any changes required to the retrofit process; and
- d) recommendations for further monitoring and evaluation.

***NOTE** It might be appropriate, with the permission of the client, to supply copies of evaluation reports (at any level) to any external quality assurance body, or (on request) to a funding organization or guarantee provider. Such bodies might require more extensive or detailed monitoring or investigation, over and above the requirements of this PAS.*

14 Claims of compliance

COMMENTARY ON CLAUSE 14

Users of this PAS are advised to consider the desirability of obtaining accredited independent assessment and certification of energy retrofitting measures. Details on providing assessment and certification are given in Regulation EC765/2008 [11] and BS EN ISO/IEC 17065.

14.1 General

14.1.1 Where claims of conformance to PAS 2035 are made, the provisions in **14.2** and **14.3** shall be followed when making claims of compliance. These provisions include identification of the basis of the claim (**14.2**) and requirements for how the claim shall be expressed (**14.3**).

14.2 Basis of claim

14.2.1 General

The claim shall identify the type of conformity assessment undertaken as one of the following:

- a) other-party validation in accordance with **14.2.2**; or
- b) self-assessment in accordance with **14.2.3**.

14.2.2 Other-party validation

Retrofit Coordinators claiming compliance with this PAS for any particular project, shall satisfy themselves that any such party is able to demonstrate compliance with recognized standards that set out requirements for organizations providing services for the assessment of processes and/or individuals.

NOTE 1 *This also includes sub-contractors claiming compliance with relevant parts and using a method of validation involving parties other than those qualifying as accredited independent third parties,*

NOTE 2 *Other-party assessment bodies are those undertaking assessment services without having achieved accreditation from the authorized accreditation service (e.g. UKAS in the UK). Such bodies might include those which, although independent of the organization undertaking the assessment, cannot demonstrate complete independence (e.g. a quality assurance scheme such as TrustMark providing assessment services for its members or a consultant employed for such a purpose).*

NOTE 3 *An example of a recognized standard is BS EN ISO/IEC 17065.*

14.2.3 Self-assessment

Retrofit Coordinators claiming compliance with this PAS for any project, or their sub-contractors claiming compliance with relevant parts of it, shall be able to demonstrate that the activities involved have been undertaken in accordance with this PAS, and make supporting documentation available on request. The self-assessment and presentation of the results shall be carried out in accordance with BS EN ISO 14021.

NOTE *Retrofit Coordinators for whom neither independent third-party certification nor other-party validation is a realistic option may rely on self-assessment. In so doing, they should be aware that independent validation could be required in the event of a challenge and that stakeholders and interested parties could have less confidence in this self-assessment option.*

14.3 Permitted forms of disclosure

Claims of compliance with this PAS shall be made by Retrofit Coordinators using the appropriate form of disclosure.

- a) For claims of conformity based on other-party validation in accordance with **14.2.1a**):
 “Retrofit project undertaken at [insert unambiguous identification of relevant property] in accordance with PAS 2035 by [insert unambiguous identification of the claimant], [insert unambiguous identification of the validating body] validated.”
- b) For claims of conformity based on self-assessment in accordance with **14.2.1b**):
 “Retrofit project undertaken at [insert unambiguous identification of relevant property] in accordance with PAS 2035 by [insert unambiguous identification of the claimant], self-assessed.”

15 References

15.1 Retrofit framework standards

15.1.1 Standards publications

- BS 5250, *Management of moisture in buildings – Code of practice*
- BS 5410-1, *Code of practice for oil firing – Part 1: Installations up to 45 kW output capacity for space heating and hot water supply purposes*
- BS 5410-2, *Code of practice for oil firing – Part 2: Installations of 45 kW and above output capacity for space heating, hot water and steam supply service*
- BS 5440-1, *Flueing and ventilation for gas appliances of rated input not exceeding 70 kW net (1st, 2nd, 3rd family gases) – Part 1: Specification for installation of gas appliances to chimneys and for maintenance of chimneys*
- BS 5440-2, *Flueing and ventilation for gas appliances of rated input not exceeding 70 kW net (1st, 2nd and 3rd family gases) – Part 2: Specification for the installation and maintenance of ventilation provision for gas appliances*
- BS 5482-1, *Code of practice for domestic butane and propane gas burning installations – Part 1: Permanent dwellings*
- BS 5864, *Installation and maintenance of gas-fired ducted air heaters of rated heat input not exceeding 70 kW net (2nd and 3rd family gases) – Specification*
- BS 5918, *Solar heating systems for domestic hot water – Code of practice for design and installation*
- BS 5970, *Code of practice for thermal insulation of pipework and equipment in the temperature range of -100 °C to +870 °C*
- BS 6100-1, *Building and civil engineering – Vocabulary – Part 1: General terms*
- BS 6262-2, *Glazing for buildings – Part 2: Code of practice for energy light and sound*
- BS 6262-3, *Glazing for buildings – Part 3: Code of practice for fire security and wind loading*
- BS 6262-4, *Glazing for buildings – Part 4: Code of practice for safety related to human impact*
- BS 6262-6, *Glazing for buildings – Part 6: Code of practice for special applications*
- BS 6262-7, *Glazing for buildings – Part 7: Code of practice for the provision of information*
- BS 6644, *Specification for installation of gas-fired boilers of rated inputs between 70 kW (net) and 1.8 MW (net) (2nd and 3rd family gases)*
- BS 6798, *Specification for installation and maintenance of gas-fired boilers of rated input not exceeding 70 kW net*
- BS 6891, *Installation of low-pressure gas pipework of up to 35 mm (R1 1/4) on premises*
- BS 7386, *Specification for draughtstrips for the draught control of existing doors and windows in housing (including test methods)*
- BS 7593, *Code of practice for treatment of water in domestic hot water central heating systems*
- BS 7619, *Extruded cellular unplasticized white PVC (PVC-UE) profiles – Specification*
- BS 7671, *Requirements for electrical installations – IET Wiring Regulations*
- BS 7880, *Code of practice for draught control of existing doors and windows in housing using draught strips*
- BS 7913, *Guide to the conservation of historic buildings*
- BS 7974, *Application of fire safety engineering principles to the design of buildings – Code of practice*
- BS 8000-0, *Workmanship on building sites – Part 0: Introduction and general principles*
- BS 8102, *Code of practice for protection of below ground structures against water from the ground*
- BS 8123-4, *Windows and doors – Part 4: Code of practice for the survey and installation of windows and external doorsets*
- BS 8550-0, *Flood resistant and resilient construction – Guide to improving the flood performance of buildings*
- BS 8558, *Guide to the design, installation, testing and maintenance of services supplying water for domestic use within buildings and their curtilages – Complimentary guidance to BS EN 806*

- BS 8660-1, *Gas-fired micro-cogeneration appliances of rated thermal input not exceeding 70 kW net – Part 1: Specification for selection, installation, inspection, commissioning, servicing and maintenance of Stirling engine micro-cogeneration appliances*
- BS 40101, *Building performance evaluation of occupied and operational buildings (using data gathered from tests, measurements, observation and user experience) – Specification*
- BS 85500, *Flood resistant and resilient construction – Guide to improving the flood performance of buildings*
- BS EN 1264-1, *Water based surface embedded heating and cooling systems – Part 1: Definitions and symbols*
- BS EN 1264-2, *Water based surface embedded heating and cooling systems – Part 2: Floor heating: Prove methods for the determination of the thermal output using calculation and test methods*
- BS EN 1264-3, *Water based surface embedded heating and cooling systems – Part 3: Dimensioning*
- BS EN 1264-4, *Water based surface embedded heating and cooling systems – Part 4: Installation.*
- BS EN 1264-5, *Water based surface embedded heating and cooling systems – Part 5: Heating and cooling surfaces embedded in floors. Determination of the thermal output*
- BS EN 1670, *Building hardware – Corrosion resistance – Requirements and test methods*
- BS EN 3781, *Refrigerating systems and heat pumps – Safety and environmental requirements – Basic requirements, definitions, classification and selection criteria*
- BS EN 3783, *Refrigerating systems and heat pumps – Safety and environmental requirements – Installation location and personal protection*
- BS EN 3784, *Refrigerating systems and heat pumps – Safety and environmental requirements – Operation, maintenance, repair and recovery*
- BS EN 8061, *Specifications for installations inside buildings conveying water for human consumption – General*
- BS EN 8064, *Specifications for installations inside buildings conveying water for human consumption – Installation*
- BS EN 8065, *Specifications for installations inside buildings conveying water for human consumption – Operation and maintenance*
- BS EN 12828, *Heating systems in Buildings – Design for water-based heating systems*
- BS EN 12831-1, *Energy performance of buildings – Part 1: Method for calculation of the design heat load – Space heating load, Module M3-3*
- BS EN 12831-3, *Energy performance of buildings – Part 3: Method for calculation of the design heat load – Domestic hot water systems heat load and characterisation of needs, Module M8-2, M8-3*
- BS EN 13120, *Internal blinds – Performance requirements including safety*
- BS EN 13141-1, *Ventilation for buildings – Performance testing of components/products for residential ventilation – Part 1: Externally and internally mounted air transfer devices*
- BS EN 13141-4, *Ventilation for buildings – Performance testing of components/products for residential ventilation – Part 4: Fans used in residential ventilation systems*
- BS EN 13141-6, *Ventilation for buildings – Performance testing of components/products for residential ventilation – Part 6: Exhaust ventilation system packages used in a single dwelling*
- BS EN 13141-7, *Ventilation for buildings – Performance testing of components/products for residential ventilation – Part 7: Performance testing of a mechanical supply and exhaust ventilation units (including heat recovery) for mechanical ventilation systems intended for single family dwellings*
- BS EN 13141-8, *Ventilation for buildings – Performance testing of components/products for residential ventilation – Part 8: Performance testing of un-ducted mechanical supply and exhaust ventilation units (including heat recovery) for mechanical ventilation systems intended for a single room*
- BS EN 13141-9, *Ventilation for buildings – Performance testing of components/products for residential ventilation – Part 9: Externally mounted humidity controlled air transfer device*
- BS EN 13141-10, *Ventilation for buildings – Performance testing of components/products for residential ventilation – Part 10: Humidity controlled extract air terminal device*

BS EN 13141-11, *Ventilation for buildings – Performance testing of components/products for residential ventilation – Part 11: Supply ventilation units*

BS EN 13561, *External blinds and awnings – Performance requirements including safety*

BS EN 13659, *Shutters and external venetian blinds – Performance requirements including safety*

BS EN 14336, *Heating systems in buildings – Installation and commissioning of water-based systems*

BS EN 15316-4-8, *Heating systems in buildings – Method for calculation of system energy requirements and system efficiencies – Space heating generation systems, air heating and overhead radiant heating systems*

BS EN 16484-1, *Building automation and control systems (BACS) – Part 1: Project specification and implementation*

BS EN 16883, *Conservation of cultural heritage – guidelines for improving the energy performance of historic buildings*

BS EN 31010, *Risk management – Risk assessment techniques*

BS EN 62446-1, *Photovoltaic (PV) systems – Requirements for testing, documentation and maintenance – Part 1: Grid connected systems – Documentation, commissioning tests and inspection*

BS EN ISO 11600, *Building construction – Jointing products – Classification and requirements for sealants*

BS EN ISO 14021, *Environmental labels and declarations – Self-declared environmental claims (Type II environmental labelling)*

BS EN ISO 13788, *Hygrothermal performance of building components and building elements – Internal surface temperature to avoid critical surface humidity and interstitial condensation – Calculation methods (ISO 13788:2012)*

BS EN ISO/IEC 17065, *Conformity assessment – Requirements for bodies certifying products, processes and services*

CWA 17382, *Sustainable energy retrofit process management for multi-occupancy residential buildings with owner communities*

PAS 2030:2023, *Installation of energy efficiency measures in existing dwellings – Specification*

15.1.2 MCS standards

MCS Installer Standards [N1]

MCS Product Standards [N2]

15.1.3 Insulation standards and guides

- Specification for the installation of external wall insulation ensuring the safety and operation of fuel burning appliances [12]
- External wall insulation specification for weathering and thermal bridge control [13]
- External wall insulation pre-installation building inspection checklist [14]
- Retrofit internal wall insulation. Guide to best practice [15]
- Retrofit floor insulation – Suspended timber floors [16]
- Retrofit floor insulation – Solid floors [17]
- CITB loft insulation guide TRM 152/1 [18]
- Room in roof insulation guide [19]
- Guidance on extending the roof line on domestic properties to ensure sufficient overhang to accommodate external wall insulation [7]

15.1.4 Ventilation standards and guides

Ecodesign Commission Regulation (EU) 1253/2014 (energy efficiency of ventilation) [20]

BESA DW 144, *Guidance on ductwork for MVHR* [21]

BESA DW 154, *Specification for plastics ductwork* [22]

BSRIA Guide 46/2022, *Domestic ventilation systems* [N7]

BSRIA Guide 43/2013, *Flexible ductwork* [N13]

15.2 List of references (other than formal standards, for guidance only)

Climate Change Tools online guidance for architects consisting of seven guides:

- a) Climate change briefing;
- b) Carbon literacy;
- c) The principles of low carbon design and refurbishment;
- d) Low carbon standards and assessment methods;
- e) Low carbon design tools;
- f) Skills for low carbon buildings; and
- g) Whole life assessment for low carbon design.

Annex A (normative) Qualifications

COMMENTARY ON ANNEX A

To meet the requirements of this PAS, Recognition of Prior Experience and Learning (RPEL) processes should lead to a nationally recognized vocational or professional qualification that appears in the Register of Regulated Qualifications maintained by Ofqual for England and by its equivalents for the devolved nations.

A.1 Qualifications for Retrofit Assessors

A.1.1 A Retrofit Assessor shall be a domestic energy assessor certified and registered by an assessor body, or who is working towards such certification and registration via a recognized RPEL process or via a training course that appears on the register maintained by Ofqual (for England), the Council for Curriculum Examinations and Assessment (for Northern Ireland), the Scottish Qualifications Authority (for Scotland) or Qualifications in Wales (for Wales), or a RICS registered surveyor (AssocRICS, MRICS or FRICS).

NOTE *Retrofit Assessors can be registered with TrustMark.*

A.1.2 Where the dwelling to be assessed is traditionally constructed, the Retrofit Assessor shall meet the requirements of **A.1.1** and shall also hold one of the following qualifications:

- Level 3 Award in Energy Efficiency for Older and Traditional Buildings;
- Scottish Level 6 Award in Energy Efficiency Measures for Older and Traditional Buildings; or
- Welsh Level 3 Award in Energy Efficiency Measures for Older and Traditional Buildings.

NOTE *These three qualifications are almost identical and may be regarded as interchangeable for the purpose of this PAS. The Scottish qualification has been withdrawn and the Welsh qualification is no longer available, but holders of these qualifications still meet the requirements of A.1.2.*

A.2 Qualifications for Retrofit Coordinators

A.2.1 A Retrofit Coordinator shall be a person who holds a Level 5 Diploma in Retrofit Coordination and Risk Management, or who can provide evidence of currently working towards such a qualification via a recognized RPEL process or via a training course that appears on the register maintained by Ofqual (for England), the Council for Curriculum Examinations and Assessment (for Northern Ireland), the Scottish Qualifications Authority (for Scotland) or Qualifications Wales (for Wales), or holds the OCN NI Level 5 Extended Certificate in Retrofitting Domestic Properties 610/0595/2.

NOTE *Building-related professional or vocational qualifications are required as pre-requisites for the Level 5 Diploma in Retrofit Coordination and Risk Management. The awarding body or an appropriate training organization can be contacted for further information.*

A.2.2 A Retrofit Coordinator for a project involving any traditionally constructed building shall also hold one of the Level 3 or 6 qualifications listed in **A.1.2**.

A.3 Qualifications for Retrofit Designers

A.3.1 Where a single improvement measure is proposed, a Retrofit Designer shall be a specialist designer or specifier of that measure, and hold a measure-specific qualification via a recognized RPEL process or via a training course that appears on the register maintained by Ofqual (for England), the Council for Curriculum Examinations and Assessment (for Northern Ireland), the Scottish Qualifications Authority (for Scotland) or Qualifications in Wales (for Wales), or qualified in accordance with **A.3.7**.

A.3.2 Where the only improvement measure proposed is a single proprietary system, a Retrofit Designer shall be a specialist designer or specifier of that system who has been trained and approved by the manufacturer or supplier of that system or qualified in accordance with **A.3.7**.

A.3.3 Where the only improvement measure proposed is a combustion appliance, the Retrofit Designer shall be a specialist designer or specifier who has been trained and approved by the manufacturer and/or for gas installations holds Gas Safe registration or for oil heating holds competent person registration, or a chartered building services engineer (registered with CIBSE, IMECHE or CABE).

A.3.4 Where the single measure is a system covered by the MCS ([N1], [N2]), the Retrofit Designer shall be a specialist designer or specifier of the system who is MCS certified or a chartered building services engineer (registered with CIBSE, IMECHE or CABE).

A.3.5 For projects with two interacting fabric improvement measures, a Retrofit Designer shall be qualified in accordance with **A.3.7** or:

- a specialist designer or specifier of one of the measures which is approved under an agreement certified scheme, and hold a measure-specific qualification via a recognized RPEL process or via a training course that appears on the register maintained by Ofqual (for England), the Council for Curriculum Examinations and Assessment (for Northern Ireland), the Scottish Qualifications Authority (for Scotland) or Qualifications in Wales (for Wales), and take on design responsibility for the interacting measure; or

NOTE 1 Both measures should have a specialist designer as outlined in **A.3.1**, but one could be the Retrofit Designer for compliance with this PAS.

- a specialist designer or specifier of a system who has been trained and approved by the manufacturer or supplier of that system and be part of an industry quality assurance scheme in accordance with Annex B.

NOTE 2 Clause 8 requires that the Retrofit Designer follow the whole-house approach and, among other requirements, should be responsible for ventilation and overheating as part of the retrofit design.

NOTE 3 For example, two fabric interacting measures are cavity wall insulation and loft insulation. There may be two separate specialist designers or specifiers for the cavity wall insulation and the loft insulation, where one of these might take on the role of the PAS 2035/2030 Retrofit Designer. In this case, they should provide a suitable retrofit design including all architectural details between the loft and wall insulation, as well as taking on design responsibility for the whole-house approach, including ventilation (see Note 1 and Clause 8). For external wall insulation and loft insulation, there might be a system designer for the EWI and a specialist designer or specifier for the loft insulation. Either could take on the role of the PAS 2035/2030 Retrofit Designer.

NOTE 4 Interacting fabric measures refer to measures that meet at junctions, corners and edges, for example wall and roof, or wall and floor, or wall and windows.

A.3.6 In all cases where there is a designer as specified in **A.3.1**, **A.3.2**, **A.3.3**, **A.3.4** and **A.3.5**, the Retrofit Designer qualifications shall be reviewed by a Retrofit Coordinator qualified in accordance with **A.2**.

NOTE Responsibility for design rests with the specialist designer, and not with the Retrofit Coordinator.

A.3.7 For projects with three or more interacting fabric improvement measures, or that include any building fabric insulation measures or replacement windows on a high-rise or system-built dwelling, a Retrofit Designer shall be:

- a chartered architectural technologist (MCIAT or FCIAT) registered by the Chartered Institute of Architectural Technologists (CIAT); or
- an architect registered by the Architects Registration Board (ARB); or
- a professional member of the Chartered Institute of Building (MCIQB or FCIQB); or
- a chartered building surveyor (MRICS or FRICS).

A.3.8 For all projects where the building(s) to be improved (or any part of it) is traditionally constructed, and the proposed EEM(s) (this includes single measures) are likely to have an impact on the heritage significance and/or building fabric of the building, the Retrofit Designer shall be qualified in accordance with **A.3.7** and either have the Level 3 or 6 qualification as specified in **A.1.2** or conservation accredited with one of the following:

- Chartered Institute of Architectural Technologists (CIAT);
- Chartered Institute of Building (CIOB);
- Conservation Accreditation Register for Engineers (CARE);
- Register of Architects Accredited in Building Conservation (AABC);
- Royal Institute of British Architects (which incorporates the Royal Society of Architects in Wales and the Royal Society of Ulster Architects (RIBA, RSAW, RSUA));
- Royal Institution of Chartered Surveyors (RICS); or
- Royal Incorporation of Architects in Scotland (RIAS).

A.3.2 For other projects with two or more EEMs not classified by **A.3.5**, **A.3.7** or **A.3.8**, a Retrofit Designer shall be as qualified per **A.3.7** or a Retrofit Coordinator qualified in accordance with **A.2**.

A.4 Qualifications for Retrofit Evaluators

A.4.1 A Retrofit Evaluator shall be a Retrofit Coordinator qualified in accordance with **A.2**.

***NOTE 1** Although the role of Retrofit Evaluator is filled by a Retrofit Coordinator, the separately defined role of Retrofit Evaluator is retained so that specialist qualifications that are proposed for this role can be added to later editions.*

***NOTE 2** Where a retrofit evaluator is undertaking further monitoring and evaluation, they should be skilled in planning building performance evaluation projects and identifying cross-correlations among performance parameters and knowledgeable in the probable root causes of performance anomalies. Guidance in BS 40101 on qualifications for Retrofit Evaluators should be followed.*

A.5 Multiple roles

***NOTE** It is not a requirement that the roles of Retrofit Assessor, Retrofit Coordinator, Retrofit Designer and Retrofit Evaluator are filled by separate individuals. The same person can have two or more of these roles provided that they are qualified for each role, as defined, and either there is no conflict of interest involved or any conflict of interest is reported to the client and appropriately managed.*

A.5.1 Where further monitoring and evaluation (see **13.5**) is carried out, the Retrofit Evaluator shall not be the same person as the Retrofit Coordinator, and shall be independent of the Retrofit Assessor, the Retrofit Coordinator, the Retrofit Designer and the Main Contractor or Retrofit Installer.

***NOTE** Where basic evaluation (see **13.4**) is carried out, the Retrofit Evaluator and the Retrofit Coordinator can be the same person.*

A.5.2 If the Retrofit Evaluator is not independent of the Main Contractor or Retrofit Installer, this shall be declared to the client.

Annex B (normative)

Industry Quality Assurance Schemes

B.1 An industry quality assurance scheme for Retrofit Installers shall:

- a) be operated by a body independent of the system provider and the contractor or installer (referred to in this Annex as the scheme operator);
- b) subject system providers to initial and regular assessments of their technical and financial resources and documented management systems;
- c) include provision for the imposition of sanctions (including possible removal from the scheme) on members who do not comply with the scheme rules;
- d) require maintenance by the scheme operator of expertise to investigate complaints and assist with their resolution;
- e) require that:
 - 1) systems and their components are subject to independent technical approval;

NOTE Approval should be from a UKAS accredited body.
 - 2) the accredited body carries out independent checks of manufacturing activity at least annually;
 - 3) any equipment used to install a system is tested, calibrated and plated for the system;
 - 4) procedures are in place to verify that only installers approved by the system providers can purchase or install their systems;
 - 5) materials and components for systems are appropriately stored and handled, and traceable via an audit process;
 - 6) systems documentation includes generic installation method statements for their correct installation;
 - 7) systems documentation includes appropriate care and maintenance instructions;
 - 8) systems are covered by independent guarantees of the materials and products used, and of any designs prepared by system providers; and
 - 9) system providers hold appropriate professional indemnity assurance;
- f) require independent checks of compliance with any requirements for independent surveillance of pre-installation inspections;
- g) provide for random targeted quality inspections by the scheme operator of installations at a rate of not less than 1% of installations by each scheme member;
- h) require system providers to:
 - 1) train installers of their systems;
 - 2) assess installers' qualifications and competence;
 - 3) issue system-specific "competence cards" to qualified and competent operatives;
 - 4) provide qualified and competent operatives with CPD; and
 - 5) re-assess competence at least bi-annually, and maintain records of their training and CPD;
- i) require system providers to make comprehensive good practice guidance available in relation to their systems, covering:
 - 1) assessment for suitability;
 - 2) installation;
 - 3) dealing with non-standard installations;
 - 4) guidance on handover to users;
 - 5) guidance for users;
 - 6) complaint handling; and
 - 7) remedial procedures;
- j) require system providers to make available regularly updated technical notes to advise installers of trends, identified technical issues, system changes or changes to installation procedures or requirements for qualifications and competence;
- k) subject installers of systems to regular random quality inspections by the scheme operators, at a rate not less than 1% of all installations; these inspections shall be additional to any certification body surveillance and shall focus on system-specific performance and quality;
- l) require installers of systems to provide the scheme operator with evidence of compliance with the relevant legislation through membership of a competent person scheme (where applicable), and of certification under PAS 2030;

NOTE Relevant legislation can be found in the Building Regulations [7].
- m) require installers to provide independent guarantees of their work covering pre-installation inspections, any designs they prepare, and installation workmanship;
- n) require installers to operate complaints handling procedures and to provide customers with access to alternative dispute resolution; and
- o) require installers' compliant handling procedures to be audited annually by the scheme operator.

Annex C (normative)

Requirements for provision of adequate ventilation

COMMENTARY ON ANNEX C

Annex C covers ventilation of spaces within the thermal envelope of a dwelling. Clauses in Annex C apply where they are of a higher standard than the standards in force for the relevant devolved nations, as follows:

- for Wales, Building Regulations – Approved Document F: Ventilation [N4];
- for Scotland, Scottish Building Standards Technical Handbook: Domestic [N5];
- for Northern Ireland, Building Regulations (Northern Ireland) Guidance: Technical Booklet K: Ventilation [N6]; and
- for England, Building Regulations – Approved Document F: Ventilation [N3] (referred to in this Annex as “Approved Document F”).

C.1 Traditionally, UK dwellings have relied on wind-driven air infiltration, stack-effect and air leakage to provide an amount of ventilation, i.e. to expel “stale” air (containing pollutants such as moisture and high concentrations of carbon dioxide), to provide a supply of “fresh” (i.e. external) air, and to maintain IAQ. The average air permeability of dwelling envelopes in the UK (with fans and background ventilators sealed), as measured by BRE research [23], is on average 11.5 ach at 50 Pa, and infiltration and air leakage provide most (approximately three-quarters) of the required ventilation.

NOTE DLUHC and BSRIA research studies have found similar measurements.

Since the 1970s the installation of double-glazed, draught-stripped windows, the draught-stripping of external doors and the insulation of lofts and cavity walls have gradually improved energy efficiency but also reduced the air permeability of many homes, reducing infiltration and air leakage. In some cases, this has been compensated for by introducing intermittent extract ventilation fans into “wet” spaces (kitchens and bathrooms) to expel moist stale air and by installing background ventilators (air inlets, commonly known as trickle ventilators) in other spaces to provide balancing supplies of fresh air. However, the existence of a ventilation system is not proof that a building is adequately ventilated, and many existing buildings that have undergone energy efficiency improvements are not adequately ventilated.

Improving the airtightness of a dwelling to reduce “adventitious” or uncontrolled wind-driven air infiltration and air leakage, when combined with

the provision of adequate controlled ventilation, significantly improves energy efficiency. However, without adequate ventilation, the installation of any additional insulation or airtightness measure anywhere in the building, or the blocking of any existing ventilator, reduces the infiltration and air leakage rate, and increases the risk that there is insufficient ventilation to maintain adequate IAQ. Poor IAQ includes high relative humidity (which carries a risk of condensation and mould growth) and high concentrations of pollutants such as VOCs and dust mites, all of which are associated with serious health risks for occupants as well as potential damage to building finishes, fabric and structure.

C.2 Assessment of existing ventilation

COMMENTARY ON C.2

Subclause 7.3.2 requires Retrofit Assessors to identify and assess existing ventilation systems and confirm that they are working correctly as part of the whole-dwelling assessment.

C.2.1 As required in 8.2.13, if the package of specified EEMs falls into:

- a) category B or C as defined in Diagram 3.1 and Table 3.1 in Approved Document F [N3] of this PAS; or
- b) there is evidence of condensation and/or mould growth in the dwelling in the Retrofit Assessment;

the Retrofit Designer shall confirm the adequacy of the existing ventilation (if any) of the dwellings(s) as revealed by the dwelling assessment report and, if necessary, include in the design a specification for upgrading the ventilation of the dwelling(s). Upgrading of ventilation shall be in accordance with this Annex.

C.2.2 An acceptable, complete ventilation system for a dwelling with Category C EEMs shall be:

- a) a continuous MEV system that extracts moist, “stale” air from all “wet” rooms combined with correctly sized background ventilators (to admit “fresh” external air) in all living spaces and bedrooms (but not in “wet rooms”), and has been properly commissioned; or
- b) a whole-dwelling supply and extract MVHR system that extracts moist “stale” air from all wet rooms, supplies “fresh” external air to all living spaces and bedrooms, and has been properly commissioned and balanced; or

- c) other ventilation systems, if they can be shown to meet an equal level of performance and ventilation effectiveness, and extract moisture at source. In this case, expert advice shall be sought.

NOTE 1 Wet rooms include kitchens, bathrooms, shower rooms, utility rooms, and WCs without openable windows. Background ventilator sizes are defined by the relevant devolved nations' regulations ([N3], [N4], [N5], [N6]). However, minimum background ventilator sizes for MEV systems should be 4000 mm². Background ventilators should not be installed with MVHR systems, or in wet rooms of continuous MEV systems.

NOTE 2 Expert advice means advice from a competent, suitably qualified person. Examples of a suitable qualified competent person could be a member of a professional ventilation trade body a chartered or professional engineer, a building services specialist or a specialist ventilation manufacturer.

C.2.3 An acceptable, complete ventilation system for a dwelling with Category B EEMs shall be in accordance with C.2.2, or an existing intermittent extract ventilation (IEV) system consisting of correctly sized extract fans in all "wet" rooms and correctly sized background ventilators (to admit "fresh" external air) in all rooms in the dwelling(s), including living spaces, bedrooms and "wet" rooms.

NOTE 1 If the proposed energy efficiency improvement measures are either intended to reduce the air permeability of the building envelope below 5 m³/(h.m²) at 50 Pa, or might do so, a home with an existing IEV system as described in C.2.3 or lesser provision, may either need to be upgraded to a continuous mechanical system or expert advice be sought for the sizing and position of ventilators.

NOTE 2 See C.1.2, Note 2, for guidance on expert advice.

C.3 Upgrading of ventilation

NOTE Some of the following clauses refer to the ventilation equipment testing standard series BS EN 13141. The relevant clauses of each part of BS EN 13141 are as follows:

- Equipment type Test standard Intermittent extract fans: BS EN 13141-4;
- Cooker hoods: BS EN 13141-3;
- Background ventilators without humidity control: BS EN 13141-1:2019, 5.1 and 5.2. Background ventilators should meet the performance standards for both air flow from outside to inside the dwelling, and air flow from inside the dwelling to outside;
- Continuous mechanical extract ventilation systems: BS EN 13141-6;

- Mechanical ventilation with heat recovery: BS EN 13141-7; and
- BS EN 13141-8 – for internal and external leakage and for mixing.

C.3.1 Where there is evidence of surface condensation or mould growth in the home, but no insulation or airtightness measures are proposed, and the ventilation is inadequate as it does not comply with Approved Document F [N3], Table D1, then the ventilation system shall be upgraded. Whether the ventilation system is deemed adequate or inadequate, the Retrofit Coordinator shall provide advice to the client on managing condensation, damp and mould in their home.

NOTE 1 A small amount of condensation in bathrooms around sinks or showers, or around the edge of windows in extreme weather conditions, is normal. This should be wiped away on a regular basis to prevent damage or mould growth.

NOTE 2 The IAA and UKCMB have produced A homeowners guide to condensation in your property [24] and a video⁹⁾ that might be useful for Retrofit Coordinators when putting together advice for occupants.

C.3.2 Where ventilation is to be upgraded and it is shown by an approved airtightness testing methodology (as detailed in CIBSE guidance [N9]) that the air permeability of the building envelope, after installation of the proposed energy efficiency measures, is not less than 5 m³/(h.m²) at 50 Pa, an acceptable type of ventilation shall be a system outlined in C.2.2 or IEV tested in accordance with BS EN 13141-4 as described in C.2.3.

C.3.3 In all other cases where ventilation is to be upgraded, the minimum acceptable type of ventilation shall be:

- a) continuous MEV consisting of one (centralized) or more (centralized or de-centralized) fans tested in accordance with BS EN 13141-6 and extracting moist "stale" air from all "wet" spaces, combined with background ventilators tested in accordance with BS EN 13141-1 in all living spaces and bedrooms to admit a balancing supply of "fresh" external air; or
- b) continuous whole-dwelling MVHR tested in accordance with BS EN 13141-7, extracting moist "stale" air from "wet" spaces and providing a balanced supply of "fresh" external air to all living spaces and bedrooms; or

⁹⁾ Available at <https://ukcmb.org/2017/11/02/ukcmb-launches-a-new-video-on-moisture-guidance-for-existing-homeowners/>.

- c) other continuous ventilation systems, if they can be shown to meet an equal level of performance and ventilation effectiveness, and extract moisture at source. In this case, expert advice shall be sought.

NOTE 1 See C.1.2, Note 2, for guidance on expert advice.

NOTE 2 The whole-dwelling ventilation rate induced by the ventilation system (MEV or MVHR) should meet the minimum extract rates provided by the standards of the relevant devolved nation ([N3], [N4], [N5], [N6]). The minimum whole-dwelling ventilation rate for the supply of air to the habitable rooms in a dwelling should meet this in clause 1.24 of Approved Document F [N3].

NOTE 3 Air flow rates for MEV or MVHR should meet the noise guidance given in the standards for the relevant devolved nation ([N3], [N4], [N5], [N6]).

NOTE 4 MVHR provides benefits from the recovery of heat from exhaust air, reducing heating demand. The use of MVHR is a requirement of the Passive House EnerPHit standard [25], if it is adopted. MVHR was primarily developed for new dwellings, so it requires careful design and planning to install it in existing dwellings, especially small ones. For adequate performance and heat recovery efficiency, fan boxes, heat exchangers and ductwork should not be installed in unheated spaces, and ducts on the cold side of the heat exchanger should be insulated and vapour sealed to reduce condensation risk. To achieve adequate performance and noise levels, ductwork should be as short and straight as possible. Attention should be given to balancing and commissioning MVHR systems in accordance with manufacturers' instructions and recommendations.

C.3.4 In all cases where ventilation is upgraded, purge ventilation shall be installed in any habitable room that does not already have such provision. Cross-ventilation shall be verified to allow sufficient air transfer between rooms in a dwelling.

NOTE 1 Purge ventilation can be provided by means of openable windows, or by mechanical means if window opening is not possible.

NOTE 2 For details on providing purge ventilation, see standards for the relevant devolved nation ([N3], [N4], [N5], [N6]).

NOTE 3 Examples of cross-ventilation include door undercuts, transfer air grills, or paths around door frames between rooms. Details on sizing of cross-ventilation is given in the standards for the relevant devolved nation ([N3], [N4], [N5], [N6]).

C.3.5 Ventilation systems shall conform to *Domestic ventilation systems* [N7].

NOTE Attention is drawn to *EcoDesign Commission Regulation (EU) 1253/2014* [20].

C.3.6 Whichever of the options (C.3.3) is adopted, the whole-dwelling ventilation rate shall be controlled automatically so that it can maintain good internal air quality and avoid waste of energy. The air flow rate of continuous mechanical ventilation systems shall not be controlled solely by light switches or manual switches. Controls shall also respond to a local control parameter in order to automatically regulate the ventilation air flow rates between background rate and high rate.

NOTE 1 The automatic control process is sometimes referred to as "demand control". Demand control complements the provision of adequate capacity in a ventilation system (over and above minimum regulatory requirements) by eliminating unnecessary energy use and noise.

NOTE 2 A control parameter is a measurable variable or variables that are assumed to be representative of the ventilation demand, e.g. the level of relative humidity (RH) carbon dioxide, volatile organic compound (VOC) or other gases, or presence, motion or occupancy detection from infrared body heat or from reflection of ultrasonic waves, electrical signals from human operation of lights or equipment.

NOTE 3 If RH is used as a control parameter, any humidity-controlled air terminal or air inlet devices should be tested in accordance with BS EN 13141-9 and BS EN 13141-10.

C.3.7 Single-room heat recovery ventilators (SRHRVs) or alternate flow heat recovery (AFHR) fans tested in accordance with BS EN 13141-8 shall be specified to complement an existing or new ventilation system (e.g. in a room that is difficult to connect to a whole-dwelling system). Multiple SRHRVs or AFHR fans shall not be used as a whole-dwelling system.

C.3.8 Rigid ducts shall be used wherever possible. However, flexible ductwork, where installed, shall be used only for final connections and kept as short as possible (no more than 1m); and installed so that the full internal diameter is maintained along the length of the duct and flow resistance is minimized.

NOTE This is achieved by pulling the duct taut; and checking that ductwork is not at all compressed. Flexible ductwork shall be installed to meet the standards of BSRIA's BG 43/2013 [N13].

C.3.9 Ductwork installations shall be designed and installed to minimize the overall pressure losses within the system by minimizing the number of bends required, the overall length and installing appropriately sized ducts for the air flow rate.

C.3.10 Air flow shall not be significantly restricted by air terminals at the end of duct. Each air terminal shall have a free area of at least 90% of the free area of its associated duct.

NOTE Specifiers might also wish to consider BESA guidance, DW 144 [26] or DW 154 [27], as appropriate.

C.3.11 Where any new or upgraded ventilation system is proposed, the ventilation system design shall include calculations provided by a technical consultant, specialist designer or the supplier of the system, to demonstrate that the whole-dwelling ventilation rates specified are provided by the equipment proposed.

C.3.12 The retrofit design shall specify that the ventilation system is to be installed by operatives registered with a relevant competent persons scheme and approved by the manufacturer or supplier of the system.

NOTE Competent persons schemes should be compliant with the mechanical ventilation standards for the relevant devolved nations ([N3], [N4], [N5], [N6]).

C.3.13 The complete ventilation system shall be inspected to confirm that new and existing components achieve a functional performance. New mechanical ventilation systems shall be tested and, where adjustable, air flow rates shall be commissioned.

NOTE Performance standards and testing and commissioning procedures should be compliant with the standards for the relevant devolved nations ([N3], [N4], [N5], [N6]).

Annex D (normative)

Requirements for dealing with interactions between EEMs

COMMENTARY ON ANNEX D

When energy efficiency measures are installed in any existing building it is essential to take account of the fact that some measures can impact on the performance of other measures or can themselves be impacted by those measures. There are also energy efficiency measures that when installed in a building without appropriate care can significantly impair the functionality of the building.

For this reason, PAS 2035 emphasizes the need for the Retrofit Designer to consider and make adequate provision for the interfaces between the energy efficiency measures in the retrofit design. PAS 2030 also imposes responsibilities on installers of energy efficiency measures to be alert to these potential issues and to closely follow the retrofit design. This extends to the requirement for installers to pay attention to such matters during the pre-installation building inspection and to bring any perceived issues that they believe not to have been adequately provided for in the retrofit design to the attention of the Retrofit Coordinator.

D.1 Avoidance of thermal bridging

The retrofit design shall include construction details for eliminating thermal bypass and minimizing thermal bridging at corners, junctions and edges of insulation layers either occurring because of geometry or resulting from discontinuity of the insulation or from insulation being thinner than in the adjacent area (e.g. at window reveals, around meter boxes).

NOTE *These construction details should be based on accepted industry guidance or standards, e.g. External Wall Insulation Specification for Weathering and Thermal Bridge Control [13] (see 10.9.1). Alternatively, temperature factors for construction details should be calculated in accordance with IP1/06 [N8]. Temperature factors (f_{Rsi}) should be not less than 0.75.*

D.2 The Measures Interaction Matrix

Figure D.1 provides information about the nature of relationships between co-installed EEMs, identifying measures that are independent and do not interact and measures that are not appropriate together and shall not be combined; other intermediate relationships (e.g. when a construction detail is required for an interface) are also identified. These relationships shall be reviewed by the Retrofit Designer when developing the retrofit design.

Figure D.1 – The measures interaction matrix



Annex E (normative)

Requirements for the assessment of significance for traditional buildings

NOTE 1 A building's significance is the value it has for today and future generations. This might be due to the dwelling's design, construction and craftsmanship, or its association with an historical event or person, or cultural practices.

The setting of a dwelling, its relationship to its surroundings, might also be part of its significance. For example, in terraced housing, the context of the individual dwelling within the whole terrace can be an important element of its significance. If one part of the terrace is changed this might diminish the significance of the whole terrace. Significance can be looked at in terms of the key values as shown in Table E.1.

Table E.1 – Key values of significance

Values ^{A)}	Explanation	Example
Architectural and aesthetic	The quality of design, construction and craftsmanship of buildings and the character of their setting.	Local materials, decorative brickwork or render, arches, lintels and other details all contribute.
Communal	Many people value the appearance of older buildings.	Traditional buildings and associated streetscapes provide a clear sense of place and identity.
Evidential	Older buildings and their setting can inform us about how and why they were built, and how they were used.	Surviving original fabric provides valuable evidence.
Historical	Buildings may have associations with specific people or events or illustrate a past way of life.	The birthplace or residence of a historical figure, or an association with a particular industry.

^{A)} Table E.1 draws on guidance from BS 7913 and is adapted for use in unprotected traditional buildings.

NOTE 2 Retrofit work can also provide an opportunity to reveal and enhance significance. For example, a new double-glazed timber sash window to the original pattern might replace a later replacement window that has diminished the significance of the dwelling.

E.1 Assessing significance

E.1.1 Where an assessment identifies that a traditional building has some significance, particularly associated with architectural appearance, the Retrofit Designer (and Retrofit Co-ordinator) shall take this into account when selecting and designing retrofit measures.

NOTE An assessment of significance gives an understanding of what matters and why. It can then be used to assess the impact of any proposals for retrofit on that significance.

E.1.2 Once measures have been identified, if a proposed measure has an impact on an aspect of a building identified as significant, a Heritage Impact Assessment shall be carried out as part of the options appraisal in accordance with BS 7913.

NOTE Any opportunities for enhancing significance should also be considered.

E.1.3 Assessing significance shall be undertaken before retrofit proposals are formulated and the design work starts. The assessment shall be proportionate to the building's importance; many traditional buildings need only a brief assessment.

NOTE Where the building has some form of local designation (for example local listing) and a proposed change requires planning permission, the assessment might help the local planning authority come to a judgement about the level of impact and therefore the merits of any proposal.

E.1.4 The Significance Survey Checklist in Table E.2 shall be used by a Retrofit Assessor qualified in assessment of traditional buildings (A.1) to capture the key aspects of significance.

NOTE A desk-based exercise can establish via the local planning authority whether the documentary history and significance of the dwelling is already recorded. Although the dwellings being assessed here are not nationally designated, they might still have a form of local recognition or designation.

This might be in the form of:

- a) local listing;
- b) inclusion in the Local Plan; and
- c) inclusion in the Historic Environment Record (HER).

E.1.5 Where retrofit might affect the appearance of a dwelling, an analysis of any significant building elements and materials shall be undertaken, including the following building elements:

- walls;

NOTE 1 External wall materials are an essential part of the character of a building. Local materials are particularly important to a sense of place, but so is the way they were used, the coursing and dressing of stone, the bonding of brick, the forming of arches and the decoration of render. Such significance might have been diminished by changes such as cement repointing or renders – which can also affect building performance.

- windows and doors;

NOTE 2 Traditional windows, their glazing, and the detailing of their openings are important parts of the character and significance of older houses and historic areas. They are integral to the design, often made with great skill and ingenuity with materials of a higher quality than are generally available today. Original doors are comparatively rare but, where they remain, they are an important reference to the original design.

- roofs; and

NOTE 3 Some terraces of housing still have relatively uniform roof materials which contribute to the significance of the entire terrace. The roof structure is also likely to be the least altered part which can hold important information about the dwelling's age and significance. Roof coverings, like wall materials, can also have a local significance, and chimneys also contribute to the character of an area.

- internal features.

NOTE 4 The layout and detailing inside a dwelling, including joinery, plasterwork and floor surfaces, chimney breasts and fireplaces all contribute to a dwelling's character. Some internal historic features might be affected by retrofit works. For example, ceiling cornices are likely to be obscured by internal wall insulation. Solid floor insulation will affect any decorative tiled floors. Suspended timber ground floors can be retained with carefully designed insulation measures.

E.1.6 Where the presence of features such as those listed above are identified, the appropriate box shall be ticked on the PAS 2035 Significance Survey Checklist shown in Table E.2 along with detail of the features and accompanying photographs of that feature.

Table E.2 – PAS 2035 significance survey checklist

Address		
FORM AND CONTEXT		
Year built (or range of dates)		
Local recognition Add notes	Is the building locally listed, mentioned in the Local Plan or in the Historic Environment Record?	Yes/No
Built form (Tick one)	Mid-terraced	
	End terrace	
	Semi-detached	
	Detached	
	Apartment	
Setting Add notes	Is there similarity to adjacent buildings? (e.g. similar roof covering or wall materials)	Yes/No
	Importance in townscape/landscape or associations with people/events	Yes/No
BUILDING ELEMENTS		
Roof (Main section)	Is the roof covering significant? (e.g. natural slate, hand-made clay tile, stone, metal, thatch)	Yes/No
Walls (Main section)	Is the exterior wall surface significant? (e.g. brick, stone, lime render)	Yes/No
	Are any features visible? (e.g. brickwork patterns, oversailing courses, mouldings)	Yes/No
	Is the exterior wall surface significant? (e.g. brick, stone, lime render)	Yes/No
Windows	Are any of the windows of the original pattern?	Yes/No
	Is there any historic glass present	Yes/No
Internal features	Are there any internal features of significance on external walls?	Yes/No
	Are there any significant ground floor materials present? (e.g. stone, decorative tile or original floorboards)	Yes/No
Windows	Are any of the windows of the original pattern?	Yes/No
OTHER CONSIDERATIONS		
Alterations Add notes and dates	Have there been any substantial changes to the building which have diminished or enhanced significance?	Yes/No
Enhancement	Is there potential to enhance significance? (e.g. restoring windows to their original pattern)	Yes/No
NOTES	1. 2.	

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BS 85500, *Flood resistant and resilient construction – Guide to improving the flood performance of buildings*

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BS EN 13141-9, *Ventilation for buildings – Performance testing of components/products for residential ventilation – Part 9: Externally mounted humidity controlled air transfer device*

BS EN 13141-10, *Ventilation for buildings – Performance testing of components/products for residential ventilation – Part 10: Humidity controlled extract air terminal device*

BS EN 31010, *Risk management – Risk assessment techniques*

BS EN ISO 13788, *Hygrothermal performance of building components and building elements – Internal surface temperature to avoid critical surface humidity and interstitial condensation – Calculation methods (ISO 13788:2012)*

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