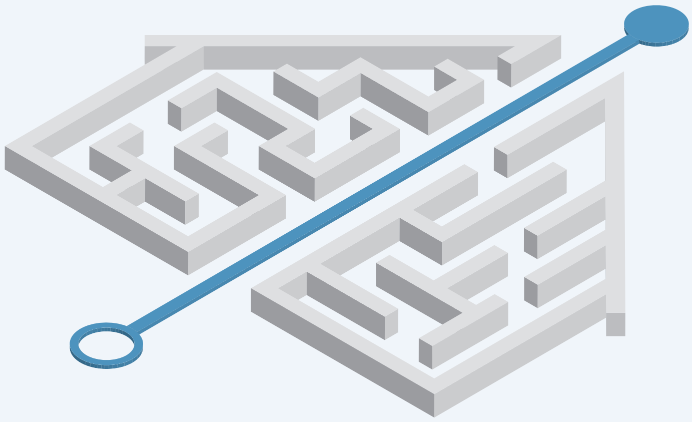

CLOSING THE GAP BETWEEN

DESIGN & AS-BUILT PERFORMANCE

END OF TERM REPORT

July 2014

APPENDIX D

ZERO CARBON HUB

The Zero Carbon Hub was established in 2008, as a non-profit organisation, to take day-to-day operational responsibility for achieving the government's target of delivering zero carbon homes in England from 2016. The Hub reports directly to the 2016 Taskforce.

To find out more, or if you would like to contribute to the work of the Zero Carbon Hub, please contact: info@zerocarbonhub.org.

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This document contains Appendix D to the End of Term Report, which is available from www.zerocarbonhub.org

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APPENDIX D: TESTING WORK GROUP PROPOSALS

The Testing Work Group was divided into four sub-groups, each of which considered different types of tests relating to the following areas:

1. Air permeability
2. Thermal building elements and junctions
3. Whole dwelling thermal heat loss coefficient
4. Services

Each sub-group produced a paper containing analysis of current testing techniques and recommendations for their future development, which are set out in this appendix. It should be noted that these papers are presented here as provided by the sub-groups, with only relatively minor amendments and edits. Many of the recommendations made have been included in or informed the main report,[1] but some additional Work Group commentary and recommendations are included here.

1. See in particular pages 43-45 of the End of Term Report. To download the report please visit: www.zerocarbonhub.org/full-lib

1. Air Permeability Testing

Air permeability testing is a regulatory requirement for new dwelling developments, which typically means that a high proportion of units (if not all) will be tested on any site. It therefore is already implemented at scale and is well developed. However, some potential improvements and developments are suggested below.

1.1. Existing Test Methodologies

In England and Wales compliance testing is conducted against ATTMA Technical Standard L1, which is based on EN 13829 and CIBSE TM23, both of which are established methodologies for testing the air permeability of whole buildings. Other methodologies do exist which have not been so thoroughly tried and tested but play a part in understanding air permeability from a research perspective, alongside the standardised test methods (for example, pulse testing).

Current Issues

Like all repeatable, standardised testing, the methodology includes some compromises which reduce the 'reality' of the results, for example:

- Results are taken at a 50Pa pressure difference, which is more than 10 times typical, natural pressure difference conditions;
- 'Planned' ventilation is excluded from the test; for example, trickle vents and extract fans are taped during the test, so leakage that occurs through these under normal conditions is not accounted for;
- The ground floor area is included in the calculation which gives a better impression of performance than in reality as air loss through the ground is negligible (if any); and
- Variation in testing 'direction' (i.e. whether the test is conducted under positive or negative pressure) can affect the result, so it would be preferable if all tests were conducted in the same direction.

However, these compromises have been accepted for some time and are largely the result of developing a methodology that can be applied consistently. For example, if the extract vents were not taped they would leak heavily at a 50Pa pressure difference but, in practice, leak much less at 5Pa. But if the testing was done at 5Pa it would make achieving an appropriate percentage accuracy almost impossible and comparison of results very difficult.

The above compromises are acceptable based on demand for a method that is practical and cost-effective to conduct on site and that can be benchmarked between buildings and sites over time. It is important that ongoing research is carried out to understand the impact of these compromises so that results can be validated appropriately for use in SAP.[2]

2. See Appendix B, Evidence Update, particularly the 'Summary of Testing Findings' section on pages 70-73. Available from: www.zerocarbonhub.org/full-lib

An additional issue occurs if the test is not conducted correctly (knowingly or accidentally), compromising the results. It is difficult to know what proportion of testing is undertaken incorrectly and the degree of variation between what was entered into SAP for these units as opposed to the level of air leakage that is actually occurring. If a high proportion of air test results are incorrect then there could be a significant impact on the gap between expected and actual building energy performance.

1.2. Suggested Test Methodology Developments

While improvements could be made to the test methodology, these would not be as effective as improved third party checking and enforcement. No change to the method is proposed, rather that regulatory requirements are changed to:

a) Remove ambiguity

Currently there are three options for who can conduct a test on a new dwelling allowed by Approved Document L1A:

1. UKAS accredited organisations;
2. BINDT Registered individuals; or
3. Any individual that the Building Inspector is satisfied is competent to undertake the testing.

ATTMA are currently in the process of establishing a Competent Persons Scheme (CPS certified) that will be referred to in future Building Regulations and will provide a much more robust method for establishing and checking competence. However, it is unlikely that the option for an 'alternative' will be removed and so it is important that the requirements for verification by Building Control are defined. In addition, it should be considered whether results from non-competent persons also carry a small penalty in SAP so that the CPS certified route is incentivised.

The requirements for the CPS certified scheme should include appropriate training / competence, appropriate equipment / calibration, checks on submitted results and observation of testing.

b) Improve checks and balances

To minimise the opportunities for mistakes, shortcuts, manipulation or fabrication, checks and balances need to be improved. CPS certified results should be based on the testing results being uploaded to a central lodgement location that can only be accessed by suitably competent people and should include automatic and manual checks on the data that is entered to minimise the opportunity for falsification or error. The required information would be mandatory and a report or certificate could only be generated once the information has been submitted. Building Control would have access to this information, as would SAP assessors and other interested parties.

Again, the information required by Building Control from non-CPS certified individuals should be defined and include a similar level of detail.

c) Improve data collection requirements

The current data collection requirements are summarised below, along with some suggested improvements for combined testing, reporting format and error analysis.

- **Season:** All year round, environmental conditions are taken into account. Strong winds may mean that testing cannot be conducted on certain days.
- **Timescales:** Air testing of an apartment should take 15-30 minutes including set-up; a large house may take 60 minutes.
- **Location:** Units in all locations can be tested.
- **Stage of Construction:** Compliance testing typically takes place at the very end of the project. Projects seeking high performance tend to also conduct testing on completion of the fabric / air barrier to address issues at a stage when they are accessible and solvable.
- **Apparatus and Calibration:** Equipment is widely available and relatively low cost: a set of domestic testing equipment starts from around £2,500, including UKAS calibration.
- **Variations or Combined Testing:** Air testing can be conducted in combination with infra-red thermography to assist in the identification of air infiltration paths. The test methodology can be relatively easily adapted on specific projects to account for the issues listed in Section 1.1. This would be beneficial to understand variation in results.
- **Reporting Format:** The way results are presented should be standardised. Currently, this may vary from a hand-written piece of paper with a house number and air permeability, to a detailed report including test data and calculations. For CPS certified results, the lodgement / submission process would standardise this information as well as the format of the certificate / reports. A similar format should be defined for non-CPS certified individuals.
- **Error Analysis:** CPS certified test data should be lodged for verification checks. In addition, audit visits / spot checks should take place.
- **Data and Report Interpretation / Analysis:** CPS certified test data should be lodged for analysis of trends across apartments, house types, locations, etc.

2. Thermal Building Elements and Junctions Testing

It is considered that the variation between expected performance of building elements in terms of thermal transmittance based on calculation and that which is actually realised in real buildings makes a significant contribution to the Performance Gap.

There is currently no regulatory requirement for field or laboratory testing of either thermal transmittance of construction elements (here used to denote walls, floors and other major elements), or the junctions between elements of construction; referred to as U-values and Psi-values respectively. At present, the accepted methods for evaluation of U-values and Psi-values are based on arithmetical models that use either tabulated or tested values for the thermal performance of the components of construction.

The process to arrive at a declared thermal value for most insulation products (normally the dominant factor in the value obtained from a U-value calculation) is formalised in hEN standards and includes safety factors that should mean that the declared value is conservative. Corrections can be applied to the tested value of the insulation for moisture content, temperature and natural convection to arrive at a design value.

Standardised calculation methods are used that reflect the designed characteristics of the elements of construction including (for U-value calculations) repeating thermal bridges, with correction for high thermal conductivity penetrations through the insulation and air gaps in and adjacent to the insulation layer.

Current Issues

Current issues which may contribute to the Performance Gap include the following:

- Where a hEN standard does not exist for a particular type of product there is less certainty regarding the declared performance.
- As noted above, there is currently no regulatory testing required for U-values or Psi-values, in the laboratory or in the field, and test methods need to be developed.
- The calculated U-values and Psi-values assume steady state conditions on both the cold and warm side of the structure and it is therefore implicit that the calculation models require that the structure is completely resilient to the effects of varying surface conditions, particularly external conditions such as wind, moisture and solar.
- Quantification of build variability (i.e. the tolerance of the construction thermal performance to variations from the assumptions made about accuracy of construction in the calculation model) needs to be improved. The tolerance of performance to build variability is likely to be further influenced by exposure to different degrees of surface and external effects, so full quantification is a major task.

The nature and impact of surface and external effects are likely to vary for different types of construction. For example not only will a metal clad wall and a masonry wall react differently to moisture 'surface effects', but different types of masonry walls will react differently to moisture effects depending on the moisture absorption characteristic of the masonry. Wind may have a greater influence on constructions with internal air cavities than those without. Within a single construction type, if the main element has many interruptions (e.g. multiple window and door openings), the effect of wind may be different than if there are no interruptions (e.g. a plane wall with no openings).

The nature of the calculated U-value therefore needs to be carefully considered when deciding to test either a prototype or at scale, and also when reaching conclusions about test results. Charging and discharging of heat or moisture into or from the structure could confound measurements. Equally, if a construction is not fully resistant to the effects of wind within the construction, this will further confound the measurements (this excludes air movement through the construction which would normally be captured in an air leakage value in an assessment of new build). Eliminating these surface and external effects by controlling the environment acting on both surfaces will result in a measurement of U-value in the conditions it was calculated. However, as the surface and external effects will be present in the real life use of the construction element, it needs to be recognised that there is a need to regularise for real conditions.

It is possible to test prototypes (not necessarily for compliance purposes but for research into the dependency on precision of assembly) in laboratories with surface and external effects eliminated according to internationally standardised methods. It is also possible to extend these tests to simulate surface and external effects not covered by standards. By definition it is not possible to test at scale in laboratories and so a regularisation for surface and external effects needs to be made for every field measurement to relate back to a calculated U-value.

2.1 Existing Test Methodologies

Existing methodologies for testing thermal transmittance are discussed below, along with a summary of whether they are applicable as a 'prototype' method or 'at scale'. [3]

Hot Box: Prototype in Lab[4]

An international standard currently exists to control surface and external effects, which measures energy input to maintain temperature difference and hence give accurate results.

Hot box testing can measure plane elements, plane elements with openings and two dimensional junctions in plane elements (and associated thermal bridging); however it is not standard to measure a junction that includes a change of direction (three dimensional).

In terms of timing, as this is a laboratory test it is not dependent on the season, and the time taken to undertake the test is a matter of days.

3. For the purposes of this appendix, 'prototype' is considered to be possible either in lab conditions or in a real building prototype in the field. 'At scale' is considered to be in the field in real buildings as constructed for sale.

4. Environmental chambers also create a location to test thermal performance in the laboratory.

Heat Flow Meters: Prototype in Lab / Field, or At Scale in Field

International standards currently exist for the use of heat meters in laboratories, either in a hot box or in an environmental chamber. Heat flux meters are highly susceptible to surface and external effects and these can be controlled in a lab to maximise accuracy.

When used for prototype in the field, additional measurements are needed to understand surface and external effects. When used at scale in the field, they are highly susceptible to surface effects, with limited scope to make many other measurements or restrict the effects. This lowers the level of confidence that can be applied to the outcome

Thermography: Prototype in Lab / Field, or At Scale in Field

Thermography does not measure U-values or Psi-values, but measures surface temperature and is thus a useful check to see if there are irregularities in heat flow. The output is highly affected by surface and external effects.

2.2 Suggested Test Methodology Developments

The Work Group proposes that there are two key requirements for the development of U-value and Psi-value test methodologies:

- Formalising research processes so that test outputs are comparable and robust information can be generated to improve the reliability of U-value and Psi-value calculations.
- Developing a compliance methodology that allows the declaration of performance for an element of construction, either wholly based on in-situ testing or on calculations with confirmation and corrections generated from in-situ testing. Where a test methodology has the potential to be used as evidence for a compliance methodology it is noted, however, that a BSI, CEN or ISO standardised test protocol must be available. The in-situ measurement cannot be disaggregated to an individual product performance out of the context of the construction element in which it is tested.

Some specific recommendations for test methodology developments are made below.

Registering and Mapping the Tested Installation

As a general recommendation, to account for build variability, it is recommended that in all tests undertaken, a standardised method for registering the precision of assembly of the test specimens is developed. This should include a quality control procedure for the particular construction tested.

Hot Box – Prototype in Laboratory

There is currently no international standard for U-values or 3D thermal bridging to allow for surface and external effects. Some limited experimental work has been done where the standard hot box technique has been amended to include surface and external effects, but more work needs to be carried out to regularise this. Reporting format, error analysis, data and report interpretation and analysis should be similar to current hot box outputs.

There are a limited number of hot boxes available and they must be amended from the standard set up: significant calibration is needed to make sure that the effects are representative, with further calibration for three dimensional test samples.

Passys Type Cell - Prototype in Field

This is essentially a hot box / environmental chamber, but located outdoors with one side (or potentially more) as an aperture to receive elements of construction for testing (it could alternatively be a well-characterised building). The cell exposes the element of construction to surface and external effects and can measure energy input as well as heat flow with heat flow meters. There are currently no operational Passys cells in the UK.

The testing timing is probably limited to the colder months from November to March. There is no control over weather so timings for testing for a suitable range of surface and external effects is not strictly definable.

Reporting would need to include extremely precise information on the element of construction, with details of tolerances of critical layers including videos of assembly and sequencing photographs; details of weather conditions relating to surface and external effects; energy consumption (and conversion to U-values); and heat flow meter results. Error analysis, data and report interpretation analysis would need to be refined.

3. Whole Dwelling Thermal Heat Loss Coefficient Testing

There are currently various existing whole dwelling heat loss test methodologies, though none are formally standardised or required by regulation. The current methodologies are summarised below, along with a discussion of the developments which the Testing Work Group suggests are required to improve their robustness and usability.

3.1 Existing Test Methodologies

Whole House Heat Loss Test – Coheating - Prototype in Field

The primary output from this test is a heat loss coefficient per unit temperature, disaggregated down to a fabric and background ventilation heat loss coefficient. The heat loss output of the coheating test can be compared to the heat loss coefficient in SAP.[5]

At its simplest, the equipment required is a weather station, electrical resistance heaters, air circulation fans, internal temperature and humidity sensors and electrical power consumption monitoring. Test reports should include location, date, weather data, energy consumption, internal temperatures, full detailed plans and pressurisation test results.

The coheating test methodology provides a good platform for a research and development test to prove the competence of a construction typology, matched to process and quality mapping during the construction of the prototype and the translation of this into a process and quality control procedure for that typology when it is put into mainstream production. A 'round robin'[6] to understand the reproducibility of results showed this to be reasonable: variability was thought primarily to be due to variance in procedures, lack of adherence to protocol, variability in testing experience and unsuitable weather conditions during some of the tests.

5. There are two components to the ventilation heat loss in SAP: purpose provided ventilation and background ventilation. In the coheating test only the background ventilation heat loss is measured and aggregated together with the fabric heat loss.

6. NHBC Foundation, Review of Co-Heating Test Methodologies (2013) NF 54 http://www.nhbcfoundation.org/Publications/Primary-Research/Review-of-co-heating-test-methodologies-NF54

Current Issues

As noted above, there are no formally standardised test methods available for whole house heat loss tests, and consequently no possibility to accredit testing organisations to undertake the tests. However, a test protocol has been developed by Leeds Metropolitan University[7] which also discusses data analysis techniques, and work is currently being undertaken in CEN to develop a formally standardised coheating test methodology based on the existing protocol. The current test is considered to be time-consuming, expensive, complicated and highly weather dependent, and also requires stable internal conditions. This makes it unattractive as an end-of-line test for new build housing, even if only a very small sample size is required. Further details are given below:

- The test must be carried out on uninhabited dwellings;
- It is restricted by weather conditions, so is typically only possible between November and March;
- It takes approximately two weeks, but it is not possible to be certain whether the dwelling has been exposed to a full range of potential 'surface and external factors' in that period.
- The test is relatively straightforward to undertake in detached, semi-detached and terraced dwellings, but becomes much more complex to undertake in apartments, due to a large number of boundary conditions.
- The test is post-construction and should be undertaken only after moisture levels within the dwelling have reached equilibrium.
- Error analysis, data and report interpretation and analysis need to be developed for the formal standard, but an initial outline is provided by the coheating test protocol.
- The heat loss coefficient in SAP is based on calculated inputs, such as areas, U-values and Psi-values. It is likely that there are Performance Gap issues due to input errors and calculation issues associated with SAP which need to be taken into account when comparing SAP heating coefficient with coheating test results, but these are not fully understood.

A crucial Performance Gap issue around whole house heat loss testing is that when tests have been undertaken, they have commonly shown differences between the whole house heat loss coefficient predicted in SAP and the actual values measured in coheating tests undertaken for research purposes. It is considered that there should be strict governance of product performance declarations for the critical components and the calculation methodologies used to collect the predicted heat losses, with investigation required to find:

- Errors in the methodology;
- Variance between the assumptions used in the calculations and what was achieved; and / or
- Some unexpected factor.

7. Johnston, D., Miles-Shenton, D., Wingfield, J., Farmer, D., Bell, M. (2012) Whole House Heat Loss Test Method (Coheating) Available from http://www.leedsmet.ac.uk/as/cebe/projects/iea_annex58/whole_house_heat_loss_test_method (coheating).pdf

When data acquisition and analysis methods are developed, the final As-Built SAP could potentially include data and corrections derived from real life testing.

There are a number of other emerging test methods which may help address some of the issues identified, including some that may better suit the needs of the house building industry as an end-of-line pre-occupancy test or potentially post-occupancy monitoring. Some of these emerging test methods are summarised below.

3.2 Suggested Test Methodology Developments

Coheating Test - Prototype in Lab

Some limited experimental work has already been done to include a heated construction inside a large environmental chamber, which generates simulations of weather (surface and external effects). However a further developed and formally standardised coheating test methodology with accreditation for testing organisations is needed for undertaking coheating tests in environmental chambers. As with the original coheating test outlined above, the primary output would be heat loss coefficient per unit temperature, broken down to a fabric and a background ventilation heat loss coefficient (along with details of energy consumption, conversions to U-values and heat flow meter results). The equipment required would be very similar, and the report would contain the same items plus a profile of the conditions created and details of any amendments made to the construction being tested for the purposes of the test. This would include very precise information on the construction, with details of tolerances of critical layers, including videos of assembly and sequencing photographs. Error analysis, data and report interpretation / analysis would need to be developed but an outline is provided in the original coheating test protocol.

As the test would be undertaken in a laboratory it would be non-weather or season dependent; however the simulated weather conditions must be representative and work is needed to define this. The test itself should take no more than two weeks and is likely to be considerably shorter, but the time required to assemble the construction in the chamber and for it to reach equilibrium is considerably longer (potentially several weeks). There are currently very few environmental chambers available but the apparatus for making measurements is well understood and calibration methods exist.

Dynamic Test Methods – Prototype or At Scale in Field

A number of dynamic test methods are under development including Pstar, Cooldown and QuB (Quick U-value of Buildings). They promise a much shorter test period using dynamic characteristics to arrive at a result. The primary outputs are whole house heat loss coefficient per unit temperature and thermal mass.

Integrated Coheating - Prototype or At Scale in Field

A formally standardised coheating test methodology with accreditation for testing organisations using the dwelling's installed heating system is being developed. As for the standard coheating test, the primary output is a whole dwelling heat loss coefficient per unit temperature. In addition to the standard coheating test, this test has the potential to provide information on space heating services operation and efficiency, which would be extremely valuable.

In Use Monitoring – At Scale in Field

This method involves monitoring heat input, weather and occupation to enable fabric performance to be determined. The primary output would be heat loss coefficient per unit temperature, but other information generated would include occupancy data, services use and possibly measurements of thermal elements.

This test can be undertaken on inhabited dwellings and it separates hot water usage and monitors occupancy to allow for separation of the fabric heat loss component of energy usage. At its simplest the equipment required is a weather station and internal temperature and power consumption, but additional equipment gives further information and allows more detailed analysis. The report should include at least location, weather data, energy consumption, internal temperatures, occupancy profile and full detailed plans of the dwelling. Error analysis, data and report interpretation / analysis need to be further refined.

This method is also discussed in Appendix F 'Assured Performance Work Group Proposals'.

Energy Monitoring – At Scale in Field

This method involves monitoring energy consumption and weather data across a large number of dwellings to enable fabric performance to be determined at an aggregate level. The primary output would be heat loss coefficient per unit temperature.

This test can be undertaken on large numbers of inhabited dwellings, and uses algorithms to establish the heat loss coefficient of a group of dwellings. At its simplest, the measurements required are weather data and periodic power consumption per property. The length of the monitoring period would need to be established. The output relates to a population of dwellings and is not suitable to breakdown to the single dwelling; however a report would include location, weather data, energy consumption and floor area per dwelling, for each dwelling in the population. Standardised methods of error analysis, and data and report interpretation / analysis need to be developed.

4. Services Testing and Commissioning

During the course of the Performance Gap project it has become clear that in addition to considering the fabric of the building, there is increasing evidence that the mechanical and electrical services installed in dwellings also have performance uncertainties. This is partly due to the rapid increase in the uptake of new heating, domestic hot water, ventilation and control technologies that have been driven by updates to Part L of the Building Regulations, and also due to the great variability in occupant knowledge, motivation and lifestyles. Clearly design assumptions have to use some standardised pattern, as is assumed in SAP, but even applying this standard demand pattern, the outcomes of the system performance (as opposed to the performance of individual components) will depend crucially on the quality of the integration of the elements and the overall commissioning of the system.

4.1 Existing and Proposed Testing and Commissioning Methods

Testing

The following tests are needed for services in a dwelling:

- **Ventilation system test:** A system test to demonstrate that the air movement system can ventilate the required rooms to the required level of air changes; also that the air handling system and the heating system can together deliver a comfortable environment.
- **Ventilation system efficiency test:** To demonstrate whether the system delivers the air changes with the stated power input.
- **Hot water/ space heating system test:** To test whether the hot water system is capable of delivering the required amount of hot water; also to demonstrate that the heating system delivers sufficient outputs to heat the rooms as desired, and that this can be controlled adequately by the end user.
- **Hot water system efficiency test:** To demonstrate whether the hot water system is as efficient as stated and can provide the amount of hot water required by end users simultaneously. The speed of heating a hot water tank may indicate the efficacy of a system. Where there is a known or reference design it will be possible to identify failing installations relatively quickly.
- **Boiler controls test:** To establish whether the boiler responds correctly to control signals.
- **Temperature control test:** To test whether the heating system delivers the required room temperatures.

In theory, services are less prone to problems caused by site issues than building fabric. Services installers tend to work within the envelope in dry conditions, and are less subjected to the vagaries of the weather. If a services system installation is prototyped and tested adequately, then it should be possible to install most systems reliably at scale. Provided that sufficient information is given to the installer, a compliant system should be achievable.

However, there are issues caused by the lack of a commonly used methodology for the in-situ testing of mechanical services in domestic buildings. The majority of services tests are laboratory tests, which are for components or parts of a system rather than the behaviour of the entire system. There is also no known laboratory protocol for the testing of a full service system.

There are also substantial questions around the performance of newer and innovative services. There has been rapid development of new types of systems and system components in the last decade, but there is an emerging problem with installations of unfamiliar services both from an installer and end user perspective.

Commissioning

Research such as the TSB Building Performance Evaluation programme has consistently revealed deficiencies in the commissioning of even quite simple systems. With the likely increase of smart controls, the growing occurrence of complex systems and the relatively low levels of skills available in the installer community, the likelihood of achieving as-designed performance is at risk.

This situation is not new in the world of commercial buildings, where complex systems with many discrete components installed by a variety of specialist contractors is commonplace. What has evolved in this market is a well developed role for the commissioning engineer, assisted by a variety of industry-supported guides and processes that bring a degree of order and traceability to the activity of putting systems into work in the designed manner. Key to this are well documented records of measurements taken and adjustments made. These form part of the handover package and are available for scrutiny should the system subsequently fail to meet the designer's expectations for comfort and performance.

There are commissioning guides for commercial buildings and for communal services, but not for individual domestic homes. Although the Building Regulations require commissioning of systems in domestic premises, the supporting requirements are less well articulated and tend to refer to the performance of individual components rather than to the system as a whole. Thus boilers are checked for combustion efficiency using flue gas analysis, but their setting - and those of associated components such as thermal storage tanks used with solar heating - is less well documented.

The Renewable Heat Incentive will require the installation of heat metering for communal domestic systems, which will introduce the concept of commissioning and metering to clients and installers in the domestic sector.

4.2 Suggested Testing and Commissioning Practice Developments

Define New Testing Protocols

For each of the tests set out above, the following details need to be agreed and defined:

- **Definition:** the nature of each test, what form the output takes, etc.
- **Data collection requirements:**
  - **Season:** Services can be tested at any time during the season.
  - **Timescales:** Most services can be tested within 24 hours of installation.
  - **Location:** Certain systems are subject to location specific issues, for example: photovoltaic panels depend on the availability of direct sunshine and can be compromised by tree growth or nearby buildings; solar thermal suffers from similar effects.
  - **Stage of construction:** In the construction phase some testing is possible, such as ductwork flow rates and visual inspections of pipework and ductwork. Air leakage tests of ductwork should be carried out before plasterboard linings are applied. Plumbing is often installed differently in identical dwellings even with the same system elements, so plumbers need drawings to follow to ensure even performance and easy maintenance.
  - **Apparatus and calibration:** Use of thermal imaging is possible to identify hot spots and check the proper working of an installation. It can also be used as a diagnostic tool to find hidden hotspots that are evidence of poor pipework insulation or air duct leakage.

A laboratory protocol needs to be developed for the testing of a services system including hot water, domestic heating and domestic ventilation systems.

Improve Commissioning Guidance

There is an urgent need for the development and implementation of improved standard and comprehensive installation and commissioning guidance for domestic building services. This would include pro-forma documentation of measurements made, so that equipment is properly set. A collaborative effort will be needed to develop the guidance, including suppliers of specialist equipment, experts drawn from the commercial application of commissioning and key stakeholders such as utilities, insurers and warranty providers. The guidance should include all systems that are currently covered in SAP, including Appendix Q, that are anticipated to be used in dwellings from 2016 onwards. A number of existing guides from BSRIA may act as examples.[8]

Competency Requirements for Testers

A new competency requirement should be introduced for those charged with ensuring that commissioning has been completed successfully. As mentioned in the Energy Literacy section of the main report, commissioning and testing should be carried out by properly trained and competent people. Compliance testing should be based on voluntary compliance schemes. Voluntary competence schemes, such as in the airtightness testing sector, incur extra costs, disadvantaging companies that do adhere to them. Without mandatory competency requirements or disincentives for use of 'non-competent' testers (e.g. in SAP), there is less certainty of outcome, so changes are needed to require or incentivise use of the competency scheme. A similar route could be used for the testing of air handling and MVHR systems.

Should a regulatory requirement not be possible, it is recommended that a testing regime be introduced, based on voluntary compliance, with an option to gain a greater benefit in SAP from a compliance certification.

Improve Testing and Commissioning of New and Innovative Services

It is recommended that once a laboratory testing protocol has been agreed, a comprehensive set of tests should be carried out in the laboratory and then in the field of all typical domestic hot water, heating and ventilation systems.

Field trials should be used to test the efficiency in practice of innovative technologies. This approach has worked well with heat pumps and condensing boilers. It is also needed for other technologies such as communal heating systems (particularly in high density apartments and considering heat losses within buildings) and waste water heat recovery systems. Further trials are also needed to test certain aspects of some technologies which have had trials already (e.g. heat pumps with continuous heating compared to use of pulsed heating). Field trials should investigate performance at the full system level.

Installation and commissioning also need to be improved. For example, the German market is characterised by users who buy a system installed by trained installer, rather than buying a series of components put together by a plumber. As problems with novel or unfamiliar services will often not be obvious to end users, the services need to be assessed by a competent person before handover.

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8. For example: Commissioning Water Systems (BG 2/2010) Parsloe C BSRIA ISBN 978086022689; Commissioning Job Book - A framework for managing the commissioning process (BG 11/2010) Hawkins G BSRIA ISBN 9780860226970; and Model Commissioning Plan (BG 8/2009) Deramchi, S., Hawkins G. BSRIA ISBN 9780860226871

Assessment of 'System-Level' Services Performance

It is recommended that a method be developed that combines elements of the SAP Product Characteristics Database (PCDB) into systems and relates their efficiency to the fabric performance of the dwelling. More guidance is also needed in SAP tools for designers to enable them to make informed choices about appropriate systems to use.

The use of the PCDB in SAP creates a market where high performance services elements are automatically brought to the top of a list, which ignores the fact that an efficient system is made up of a number of linked components. The PCDB encourages manufacturers to gain maximum benefit by testing and making small, incremental improvements, rather than considering the performance of the entire system.

The SEDBUK database and PCDB provide good precedents for the handling of data on the efficiency of services. This database should be amended to include all the components of the relevant system and be used in SAP. This would help to avoid problems caused by poor substitution of components.

Further work is also needed to understand interactions with fabric – for example the impact of thermal mass on heating types is not well understood or modelled. A benefit is given in SAP for underfloor heating, but it is not clear that underfloor heating delivers higher efficiency or better comfort for occupants in all types of buildings.

This links to the recommendation above to undertake field trials for full systems.

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