

PAS 2035:2023

Incorporating Corrigendum No. 1

Retrofitting dwellings for improved energy efficiency – Specification and guidance



Department for
Energy Security
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Published by BSI Standards Limited 2024

ISBN 978 0 539 31898 2

ICS 91.120.10, 91.140.10

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Publication history

First edition June 2019

Second edition September 2023

Amendments issued since publication

Date	Text affected
August 2024	Replacement of Figure D.1

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Foreword

Publishing information

This PAS was sponsored by the Department for Energy Security and Net Zero (DESNZ). Its development was facilitated by BSI Standards Limited and it was published under licence from The British Standards Institution. It will come into effect on 30 March 2025.

Acknowledgement is given to Dr Sarah Price, as the technical author, and the following organizations that were involved in the development of this PAS as members of the Steering Group:

- ArchiMetrics Ltd
- BSI Retrofit Standards Task Group
- Department for Energy Security and Net Zero (DESNZ)
- Department for Levelling Up, Housing and Communities (DLUHC)
- Elmhurst Energy
- Four Walls Consultants Ltd
- Glass and Glazing Federation
- Historic Environment Scotland
- Keegans
- Prewett Bizley
- QODA Consulting
- Residential Ventilation Association
- Rounded Developments Enterprises
- Scottish Government
- SOAP Retrofit Ltd
- Southern Housing Group
- Sustainable Energy
- Solid Wall Insulation Guarantee Agency (SWIGA)
- The Installation Assurance Authority
- TrustMark
- Welsh Government

Acknowledgement is also given to the members of a wider review panel who were consulted in the development of this PAS.

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PAS 2035:2023 supersedes PAS 2035:2019+A1:2022 which remains current and will be withdrawn on 30 March 2025.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

Text introduced or altered by Corrigendum No. 1 is indicated in the text by tags **[C1]** **[C1]**. Minor editorial corrections are not tagged.

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, 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.

Presentational 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

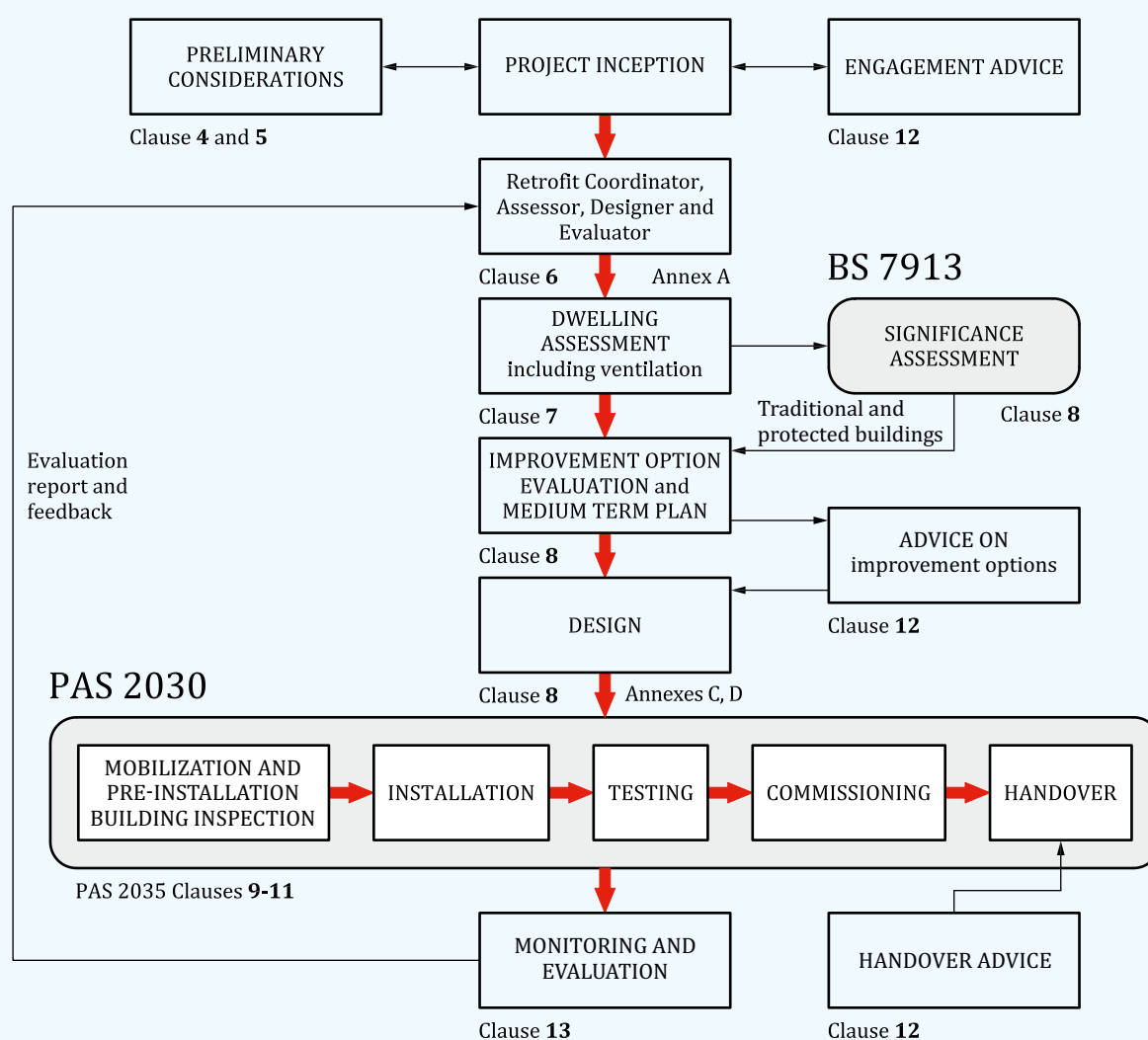
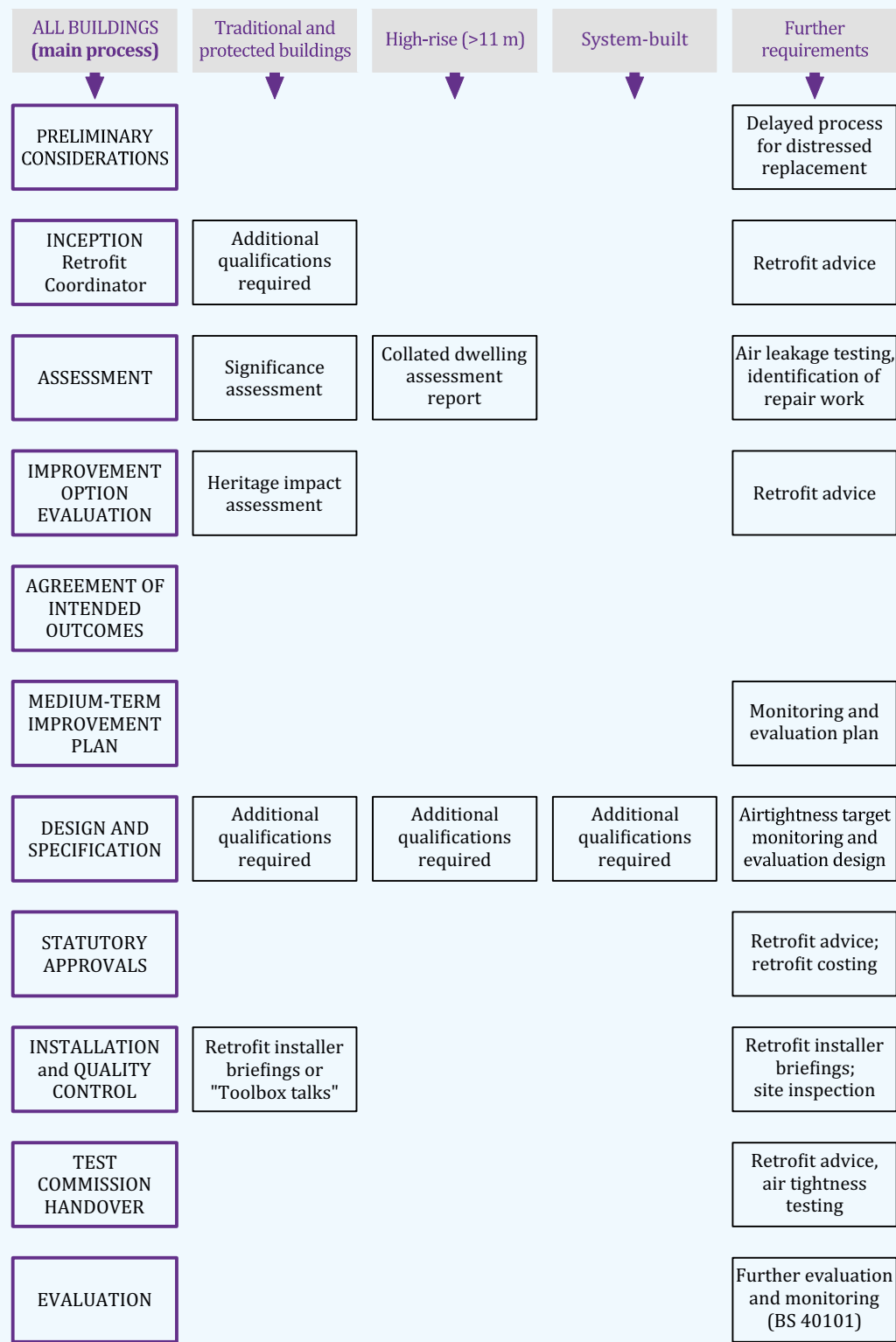


Figure 2 illustrates in more detail the process for different types of projects that users of PAS 2035 are expected to follow in order to comply with its requirements.

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-downloads>.

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 (ψ 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.