CLOSING THE GAP BETWEEN

DESIGN & AS-BUILT PERFORMANCE

Evidence Review Report

March 2014

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.

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Published March 2014

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EXECUTIVE SUMMARY

There is now clear evidence of a gap between the designed and as-built energy performance of new homes.

This gap can arise in a number of ways within the overall house-building process and, if significant and widespread, represents a number of risks to government, industry and consumers.

In February 2011, a Zero Carbon Hub task group, having reviewed historical research[1] and gathered further industry evidence, advised that future performance standards for zero carbon homes should be linked to 'as-built' performance to achieve the '2020 Ambition'.

In response to this challenge the Performance Gap project commenced at the start of 2013, bringing a wide range of participants together to establish a better understanding of the Performance Gap and to formulate any necessary solutions. The initial activities and findings are detailed in the Interim Progress Report, published in July 2013.[2]

Closing the Performance Gap – the 2020 Ambition:

From 2020, be able to demonstrate that at least 90% of all new homes meet or perform better than the designed energy / carbon performance.

1. Zero Carbon Hub, Carbon Compliance for Tomorrow's New Homes, Topic 4: Closing the Gap Between Designed and Built Performance, August 2010.

2. Zero Carbon Hub, Interim Progress Report: Closing the Gap Between Design and As-built Performance, July 2013.

Evidence Review Report

This report summarises the evidence gathering and assessment process undertaken between August 2013 and January 2014. It provides industry and government with a structured review of how and where the Performance Gap occurs within the current housebuilding process. This has involved a co-ordinated analysis of published literature and confidential industry research, and the development of a process review methodology to gather primary evidence from housebuilding delivery teams, including visits to live construction sites.

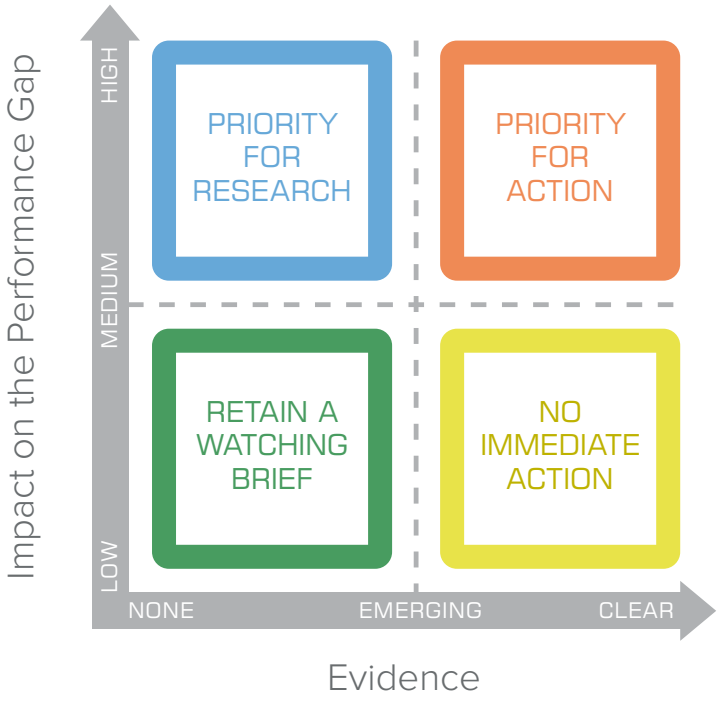
The evidence collected so far has been used to prioritise which issues are considered to be the major contributors to the Performance Gap.[1] The prioritisation process has been based upon the extent of evidence found and the significance each issue is considered to have on the Performance Gap.

Evidence Collection and Review

The evidence review encompasses a wider range of sources than any previous study of the Performance Gap to provide a balanced assessment of the issues. The aim is to consider the role all stages of the housebuilding process play rather than focussing on individual stages such as design or construction. This review has included:

- **Literature Review** in which nearly 100 reports were reviewed in detail. Around 45% were academic studies or other government or industry research, around 35% were building performance evaluation projects or other studies involving site visits and assessments of performance, around 10% were field trials, 5% manufacturer-commissioned reports and 5% guidance.
- **Housebuilding Process Review** made possible by housebuilders volunteering sites of varying sizes, types and construction methodologies. These were reviewed using interviews, a study of design information and site visits.
- **SAP Audits** undertaken for plots on each of the sites visited to investigate errors in SAP assessments and differences between the SAP assessments and site observations.
- **SAP Assessor Accreditation Organisation Questionnaire** to understand the training, examination and continual professional development regimes and to identify common areas of assessor errors found at audit and frequent questions dealt with by helplines.
- **SAP Assessor Questionnaire** to which around 150 assessors responded, providing information on how they typically work, what information they are provided with, what challenges they face and where a Performance Gap might occur.

1. *A full list of these can be found in Annex A*



Emerging Results

Drawing upon this evidence, a team from the Zero Carbon Hub and Steering Group categorised all of the issues identified using the prioritisation matrix approach presented in the Interim Progress Report (see diagram above). A ranking for the existence of evidence relating to each issue was agreed. A combination of multiple peer-reviewed industry research reports and Housebuilding Process Review examples were required to merit a position towards the right of the matrix. The team then drew upon the evidence where it existed, and their industry experience to define a range for the potential impact each issue may have on energy performance.[1]

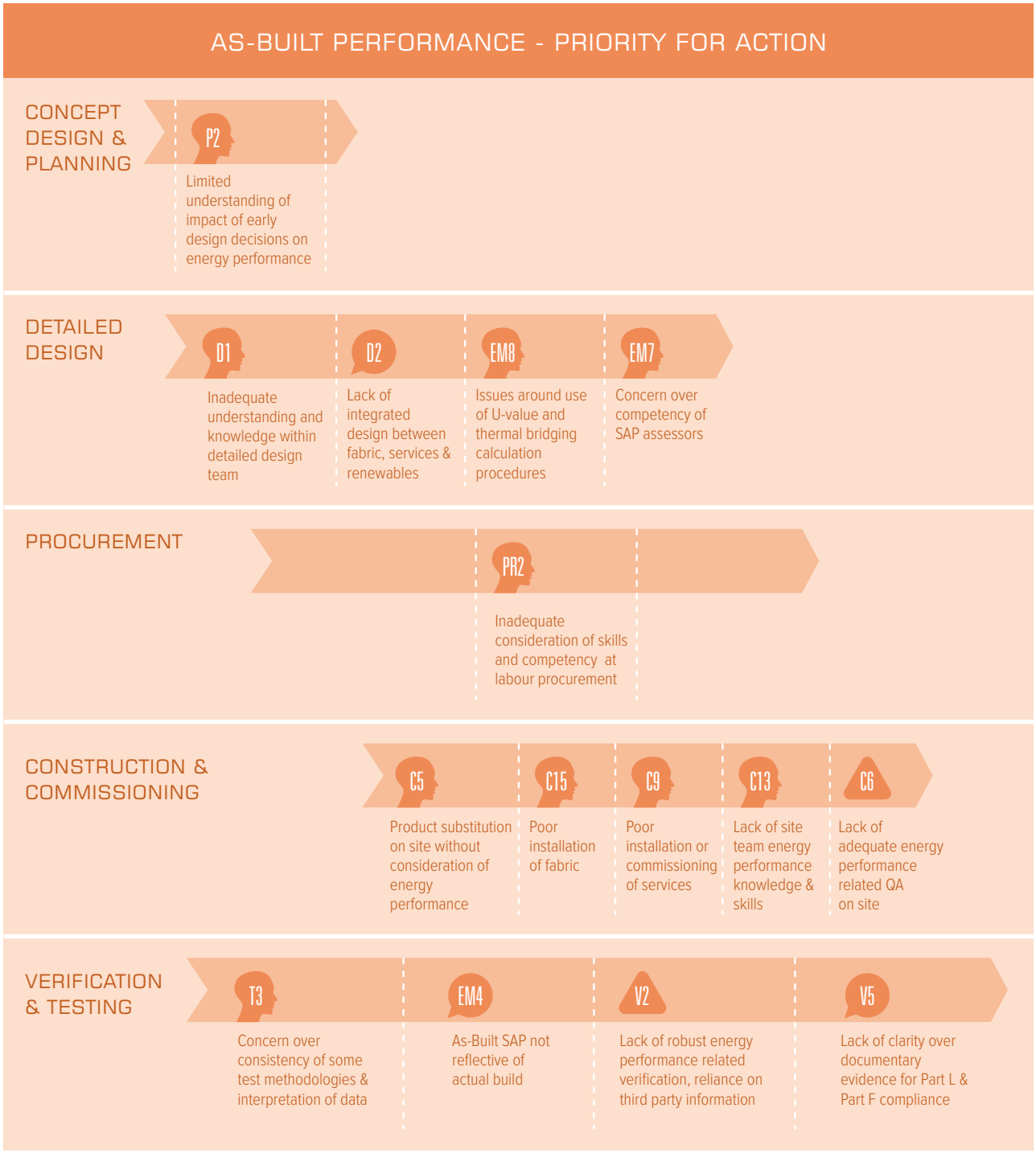
Each quadrant of the prioritisation matrix represents a different challenge:

- **Priority for Action** – Issues with a strong supporting evidence base and medium to high potential impact on the Performance Gap when they do occur.
- **Priority for Research** – Issues with emerging evidence and a suspected medium to high potential impact on the Performance Gap when they do occur.
- **Retain a Watching Brief** – Issues with limited evidence and a suspected low to medium potential impact on the Performance Gap when they do occur.
- **No Immediate Action** – Issues with a large degree of evidence but with a low impact on Performance Gap when they do occur.

This project's approach of viewing performance related issues across the housebuilding process revealed a number of cross-cutting themes including 'Knowledge and Skills', 'Responsibility' and 'Communication'.

1. See Section 2 of the main report for an explanation of the rating process.

The following diagram illustrates where the 'Priority for Action' issues occur across the delivery process and how they relate to these cross-cutting themes.[1]



CROSS-CUTTING THEMES

KNOWLEDGE & SKILLS

RESPONSIBILITY

COMMUNICATION

1. The issue references relate to different stages of the housebuilding process (e.g. C = Construction). The full list of references can be found in Annex A.

Priority for Action – 15 issues

A total of 15 issues have been found to be both supported by strong evidence from multiple sources and likely to have a significant impact on the Performance Gap. The project will now focus its efforts on developing pragmatic solutions for the following issues across the delivery process: [1]

P2 Planning and concept design teams are not sufficiently aware of the implications of early stage decisions on the energy performance of completed dwellings.

D1 Detail Design teams do not understand site and buildability issues well enough to be able to reliably design energy efficient homes with consistent as-built performance.

D2 Different aspects of design, in particular building fabric and services, are not being properly integrated. This results in unintended thermal bridging, compromised air tightness strategies and reduced system efficiencies.

EM8 Calculation assumptions for both fabric heat loss (U-values) and thermal bridging (Psi-values) do not reflect the reality of site construction, often giving lower heat losses than can actually be achieved.

EM7 SAP assessors are often unclear on modelling conventions and calculation of U-values, thermal mass, and thermal bridging, and may be expected to provide detailed design advice beyond their technical knowledge and industry experience.

PR2 Procurement teams do not prioritise energy related skills when selecting contractors, resulting in site teams that lack the knowledge to properly install services and fabric.

C5 Products with energy performance different to the intended design are being used on site without being fed back to the design team and the As-Built SAP assessment; typically foundation block work, lintels, windows and ventilation ductwork.

C15 Building fabric is often incorrectly constructed, typically cavity wall insulation, eaves to wall junction insulation and particularly the positioning of windows and doors, reducing the actual performance of the thermal envelope.

C9 Building services are being incorrectly installed and poorly commissioned, resulting in reduced system efficiency and compromising the air tightness and ventilation strategies. Common examples include missing primary pipework insulation and poorly commissioned ventilation systems.

C13 Site teams often lack the knowledge and skills to construct energy efficient homes with consistent as-built performance.

C6 Site Quality Assurance procedures prioritise other issues above energy performance; this increases the risk of improperly fitted insulation, incorrectly installed services and thermal junction detailing different to the intended design.

T3 Test methodologies for both as-built fabric and building services performance are not always consistently applied, and therefore can have implications on energy modelling assumptions.

EM4 As-Built SAP calculations are often produced without inclusion of amendments to the design specification during the procurement or construction process.

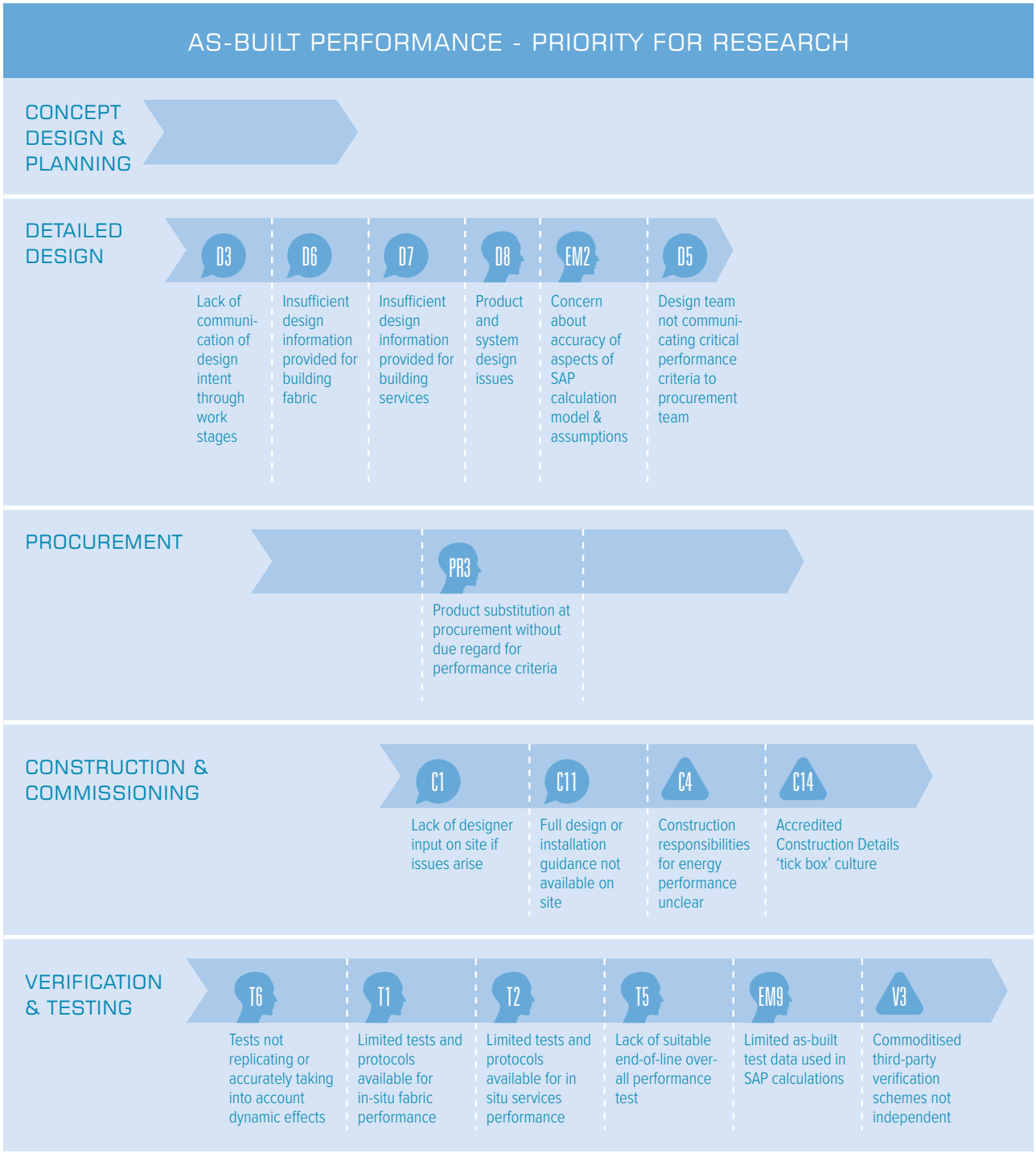
V2 Verification procedures across the housebuilding process are not prioritising energy performance. There is reliance on third-party information and inadequate time, knowledge and incentives to focus on as built performance.

V5 Inconsistent evidence is being requested by and provided to Building Control Bodies, in particular areas such as Accredited Construction Details and building services commissioning. This results in uncertainty around the actual constructed specification and energy performance.

The delivery process diagram illustrates that the majority of these issues result from a lack of 'Knowledge and Skills'. There is also a strong indication that the theme of poor 'Communication' runs through several of the Detailed Design and Verification issues. The cross-cutting nature of these themes means issues influencing the Performance Gap can be seen across the professions and trades.

1. A detailed description of the evidence review for each issue can be found in Section 3 of the main report, and discussion of next steps in Section 4.

The following diagram illustrates where the 'Priority for Research' issues occur across the delivery process and how they relate to these cross-cutting themes.[1]



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1. The issue references relate to different stages of the housebuilding process (e.g. C = Construction). The full list of references can be found in Annex A.

Priority for Research – 17 issues

A number of issues were identified that are considered to have a potentially significant impact on the Performance Gap, but for which we currently lack sufficient evidence to fully understand how extensive their contribution may be. This shortfall of evidence means these issues merit further investigation. There is a risk to industry and government that investment to develop solutions and research activities will be misplaced if these issues are prematurely considered of low importance.

The diagram opposite illustrates where the 'Priority for Research' issues have been identified. The project will continue to try and gather further evidence and develop longer term research strategies for these issues.

There is an increase in the frequency of 'Communication' themed issues within this diagram. It is perhaps not surprising that the evidence review has found emerging evidence of communication deficiencies. However, it is difficult to trace the root cause and detail of communication problems which bridge across multiple professions and teams.

Several Testing and Verification related issues are included, which are predominantly 'Knowledge and Skills' themed, indicating that there is a clear need to better understand the manner in which current methodologies reflect as-built performance. Further detail on which aspects of current practice require investigation and how they relate to design and energy modelling can be found in Section 3.

Retain a Watching Brief – 23 issues

A total of 23 issues have been classified as having a low level of evidence and likely to have a relatively low impact on the Performance Gap. Broadly speaking, little evidence of these issues was found across all sources; typically each one was raised in less than 20 medium quality reports in the Literature Review and identified in three or fewer of the sites visited. Further detail on these issues and an indication of 12 that are considered to merit closer observation is provided in Section 3.

Conclusion

The current housebuilding delivery process has been developed within a compliance regime based upon designed energy performance. However this evidence review has been conducted based on a vision of a future compliance regime focused on as-built performance. Therefore the findings should be considered with this in mind.

Having reviewed a large body of published research and conducted detailed investigations of nine current housing developments to date, with a total of 97 plots assessed, it is clear that many of the issues identified as potential sources of the Performance Gap do exist. Based on this evidence it has been possible to identify 15 issues that merit the development of comprehensive solutions in the near future, be they industry-led or where necessary involving government intervention.

These highest priority issues appear across the entire housebuilding process, for both developers using standardised housetypes and those using more bespoke designs. Consequently they are not the sole responsibility of any one discipline or sector. The theme of 'Knowledge and Skills' deficiencies is evident within all stages of the process, overlapping with other cross-cutting themes of 'Communication' and 'Responsibility'.

Another 17 issues have been prioritised as requiring further research in order to better understand their impact on the Performance Gap. Once again, many of these issues relate to a lack of 'Knowledge and Skills', particularly within the Testing and Verification stages. Of no less importance are the numerous issues relating to 'Communication' problems across the various delivery stages.

Next Steps

This Performance Gap project concludes in summer 2014, as part of the longer journey to 2020. Activity is now focused on continued evidence gathering and the 'Priority for Action' and 'Priority for Research' issues, as outlined below.

Continued Evidence Gathering

Evidence continues to be gathered and analysed, to allow a final review of the prioritisation of issues set out in this report.

In addition to the results from the first nine sites in the Housebuilding Process Review and associated SAP Audits included in this report, more are scheduled to bring the total to around 20. This will allow a range of construction types and housebuilders to be analysed: timber and masonry construction, large housebuilders and small. It is also proposed to carry out some on site testing of completed dwellings on these sites. The Testing Work Group have advised on suitable tests and protocols to use, covering both fabric and services performance.

A SAP Sensitivity Analysis is being carried out to understand the impact of potential input errors, including a consideration of the likelihood of these errors occurring.

Finally, a Work Group of building services specialists has been formed to ensure that all issues relating to services have been identified and to provide any further evidence that is available or needed to help understand the scale and nature of these issues.

Actions for Priority Issues

An Assured Performance Work Group has been formed to develop potential mechanisms that would demonstrate the '2020 Ambition': that by 2020 at least 90% of all new homes meet or perform better than their designed energy / carbon performance. These mechanisms also aim to provide industry with the necessary information to drive a continuous cycle of improvement.

Three further Work Groups are being established to understand how housebuilding delivery models of different scales and with different procurement routes could respond to the 'Priority for Action' issues, within the context of the work of the Assured Performance group.

Proposals will also be made for research strategies to address the 'Priority for Research' issues, with potential funding routes identified.

Final conclusions, proposed solutions and recommendations for further research will be detailed in the End of Term Report, to be published summer 2014.

1. INTRODUCTION

There is now clear evidence of a gap between the designed and as-built energy performance of new homes.

This gap can arise in a number of ways within the overall house-building process and, where significant and widespread, creates a number of risks.

For government, the Performance Gap would mean that new housing cannot be relied upon to play its expected, vital role in achieving national carbon budget targets. For owners and occupants, energy bills may be higher than expected, undermining buyer confidence in new (low carbon) homes. For planners, designers, manufacturers and housebuilders, underperforming new homes could impact on their reputation and business. Investigation into the Performance Gap is therefore a priority for government and a wide spectrum of groups across the sector.

Industry engagement with this project reflects its perceived importance: over 140 professionals are working with the Zero Carbon Hub to explore potential causes of the Performance Gap and to develop cost-effective and realistic proposals to help close it.

Background

In 2010, a Zero Carbon Hub report[1] reviewed historical evidence for the Performance Gap from a limited number of sources, finding evidence that a gap exists, but concluding that more work was needed to understand the scale and technical issues involved. In February 2011, a Zero Carbon Hub task group advised that future performance standards for zero carbon homes should be linked to 'as-built' performance to achieve the '2020 Ambition'.

With Government and Industry support, this Performance Gap project commenced at the start of 2013, bringing participants together from all parts of the house-building process to establish a better understanding of the Performance Gap and to formulate any necessary solutions.

Closing the Performance Gap – the 2020 Ambition:

From 2020, be able to demonstrate that at least 90% of all new homes meet or perform better than the designed energy / carbon performance.

Project Progress

The scope, objectives, and structure of the project are described in the Interim Progress Report published in July 2013.[2] The project structure consists of a Steering Group, an Industry Executive Committee, and a series of 10 specific Work Groups. The initial stages of work included the identification of a list of issues that were perceived to have an impact on the Performance Gap, based on expertise from across the housebuilding and academic sectors. Subsequently these issues were consolidated and grouped into themes (see Annex A for the full issues list).

The recent focus of the project has been on collating evidence to substantiate and prioritise the issues that emerged during the first phase of work. The Interim Progress Report identified a number of evidence collection methods, of which the most appropriate have been undertaken or are substantially underway.

Taking into account all evidence gathered to date, the concept of the Impact-Evidence Matrix proposed in the Interim Report has been used to prioritise issues. Each issue has been rated based upon the extent of evidence found and the significance each issue is considered to have on the Performance Gap.

The original project timeline has been extended to allow for a longer evidence gathering phase and for some on site testing of completed dwellings to be carried out. The project will now run until summer 2014. An updated work plan is shown on the following page.

1. Zero Carbon Hub, Carbon Compliance for Tomorrow's New Homes, Topic 4: Closing the Gap Between Designed and Built Performance, August 2010

2. Zero Carbon Hub, Interim Progress Report: Closing the Gap Between Design and As-built Performance, July 2013

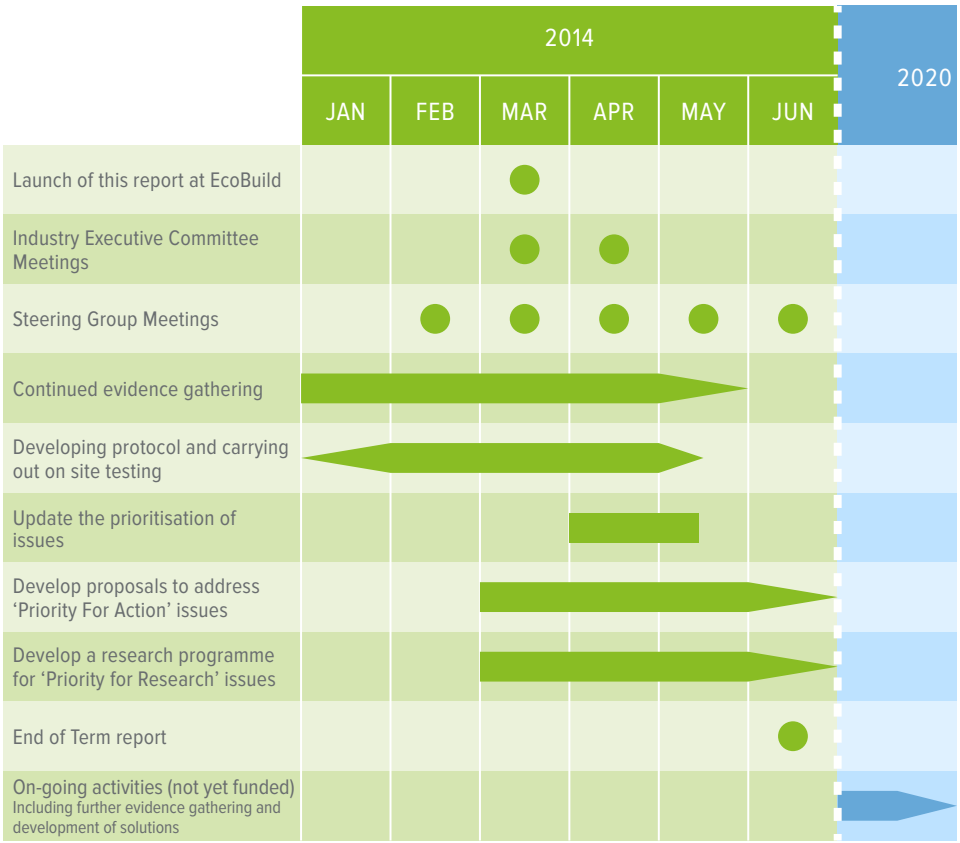
This Report

This report summarises the evidence collected so far and explains how this has been used to prioritise which issues are considered major contributors to the Performance Gap. Evidence types include both a detailed Literature Review of existing research and primary research in the form of the Housebuilding Process Review, SAP Audits, and questionnaires of SAP assessors and assessor organisations. The methodology used for collecting and assessing the evidence is explained in Section 2.

Section 3 summarises the evidence found for each issue, split into four categories.

Section 4 outlines conclusions and next steps including the remaining work involved in completing the evidence gathering and analysis, carrying out of on-site testing, proposing potential solutions and identifying areas for further work.

Work plan



2. EVIDENCE COLLECTION AND REVIEW

While the housebuilding industry has long been aware of many potential issues which might contribute to the Performance Gap, a need was identified for a more systematic review of evidence to determine which issues are particularly significant, and which require further evidence.

A wide range of evidence has been reviewed and a brief explanation of each of the sources is set out below, with a more detailed methodology available in the appendices, which can be found online.[1] A description of the process used to review the body of evidence as a whole and to rate the significance of different issues is also provided.

1. www.zerocarbonhub.org

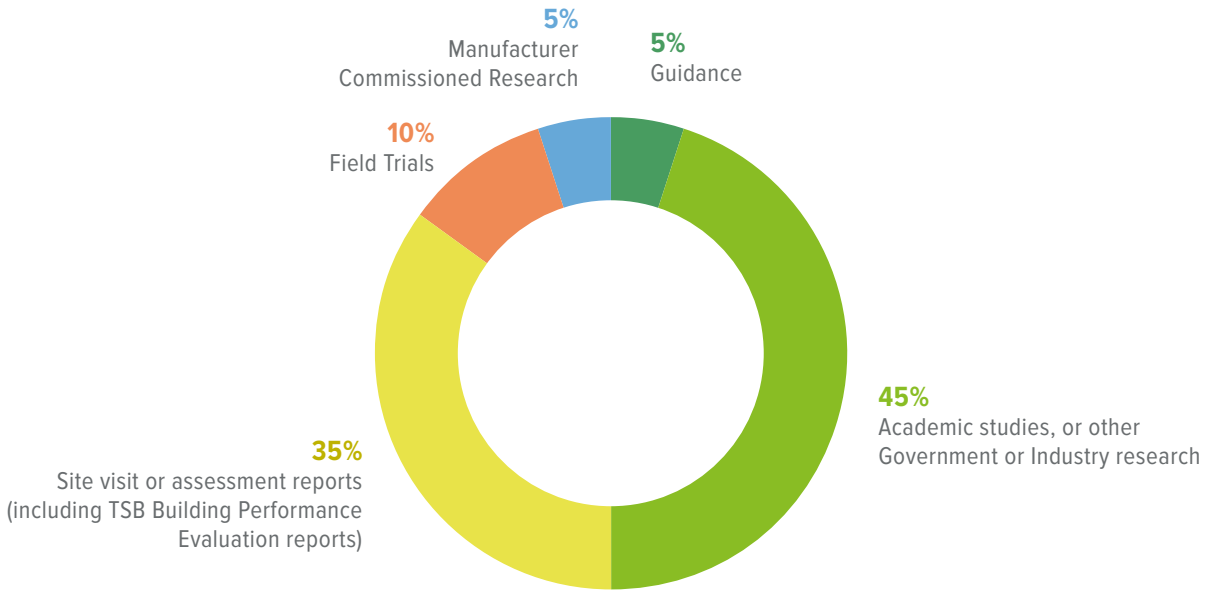
Literature Review

A Literature Review of existing research was undertaken as a key source of evidence for the project. Evidence for the Literature Review was collected over a period of nine months ending December 2013. Reports relating to the Performance Gap were gathered from a variety of sources:

- Work Group members;
- Housebuilders, manufacturers or suppliers, in confidence;
- Universities, in response to a request for relevant information;
- The Technology Strategy Board, with access to the Domestic Building Performance Evaluation Phase 1 reports given under a non-disclosure agreement;
- BRE catalogues; and
- Reference sections of other reports.

A team of experienced construction professionals reviewed almost 100 reports, split as shown in the diagram below. A list of the non-confidential reports reviewed is provided in Appendix 1 along with further detail on the methodology used.

Breakdown of literature review report types



Housebuilding Process Review

A range of housebuilders have volunteered sites of varying sizes, types and construction methods, to be reviewed using interviews, site visits and a study of design information.

The review is still underway: included in this report are results from nine sites, with a total of 97 plots assessed. All are built under 2010 Building Regulations, some with additional planning requirements such as Code for Sustainable Homes targets or renewable energy provision. Reviews of more sites are currently ongoing or planned, the results of which will be included in the End of Term Report, to be published in summer 2014.

The sites included in this report were mostly built by larger developers, typically using traditional construction; a wider range of site types and sizes is planned for the remaining stages of the review.

The reviews are carried out by a team containing a range of disciplines: a developer technical director, a developer build manager, a SAP assessor and an architect, with additional resources from services engineers and academics available where necessary.

Information is collected in three stages, outlined below:

Stage One: Preparation and Interviews

The process commences with a review of design documents and a series of interviews to help understand the development, including its energy targets, the delivery team communication processes, issues that may contribute to the Performance Gap and examples of good practice.

A structured interview is held with each of the following teams or individuals: concept design and planning team, detail design team, SAP assessor, procurement team, construction team.

Stage Two: Design Review

The review team carry out a thorough review of the design documents, to understand how the project requirements are incorporated into the working drawings and to prepare for site visits. Documents typically include specifications, construction details, working drawings, M&E design, the SAP assessment and, where available, as-built data and commissioning sheets for completed plots.

Stage Three: Site Visit and Information Collation

For each site, plots are reviewed at all stages of the build process where possible, including:

1. Sub-structure
2. Over-site
3. Over-site to joist
4. Joist to roof (including roof structure)
5. Roof to weathertight
6. First Fix
7. Dry lining / plaster
8. Second fix
9. Finals and build complete
10. Testing and commissioning

For each build stage, issues are identified that could contribute to the Performance Gap, such as product substitution, quality of workmanship and incompatibility of components. Instances of good practice are also noted. The findings are recorded in pre-prepared assessment sheets and photographs are taken.

SAP Audits

For each of the Housebuilding Process Review sites, SAP (Standard Assessment Procedure) assessments for one, two or three plots (depending on site size) are reviewed by a dedicated SAP team based on design information and observations made and recorded during the site visits. Two stages of SAP Audit are carried out for each plot:

1. A review of the original SAP assessment done by the developer's SAP assessor, which is re-calculated based on a strict interpretation of the SAP methodology and U-value conventions. This provides evidence of areas where SAP assessors are incorrectly applying SAP conventions, the frequency of errors, and the impact that these have on the DER. It should however be noted that the information provided to the SAP Audit team by the developers for this review may not in all cases be identical to that provided to the original SAP assessor.
2. SAP assessment based on site visit observations and findings from the interviews, reflecting any changes made to the constructed dwellings. This provides evidence of changes that are not being reflected in SAP assessments, their frequency and the impact that they have on the DER. However, note that it was not feasible to check all parts of the SAP assessment on site (such as dimensions), and that some of the stage 1 SAP assessments were Design Stage rather than As-Built SAPs.

SAP Audits of eight plots from four sites are included in this report, with a draft summary of the results used to inform the prioritisation of issues. Additional sites being reviewed in the ongoing Housebuilding Process Review will have SAP Audits undertaken to contribute further evidence.

For further detail regarding the Housebuilding Process Review, including the SAP Audits, please refer to Appendix 2.

SAP Questionnaires

Several issues identified as possible contributors to the Performance Gap relate to energy modelling, in particular to SAP. To help understand whether these concerns are well-founded and what impact they might have, two surveys were carried out: one for SAP assessor accreditation organisations and one for SAP assessors.

SAP Assessor Accreditation Organisations Questionnaire

A survey was compiled to understand where energy assessors of new homes may encounter difficulties that could contribute to the Performance Gap through errors in predicting the energy consumption of a dwelling. The following table shows some of the issues covered in the questionnaire.

The survey was circulated to and completed by five of the main SAP accreditation organisations, which between them have a total of over 1500 SAP assessors registered as members (On Construction Domestic Energy Assessors, referred to throughout this report as SAP assessors). Responses have been anonymously compiled and analysed for common themes, and included in the evidence base drawn upon in Section 3 of this report.

Sections and example issues addressed

1.	Company information: software used, number of registered new build assessors.
2.	New Assessors: training and examination requirements, typical test assessment mistakes, Continuing Professional Development (CPD).
3.	Audits: frequency of audits, mistakes typically found, providing feedback.
4.	EPC Feedback: number of complaints about incorrect EPCs, number of assessors that have been struck off their assessment scheme.

SAP Assessor Questionnaire

An anonymous online survey of 25 questions was compiled and circulated to new build SAP assessors via SAP assessor organisations, industry newsletters and word of mouth.

There were around 150 respondents, with all answering the first section of the questionnaire (see below) and around 130 answering the remaining sections. The responses were analysed and related to the Performance Gap list of potential issues, contributing to the analysis in Section 3 of this report. The table below shows some of the issues covered in the questionnaire.

Sections and example issues addressed

1.	About You and Your Customers: typical customers and project sizes, the number of EPCs lodged each year, information provided to new customers.
2.	Design Stage Calculations: extent of design information provided, what information is lacking, what advice and outputs are provided to customers.
3.	As-Built Calculations and Production of the EPC: information lacking at As-Built SAP stage, outputs provided to customers.
4.	Observations on the Performance Gap: frequency and nature of visits to assessed sites, observations on differences between As-Built SAP and actual dwellings as constructed.

Assessing the Issues

Compiled evidence from the Literature Review, Housebuilding Process Review, SAP Audits and SAP Questionnaires was analysed to assess the strength of evidence for the list of potential issues identified, and to determine or estimate (depending on the strength of evidence available) the relative impact that these issues might have on the Performance Gap. This allowed the issues to be grouped into four categories, as detailed in Section 3 of this report. A summary of the method is set out below.

Rationale for Evidence Rating

Issues which were well supported by both the Literature Review and the Housebuilding Process Review were ranked as strongly evidenced. This was rated on a sliding scale, as shown in the table below, with strongly evidenced issues receiving a higher rating and less well evidenced issues receiving a lower rating. For the Literature Review evidence, a lower value was given to reports containing anecdotal or less rigorously reviewed evidence; medium value for those examining particular dwellings and with some review process in place; and higher value to peer-reviewed reports and field trials.

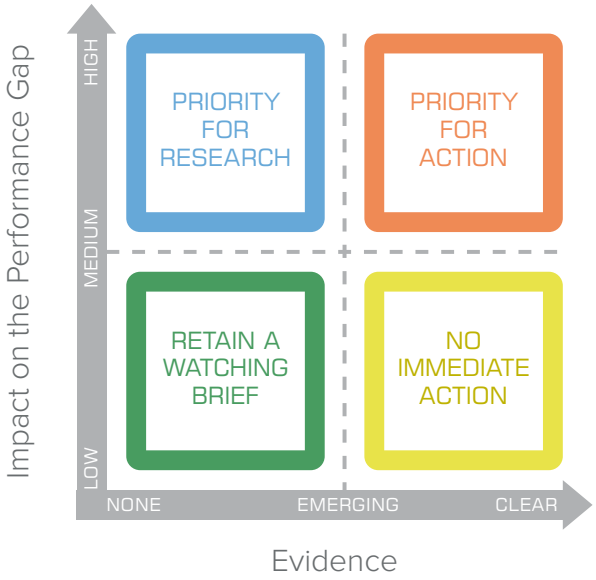
Where issues fell into one rating category for the Literature Review, and another for the Housebuilding Process Review evidence, the higher of the two ratings was taken but was reduced by one level. Where issues on the boundary of different categories were strongly supported by the SAP Questionnaires, this was used to increase their rating. Issues relating to testing were rated only on the basis of the Literature Review, because no testing has been undertaken thus far for the Housebuilding Process Review, so no evidence could be gathered on it.

Rating scales used for evidence

RATING	LITERATURE REVIEW REQUIREMENTS	SITE VISIT REQUIREMENTS
0-2	≤2 sources	0-29% of sites
2-4	≥10 sources, including at least 5 of 'medium quality'	30-49% of sites
4-6	≥20 sources, including at least 5 medium, 1 high quality	50-69% of sites
6-8	≥30 sources, including at least 5 medium, 2 high quality	70-89% of sites
8-10	≥40 sources including at least 5 medium, 5 high quality	≥90% of sites

Rationale for Impact Rating

The potential impact of each issue was qualitatively rated, based on collected evidence. It was not possible to rate each issue strictly quantitatively (for example based on its impact on a SAP rating) due to the inter-related and complex nature of the issues. For example, an issue such as 'limited understanding by design team of impact of early design decisions on performance and energy related targets' could affect various aspects of a dwelling's performance and could vary significantly depending on how teams involved at later stages responded to potential problems. However, each issue's potential impact on energy performance and knock-on impacts on other issues were considered when a rating was set. The results are presented in Section 3.



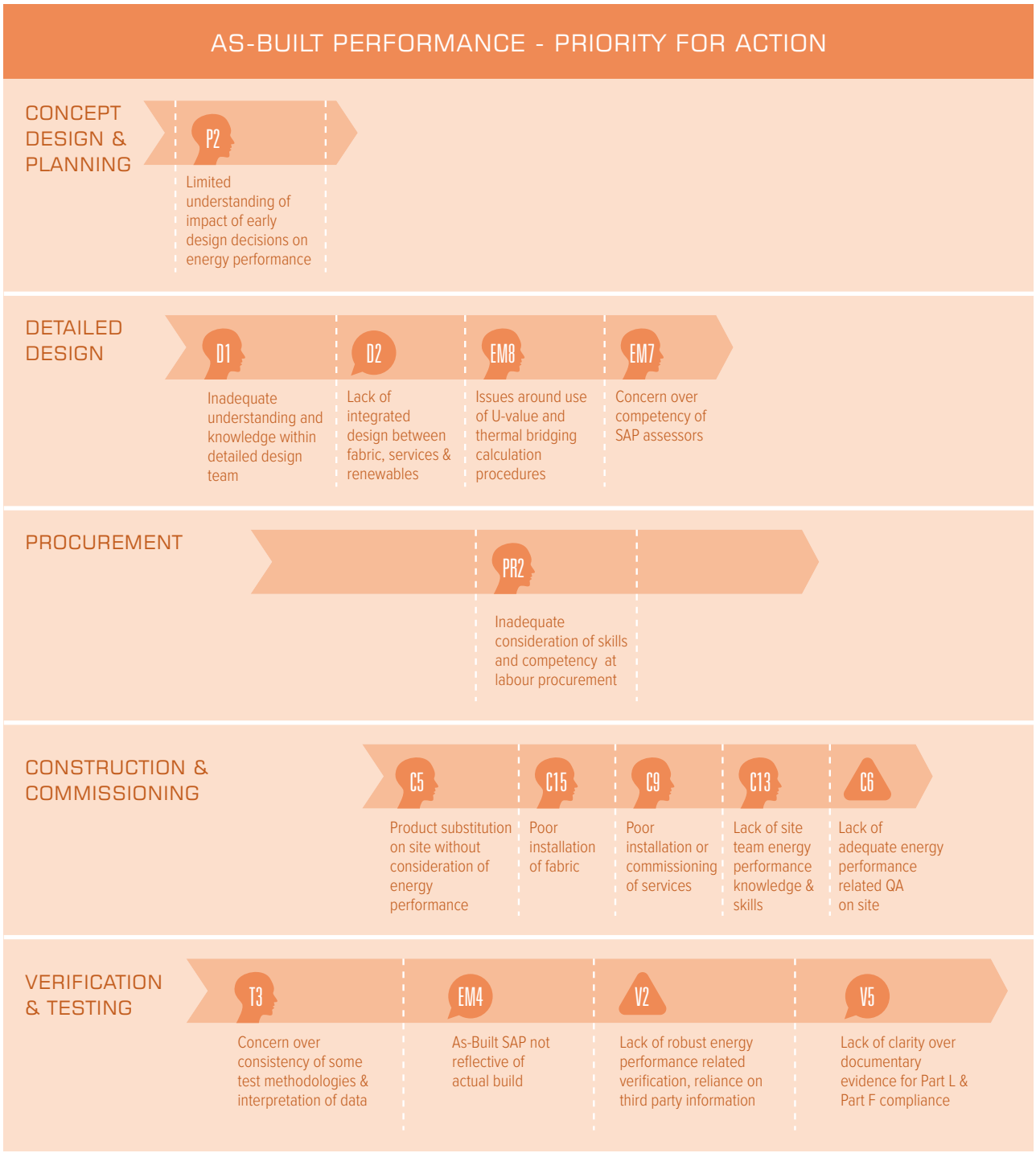
3. RESULTS

The issues have been categorised using the prioritisation matrix shown above. This section presents the results of this process and outlines the evidence for the issues.

Each quadrant of the prioritisation matrix represents a different challenge:

- **Priority for Action** – This category covers 15 issues for which a strong supporting evidence base has been found and that have a medium to high impact on the Performance Gap. For each issue, analysis is provided of the relevant evidence, with graphs, quotes and sketches where appropriate.
- **Priority for Research** – 17 issues are contained in this category, for each of which there is some emerging evidence, with a medium to high potential impact on the Performance Gap when they do occur. Some evidence is listed for each issue, justifying why it is in this category and how it may relate to other issues.
- **Retain a Watching Brief** – Evidence for the issues in this category is limited, but they are suspected of having a lower impact on the Performance Gap. A very brief summary is provided of each issue, with slightly more focus on those that may be of medium potential risk. These issues require careful monitoring by industry and government as more evidence becomes available.
- **No Immediate Action** – Any issues for which a large degree of evidence was found, and where that evidence demonstrated a low impact on the Performance Gap, are classified as 'No Immediate Action'. This would indicate a high level of confidence that these issues are not significant contributors to the Performance Gap. No issues were identified that met these criteria.

For each category, the issues are discussed in the approximate order they might occur within the housebuilding process.



CROSS-CUTTING THEMES

KNOWLEDGE & SKILLS

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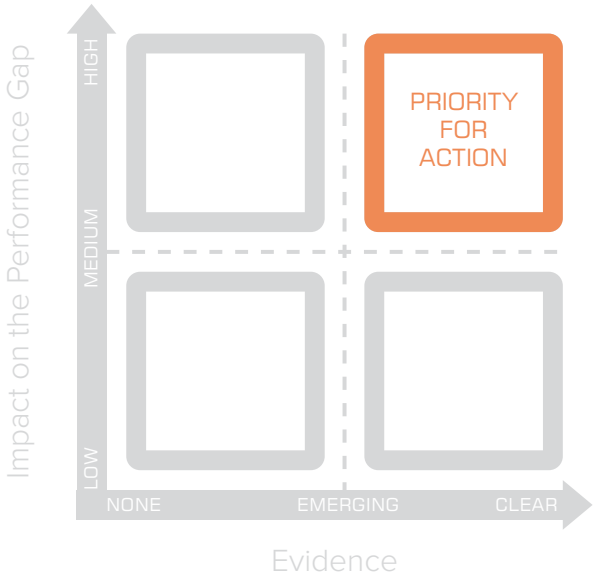


PRIORITY FOR ACTION

Analysis of the evidence clearly indicates that the 15 issues categorised as 'Priority for Action' should be tackled with immediate actions to help close the gap between designed and as-built energy performance.

This section addresses each of these issues in some detail. Analysis is given of how they overlap with one another – none are completely independent and these interactions are important in understanding their impacts. A summary is given of the evidence found for them in the Literature Review, Housebuilding Process Review, SAP Audits and SAP Questionnaires. Examples, quotes, diagrams and statistics are provided where relevant to illustrate their impact.

In the final phases of the project, proposals will be made for strategies to address these issues. These proposals will be included in the End of Term Report in summer 2014; see Section 4 for more information.

LIMITED UNDERSTANDING OF IMPACT OF EARLY DESIGN DECISIONS ON PERFORMANCE AND ENERGY RELATED TARGETS (CONCEPT DESIGN STAGE)

At the concept stage, team members may lack knowledge or experience of the impact that their design will have on the energy performance of the completed dwelling. This might include aesthetically driven choices such as form, roof shapes, orientation, layout, materials and finishes or variations to standard house types.

Evidence collected demonstrates a lack of focus on the energy implications of early design stage decisions. Developers that use more bespoke house designs, or vary in their choice of construction type, are at risk of this issue adversely affecting energy performance. Larger developers have the opportunity to influence the concept stage as they provide a catalogue of house types, and yet the issue was observed on all sites under the Housebuilding Process Review. The impact of this issue in terms of the Performance Gap is likely to vary significantly, and will be highly influenced by the level of knowledge, skills and change control later in the process.

Related Issues

The issue relates to a general lack of integrated design (D2) and may lead to problems with fabric construction and services installation (C15, C9).

Literature Review

> *As part of their remit, developers in conjunction with concept designers will introduce elevational design features such as bay windows, door recesses and balconies and other measures such as steps and staggers in terraces in order to add interest to the overall visual appeal of a development. It was clear during the design of the elevations for the house types that insufficient attention was given to the difficulties that would be created for the detailed designers.*
> **Leeds Metropolitan University, Lessons from Stamford Brook: Understanding the Gap between Designed and Real Performance, 2008**

The Literature Review found frequent instances of this issue, particularly in relation to complicated elevational features and other issues such as lack of space for services. These are being determined at the concept design stage without sufficient consideration of the difficulties that they might cause for the detailed design and construction teams. The issue was compounded where information on the details was not made available on site and where there was a lack of consideration of thermal bridging at junctions, air tightness strategies, and work sequencing. Reports such as BUILD UP Skills, UK 2020 Skills Roadmap and Action Plan, 2013, have identified a low carbon design skills and knowledge gap in the industry. Instances of inappropriate choices of low and zero carbon technologies and poor building systems integration were also identified, due to a lack of validated knowledge and perhaps also to the lack of suitable design tools.

SAP Questionnaires

Only around 40% of respondents stated that they are typically asked to undertake SAP calculations in time to influence the design of the dwelling structure. It should be noted that larger developers often use standard house types which may require less SAP assessor input at concept design stage as they are often designed to be Part L compliant with a ‘worst case’ scenario for variables such as orientation.

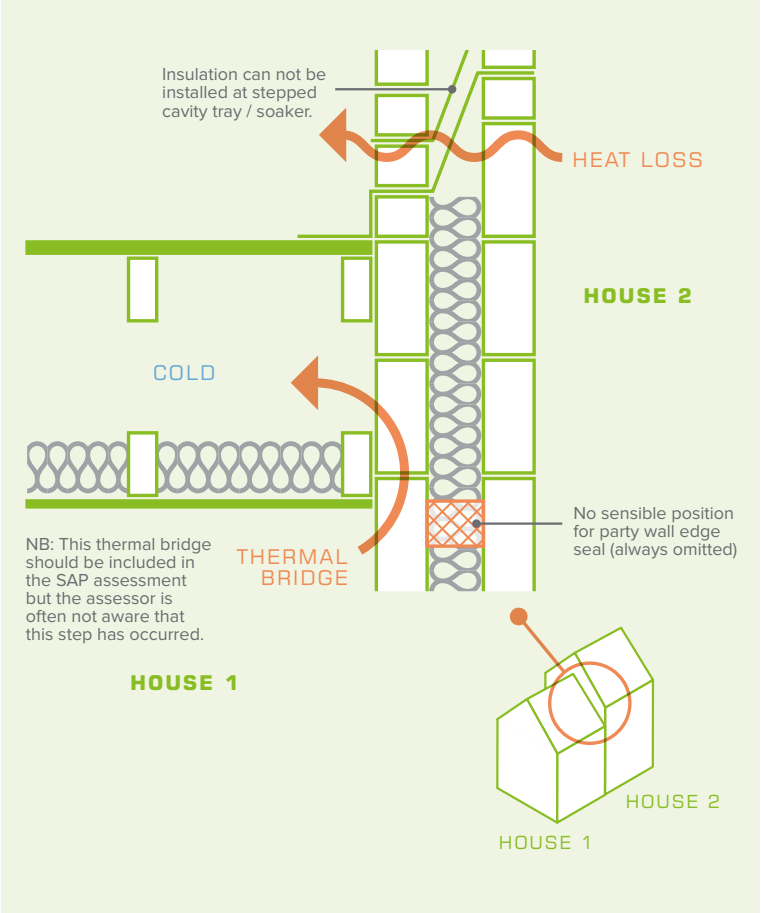
House-building Process Review

FOUND ON 100% OF SITES

As this issue exists at the very early stages of a development, evidence arose primarily in the design team interviews rather than the site visits. There is seldom direct discussion between the concept design team, detailed design team and construction team. There appears to be an assumption that thermal detailing problems resulting from the combination of various house types or the use of complex forms will be solved by the detailed design team. Similarly, it appears to be assumed that problems relating to buildability and construction phasing will be resolved by the detailed design team or construction team.

The majority of sites reviewed to date have been from larger developers where a structured handover between concept and design teams is seen as less critical. Consideration of specific energy targets on developments is not typically a high priority for the concept design team so SAP assessor input is considered unnecessary. On the sites visited, the use of standard house types was often relied upon to provide a sufficiently robust baseline for the detailed design team to develop the final strategy, despite some of the sites having targets beyond Part L.

Site observations and SAP Audits on all developments identified differences between the designed junctions and those built. The illustration provides a common example where a stepped terrace of standard house types joined together has contributed to the creation of complex roof areas, leading to difficulties in installing party wall edge seals and the full extent of insulation. This presents challenges both for the design team to provide sufficiently clear details and the construction team to replicate these robustly and efficiently on site.



Example

Examples of buildability issues were observed on several of the sites visited due to the inclusion of complex features in the design. On three sites, construction of the bays and dormers did not match the detailing assumed in the SAP assessments for linear thermal bridging - in one case this example was found to cause a deviation of just under 1% to the Dwelling Emission Rate (DER). This could represent a compliance risk particularly given that dwellings are often designed to only just comply with the Target Emission Rate, or when compounded by other deviations to the DER.

INADEQUATE UNDERSTANDING AND KNOWLEDGE WITHIN DESIGN TEAM (DETAILED DESIGN STAGE)

Detailed design team members may lack knowledge or experience of the impact that their design will have on the energy performance of the dwelling. This might include the buildability of the design, site conditions and tolerance levels, optimising thermal detailing, and the compatibility of construction systems, materials and building services.

There is strong evidence for this issue from all evidence sources. This review indicates a high potential impact on resulting energy performance; if found to be widespread, it could be a major contributor to the Performance Gap. The impact may be reduced where construction teams understand energy performance and are able to remedy design issues, or where simple or standard plan forms are used. However, all sites within the Housebuilding Process Review showed some variation to standard house type designs.

Related Issues

This issue relates to concerns over SAP assessor competency (EM7) where the assessor is actively involved in the design process. It is likely to contribute to other issues such as problems with the installation of fabric or services (C15, C9) and a lack of integrated design (D2).

Literature Review

> *Although the general principles of efficient design and construction are well known throughout the industry, the detailed knowledge and understanding that is required to ensure robust as-constructed energy and carbon performance is not.*
> **Zero Carbon Hub, Carbon Compliance for Tomorrow's New Homes Topic 4 – Closing the Gap, 2010**

Clear evidence was found in the Literature Review of inadequate understanding or consideration of services design, particularly in relation to their integration with building fabric, and to system integration for more complex or less common technologies such as heat pumps, MVHR and district heating systems. Instances of inappropriate siting of renewables were also found.

Insufficient understanding or consideration of fabric issues was also found. Examples included a lack of consideration of continuity, buildability and robustness in the design of insulation or of the air barrier. This led to increased thermal bridging, air paths being created within the structure, and difficulties with the fitting of insulation and air barriers. Common problems included thermal detailing around bay windows, integral garages, recessed doors, and balconies; fitting insulation in hard to reach spaces; air barrier integrity around services within framed constructions; thermal bypassing at junctions; and specification of inappropriate tapes and sealants.

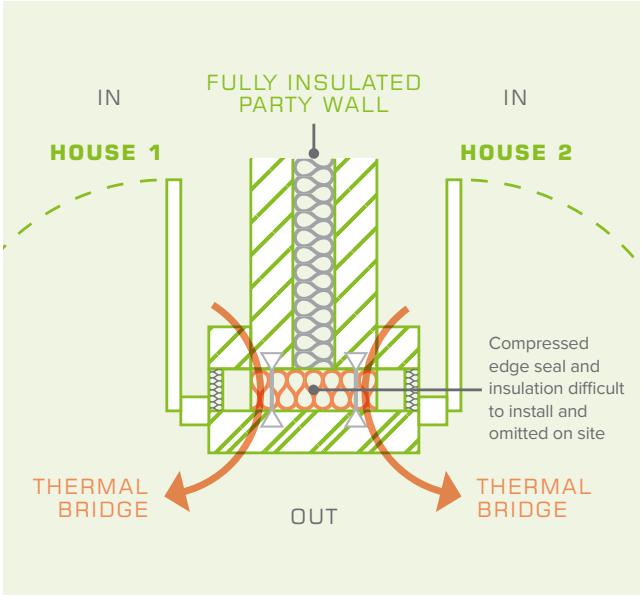
Evidence was also found of a lack of awareness that complicated details and sequencing at these details should be shown in design drawings, and of potential difficulties associated with particular constructions. Design teams were also found to lack an understanding of thermal bridging and U-value calculations.

SAP Questionnaires

Responses to the SAP Assessor Questionnaire indicated that in most cases, SAP initial design proposals do not comply with Part L1A. This may suggest a lack of knowledge in the design team on how to achieve compliance. Only 25% of assessors said that typically all necessary information is provided at the start or supplied when requested without them making assumptions or recommendations. In particular there was evidence of poor design team understanding of thermal bridging (for example, 70% of respondents frequently found that no information on thermal bridging was provided, and only just over 5% frequently found that all of the details were provided).

House-building Process Review

Instances of inadequate understanding or consideration of design implications were identified on all sites. The illustration below is an example in which the design assumed that the compressed edge seal, insulation and wall ties could all be installed practically despite the lack of space. On site, it was found that the insulation and edge seal had been omitted, as structural considerations had to take priority. This might in part be due to standard house types being drawn in isolation without consideration of how they combine on site.



The review of design drawings and site visits identified risks in the form of design ambiguity, incomplete details and specifications, and difficult to build details. Other common examples included:

- Unrealistic assumptions about the ability to fit insulation behind and around plasterboard at the eaves or into small spaces such as dormer cheeks;
- Lack of detail on how screed was to be supported at ground floor perimeters;
- Incorrect insulation detailing at the threshold;
- Incorrect details being provided to site based on old designs no longer used;
- Lack of consideration of air leakage paths from integral garages to intermediate floors;
- Lack of consideration of the impact of work sequencing or services location on insulation installation;
- Complex designs for timber frame dwellings increasing the timber fraction in walls to around double the default assumption in U-value calculations of 15%;
- Use of steps, staggers and projections creating additional thermal bridges; and
- Instances of incomplete specifications and details leading to site improvisation.

The site interviews also found that construction teams were rarely involved in design team meetings and were not always confident that feedback on buildability issues was being collected or processed well. Discrepancies between the designed and constructed fabric specification and thermal bridge junctions were found for every site SAP Audit. It should not be concluded that all of these differences were due to the design team. However, a lack of consideration of the buildability of insulation and junctions in practice appears to have increased the risk of the Performance Gap occurring.

FOUND ON 100% OF SITES

Example

EST heat pump trials[1] showed that poor practice in the design and sizing of systems can significantly affect the performance of heat pumps, with resized systems installed in the second phase of the trials showing significant system efficiency improvements of over 0.3 on the seasonal performance factor in some cases (an increase of over 10%).

Good Practice Example

On some sites, the construction team joined concept stage design meetings to provide feedback on any build concerns. One SAP assessor set early stage Psi-value targets for the timber frame supplier to ensure that all parties understood the performance requirements.

1. Energy Saving Trust, Getting Warmer: A Field Trial of Heat Pumps, 2010

D2 LACK OF INTEGRATED DESIGN BETWEEN FABRIC, SERVICES, RENEWABLES AND OTHER REQUIREMENTS (DETAILED DESIGN STAGE)

If all elements of the design are not properly integrated, building fabric and services may not perform as expected.

Evidence shows instances of and concern over a lack of integration in design elements. Where these different requirements are not properly considered and incorporated, unintended consequences - such as thermal bridging - may result. Volume housebuilders with standardised house types should be less susceptible to this problem, though they are frequently required to meet other design stipulations that result in variations to their standard building forms.

Related Issues

This issue relates to concerns over a lack of knowledge and understanding within the design team (D1) as well as a potential lack of collaborative working, with unclear responsibilities for energy performance (C4).

Literature Review

> *There is a lack of integration of ventilation strategies with other aspects of the home, and pressures on space mean that any services provided are often poorly located resulting in misuse, poor maintenance and then inefficient operation.*
>
> **Good Homes Alliance, Ventilation and Good Indoor Air Quality in low Energy Homes, 2011**

Substantial evidence was found for this issue, particularly relating to a lack of service systems integration. This included poor practice relating to components, controls, provision of insufficient space for services and lack of consideration of their impact on building fabric (for example in the location of wet rooms and their services). Reports showed evidence that designs were not being integrated to maximise efficiency and usability of services, for example by minimising MVHR ductwork runs or boiler to hot water cylinder pipework runs; or appropriate location of vents, MVHR units, controls and equipment. There was also evidence of a lack of consideration of the airtightness strategy for dwellings and its relationship with the ventilation strategy, as well as of the impact of other decisions on thermal bridging, air tightness or ventilation. Issues relating to the impact of lifetime homes requirements on thermal performance were also raised.

Improvised construction – a short piece of flexible ductwork used to negotiate a difference in levels. Due to a lack of coordinated design information, the rigid ductwork runs below the top of the internal partition.[1]

1. *NHBC Foundation, Designing Homes for the 21st Century: Lessons for Low Energy Design, 2013*

SAP Questionnaires

Responses to the SAP Assessor Questionnaire show that important information is often missing at design stage, implying that certain aspects of the design are not considered fully at a crucial stage of the development process or in relation to other design decisions. Commonly missing information included thermal bridging details, ventilation system information and air tightness targets, as well as secondary heating and water heating specifications and details of proposed renewable technologies.

Housebuilding Process Review

Instances of this issue typically related to integration of the services, with heating, hot water and ventilation being installed by a sub-contractor. Decisions over design details of this installation may be made on site without reference to the designer and the original design intention or the impact on the building fabric.

Other evidence that this issue may be occurring came from units which had lower than usual air permeability targets, but where no changes to the standard design details had been made. These sites are being built without accounting for upgraded targets, representing a lack of integration between design requirements.

Example

On one of the Housebuilding Process Review sites, a badly installed MVHR system was observed. Several of the Literature Review reports assessed poorly installed MVHR systems, including an NHBC Foundation report which found examples of efficiencies dropping below 60% due to excessive ductwork lengths and the unit being installed in the loft (compared to 90% based on manufacturer tests and 75% based on SAP assumptions).[1]

Good Practice Example

On one site, interviewed design team members explained that a services plan was decided at early design stage meetings to ensure proper integration with the fabric.

1. NHBC Foundation, Assessment of MVHR Systems and Air Quality in Zero Carbon Homes, 2013

ISSUES SURROUNDING USE OF CALCULATION PROCEDURES IN BR443 (U-VALUES) AND BR497 (PSI-VALUES) OR ASSOCIATED STANDARDS

BR443 and BR497 are standardised procedures and any changes to them would need to be carefully considered, but their calculation assumptions need to reflect current practice. As closely as practicable, they should reflect the completed building elements and take site tolerances and practices into consideration. Otherwise U-values and Psi-values – key data inputs into SAP – will not reflect actual performance, contributing to the Performance Gap.

This issue is well-evidenced, particularly in various reports which compared measured to modelled U-values. The Housebuilding Process Review and associated SAP Audits also found issues with U-value and Psi-values as-constructed not being well represented by calculation assumptions.

Related Issues

This issue relates to concerns about accuracy of aspects of the SAP calculation model and assumptions and the SAP conventions (EM2, EM3).

Literature Review

It is notable that the difference between calculated U-values and measured U-values correlates with construction type with some constructions giving significantly greater differences than others. For example, partially filled cavity walls typically showed a greater difference between calculated and measured U-values than did timber frame walls. This would appear to indicate that, for at least some types of construction, the method given in BS EN ISO 6946 does not account for all the factors that can influence a U-value and generally underestimates it, although part of this discrepancy was found to be attributable to construction defects.

BRE, DETR Framework Project Report: Field Investigations of the Thermal Performance of Construction Elements As Built, 2000

Numerous references were found for this issue from a range of sources, including a number of high-profile, peer-reviewed studies. Several reports where in situ U-values were measured showed these to be significantly higher than modelled values. Contributing factors included: timber fractions often well above the default assumptions allowed in BR443, damage to materials on site impacting on their assumed performance, tolerances exceeded on site, frequent lack of insulation in certain areas of elements, convective bypassing and poor installation of insulation boards deviating from default assumptions on air gaps used in calculations. Reports also commented on the limitations of Accredited Construction Details and default Psi-values in SAP Appendix K, which, for example, do not differentiate between different construction types or U-values. Although not dealt with in BR443, several reports also noted the limited choice of U-value options for party walls.

House-building Process Review

The issue was not as strongly evidenced in the Housebuilding Process Review, partly because testing has not yet been undertaken. However, on many of the sites, instances were found of installation of insulation which was not in line with BBA certification guidance, or as assumed in U-value or Psi-value calculations. This suggests that the correction factors which are usually taken as defaults by SAP assessors for some constructions, and which are allowed to be assumed in U-value calculations, may be optimistic (for example air gaps between insulation boards). Instances of timber fractions higher than the default values given in BR443 were observed on site. On some dwelling types, such as single aspect apartments with small façades, the impact of fabric U-value calculations may be relatively small. Conversely, on detached properties with larger exposed areas and more complicated features, the impact of U-value and thermal bridging calculations would be more significant. The SAP Audits found deviations in U-values and Psi-values on every site, though factors such as quality of construction and product substitution also contributed to these.

Example

On one of the sites, the external wall timber fraction was assumed to be 12% in the original SAP assessment, based on the manufacturer's U-value, just under the default assumption of 15% in BR443. Based on the panel designs, the SAP Audit found the actual fraction to be almost 30% - increasing the U-value from 0.20 to 0.24 and altering the DER by over 1%. This could represent a compliance risk particularly given that dwellings are often designed to only just comply with the Target Emission Rate, or when compounded by other deviations to the DER.

CONCERN OVER COMPETENCY OF SAP ASSESSORS

For an accurate SAP assessment to be undertaken, it is clearly important that SAP assessors have sufficient levels of competency – accurately inputting data, following conventions, validating assumptions, and evidencing their assessments. Where SAP assessors are providing design and specification advice they also need to be competent to do so.

SAP assessors play an influential role in both calculating the predicted energy performance of dwellings and, in many cases, providing design advice to housebuilders. Poor advice can contribute to the Performance Gap, to differing degrees.

Related Issues

This issue is related to SAP conventions not being adequate or comprehensive (EM3) and infrequent or insufficient audits of SAP assessors (EM6), which potentially leads to the As-Built SAP not being reflective of actual build (EM4).

Literature Review

Few of the reports reviewed specifically set out to investigate this issue and sometimes deviations were difficult to directly attribute to assessor competence. However, one project undertaken by AECOM for DCLG in 2009 compared AECOM SAP assessments strictly following the SAP conventions to the original SAP assessments undertaken for 82 dwellings across 45 sites.[1] The most common data input errors found in order of occurrence were: wall area (all unit types), storey height (mainly flats, and houses with rooms in roof), opening area, roof area, Zone 1 area (mostly houses), sheltered sides (mostly flats), built form area, window orientation, opening U-value and floor area. These errors were thought to be due to lack of assessor understanding of conventions and to copy and paste errors. More complicated forms, including features such as integral garages and rooms in the roof, caused problems in the convention interpretations.

Related work for DCLG found that the system for verifying competence for TER/DER calculations is unclear and that the standard of documentation submitted is not consistent.[2] Further evidence was found in TSB Building Performance Evaluation and similar reports: for example SAP assessors failed to identify different wall types and did not secure confirmation that mechanical ventilation installation checklists had been used.

SAP Question-naires

Where initial designs fail to meet Part L targets, all SAP assessors stated that they would advise on how to comply, with around 40% saying they would suggest possible general solutions and around 60% stating that they would suggest particular products and systems. These results indicate that SAP assessor levels of expertise affects the design as well as the assessment of dwellings.

1. DCLG, EEPH, AECOM, Research into Compliance with Part L of the Building Regulations for New Homes: Phase 2 Main Report, 2009

2. DCLG, Leeds Metropolitan University, AECOM, Review of the implementation of Part L 2006, 2010

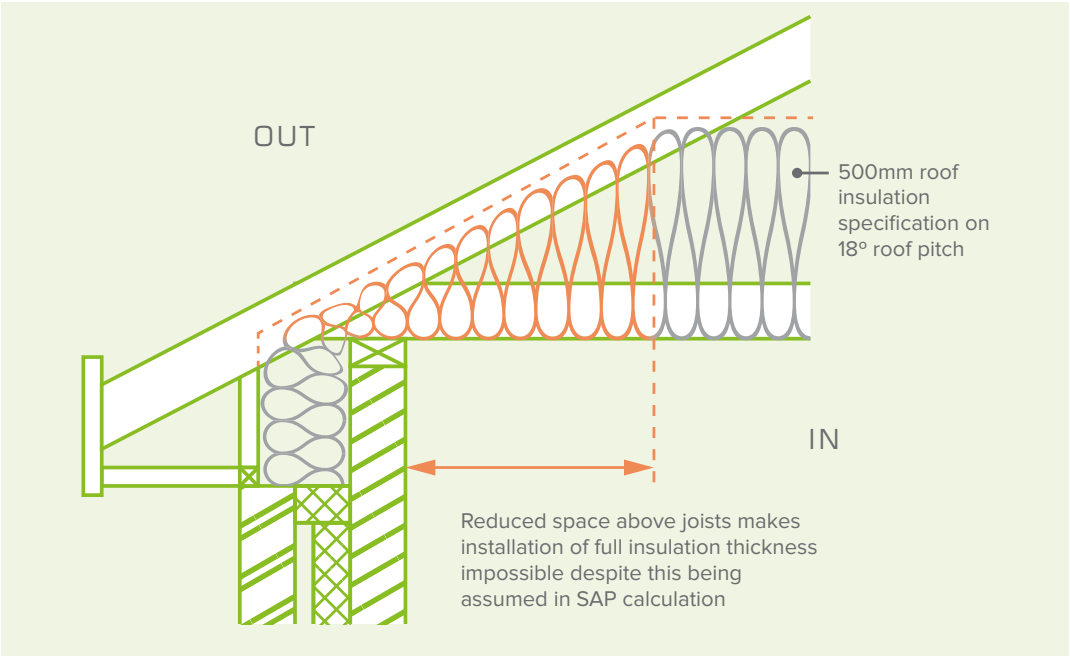
House-building Process Review

SAP assessors associated with the sites reviewed indicate that they are frequently provided with U-value information from manufacturers and suppliers. This presents a contrast to the SAP Assessor Questionnaires which found that assessors usually undertake the calculations, and may be due to these being larger developer sites, whereas the Questionnaires represent a wider cross section of the industry.

FOUND ON 100% OF SITES

All of the SAP Audits undertaken to date found errors in the original SAP assessments based on a review of the design information only (i.e. not taking into account site observations). In many cases this was the result of incorrect interpretations of conventions. The most common errors related to U-value calculations and measurements, followed by thermal mass and thermal bridging calculations, heating system errors and sheltered sides errors. Ventilation, orientation and low and zero carbon technology errors were also found, although it should be noted that it was not possible to ensure that the SAP review team had exactly the same information as the original SAP assessor. It is interesting to note that a significant proportion of the SAP assessors interviewed had an architectural or construction background, which could be a positive sign that they will consider wider issues when providing energy related advice.

An instance where such knowledge and skills should be applied is illustrated here.



It would clearly be unfair to place sole responsibility for buildability issues such as this roof insulation detail on the SAP assessor. However, the manner in which they decide to calculate the U-value is important. When calculating the roof U-value it would be incorrect to simply assume that the same thickness of insulation could be installed over the entire roof area, because of the clear impossibility of fitting this into the eaves when the roof pitch is so low.

Example

The SAP Accreditation Organisation questionnaire found that errors relating to areas, thermal bridging, U-value calculations, thermal mass parameter calculations and poor as-built stage evidence provision were commonly found at audit, although these issues were commonly being raised in helpdesk queries. This is supported by the SAP Audit work undertaken as part of the Housebuilding Process Review, which found the same common errors (and additionally heating system errors). The 2009 DCLG study referred to in the Literature Review also found measurements to be the most common data entry error.

PR2

INADEQUATE CONSIDERATION OF SKILLS AND COMPETENCY REQUIREMENTS AT LABOUR PROCUREMENT

This issue arises when labour skills and competency are not sufficiently considered or valued at the procurement stage.

Interviews for the Housebuilding Process Review revealed that skills requirements are not being prioritised at procurement. This was apparent on site where there was a lack of site team energy-related knowledge, skills or care, frequently resulting in poor quality installation of services and fabric. The potential impact is high due to the knock-on impacts for fabric or services installation quality.

Related Issues

This issue links with a lack of site team energy-performance related knowledge and skills or lack of care (C13), and the poor installation of fabric or services (C9, C15).

Literature Review

There was no strong direct evidence in the Literature Review, which might be as expected given the type of reports reviewed. These generally did not investigate what requirements for labour skills were set in the developments studied, although a couple of the TSB Building Performance Evaluation reports mentioned the issue and one specifically found a lack of coordination and appraisal of information relating to skills required for installation of more unusual fabric and services systems.

Despite the lack of direct evidence, the issue is strongly indirectly evidenced by the frequency of observations of poor quality installations (C9, C15) and the lack of site team energy-related knowledge and skills or care (C13).

House-building Process Review

The site interviews found that on the majority of sites, procurement teams were unaware of or did not require BPEC qualifications for ventilation installers, including on sites with mechanical ventilation systems. On a significant number of sites they were also unaware of MCS accreditation for renewable energy installations, although the majority of sites did not include renewable energy technologies. It was also found that contractors were generally not re-assessed if the development requires a higher energy target than usual. Instances of problems with the installation of fabric and services were found on all sites (see issues C9 and C15) which, as in the Literature Review, also provides strong indirect evidence that skills requirements may not be considered adequately at procurement, although there are also other contributing factors involved. As would be expected, this issue is not directly evidenced by the SAP Audits or site visits.

Good Practice Example

One procurement team interviewed reported that all sub-contractors are put on a pre-tender list to allow comparison on issues including energy related skills.

PRODUCT SUBSTITUTION ON-SITE WITHOUT DUE REGARD FOR IMPACT ON ENERGY PERFORMANCE

Decisions may be made on site to substitute products for alternatives that have a different energy performance from the originally specified product. This may be caused by delivery delays, to save time or money, by mistake or due to a lack of knowledge on site.

All sites investigated under the Housebuilding Process Review underwent some product substitution. Products with different performance are being substituted and even where feedback systems exist, the design and technical teams are not always notified of these changes. Product substitution may be an inevitable and necessary part of the housebuilding process and should not automatically be a concern for the Performance Gap. The substitution must, however, be for components of equivalent performance and any variation should be reported to the design team, particularly the SAP assessor. The ultimate impact of this on the Performance Gap will depend on the product being substituted.

Related Issues

This is a separate concern from product substitution made at procurement stage (Pr3), although in the evidence review it can often be difficult to determine at what stage the substitution has occurred. The issue is linked to problems over the As-Built SAP not reflecting the actual build, lack of site QA, and lack of construction team knowledge and skills (EM4, C6, C13).

Literature Review

> *The most striking observation about the application of materials and components were the number of occasions on which materials intended for one location were used in another.*
>
> **Leeds Metropolitan University, Lessons from Stamford Brook, 2008**

As might be expected, this issue was more strongly evidenced in the Housebuilding Process Review, but the Literature Review found evidence of product substitution in reports evaluating the energy performance of dwellings as-built, where there was some level of inspection or testing of dwellings. This included instances of the following types of substitution:

- Different window and door models;
- Un-insulated boards instead of insulated plasterboard;
- Different types of blown insulation;
- Different types of tapes and membranes;
- Plasterboard and wet plastering being substituted for each other;
- Mineral wool closers instead of proprietary window cavity closers;
- Different services controls being used;
- Flexible instead of rigid MVHR ductwork;
- Different types of wall ties; and
- Different insulation block thicknesses.

It was found that such substitutions can result in lower performance, either directly or through the knock-on impact on other elements – for example the use of wrongly sized components resulting in improvised modifications to construction details on site. Typically, the impacts of changes were not evaluated and changes were not being communicated to others.

SAP Questionnaires

The Accreditation Organisation Questionnaire found that window specifications were frequently not evidenced, suggesting that assessors are not told the actual product installed – though this example may more likely be due to substitution at the procurement stage. This was supported by the SAP Assessor Questionnaire, with nearly 30% of respondents stating that the window specifications were almost never provided at As-Built SAP stage; a further 35% stated that they were usually missing. A significant proportion of respondents also indicated that confirmation of heating systems and their controls was sometimes missing, particularly details of secondary heating and hot water systems.

Housebuilding Process Review

All sites reviewed found some evidence of product substitution, though it was not always clear whether it was occurring on site, at procurement or due to the supplier. Instances included incorrect blockwork, different windows, and continuous instead of split baseplates at lintels. Of particular concern is that some sites reported that no changes would be made or that if they were, they would always be reported, and yet instances were observed on site of changes that were not reflected in the SAP assessments.

The audits of the site SAP assessments found a number of issues. Some component of the heating system was varied on almost every site, windows were frequently substituted, some ventilation systems were changed and lintels were substituted. Blockwork was changed on every site, with dense blockwork being used in external walls below the damp proof course on all sites, as well as in some party walls, contrary to the original specifications.

Example

On one site visited during the Housebuilding Process Review, dense blocks were used instead of aerated blocks for the party walls and the party wall edge seal was also substituted so that the wall was not sealed in accordance with MIMA guidance. There were implications for the party wall U-value, party wall junction Psi-values, and the thermal mass parameter of the dwellings. The SAP Audit estimated the absolute total impact on the DER to be in the region of 9%.

POOR INSTALLATION OF FABRIC

Incorrectly fitted insulation may not perform as designed. This could occur where there is insufficient guidance or drawings, or a lack of knowledge or care. This may result in the site team making uninformed decisions without proper understanding of the energy strategy.

The Literature Review and Housebuilding Process Review clearly indicate that fabric is often being improperly installed, compromising crucial elements of the thermal design. These consistent results demand an increased focus on installation practices for insulation, detailing and airtightness.

Related Issues

Linked to this is the issue of responsibility for quality assurance on site (C6) and proper guidance not being available on site (C1, C11), which can result in the site team making uninformed decisions without proper understanding of the energy strategy, as well as the issue of a lack of site team knowledge and skills (C13) and potentially also design issues (e.g. D1).

Literature Review

Some of the test houses were constructed carefully in a manner that could be described as good workmanship while others were constructed in such a way as to mimic poor workmanship... features associated with poor workmanship could in some cases cause the U-value to rise by as much as 310%

BRE for EST – Thermal transmittance of dwellings before and after application of cavity wall insulation, 2008

This issue was strongly evidence in the Literature Review, particularly in the literature relating to detailed analysis of the built performance of dwellings.

Common issues identified included:

- Gaps between insulation boards in walls and roofs, and between boards and inner leaves;
- Lack of insulation and air barrier continuity at junctions (e.g. around roof trusses) or areas (e.g. in floors above integral garages);
- Inadequate sealing of party walls;
- Poor laying of insulation quilt in lofts;
- Presence of debris and mortar snots in cavity walls and dirt on foil insulation surfaces;
- Insulation missing around cavity trays, lintels, below DPC, at floor perimeter, around dormers and rooflights;
- Poor sealing (e.g. at service penetrations, plasterboard linings) and lack of attention to creating a robust air barrier;
- Gaps between pre-fabricated components and components constructed on site; and
- Window and door frames not positioned correctly in relation to cavity insulation.

These issues were shown in several cases to make significant measured differences to U-values and Psi-values compared to the calculated values. Evidence sometimes connects the issue to a lack of detailed drawings being provided or used, and is sometimes also able to show that ad-hoc changes were made on site without being documented or approved.

SAP Questionnaires

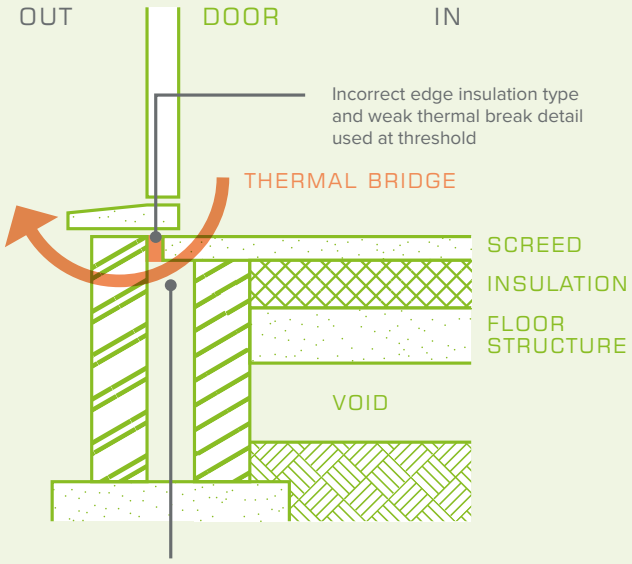
The Accreditation Organisation Questionnaire found that window specifications were frequently not evidenced, suggesting that assessors are not told the actual product installed. This was supported by the SAP Assessor Questionnaire, with nearly 30% of respondents stating that the window specifications were almost never provided at As-Built SAP stage; a further 35% stated that they were usually missing. A significant proportion of respondents also indicated that confirmations of heating systems and their controls was sometimes missing, particularly details of secondary heating and hot water systems.

Housebuilding Process Review

The site visits to date have found many of the same issues as the Literature Review. The most common related to window and door positioning relative to the insulation layer, accuracy of insulation board positioning within cavity wall and edge sealing of party walls.

The illustration provides a good example of where the detail as constructed deviates from the design.

The SAP Audits indicate that all sites show a difference in the actual thermal bridge values. Issues such as the distance of insulation boards from cavity wall blockwork and the density of foundation blockwork also impact on the SAP calculations.



Example

'Floating' insulation boards were found on many of the sites included in the Housebuilding Process Review - i.e. boards were not secured to the blockwork within partially filled cavity walls, in some cases leaving gaps of as much as 10mm. A study included in the Literature Review found that poor insulation board placement and fit increased U-values by over 350% in the case of rigid board partial fill, based on a nominal U-value of around 0.2W/m^{2}K. [1]

Good Practice Example

Many examples were found on site of insulation being installed well, including good quality mortar joints and well fitted wall ties and cavity closers. A typical eaves detail problem was overcome on one site where the bricklayer installed the insulation up and around the wall plate at first fix, aware that the roof insulation installer would have subsequently been unable to access it.

1. Hens et al, Brick Cavity Walls: A Performance Analysis Based on Measurements and Simulations, Journal of Building Physics Vol. 31 No. 2, 2007

C9

POOR INSTALLATION OR COMMISSIONING OF SERVICES

Incorrectly fitted or commissioned services may not perform as designed. This could occur where there is insufficient installation guidance or drawings, a lack of manufacturer installation or commissioning guidance or other detailed design guidance, or a lack of knowledge or care. This may result in the site team making uninformed decisions without proper understanding of the energy strategy.

There is strong evidence from both the Literature Review and the Housebuilding Process Review that services are being incorrectly installed and poorly commissioned. This can result in under-performing services and compromised building fabric air tightness, with a significant impact on the Performance Gap. It typically occurs where insufficient manufacturer guidance or design information is provided, or where there is a lack of site team knowledge, skills or care.

Related Issues

This issue relates to problems of proper guidance being produced but not available on site (C11) and of insufficient design information being provided (D7), as well as lack of site team knowledge and skills (C13) and adequate site QA (C6), lack of knowledge in the design team (D1), and also verification issues relating to commissioning (V2, V3, V5).

Literature Review

> *There was clear evidence that commissioning had not been carried out correctly and all units inspected were running in boost mode constantly (at near-maximum fan power); proper controls had not been provided; and filters were clogged with construction dust at the time of handover.*
>
> **NHBC Foundation and Zero Carbon Hub, MVHR in New Homes, 2013**

This issue is strongly supported by the Literature Review, particularly in the literature relating to field trials of particular systems and to detailed analysis of the built performance of dwellings. The evidence found poor practice relating to:

- Consistency and quality of commissioning, including MVHR and MEV systems, heating systems and low and zero carbon technologies;
- Insulation of service pipework (in heat pump trials, boiler trials, solar thermal trials);
- Ductwork insulation and layout, and use of long runs of flexible ductwork (see photo);
- Location of services;
- Installation of renewable technologies including heat pumps and solar systems;
- Services compromising the performance of the dwelling fabric (e.g. unsealed service penetrations); and
- Access to and complexity of systems and controls.

Some instances of poor practice were clearly connected to a lack of drawings or other information; other instances showed that documentation was not being requested. Generally, the evidence suggested that the industry does not fully understand or value the importance of commissioning and has some skills gaps. A recent report into construction skills in the UK identified particular skills gaps in the installation of most low and zero carbon technologies as well as in the installation of controls.[1]

1. *Build UP Skills UK, Analysis of the National Status Quo, 2012*

Unsupported flexible ductwork used to connect with MVHR fan unit below ceiling. Ductwork routing has been 'improvised' on site.[1]

House-building Process Review

Instances of this issue were found on the majority of sites, though some sites did not yet have services installed at the time of the visit. Examples were similar to those found in the Literature Review, and included:

- Poor ductwork installation including use of long runs of flexible ductwork;
- Undersizing of some ventilation terminals;
- Poor sealing of internal penetrations, for example in airing cupboards;
- Ducts or pipes being left in or below floor screed and then broken out later leaving large holes; and
- External service penetrations generally being sealed with mastic and some not being sealed at all.

Most of the sites were naturally ventilated with some using mechanical ventilation. Domestic Ventilation Compliance Guide checklists were missing on the majority of sites. Heating systems were generally installed well but there were instances of missing weather compensators and the use of 90^0 elbows to radiators and pipes being taken straight through plasterboard. Renewable technologies appeared to be installed correctly but some overshading was noted. Although perhaps a product substitution or customer add-on issue, instances of a smaller proportion of low-energy lighting than assumed in the design and SAP assessment were observed, with one plot having 70% halogen lighting.

Issues relating to heating systems were picked up in 63% of the SAP Audits to date based on site observations, though this also includes instances of product substitution and the addition of secondary heating. Issues relating to ventilation systems were picked up in 13% of the audits, but these were generally related to lack of communication to the assessor (for example a number of extract fans or a change in the system).

Example

Missing primary pipework insulation between the boiler and the hot water cylinder was observed on all but one of the sites where regular boilers were seen. The impact of this was estimated in the SAP Audit to result in a deviation of over 2% on the DER, and it would also fail to meet Part L 2010 requirements for primary pipework insulation as set out in the Domestic Building Services Compliance Guide.

Good Practice Example

One site team reported that specific meetings are held with services installers to ensure that building fabric penetrations are sized to be no larger than necessary.

1. NHBC Foundation, Designing Homes for the 21st Century: Lessons for Low Energy Design, 2013

LACK OF SITE TEAM ENERGY PERFORMANCE RELATED KNOWLEDGE AND SKILLS AND/OR CARE

Where the site team lacks knowledge and experience relating to energy performance, decisions may be made that conflict with the design and strategy for the dwelling.

Site teams face many demands, of which one is to understand and deliver often complex fabric and services designs for optimal energy efficiency. The evidence indicated that this is usually a low priority on site: many elements are being built and fitted incorrectly, with a significant impact on the Performance Gap.

Related Issues

This links closely to issues of the construction team not being provided with sufficient information, inadequate quality assurance (C6) and poor installation of fabric and services (C9, C15). It exacerbates issues where teams are making ad hoc changes to designs on site, for example due to lack of design information or difficult to build details (D6, D7, D1); as well as product substitution issues (C5). It may be caused by labour skills and competency requirements not being adequately considered at procurement stage (Pr2).

Literature Review

> *The lack of proper training of the workforce in combination with a poor liaison with the design team and system specialists resulted in significant construction faults, unplanned design solutions and wrong system commissioning.*
> **Oxford Brookes University, Understanding the Gap between As Designed and As Built Performance, 2013**

This issue was strongly evidenced by the Literature Review as well as the Housebuilding Process Review. It is closely related to issues of poor fabric and services installations (C9, C15), and so the summaries of evidence found for these issues are also relevant. Specific examples found in the literature include:

- Poor party wall sealing;
- Lack of consideration of thermal bridging;
- Failure to correctly install insulation;
- Lack of skills relating to installation of low and zero carbon technologies;
- Services installation and commissioning issues;
- Product substitutions without sufficient knowledge of or care about the impact; and
- Lack of understanding of how to install innovative products and materials.

Generally, there was evidence of a lack of: adequate training; detailed knowledge relating to energy performance issues; awareness of the impacts of changes made to the design on site, and of the impacts of one trade on another's work.

A recent assessment of construction skills in the UK found skills gaps in the manual labour workforce, in particular in the areas of understanding of the principles of heat loss, air quality, air tightness and ventilation, energy efficiency measures, and low and zero carbon technologies. A need for specialist energy-efficiency related QA skills was identified, particularly for surveyors and site supervisors.[1]

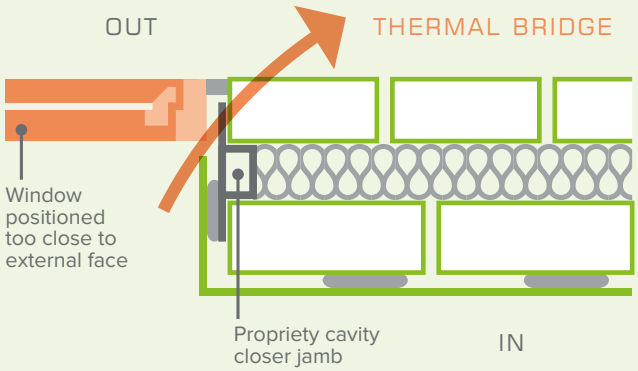
1. *Build UP Skills UK, Roadmap and Action Plan, 2013*

A recent report by Leeds Metropolitan University[1] also provided a useful review of reports which have assessed general levels of technical performance in the construction industry. It noted that concerns about customer satisfaction, number of defects and compliance with the building regulations were raised in the major housing reviews by Barker[2] and Callcutt,[3] in more specific work on defects (including insulation defects) undertaken by the BRE in the 1980s and 1990s[4] and in more recent work undertaken for DCLG in support of regulation.[5] All studies demonstrated that defects were relatively common and that tackling the issues involved remained a challenge for the industry.

House-building Process Review

Many instances were found during the Housebuilding Process Review of fabric and services being poorly installed, many of which indicate a lack of skill or care from the site team. Interviews with site managers seemed to suggest that thermal performance was not a high priority, which may result in poor energy related QA processes, a lack of feedback and a culture on site that does not promote good energy performance. This may be manifested in issues such as improperly sealed service penetrations, incomplete detailing behind skirting or under units and excessively large penetrations for ducting and pipework. Staircase strings were identified as being not fully packed out or sealed, potentially causing air leakage paths as the building settles. Screed was often poorly laid, with minimal separation at thresholds and 'bleeding' over insulation upstands. Insulation was found to be missing, did not overlap as intended or was 'floating' from its designed location.

Example



Windows were pulled forward from their design positions on all but one of the sites visited under the Housebuilding Process Review. This meant that the overlap with the cavity closer was well below the minimum requirements, with gaps sealed with mastic or foam fill which in several cases was interrupted by metal fixing straps. These issues would impact on the air barrier and insulation continuity and would increase thermal bridging around the windows, particularly in flats where glazing accounts for a higher proportion of the facade. Doors were also frequently out of position.

Good Practice Example

One build team interviewed explained that they compile a list of pre-qualified sub-contractors and score them on a monthly basis to help identify any emerging issues with the quality of their work.

1. *Leeds Metropolitan University, Building Confidence: A Working Paper, 2012*
2. *Barker for HM Treasury, Review of Housing Supply, 2004*
3. *Callcutt for DCLG, The Callcutt Review of Housebuilding Delivery, 2007*
4. *BRE, Quality in traditional housing, 1982 and Quality in new build housing, 1993*
5. *Leeds Metropolitan University for DCLG, Condensation Risk: Impact of Improvements to Part L and Robust Details on Part C, 2005*

LACK OF ADEQUATE QUALITY ASSURANCE ON SITE

There may not be adequate processes or responsibility may not be taken for carrying out energy-related quality assurance (QA) on site. This may occur where: site managers are overly reliant on sub-contractors' QA processes; there is variability in processes; there are time pressures; there is a general lack of supervision; or where there is over-reliance on Building Control.

Evidence from all sources clearly indicates that site management does not focus sufficiently on energy performance. Aspects of construction that relate to the performance of the completed building are not prioritised, resulting in improperly fitted insulation, incorrectly installed services and poorly constructed details. It is not yet clear the extent to which this may vary according to housebuilder size, construction type or contractual approach.

Related Issues

This issue is exacerbated where there is a lack of site team knowledge or skills relating to energy performance (C13). It also relates to issues with poor installation of services and fabric (C9 and C15).

Literature Review

Concerns relate to [skills] gaps for: Site supervisors understanding of the processes and quality standard of completed work needed to meet low carbon requirements.

Build UP Skills UK, Analysis of the National Status Quo, 2013

As would be expected, this issue was more strongly evidenced by the Housebuilding Process Review, but evidence was also found in literature which related to detailed field investigations of dwellings. Examples found included lack of adequate procedures; to check different stages of MVHR installations; to ensure the air barrier is not compromised; and to check the quality of insulation installation; as well as a lack of documentation of procedures. Given the frequency of observations of issues with components such as insulation boards, it is clear that better QA is required for basic elements, though some reports also highlight the need for even more improvement in QA where higher than usual energy standards are targeted or relatively unusual details or services are involved.

A BRE study in the 1980s of common defects on construction sites raised similar issues to the Build UP Skills report referenced above, noting a lack of adequate site QA, and that even where issues are identified, it is often unclear who has the responsibility or authority to implement remedial action.[1]

A very substantial body of evidence relating to the poor installation of fabric and services was found in the literature, which is arguably also evidence of a lack of adequate site QA (see issues C9, C13, C15).

1. *BRE, Achieving Quality on Building Sites 1987*

House-building Process Review

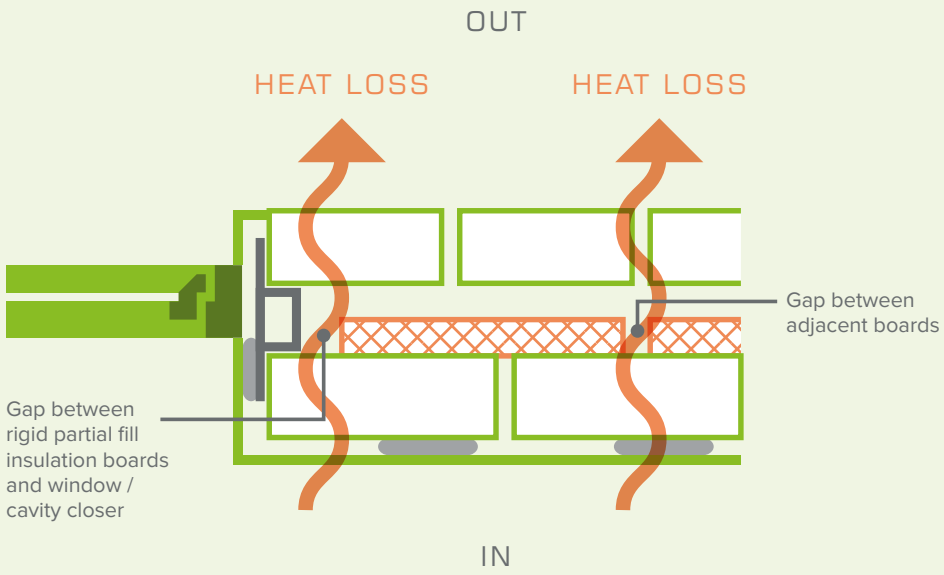
Numerous examples of issues with the quality of installations of fabric and services have been identified, of varying severity. One element of the site interviews also focussed on understanding how a site manager's time is typically spent, with senior site managers reporting that they spend on average around 55% of their time on site, site managers 65%, and assistant site managers around 85%.

FOUND ON 100% OF SITES

A trend is also appearing of areas likely to need greater attention to ensure quality is maintained. These include: sealing of services penetrations, reducing 'float' of rigid insulation within masonry cavities, accurate positioning of windows and doors, soffit insulation around single lintels, airtightness sealing behind bathroom and kitchen units (where this is the chosen strategy), party wall edge sealing, screed breaches of floor edge insulation and connection of cavity insulation to cavity closers at openings.

Example

Many examples were observed on site of cavity insulation board stopping short of cavity closers at openings and of gaps between boards leading to increased heat loss, as shown in this illustration.



CONCERN OVER CONSISTENCY OF SOME TEST METHODOLOGIES AND INTERPRETATION OF DATA AND GUIDELINES

Whilst all tests would be expected to have a degree of error, this issue occurs where tests are not carried out or interpreted consistently, generating results outside acceptable limits. This may be due to problems relating to the competency of testers, the clarity of testing guidance and the support available.

The presence of this issue has been clearly supported by the Literature Review. Studies by research institutions, universities and manufacturers have identified problems around the consistency of the application of as-built tests and interpretation of results, for both as-built fabric and building services. It is still difficult to gauge the impact of this on as-built performance, but it should be concluded that because certain tests inform both the initial energy modelling assumptions and the final As-Built SAP assessment, the impact is fairly consistent across industry, irrespective of housebuilder size or contractual approach. The potential impact will vary depending on the type of test: some tests produce inputs to SAP, while others may be used to help identify, measure and potentially reduce the Performance Gap.

Related Issues

This issue includes concerns with air tightness testing and is therefore related to limitations of the air-pressure testing methodology (T4), and may relate to difficulties in accounting for dynamic effects (T6).

Literature Review

> *During performance tests undertaken by BSRIA in 2011, 95% of systems failed to meet the airflow rates set out in Building Regulations guidance. The existing performance test procedures used in the domestic property sector are not robust, easily repeatable or easy to put into practice.*
> **BSRIA, Domestic Ventilation Systems Guide, 2013**

Whilst the majority of the literature reviewed was not directed specifically towards assessing the consistency of test methods, evidence was found of issues relating to various types of test. The majority of these related to the consistency of application of the tests and interpretation of the results.

Evidence was found for a lack of consistency in air pressure testing (the only as-built test to be used as a SAP input). A few reports noted that the methods of testing vary (pressurisation, depressurisation, mixture of both) and that the results from each test may vary, depending on factors such as the effectiveness of seals, external conditions, the equipment used, and tester competency. Examples of a lack of competency included miscalculation of the envelope area and testers not recognising conditions that would produce unreliable results. Issues were also identified relating to services testing, where different system boundaries were used in different tests. There was evidence of commissioning measurements differing between organisations and of independent test results differing from manufacturer test results. More generally, there was some evidence of issues with the quality of equipment, use of different equipment by different testers, poor calibration of tools, and some evidence suggested that the appropriate correction factors were not always being used for particular instruments (e.g. for airflow measurements).

The majority of references in the Literature Review related to co-heating testing, and several to heat flux testing. These test results are not inputs to SAP but are used in some cases to test the actual performance of dwellings or dwelling elements and so help to define and potentially close the Performance Gap. The methodology for co-heating tests is still evolving, and although many studies demonstrated the usefulness of the test and its ability to achieve reliable results if carried out well, there was some evidence of different practices and interpretations of results by different testing organisations even where they have attempted to harmonise their approaches, as well as difficulties in accounting for the impact of dynamic effects, non-standardisation of equipment specifications and calibration, and a lack of protocols for the analysis of test data and presentation of results (although it should be noted that an updated protocol has just been produced). Heat flux test results were also found to vary depending on location, number and density of sensors, with the potential for misleading results, if for example too few sensors are used. It was noted that there are also difficulties in interpreting thermography tests and limits on the conditions in which tests give meaningful results.

House-building Process Review

Understandably, due to the research and technical nature of this issue, there was no significant evidence identified during either the development team interviews or site visits.

EM4

AS-BUILT SAP NOT REFLECTIVE OF ACTUAL BUILD

In order to provide a robust As-Built SAP calculation it is important that the inputs used reflect the final build specification on site.

Where inputs to As-Built SAP calculations do not reflect the actual built dwelling, there will be an inevitable Performance Gap. If SAP assessors are not provided – or are not using – updates to specifications and design changes, they will be unable to provide an accurate As-Built SAP. There are multiple causes for this problem, which involve all stages of the housebuilding process. These include practical issues of communication as well as process problems.

Related Issues

U-value and Psi-value calculation or convention issues, for example where calculated U-values do not reflect in situ performance, relate closely to this issue, but have been considered separately (EM8). This issue is also related to many others, including product substitution on site (C5) or at procurement (Pr2), lack of robust energy performance related verification (V2), installation quality or deviation from designs (C9, C15), SAP assessor competency and auditing (EM5, EM7), and QA and verification process issues (C6, V2, V3, V4, V5). It may also be associated with SAP assessors facing commercial pressure to provide a good result (EM1), although this is hard to evidence.

Literature Review

> *Incorrect, incomplete or contradictory design information is being given to the SAP assessor... In addition to errors in the SAP submissions it was observed that many of the SAP analyses are not being updated to reflect changes made during the construction process.*
> **DCLG, EEPH, AECOM, Research into Compliance with Part L of the Building Regulations for New Homes- Phase 2 Main Report, 2009**

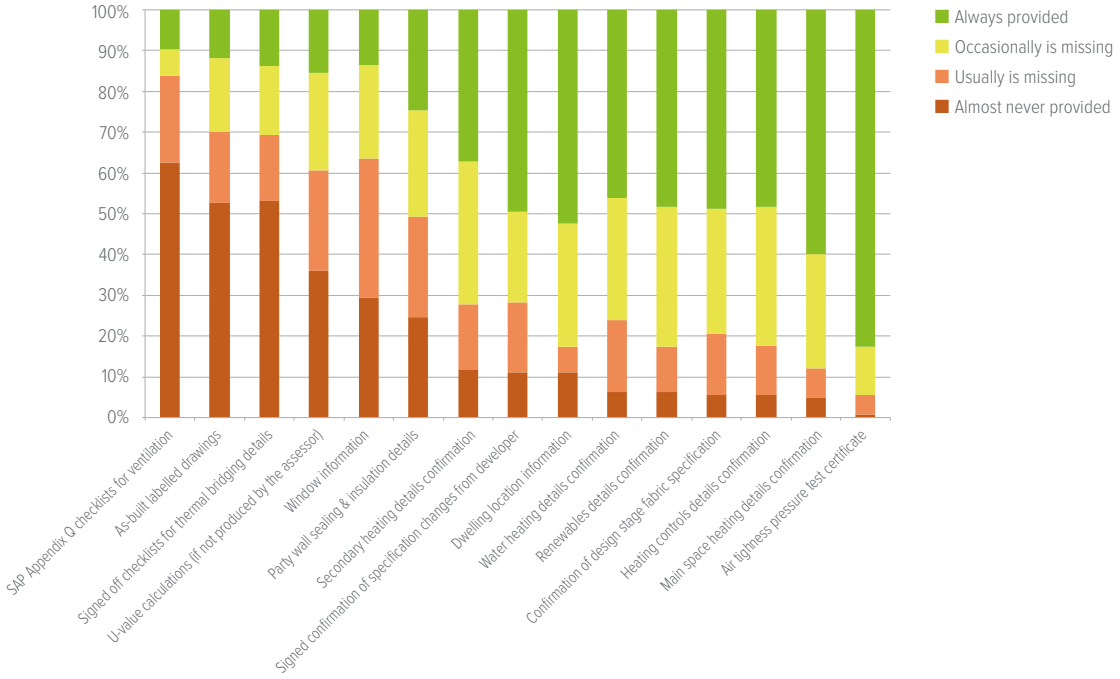
The DCLG report referenced above found that information issues were particularly common for certain inputs, notably: U-values, domestic water heating source, heating system, Accredited Construction Details and mechanical ventilation system. The main variances were seen to occur due to poor communication, lack of change control, a diffuseness of responsibility and SAP assessments being completed off-plan and often late in the construction process. It was found that SAP assessors do not usually get signed confirmation from developers of the assumptions they have made, some of which were found to be very lenient.

The Literature Review also found references to this issue in the TSB Building Performance Evaluation Phase 1 reports, and other studies focussing on dwelling testing. A variety of discrepancies were found including changes to volume, product substitution, insulation missing or poorly installed, different constructions for particular elements not being differentiated by the assessor, changes to insulation thicknesses, thermal bridging junctions, low energy lighting, heating controls, ventilation models, heating system models and additional secondary heating.

SAP Questionnaires

Only 50% of SAP assessors said that developers always provided confirmation of the as-built specification. Air tightness test certificates were the only items which appear to be regularly provided as can be seen in the following graph.

SAP Assessor Responses to Question: 'In your experience, in what areas is information sometimes lacking at the As-Built SAP / EPC Stage?'



35% of respondents said they had never visited any completed dwellings which they had assessed. The observations of those who had been to site (e.g. for Code for Sustainable Homes assessments) corroborated earlier DCLG interviews with SAP assessors which found significant unreported changes were observed when assessors visited sites. The SAP accreditation organisations reported that at audit it was common to find poor evidence provision of changes to the specification, and in some cases it was provided after the EPC lodgement date. Common SAP assessor errors picked up at audit are discussed under issue EM7.

House-building Process Review

A considerable quantity of evidence was found to support this issue during the review process. As illustrated in the table shown as an example below, a number of common discrepancy areas can be identified. It was also found that confirmation of there being no variation from the original specification is frequently signed off by technical managers, rather than the site managers who may be more familiar with any variations occurring on site.

FOUND ON 100% OF SITES

Example

The SAP Audit draft results, which include four sites (eight plots) in all instances found changes occurring in constructed dwellings that are not being reflected in SAP assessments. The discrepancies found are summarised in the table. On average across all plots audited an absolute DER deviation of 17% was found.

SAP Audit draft results

SAP ENTRY AREA	FREQUENCY OF DEVIATION (% OF PLOTS)	AVERAGE ABSOLUTE DER DEVIATION (%)
Measurements	25%	0.6
U-values	100%	5.6
G-Values	100%	1.9
Thermal Mass	50%	0.5
Linear Thermal Bridging	100%	7.1
Ventilation	13%	2.3
Heating System	63%	2.3

LACK OF ROBUST ENERGY-PERFORMANCE RELATED VERIFICATION

This issue is concerned with the lack of robust verification focussing on energy performance, for example by Building Control Bodies (BCBs) or warranty providers. This may be due to reliance on third-party information, or lack of knowledge, time or incentives to focus on energy performance.

There is clear evidence that energy performance verification is not sufficiently robust. The Literature Review and SAP questionnaire indicate that the Building Control process is overly reliant on third-party information, and that there is insufficient time, knowledge or incentives to focus on energy performance. There are knock on impacts for a range of other issues, with significant consequences for the Performance Gap. The scale of this problem might be reduced where there is a robust process for energy related quality assurance and procedures on site, though typically these have not been common within the evidence review.

Related Issues

The issue is related to other verification issues, such as lack of clarity over what documentary evidence is required or acceptable for Part L and Part F compliance (V5) and lack of clear outputs for verifiers to check modelling assumptions or transparency in models (EM5), as well as potential problems with third party schemes (V3) and lack of BCB enforcement ability (V4). It is distinct from lack of adequate QA on site (C6).

Literature Review

> *Participants from both the BCB side of the industry and the developers stated that the emphasis at the end of the works is practical completion and payment. Professionals and subcontractors may have left site having delivered their contracted work and been paid for it. There was a general perception that the developer does not need to provide evidence that the works are in accordance with any particular design or specification.*
>
> **Leeds Met University & AECOM for DCLG, Review of the implementation of Part L 2006, 2010**

The Literature Review found evidence for this issue in several sources, the strongest being various reports commissioned by DCLG to investigate compliance with Part L 2002 and 2006. For example, the project investigating 2002 compliance found that BCBs are not able to check all elements as they are only required to visit at certain points of the construction process. It also found that wet services were often not being checked, with over 70% of Building Control Officer respondents stating that they did not inspect wet services, as they believed that these were covered by competent person schemes; also that heating controls were rarely checked as BCBs were not sure what to look for, and that inadequate provision of low energy lighting was often overlooked.

The reports investigating 2006 compliance suggested that developers understand the areas that are unlikely to be checked, such as thermal bridging details and heating controls; found anecdotal evidence of BCBs giving incorrect advice or overlooking elements of compliance; that BCBs do not check that the drawing issues used for the SAP assessment match the plans submitted for other areas of regulation; and that updated As-Built SAP calculations often do not seem to be submitted to Building Control. It also found that a number of builders – thought to be smaller builders - obtain an RDSAP existing dwelling EPC on a new dwelling and then submit the RDSAP EPC to Building Control along with an air permeability test result.

The report also found that BCBs were often unsure how to determine whether a dwelling's TER and DER are accurately given and verify submitted calculations. It was generally felt there was a lack of clear guidance on this. BCBs reported that they had limited tools and abilities to verify the use of thermal bridging details; that they were concerned about product substitution but that it was difficult to tell whether products had been substituted; and that they often did not receive commissioning certificates and seemed reluctant or unable to spend the time it would take to chase these. It was also found that SAP assessors were rarely providing the documentation to BCBs that they should - for example lists of specifications were often omitted.

A very substantial body of evidence relating to the poor installation of fabric and services was found in the literature, which is arguably also evidence of a lack of adequate site QA.

SAP Questionnaires

This issue was supported by several of the SAP Questionnaire findings. Assessors responded that information was commonly lacking at As-Built SAP stage and that when they did go to site for other reasons, they often observed differences between what was in the As-Built SAP and what was actually built (see issue EM4), which suggests that these elements are not being picked up by Building Control.

Over 40% of respondents also stated that they were aware of instances of BCBs accepting RDSAP EPCs for a new dwelling instead of a full SAP As Built EPC (14% stated that this was a frequent or quite frequent occurrence), suggesting BCBs are not always making this basic check.

The SAP Accreditation Organisation Questionnaire responses showed that audits of SAP assessments commonly found that evidence was of poor quality or lacking, which emphasises the importance of BCBs making checks on site.

Housebuilding Process Review

FOUND ON 100% OF SITES

This issue was evidenced on all sites, although as would be expected, most of the evidence was indirect – for example, arguably some of the changes from designs observed on sites ought to have been picked up by BCBs or warranty providers. Evidence was however provided by the site interviews, for example the fact that Domestic Ventilation Compliance Guide checklists were missing on the majority of sites suggests that these are not being checked. Teams also reported that in nearly all cases, the sign-off of the As-Built SAP specifications and assumptions is being provided by technical managers who may not be aware of changes during construction, rather than those on site, which suggests that this is not often challenged. Observations of under or over-provision of trickle vents, and changes to various elements of the specification were also made, which suggest that these may not usually be picked up by verifiers. The experience of the SAP Audit team in attempting to track down evidence of window specifications also suggested that these are not being checked – it was hard to get this evidence, which was never held by developers (suppliers had to be asked), and the datasheets often did not match the labels found on site.

Example

SAP Audits were undertaken as part of the Housebuilding Process Review, the second stage of which aimed to identify whether changes were being made on site which were not reflected in the SAP assessments. 100% of the SAP Audits found deviations based on observations on site compared to the SAP assessments based on design information.

V5

LACK OF CLARITY OVER DOCUMENTARY EVIDENCE REQUIRED OR ACCEPTABLE FOR PART L AND PART F COMPLIANCE

This issue occurs when any of the parties involved in a development are unsure about the documentary evidence needed for Part L compliance, or related areas of Part F compliance such as ventilation commissioning checklists. Parties who may not be clear about what information is required include the developer, client, SAP assessor, construction team or Building Control Bodies (BCBs). This will impact on the Performance Gap where it means that evidence is missing, inaccurate or incomplete, making it difficult to verify whether the development as constructed matches what was designed; or when it leads to checks or commissioning not being undertaken correctly.

The evidence shows that there is a lack of consistency firstly in what evidence BCBs request and secondly in what they are provided with. There is also a lack of consistency in the evidence SAP assessors themselves are provided with to inform their As-Built SAP assessments which form the basis of Part L compliance checks. The evidence suggests that commissioning certificates and confirmation of the as-built specification are both commonly lacking, and in some cases the SAP As-Built Compliance Reports are not provided. Even when the required items are provided, BCBs may be unable to check details such as thermal bridging and U-value calculations. The lack of a robust and consistent verification system is likely to contribute significantly to the Performance Gap.

Related Issues

This issue relates to other verification issues, such as a lack of robust energy-related verification (V2), as well as to SAP assessor competency issues (EM7).

Literature Review

> *Building Control does not give consistent advice as to the required submission*
> **EEPH and AECOM for DCLG, Research into Compliance with Part L of the Building Regulations for New Homes – Phase 2 Main Report, 2009**

The majority of sources reviewed did not specifically set out to investigate this issue, however it was evidenced in several reports. The strongest evidence came from work undertaken by DCLG to investigate compliance with Part L 2006. As noted for the issue of robust energy-performance related verification, BCBs reported that they had limited tools and abilities to verify what thermal bridging details are used. They often did not receive commissioning certificates and reported that they were unable to chase them. It was also found that SAP assessors rarely provided required documents to BCBs such as specifications and confirmation of changes to specifications. The project also found that there was inconsistency in the evidence requirements of different BCBs for the as-built submission; that SAP assessors sometimes had to advise BCBs of the requirements; and that the wording of Appendix A of Approved Document L1A 2010, which provides guidance on how to provide evidence of compliance, is interpreted differently by different readers.[1]

1. See Appendix A of HMG, Approved Document L1A, 2010 Edition

For example, some BCBs were found not to require air tightness test results; others required SAP calculation details, while others required only the TER and DER, or even just a notice stating that the TER had been met. Developers also reported that they currently do not allocate sufficient resources to the provision of evidence because it is not taken seriously.[1] Several of the reports which covered projects where building performance was analysed in detail also found that commissioning and test documentation was lacking.

SAP Questionnaires

The SAP Accreditation Organisation Questionnaire found that when audits of SAP assessments were undertaken poor evidence provision was commonly found, and confirmation of any changes to the specification was often missing, and in some cases provided after the EPC lodgement date.

The SAP Assessor Questionnaire found that different assessors provided different outputs at the As-Built SAP stage, with not all assessors even providing the As-Built Building Regulations Checklist (11% did not indicate that they provide this) required by Part L, but all providing the EPC or a link to it. 55% provided the SAP data input sheet, which is good practice though not an explicit requirement, and a minority provided some other information (less than 5% specifically mentioned some form of confirmation of specification or assumptions used – and some referred to the design stage specification only or a reminder to provide outstanding evidence, but after the As-Built SAP was issued; 13% specifically mentioned various SAP worksheets; and 2% specifically mentioned provision of U-value calculations to support the as-built energy assessment). Only 50% of assessors said that developers always provided confirmation of the as-built specification to them, although this does not necessarily mean this is not provided to Building Control as required by Part L. Additionally, signed off process sheets for thermal bridging details, SAP Appendix Q checklists for ventilation, and updated as-built drawings were reported as almost never provided to assessors by over half of the respondents – other evidence requirements which feed into the As-Built SAP assessment. Air tightness test certificates was the only item which well over 50% of respondents said was always provided, but over 5% still stated that these were almost never provided or usually missing, and a further 12% that they were occasionally missing. These findings indicate a lack of clarity on what information is required.

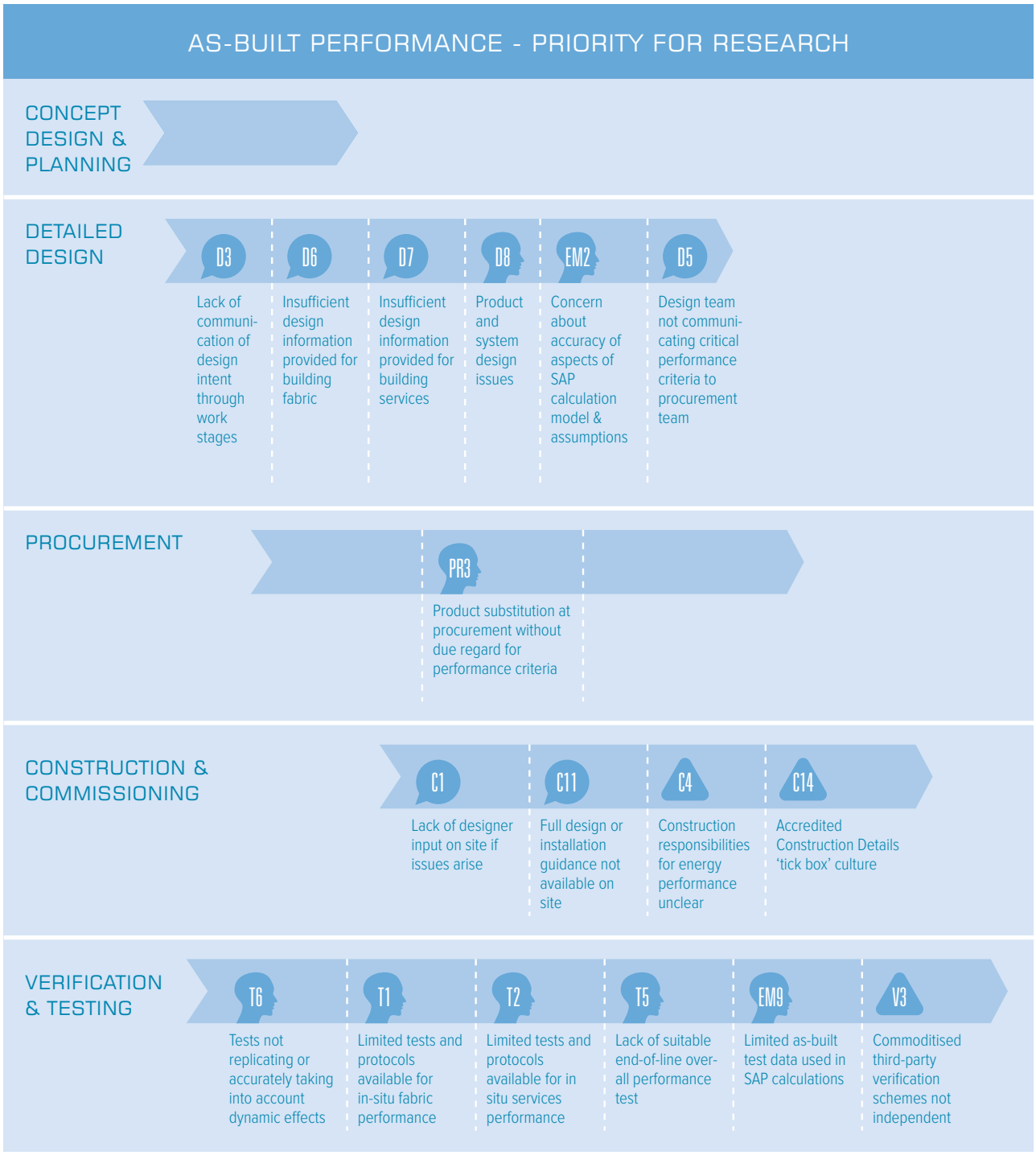
House-building Process Review

Many of the interviews with design team members identified this as an issue. Instances were found of Domestic Ventilation Compliance Guide commissioning checklists not being provided to the developer, so an assumption is made that services are performing as intended. There were also instances where As-Built SAP details were being signed off by Technical Managers, rather than Site Managers, who may not have the site knowledge of the actual build. Under the audits of the SAP assessments, some evidence, such as window specifications, was very hard to obtain, with developers not holding this information, which suggests that accurate, complete and up-to-date specification information often cannot be provided to BCBs either.

Example

Over 40% of respondents to the SAP Assessor Questionnaire stated that they were aware of instances of BCBs accepting RDSAP EPCs for a new dwelling instead of a full SAP As-Built EPC (14% stated that this was a frequent or quite frequent occurrence).

1. *EEPH and AECOM for DCLG, Research into Compliance with Part L of the Building Regulations for New Homes - Phase 2 Main Report, 2009; and Leeds Metropolitan University and AECOM for DCLG, Review of the implementation of Part L 2006, 2010*



CROSS-CUTTING THEMES

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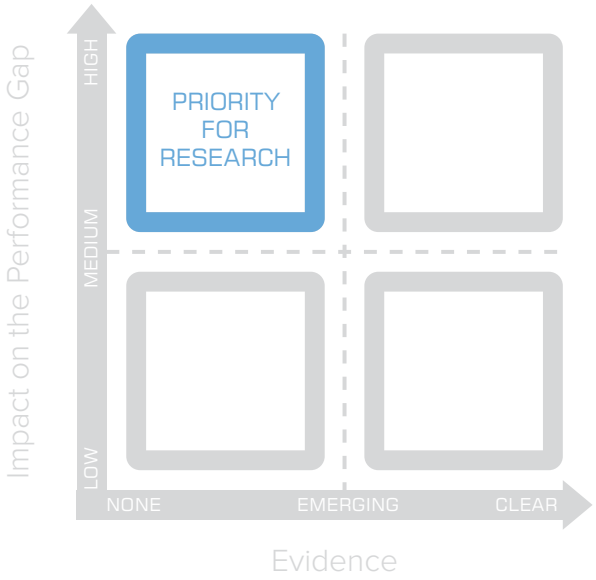


PRIORITY FOR RESEARCH

17 issues were identified that are considered to have a potentially significant impact on the Performance Gap, but for which sufficient evidence is currently lacking to fully understand how extensive this contribution may be.

This section of the report addresses each of these issues, assessing what evidence we currently have and in some cases suggesting why the issue may not be appearing within the existing evidence. The shortfall of impact related evidence means that these issues merit further investigation. There is a risk to industry and government if they are prematurely seen as being of low importance.

D3 LACK OF COMMUNICATION OF DESIGN INTENT THROUGH WORK STAGES

Important aspects of the design may be changed or misunderstood as the development progresses, without due consideration of their potential impact on the Performance Gap. For example, the contract may be structured so that there are different designers involved at concept, detailed and site stages. Similarly, specialist consultants may only be involved at certain stages of design and construction. Where this results in deviation from the original design, failure to communicate an important change could result in a significant impact, whereas some changes may have no impact. The extent of the impact on the Performance Gap may also vary depending on the size of the housebuilder - for example, larger housebuilders with robust, standardised designs may require less communication between the detailed design team and the construction team. This issue links to construction issues where there may be a lack of designer input available to site if problems or queries arise (C1) or where design information is produced but not made available on site (C11).

This issue was referenced in several sources in the Literature Review, including several industry and academic studies. These found problems with training, learning to use new products or technologies, and a lack of detailed design information, which shows some failure to properly communicate design intent.

The Housebuilding Process Review identified this issue in a third of site interviews, typically relating to insufficient handover procedure from one stage to the next; either from concept designer to detailed designer; or from the designers to the site team. A particularly interesting theme has emerged that site managers, and in some cases sub-contractors, see it as their role to 'solve' detailing and sequencing issues on site if they have not been sufficiently provided by the detailed design team. The eventual impact on energy performance of such problem-solving on site is very difficult to evidence from the research to date.

Part of the reason why there is relatively little evidence for this issue may be because it is difficult to monitor all communications on a project and also to distinguish whether the design intent was fully communicated but not followed, or not sufficiently well communicated.

D6 INSUFFICIENT DESIGN INFORMATION PROVIDED FOR BUILDING FABRIC

Design information on the building fabric may be insufficient or not produced at all. As a result, the contractor or sub-contractor may have to make design decisions on site which could be contrary to the original design intent. The impact of this on energy performance may relate to the knowledge and skills of the site team (C13) and their general ability to install the fabric (C15), and to whether designer input is easily available on site when an issue arises (C1). Where the sub-contractor works regularly with the housebuilder, or the house is of a standardised design, they may better understand the original design intent. Cases where design information is produced but not available on site are considered separately (C11), although it can be hard to distinguish between these two issues.

This issue was found frequently in the Literature Review, including in a number of high-profile peer-reviewed documents which express concern over the extent of design input left to suppliers and sub-contractors. The Leeds Metropolitan University study of Stamford Brook, for example, found that for some details - such as dormer windows, balconies and recessed front doors - no design detail was provided resulting in design taking place ad-hoc on site and creating a Performance Gap.

The Housebuilding Process Review identified this issue on two-thirds of sites. For example, in the site interviews some reported budget constraints limiting the extent of design drawings so that in some cases full details were not prepared. On some sites design information with incorrect details was found which required modifications on site; as well as instances of insufficient information for complex details such as varying roof heights and bay windows where site improvisation and difficulties in construction were observed.

The SAP Assessor Questionnaire also found that information on thermal bridging was frequently missing which suggests that information on this is often insufficient.

INSUFFICIENT DESIGN INFORMATION PROVIDED FOR BUILDING SERVICES

Sufficient detailed design information for the building services may also not be produced. This could result in the contractor or sub-contractor having to make decisions on site which may be contrary to the original design intent, and could lead to poor installation of services (C9). The impact of this may depend on the skill of the worker (C13) and whether the design information that does exist is actually available on site (C11). A sub-contractor with experience of energy considerations may be able to find a robust design solution. Similarly, if the sub-contractor works regularly with the housebuilder, they may better understand the original design intent. Cases where design information is produced but not available on site are considered separately (C11), although it can be hard to distinguish between these two issues.

The Literature Review identified this issue in a range of reports, with many instances of services installation compromising the fabric design. It was identified as an issue in more than half of the Housebuilding Process Review interviews, with issues such as incompatibility of weather compensators on boilers, incorrect zoning of heating and incorrect installation of boiler flues. There was also evidence of renewable technologies usually being entirely designed, fitted and commissioned by the supplier, which may often be a robust and commercially efficient approach, but potentially reduces the opportunity for integrated design (D2).

PRODUCT AND SYSTEM DESIGN ISSUES

There is a concern that where product or system design and performance is not sufficiently robust they will not perform as intended, resulting in a Performance Gap. Several reports in the Literature Review identified this issue, providing reasonably extensive evidence. These mention problems with thermal bridging, U-values and overall performance for products such as doors, windows, MVHR systems, thermostats, pipework, underfloor heating, SIPS systems, CHP systems, heat pump systems and more. Issues relating to individual products were often quite specific, with some more general findings relating to system design problems. The issue was not directly evidenced in the Housebuilding Process Review, although problems with MVHR system design and the performance of boilers and windows were raised in some site interviews as potential Performance Gap issues.

More evidence for this review might be available if there were more tests of in situ fabric and services performance (T1 & T2). In the absence of these it is difficult to robustly gauge the impact of any such concerns on energy performance.

CONCERNS ABOUT ACCURACY OF ASPECTS OF THE SAP CALCULATION MODEL AND ASSUMPTIONS

In order to avoid creating a Performance Gap, it is important that the SAP model is accurate – though it should be recognised that SAP is based on standard occupancy assumptions, and that some issues may be better addressed at their root causes rather than by amending the calculation model itself. This issue links to the lack of suitable end-of-line overall performance test to validate energy calculation models (T5), and is contributed to by issues surrounding the use of calculation procedures in BR443 and BR497 (EM8).

Whilst validation exercises have been carried out for BREDEM, the model behind SAP, some potential areas for improvement were suggested in the Literature Review. One study questioned the sample size and geographic spread used to validate the BREDEM model, and also the lack of recent validation exercises focussing on recent new build homes. Other reports suggested that some factors were not accounted for sufficiently or accurately in SAP, including the quality of fabric and services installations. Suggested areas of concern included thermal bypassing at areas other than the party wall, thermal bridges, thermal mass, air change rates for flats, party wall U-value options, and the treatment of more complicated forms such as integral garages and conservatories. Concerns related to services included systems interactions, secondary heating use, heating zoning, electricity use by certain services, and prediction of performance of some low and zero carbon technologies. A recent report by Zero Carbon Hub[1] concluded that the underlying physics of SAP is robust but also found that greater understanding is required of as-constructed and as-installed performance, particularly in establishing the impact of air movement around insulation layers, thermal bypassing (all forms) and the 'whole systems' effects of services. A related issue was also raised by some SAP assessors who reported that different software products implementing SAP can give different results, though this claim needs further investigation. Generally the references pointed towards a need for further research and validation of some of the model's assumptions, as the particular points raised were not always analysed in detail or across a large sample.

The issue was also found on several sites, where it generally related to thermal bridges not being accounted for in SAP – for example bay window jambs, beams within the structure, and screed at thresholds. However, as might be expected, other issues with SAP calculation procedures were not very strongly supported by site observations.

1. Zero Carbon Hub, Carbon Compliance for Tomorrow's New Homes, Overview of Findings and Recommendations, 2010.

DESIGN TEAM NOT COMMUNICATING SUFFICIENT INFORMATION REGARDING CRITICAL ENERGY PERFORMANCE CRITERIA OF COMPONENTS TO PROCUREMENT TEAM

As well as the more general issue of design intent not being properly communicated through build stages (D3), there are concerns over the link between design and procurement. Design specification of certain materials may be critical to final energy performance. Where the procurement team are not made sufficiently aware of this, alternative materials or components may be purchased, with a potentially detrimental impact on the finished build. The impact of this issue depends on the type of information not provided and the risk may be reduced where established supply chain frameworks are used. There are close links between with this issue and concerns of product substitution at procurement (Pr3).

Evidence for this specific issue is very limited, partly because it is difficult to tell what information has been passed from the design team to the procurement team. The Literature Review identified relatively few instances, including one in which the air tightness target was not communicated to procurement resulting in poorer performance on completion, and another in which a lack of clear information resulted in the purchase of less efficient services. In the Housebuilding Process Review incorrect window lintel baseplates were identified, which has the potential to result in higher thermal bridging than assumed in the design. It was also frequently observed that U-values and g-values of the windows installed differed from those in the design, which may be due to the procurement team not being informed of the importance of these criteria.

PRODUCT SUBSTITUTION AT PROCUREMENT WITHOUT DUE REGARD FOR PERFORMANCE CRITERIA

There is some evidence of product substitution taking place at procurement stage, which may result in materials and components that do not meet necessary performance criteria. The impact of this will depend on the materials being replaced, but has the potential to be significant. The issue is related to poor communication between design and procurement teams (D5). It is also sometimes difficult to determine whether substitutions are occurring at procurement or on site – the latter has been discussed separately (C5).

Under the Literature Review, there are only a few sources that reference this issue. These found examples of MVHR systems being changed and originally specified materials being replaced due to unavailability of the original specification. Two-thirds of sites on the Housebuilding Process Review had instances of this occurring. However as the difference in specification only became evident during site visits it is difficult to confidently identify at which stage in the process the substitution occurred. One site had at least six different examples of product substitution, including the substitution of dense blocks in the trench, block types in party walls, wall insulation, lintels, fan lights and lighting. The SAP Audits have shown that these substitutions can have a significant impact on energy performance.

C1 LACK OF DESIGNER INPUT AVAILABLE TO SITE IF ISSUES ARISE

Depending on the designer's contract, they may have a limited scope to provide design advice to site. Where a site is efficiently managed, with all design information and details available, or where the dwellings are of a standardised design, there may be little need for designer input, resulting in a small impact on overall energy performance. Conversely, in instances where the site team lack knowledge of energy performance, or there is insufficient design information provided from the outset, this could have a much bigger impact. It therefore links to issues where designers are not providing sufficient design information (D6 & D7) or the design information produced is not available on site (C11), or where site team knowledge is lacking (C13).

This issue was only identified in a few sources in the Literature Review, including instances of product substitution to resolve a perceived design flaw, without first consulting the design team. It occurred at a third of sites under the Housebuilding Process Review: one site started construction before the design was complete and at another site build-up details were incomplete - both required the site team to solve problems themselves. It is possible that more evidence for this issue was not collected because it is difficult to identify whether the designer is unable to provide information or the construction team are not asking for it.

As mentioned previously, in some cases site managers and sub-contractors see it as their role to 'solve' detailing and sequencing issues on site if they have not been sufficiently provided by the detailed design team. The eventual impact on energy performance of such problem-solving on site varies but could be significant.

C11 FULL DESIGN INFORMATION OR INSTALLATION GUIDANCE PRODUCED BUT NOT AVAILABLE ON SITE

Design information or installation guidance may be produced by the design team but not available to workers on site. The contractor or sub-contractor may then make uninformed decisions. Depending on the nature of the item, this may or may not have a significant impact on the energy performance of the building. This issue particularly relates to instances where there is a lack of communication of design intent through work stages (D3). In the evidence it is often hard to differentiate it from issues where sufficient design information has not been produced (D6, D7).

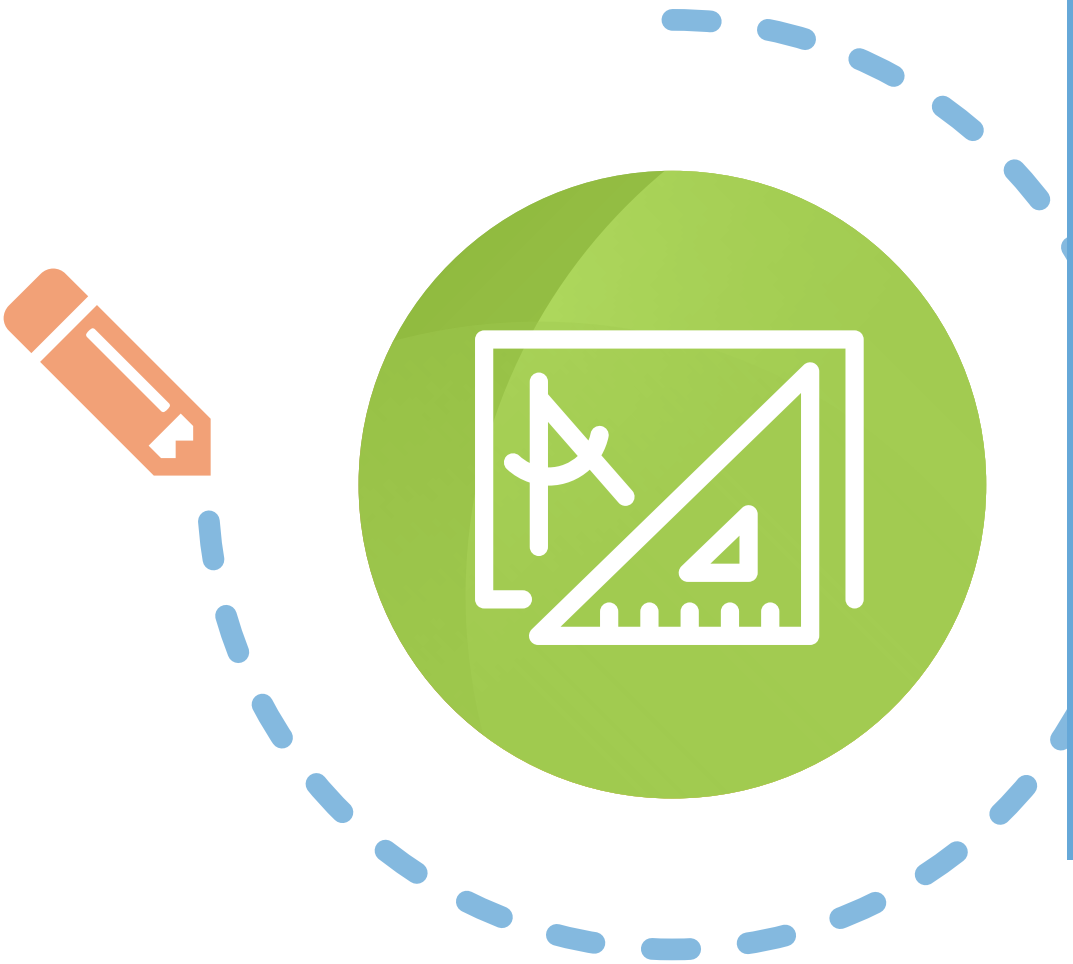
There are relatively few sources of evidence for the existence of this issue. Some documents in the Literature Review mention it, with instances of site workers using large scale general arrangement drawings rather than the available details.[1] One project reported a lack of handover between the design and construction stages, with some technical details unavailable at the start of the construction process. From the Housebuilding Process Review, this issue was noted at only one site, where it led to the incorrect fitting of insulation. However it was also noted that BBA certificates were usually not held on site.

C4

CONSTRUCTION RESPONSIBILITIES FOR ENERGY PERFORMANCE UNCLEAR

Lack of consistent collaboration or coordination for the responsibility of energy performance on site may result in trades carrying out work that compromises the overall strategy. For example, services may be installed that penetrate and damage the air barrier or cause thermal bridging. The issue is related to a lack of team knowledge and skills (C13). Use of an experienced team, particularly in combination with standard house types, may reduce the impact of this issue.

Several sources identified this as an issue in the Literature Review, including peer-reviewed reports focusing on evaluation of building performance, where it was found that construction responsibilities relate to individual components but not the interactions between them, leading to performance issues. Within the Housebuilding Process Review, two-thirds of sites found some evidence for this issue. These typically involved the work of sub-contractors impacting on the fabric: electricians failing to seal holes, airing cupboard penetrations being left open, service penetrations not being core drilled, insulation being disturbed and penetrations not being properly sealed.



C14

ACCREDITED CONSTRUCTION DETAILS 'TICK BOX' CULTURE

There may be instances where the information for the As-Built SAP is confirmed by developers as unchanged from the Design Stage SAP, without detailed checks or discussion with the construction team. This may be because they consider that their site management and change control procedures would flag any deviations from the original design. A specific issue has been identified with the use of Accredited Construction Details or other thermal bridging details not being checked. On occasions where the deviation is significant, this can have a large impact on the Performance Gap. Linked issues that may contribute to this include insufficient quality assurance (C6), competency of SAP assessors (EM7) and a lack of responsibility for energy performance (O3). It contributes to the As-Built SAP not reflecting the actual build (EM4).

A number of high quality publications identified this issue in the Literature Review. These included site observations of significant variation from the accredited details due to changes in materials, issues with the quality of installations or buildability, and lack of detailed drawings on site. Reviews of compliance with Part L also found that incorrect or incomplete information was commonly provided to SAP assessors on thermal bridging and that all parts of the industry were aware that checks were weak and relevant detailed drawings were infrequently held on site.[1]

Evidence of this issue was produced during the Housebuilding Process Review. One example was where adequate room to install rigid roof insulation into the eaves was available but not fitted at the wall junction in line with the detail provided. This site modification was not recorded in the SAP assessment. Other sites identified different lintel specifications, lack of thermal lining in reveals, incorrect window alignment with the insulation layer and lack of edge insulation at the floor perimeter. The SAP Audits found deviations from thermal bridging designs on 100% of sites, and these were shown to have a significant absolute impact on the DER – on average over 7%, based on the audits undertaken to date.

The SAP Assessor Questionnaire found that only 6% of respondents stated that customers frequently advised which details were followed and provided all of the required details, with 6% also saying details were frequently provided but only for some junctions. 70% said that they frequently found that no information was provided, and 60% that they were frequently left to determine what details were used from the drawings. 53% said that signed off checklists for thermal bridging were almost never provided at the As-Built SAP stage, with a further 16% stating that they were usually missing and only 14% stating they were always provided. The SAP Accreditation Organisation Questionnaire confirmed that audits commonly identified poor provision of evidence.

TESTS NOT REPLICATING OR ACCURATELY TAKING INTO ACCOUNT DYNAMIC EFFECTS

There is concern that testing methodologies may not properly account for dynamic effects such as solar gain, wind speed and other microclimate effects. As a result they may be providing inaccurate results, reducing the validity of conclusions being made about the performance of fabric or services. This relates to other issues about limited tests and agreed protocols and consistency of tests (T1, T2, T3).

Several reports from the Literature Review have mentioned this issue. These express concern over not accounting for 'wind-washing', during which wind increases air flow within the structure, where it can then pass through and around insulation, increasing heat loss. It is also suggested that there should be more research into the impact of weather conditions, in particular solar gain, on co-heating tests. Again this issue was not raised in the Housebuilding Process Review as testing was not undertaken.

LIMITED TESTS AND AGREED PROTOCOLS AVAILABLE FOR IN SITU FABRIC PERFORMANCE MEASUREMENT

There are limited in situ fabric performance tests – for example heat flux testing, thermography and the co-heating test – and some of those that do exist lack comprehensive industry-wide protocols for implementing them or interpreting the results. Where the final performance cannot be measured, it may be hard to provide feedback on actual delivered performance and understand the impact of any problems arising during fabric installation (C15). It is also difficult to understand the impact of this issue on the Performance Gap, particularly as it can be seen as more of a solution than a route cause of current problems.

The issue was referenced in several sources in the Literature Review, with some reports providing detailed commentary on the limitations of the existing testing methodologies. As might be expected, the issue was not raised in the Housebuilding Process Review as testing was not undertaken. Further work may be needed to identify the potential for in situ fabric tests to minimise the Performance Gap.

1. Leeds Metropolitan University for DCLG, Condensation Risk: Impact of Improvements to Part L and Robust Details on Part C, 2005

LIMITED TESTS AND AGREED PROTOCOLS AVAILABLE FOR IN SITU SERVICES PERFORMANCE MEASUREMENTS

There are a limited number of tests available for installed services, without which there can be less confidence over system performance. The extent of this problem depends on the complexity of the services and systems in question: simple tests may be sufficient for simple technologies, but more complex systems, such as whole house heat recovery and ventilation, may require more complex tests. The type of technology also relates to the impact on the Performance Gap; where the service forms a major part of the energy strategy, under-performing may result in significant repercussions. This also relates to construction issues for the proper installation and commissioning of services (C9), as well as the lack of an overall test for end-of-line performance (T5).

The Literature Review identified this issue in a substantial number of reports, of which several are peer-reviewed papers. Concern was raised that independent checks may be necessary to verify the performance of commissioned services. When subjected to independent systems testing, a number of technologies - including underfloor heating, heat pumps, MVHR, boilers and hot water cylinders - were found to underperform compared to manufacturers' expectations. The Housebuilding Process Review identified this issue only in the site interviews where some interviewees expressed concern that products were "...not doing what they say on the tin".

LACK OF SUITABLE END-OF-LINE OVERALL PERFORMANCE TEST TO VALIDATE ENERGY CALCULATION MODELS, PRODUCTS AND BUILDING FABRIC

There is currently no industry agreement on a standard test or protocol for an overall, end-of-line test of energy performance. This is related to issues of limited testing and protocols for in situ fabric (T1) and services (T2) performance.

In the Literature Review, several sources identified this issue, including a number of detailed, peer-reviewed studies. These discuss some of the inevitable limitations of existing tests such as the co-heating test – for example this cannot be undertaken all year round and tests the building fabric but not the building services. Limitations of current tests generally include cost, duration, timing and practicality. In one case, there was found to be no test that would account for a particular technology, which relates to concerns over testing innovative or less mainstream products (T7). The Housebuilding Process Review did not highlight this as an area of concern, partly as testing was not undertaken as part of the review.

1. EEPH and AECOM for DCLG, Research into Compliance with Part L of the Building Regulations for New Homes Phase 2 Main Report, 2009; Leeds Metropolitan University and AECOM for DCLG, Review of the Implementation of Part L 2006, 2010

LIMITED AS-BUILT TEST DATA USED IN SAP CALCULATIONS

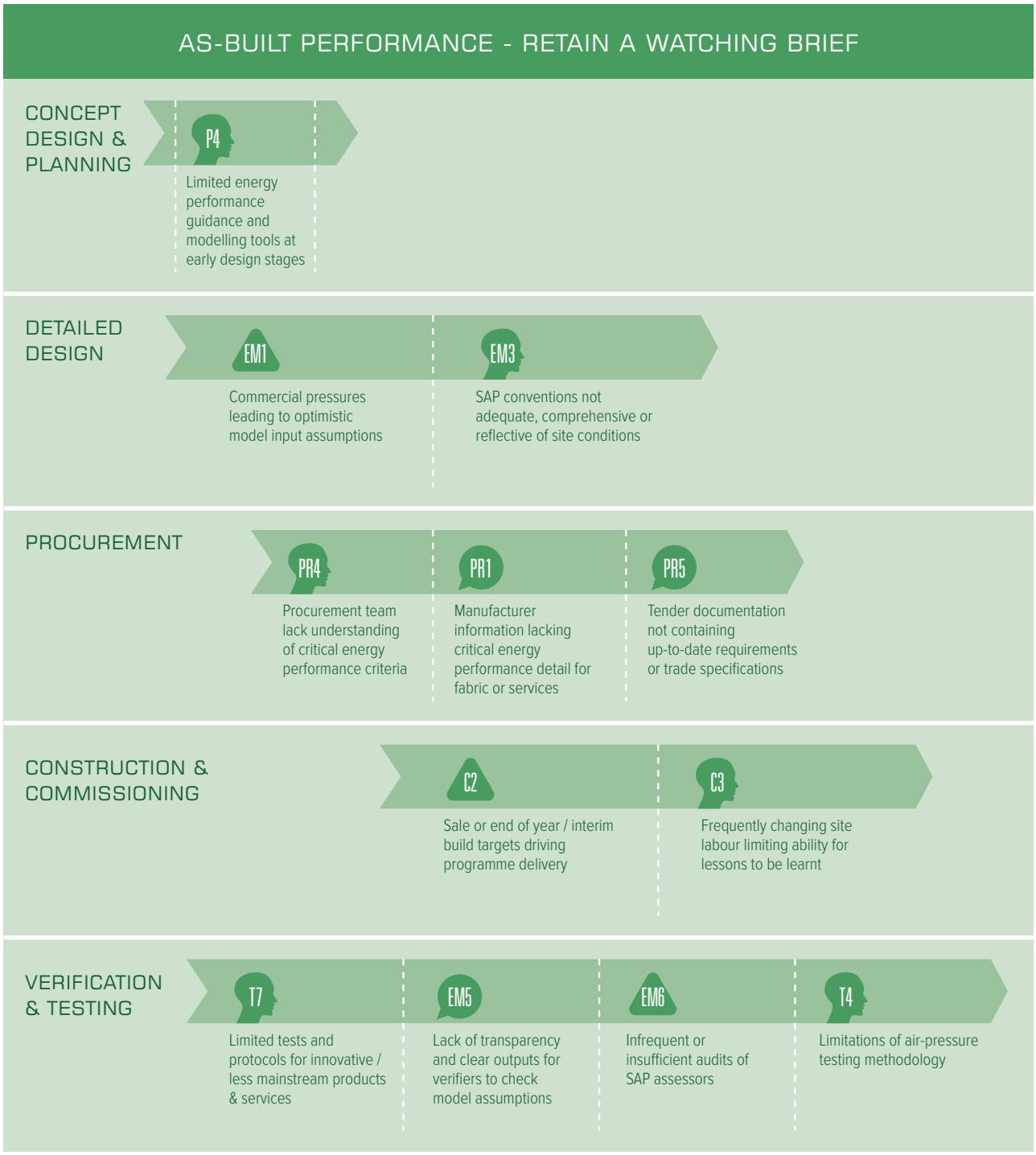
In the context of the Zero Carbon Hub's recommendation that future Part L carbon compliance requirements are set based on as-built rather than as designed performance, the fact that SAP only currently uses site test results for air tightness is a concern. This increases the likelihood that the As-Built SAP may be based almost completely on notification from the developer of changes made since the design and procurement stages, which reduces confidence that the As-Built SAP is truly reflective of the build (EM4), particularly as SAP assessors report that confirmation of key information is often missing.

Several sources in the Literature Review identified this as a problem, with concern over the extent of available as-built test data in general, and the ability of SAP to properly analyse built performance. The Housebuilding Process Review was unable to find any direct evidence for the extent of this as an issue. This might be expected, given that the nature of this issue is closer to a solution for a future compliance and verification landscape, rather than a source of concern within existing delivery teams. This issue relates to the limitations of available tests for in situ fabric and services performance (T1, T2).

COMMODITISED THIRD-PARTY SCHEMES NOT INDEPENDENT OR CHECKS NOT ADEQUATE (INCLUDING COMPETENT PERSONS SCHEMES)

Where third-party schemes have inadequate checks or an insufficiently robust procedure, there may be a knock-on impact on many other issues. For example, where an air pressure test does not follow guidelines, a significant Performance Gap may be created when this result is used to produce an As-Built SAP calculation.

The Literature Review found limited evidence for this issue, which was referenced in relatively few sources. One study found that independent checks may be necessary to demonstrate the accuracy or validity of commissioned systems, with others raising concerns over installers and testers signing off their own work, and finding discrepancies between air tightness tests undertaken by different parties. Under the Housebuilding Process Review, concern was raised in one interview about air pressure testers allowing labourers to apply mastic while testing is carried out.



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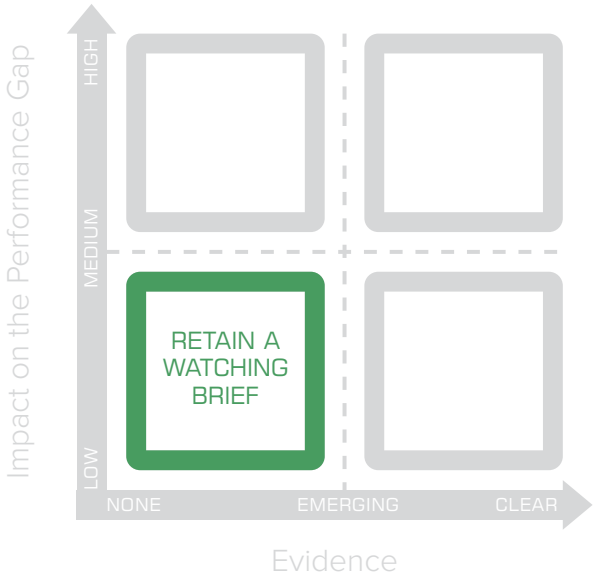

RETAIN A WATCHING BRIEF

This section presents the remaining 23 issues. A low level of evidence has been found for these and they are considered to have a medium to low impact on the Performance Gap.

Relatively little evidence of these issues was found across all sources; typically each one was raised in less than 20 medium quality reports in the Literature Review and identified in a third or less of the sites visited. In all cases, it is suggested that more evidence for their existence and impact be found or produced, to improve understanding of their role.

Of these issues, some are classified as being of slightly more concern, so the production of more evidence should be prioritised for these. These 'Key Issues' are explained below, with a brief consideration of what impact they might have on the Performance Gap. There then follows a list of the remaining issues which also require more evidence.

LIMITED GUIDANCE, MODELLING TOOLS AND STANDARDS AVAILABLE TO EVALUATE AND REVIEW ENERGY PERFORMANCE AT EARLY DESIGN STAGES

Without an appropriate tool, design decisions may be made that impact negatively further down the process chain. Links closely to the issue of lack of suitable tool for detailed design that incorporates a compliance check (D4).

COMMERCIAL PRESSURES LEADING TO OPTIMISTIC SAP INPUT ASSUMPTIONS

The impact of this depends on the variable in question. It may also be hard to differentiate between optimistic assumptions, a lack of assessor knowledge and deliberately incorrect inputs.

SAP CONVENTIONS NOT ADEQUATE, COMPREHENSIVE OR REFLECTIVE OF SITE CONDITIONS

The impact of this depends on the convention in question: where it is central to the model, the impact on the gap will be greater. If SAP fails to accurately reflect actual site conditions, the Performance Gap may be increased.

PROCUREMENT TEAM LACK OF UNDERSTANDING OF CRITICAL ENERGY-PERFORMANCE RELATED CRITERIA

Where there are insufficient checks in the process, procurement decisions may be made that are contrary to design intent. This links to issues of communicating design intent (D3) and communication within the team and across project stages.

MANUFACTURER INFORMATION LACKING CRITICAL ENERGY PERFORMANCE DETAIL, RELATING TO EITHER BUILDING FABRIC OR SERVICES

The impact of this depends on the product type and whether efforts are made to source missing information. The impact may be reduced where volume builders have established supply chains in place.

TENDER DOCUMENTATION NOT CONTAINING UP-TO-DATE REQUIREMENTS OR TRADE SPECIFICATIONS

Depending on what elements are out of date, poorer performing materials, components and services may be specified. These could limit the built performance and not comply with the designer's intentions and requirements, linking to communication and responsibility issues.

SALES OR YEAR-END/INTERIM BUILD TARGETS DRIVING PROGRAMME DELIVERY

These delivery drivers may put phasing out of sequence and require site workers to accelerate their programme, potentially compromising construction quality. The impact of this is difficult to measure but may be significant for the units concerned.

FREQUENTLY CHANGING SITE LABOUR LIMITING ABILITY FOR LESSONS TO BE SHARED OR LEARNT

The impact of this depends on the handover process and feedback protocols; where it occurs, it may make it more difficult to deliver good performance.

LIMITED TESTS AND AGREED PROTOCOLS FOR INNOVATIVE/ LESS MAINSTREAM PRODUCTS AND SERVICES

Where a new product enters the market without passing through a robust testing protocol, its performance may be over- or under-stated, and its impact on other aspects of the build may not be properly understood.

LACK OF TRANSPARENCY AND CLEAR OUTPUTS FOR VERIFIERS TO CHECK MODELLING ASSUMPTIONS

Without easily available and clear outputs from energy modelling software, it may be more difficult to audit or verify the modelling process and the assumptions used. Designers may also be less able to understand the impact of their design on the building performance.

INFREQUENT OR INSUFFICIENT AUDITS OF SAP ASSESSORS BY LICENSING ORGANISATIONS

If SAP assessors are not frequently audited, they may repeatedly use incorrect assumptions or inputs, contributing to the Performance Gap.

LIMITATIONS OF AIR-PRESSURE TESTING METHODOLOGY

Being the only as-built test used in SAP, this requires a robust methodology, third party certification, protocol and QA process to ensure results are reliable. This issue is closely related to more general concerns over the consistency of some test methodologies (T3).

Retain a Watching Brief: Remaining Issues

Limited understanding by planners or funders of the impact of phasing or aesthetic requirements on performance and energy related targets, e.g. form, house type variations, roof shapes, orientation, materials and finishes.

Inconsistent setting of standards and targets between local authorities leading to increased complexity of solutions.

Lack of suitable design tool that incorporates compliance check.

Limited ability to include new technologies in SAP calculations.

Concerns about the robustness or lack of overheating checks outside SAP.

Lack of understanding in sales team of impact of changes, e.g. customer add-ons which affect SAP.

Lack of ability to identify some products on-site/in situ, e.g. by operatives or for QA or audit purposes.

Short term fixes and improvisations on site without understanding of long-term impact, e.g. mastic for achieving required air pressure test result.

Site management - inadequate consideration of sequence of trades and activities on site, later phase work undermining previous works.

Lack of robust verification of planning requirements and standards at completion.

Lack of Building Control enforcement ability relating to Part L issues.

4. CONCLUSIONS AND NEXT STEPS

Having reviewed a large body of published research and conducted detailed investigations of current housing developments, it is clear that many issues identified as potential sources of the Performance Gap do exist.

Based on this evidence it has been possible to identify 15 issues that merit the development of comprehensive solutions in the near future, be they industry-led or where necessary involving government intervention.

These highest priority issues appear across the entire housebuilding process, for both developers using standardised housetypes and those using more bespoke designs. Consequently they are not the sole responsibility of any one discipline or sector. The theme of 'Knowledge and Skills' deficiencies is evident within all stages of the process, overlapping with other cross-cutting themes of 'Communication' and 'Responsibility'.

Another 17 issues have been prioritised as requiring further research in order to better understand their impact on the Performance Gap. Many of these issues relate to a lack of 'Knowledge and Skills', particularly at the Testing and Verification stages. Equally important are issues relating to 'Communication' problems across the various delivery stages.

The current housebuilding delivery process has been developed within a compliance regime based upon designed energy performance. However this evidence review has been conducted based on a vision of a future compliance regime focused on as-built performance. Therefore the findings should be considered with this in mind.

Next Steps

This Performance Gap project concludes in summer 2014, with the publication of an End of Term Report. A number of tasks are underway or proposed for completion during this period. These include continued evidence gathering, testing of completed homes and developing strategies to address the priority issues. Following conclusion of this project, more work is needed for the longer journey to 2020.

Continued Evidence Gathering

Evidence continues to be gathered and analysed to help understand the Performance Gap, as explained below. Based on the final evidence collection, there will be a review of the prioritisation of issues set out in this report

In response to a need identified in the Interim Report, a Work Group of building services specialists has been formed to ensure that all issues relating to services have been identified and to provide any further evidence that is available or needed to help understand the scale and nature of these issues.

Housebuilding Process Review and SAP Audits

As mentioned in Section 2, the Housebuilding Process Review and the associated SAP Audits are still underway. Results from the first nine sites are included in this report and more are scheduled or in process to bring the total to around 20. This will allow a range of construction types and housebuilders to be analysed: timber and masonry construction, large housebuilders and small. The review is scheduled to continue until April 2014.

SAP Sensitivity Analysis

Where SAP inputs do not truly reflect the features of a completed home, this could significantly contribute to the Performance Gap. A sensitivity analysis is therefore being carried out to evaluate the risk associated with different potential errors, based on the impact incorrect inputs might have on the SAP results. This also considers the likelihood of these errors occurring based on the experience of project team members, the SAP Questionnaire results and the findings of the Housebuilding Process Review SAP Audits.

Initial calculations of the effect of discrepancies on the DER suggest that of the measures identified as having a high probability of occurring, those with the biggest impact include thermal bridging inputs, the use of default thermal mass and selecting the wrong number of ‘sheltered sides’.

Testing

Testing of completed dwellings is important to establish the nature and scale of the Performance Gap, both in terms of components and the whole system. While testing of individual products takes place to the relevant British and ISO standards under specified conditions, it is important to understand how products perform on site in conjunction with one another.

A dedicated Testing Work Group has appraised existing lab and field tests for building fabric and services, including procedures that the industry currently uses to demonstrate compliance with Building Regulations. The group has highlighted shortcomings and areas of concern, as well as advising on the tests they consider to be robust.

Further to the Housebuilding Process Review, testing is planned for a number of properties on the review sites. A set of recommended tests is being compiled, along with critically appraised protocols, which will be implemented to the fullest extent possible within the constraints of time, sites and available resources.

Actions for Priority Issues

An Assured Performance Work Group has been formed to develop potential mechanisms that would demonstrate the '2020 Ambition': that by 2020 at least 90% of all new homes meet or perform better than their designed energy / carbon performance. These mechanisms also aim to provide industry with the necessary information to drive a continuous cycle of improvement.

Three further Work Groups are being established to understand how housebuilding delivery models of different scales and with different procurement routes could respond to the 'Priority for Action' issues, within the context of the work of the Assured Performance group.

Proposals will also be made for research strategies to address the 'Priority for Research' issues, with potential funding routes identified.

Final conclusions, proposed solutions and recommendations for further research will be detailed in the End of Term Report, to be published summer 2014.

Acknowledgements

More than 140 people have contributed their time and energy to this phase of the project, for which we are hugely grateful. We would particularly like to thank the developers that have volunteered sites for the Housebuilding Process Review, the Housebuilding Process Review team, the Evidence Collation team and those that have given us access to confidential information for the Literature Review.

Abbreviations

BCBs	Building Control Bodies
BPEC	British Plumbing Employers Council
BREDEM	Building Research Establishment Domestic Energy Model
DER	Dwelling Emissions Rate
EPC	Energy Performance Certificate
MCS	Microgeneration Certification Scheme
MEV	Mechanical Extract Ventilation
MVHR	Mechanical Ventilation with Heat Recovery
QA	Quality Assurance
RDSAP	Reduced Data Standard Assessment Procedure
SAP	Standard Assessment Procedure
TER	Target Emissions Rate

Annex A: Issues list

REF	WHAT MIGHT BE HAPPENING TO CREATE THE PERFORMANCE GAP?	PAGE
LAND ACQUISITION, CONCEPT DESIGN & PLANNING		
P1	Limited understanding by planners or funders of the impact of phasing or aesthetic requirements on performance and energy related targets, e.g. form, house type variations, roof shapes, orientation, materials and finishes.	68
P2	Limited understanding by concept design team of impact of early design decisions on performance and energy related targets (aesthetics - form, house type variations, roof shapes, orientation materials and finishes, phasing).	22
P3	Inconsistent setting of standards and targets between local authorities (methodology and/or level) leading to increased complexity of solutions.	68
P4	Limited guidance, modelling tools and standards available to evaluate and review issues associated with energy performance at early design stages, including overheating.	66
DETAILED DESIGN		
D1	Inadequate understanding and knowledge within design team e.g. buildability, thermal detailing, tolerances, construction systems and materials, site conditions, SAP and energy issues, performance.	24
D2	Lack of integrated design between fabric, services, renewables and other requirements, e.g. due to lack of specialist input.	26
D3	Lack of communication of design intent through work stages, e.g. due to discontinuities in design team, specialist involvement or general work contract structure.	54
D4	Lack of suitable design tool that incorporates compliance check.	68
D5	Design team not communicating sufficient information regarding critical energy performance criteria of components to procurement team.	57
D6	Insufficient design information provided for building fabric, potentially leading to critical decisions being left to contractor/sub-contractor at construction phase.	54
D7	Insufficient design information provided for building services, potentially leading to critical decisions being left to contractor/sub-contractor at construction phase.	55
D8	Product and system design issues, e.g. concerns about robustness of product design, systems design issues.	56
PROCUREMENT		
Pr1	Manufacturer information lacking critical energy performance detail, relating to either building fabric or services.	66
Pr2	Inadequate consideration of skills and competency requirements at labour procurement (fabric & services).	32
Pr3	Product substitution at procurement without due regard for performance criteria.	57
Pr4	Procurement team lack of understanding of critical energy-performance related criteria.	66
Pr5	Tender documentation not containing up-to-date requirements or trade specifications.	67

REF	WHAT MIGHT BE HAPPENING TO CREATE THE PERFORMANCE GAP?	PAGE
CONSTRUCTION AND COMMISSIONING		
C1	Lack of designer input available to site if issues arise, e.g. due to type of contract.	58
C2	Sales or year-end/interim build targets driving programme delivery - putting labour out of sequence and potentially compromising construction quality.	67
C3	Frequently changing site labour limiting ability for lessons to be shared or learnt.	67
C4	Construction responsibilities for energy performance unclear, lack of collaborative working, e.g. services penetrating air barrier.	59
C5	Product substitution on site without due regard for impact on energy performance.	34
C6	Lack of adequate quality assurance on site and responsibility for QA, e.g. due to site managers being overly reliant on sub contractors' QA processes, variability in processes, lack of supervision, reliance on Building Control.	42
C7	Lack of understanding in sales team of impact of changes, e.g. customer add-ons which affect SAP.	68
C8	Lack of ability to identify some products on site/in situ, e.g. by operatives or for QA or audit purposes.	68
C9	Poor installation or commissioning of services, e.g. due to installation guidance or design drawings not followed, lack of manufacturer installation and/or commissioning guidance.	38
C10	Short term fixes and improvisations on site without understanding of long-term impact, e.g. mastic for achieving required air pressure test result.	68
C11	Full design information or installation guidance produced but not available on site.	58
C12	Site management - inadequate consideration of sequence of trades and activities on site, later phase work undermining previous works.	68
C13	Lack of site team energy performance related knowledge and skills and / or care.	40
C14	Accredited Construction Details 'tick box' culture, i.e. recorded in SAP but not built on site.	60
C15	Poor installation of fabric, e.g. due to installation guidance or design drawings not followed.	36
VERIFICATION		
V1	Lack of robust verification of planning requirements and standards at completion.	68
V2	Lack of robust energy-performance related verification, reliance on third-party information (e.g. by Building Control or warranty providers).	48
V3	Commoditised third-party schemes not independent or checks not adequate (including Competent Persons Schemes).	63
V4	Lack of Building Control enforcement ability relating to Part L issues.	68
V5	Lack of clarity over documentary evidence required or acceptable for Part L and Part F compliance.	50

REF	WHAT MIGHT BE HAPPENING TO CREATE THE PERFORMANCE GAP?	PAGE
TESTING		
T1	Limited tests and agreed protocols available for in situ fabric performance measurement.	61
T2	Limited tests and agreed protocols available for in situ services performance measurements, including for system performance.	62
T3	Concern over consistency of some test methodologies and interpretation of data and guidelines.	44
T4	Limitations of air-pressure testing methodology (QA, robustness of third party certification, protocols).	68
T5	Lack of suitable end-of-line overall performance test to validate energy calculation models, products and building fabric.	62
T6	Tests not replicating or accurately taking into account dynamic effects, e.g. solar gain, microclimate, wind speed, weather effects.	61
T7	Limited tests and agreed protocols for innovative/less mainstream products and services.	67
ENERGY MODELLING TOOLS AND CONVENTIONS		
EM1	Commercial pressures leading to optimistic SAP input assumptions.	66
EM2	Concerns about accuracy of aspects of the SAP calculation model and assumptions, e.g. thermal mass, hot water, ventilation, overheating, cooling, lighting, thermal bridging, weather, solar shading, community heating, particular technologies.	56
EM3	SAP conventions not adequate, comprehensive or reflective of site conditions.	66
EM4	As-Built SAP not reflective of actual build.	46
EM5	Lack of transparency and clear outputs for verifiers to check modelling assumptions (including designers to verify material performance assumptions, BC and others).	67
EM6	Infrequent or insufficient audits of SAP assessors by licensing organisations.	68
EM7	Concern over competency of SAP assessors (accuracy of data input, following of conventions, validation of assumptions, provision of design and specification advice).	30
EM8	Issues surrounding use of calculation procedures in BR443 (U-values) and BR497 (Psi-values) or associated Standards.	28
EM9	Limited as-built test data used in SAP calculations (only air-pressure testing).	63
EM10	Limited ability to include new technologies in SAP calculations.	68
EM11	Concerns about the robustness or lack of overheating checks outside SAP.	68

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