

CLOSING THE GAP BETWEEN

DESIGN



AS-BUILT
PERFORMANCE

END OF TERM REPORT

July 2014





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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EXECUTIVE SUMMARY

Context, Future Vision & Drivers for Change

For some time, the Government has had concerns about the potential gap between design and as-built energy performance, following research into this issue by several universities and specialist projects. Indeed, such was its concern that it invested £8 million into a research programme by the Technology Strategy Board to look into Build Performance. The Government subsequently undertook a consultation into a regulatory option to help close the Performance Gap as part of the Building Regulations Part L 2013 review, which led to the Zero Carbon Hub being commissioned to undertake a full and comprehensive review of possible causes of and solutions to the Performance Gap.

This is also in the context of a previous Zero Carbon Hub Task Group which in February 2011 made recommendations as to the level of on-site carbon reduction ('Carbon Compliance') required for Zero Carbon Homes, based on closing the Performance Gap and achievement of the '2020 Ambition'.

This report draws together the findings of the Zero Carbon Hub project on Closing the Gap Between Design and As-Built Performance. It builds on two previous outputs; the *Interim Progress Report* (July 2013) and the *Evidence Review Report* (March 2014), together with subsequent work continuing the evidence gathering process and developing solutions to tackle various aspects of the Performance Gap.

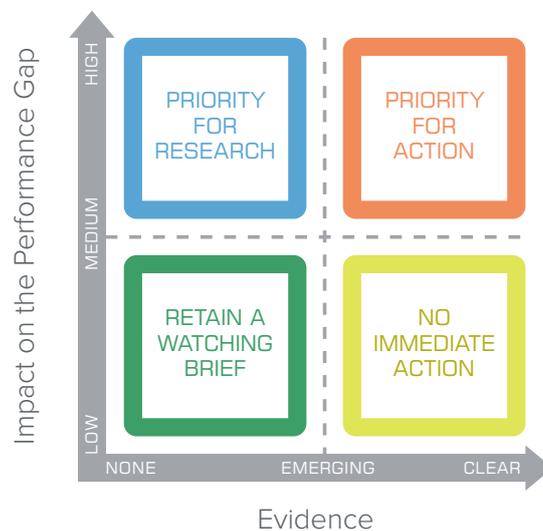
The project, commenced in early 2013, aimed to: review evidence for the significance of the gap; explore potential reasons for it; set out proposals to address the issues identified; establish areas for further research; and to put forward potential methodologies to enable the industry to demonstrate progress in achieving the '2020 Ambition'. It has been a collaborative process that has brought together a wide range of participants from across industry, involving 160 experts who have worked enthusiastically to provide evidence and solutions to the many diverse areas of the Performance Gap.

CLOSING THE PERFORMANCE GAP: THE 2020 AMBITION

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

From a government perspective, a gap in a building's energy and carbon performance undermines its vital role in delivering the national carbon reduction plan, as well as presenting reputational dangers to the industry and undermining consumer confidence if energy bills are higher than anticipated. Identifying the origin, size and extent of any gap between design and as-built performance is, therefore, seen as a high priority for not only government, but also industry.

A list of potential issues creating this gap was drawn up, spanning the entire design and delivery process, from site acquisition, through design, to statutory approvals, procurement, construction and commissioning. A detailed evidence gathering process was then carried out, including questionnaires, an analysis of SAP, a co-ordinated analysis of published and confidential literature, and the development of a *Housebuilding Process Review* method to gather primary evidence from 21 live housebuilding sites from 13 developers. The issues suspected of contributing to the Performance Gap were then categorised, based on the strength of evidence and the relative impact of each. From this, 15 were defined as 'Priority for Action', a further 17 as 'Priority for Research' and the remainder as 'Retain a Watching Brief'.



The information reviewed and gathered revealed widespread evidence of a Performance Gap and that all stages of the process of providing new homes have the potential to contribute to it, either inadvertently, or as a consequence of conflicting drivers within the industry or through poor practice. Three cross-cutting themes were identified as primary contributors to the problem: lack of understanding, knowledge and skills; unclear allocation of responsibility; and inadequate communication of information.

A pan-industry shift in focus is required to create the necessary cultural change to address the issues identified. This will require a similarly systemic process to the embedding of health and safety within the industry consciousness and everyday quality processes.

The level of engagement in this project is a clear indication of the commitment by industry to close the Performance Gap, particularly from those companies seeking to deliver the highest quality low carbon homes but who are cautious about proactively marketing or guaranteeing as-built performance without being able to ensure consistent and demonstrable delivery in practice.

The scale of change in business practice envisaged within the tight timeframe of the '2020 Ambition' will only be possible if there are clear drivers to underpin it. In the context of pressures for increased housing supply and recent government efforts to reduce the regulatory burden, industry is also keen to embrace the opportunity to address the issue in a manner that is practically and commercially viable.

However, if a market advantage already existed for delivering high quality, low energy cost homes it would already be being exploited. Therefore it is believed that a clear regulatory commitment, appropriately designed, will help catalyse early action across the entire industry. A key aspect of any such regulatory driver must be the ability for industry to develop alternative approaches in a manner similar to the creation of Robust Details.

An example of industry developing innovative alternatives to regulation:

As a result of increasing occupant complaints, the Government announced in 2001 its plans to require post-completion acoustic testing under Part F of the Building Regulations. This galvanised industry to invest in innovative solutions to develop a more commercially viable method of demonstrating compliance. The resulting Robust Details scheme was launched in 2004 using a combination of type testing, process control and randomised end-of-line testing to ensure quality is maintained.

The success of such a period of rapid innovation is predicated on industry working together to demonstrate to government that it can improve and maintain quality outputs. Well targeted government funding for research and development, via bodies such as the Technology Strategy Board, is required to accelerate cross-sector innovations.

Areas for Change

A number of solutions, grouped into five key themes, have been proposed to address, in particular, the priority issues identified in the *Evidence Review Report*. These are outlined below and are summarised at the end of the Executive Summary. While some may apply across the entire industry, others may only be relevant to certain sectors, professions or organisations.

Energy Literacy

Across the whole construction industry there is limited understanding of as-built energy performance and the existence of the Performance Gap. Consequently there is an urgent need to emphasise energy performance issues in training of new entrants and to provide additional training and Continuing Professional Development for existing members of the industry. This includes clients, planners, designers, architects, engineers, SAP assessors, energy modellers, developers, contractors, procurers, site managers, materials suppliers, operatives, commissioners, testers, verifiers, valuers and insurance bodies. An industry recognised card scheme should be developed to enable operatives and professionals to demonstrate that they have the necessary energy performance knowledge and skills.

Improving Quality Output

There must be strong actions to improve as-built energy performance by encouraging design continuity, identifying responsibility for championing energy performance, introducing 'gateways' and improving learning loops. There is a need to create a more robust industry-led approach to construction detailing, linked to improved quality control from design through to the construction and commissioning phase.

There is a clear need for manufacturers to address many areas of the Performance Gap, including via improved product labelling, design and installation instructions. Procurement teams need to prioritise energy performance when procuring materials and labour. Furthermore, improved quality control, from design through to the construction phase, is required together with rigorous independent commissioning of services.

National Compliance Method and Regime

The Standard Assessment Procedure (SAP) is a critical element within the assessment of a building's energy and carbon performance. Changes are required to increase the usefulness of the outputs for developers, designers, statutory bodies and occupants. A more comprehensive Product Specific Plain Language Compliance Report, signed by the housebuilder, should be implemented.

Conventions used for calculating key inputs related to both the fabric and building services need to be reviewed and in some cases linked to qualification schemes to ensure only those with sufficient knowledge provide this service. In a similar manner, the governance of SAP accreditation schemes, assessors and role of Building Control needs to be reviewed.

Demonstrating Performance

There is a clear need to refine existing diagnostic tests to make them more useful, usable and consistent, and to develop new techniques. In addition, manufacturers need to develop and adopt testing methods that better reflect the performance of their products as 'systems' within actual buildings. There remain conflicting views on the most commercially viable way to demonstrate a building's as-built performance, however the development of appropriate testing, measuring and assessment techniques is urgently required to enable the '2020 Ambition' to be demonstrated.

Continued Evidence Gathering

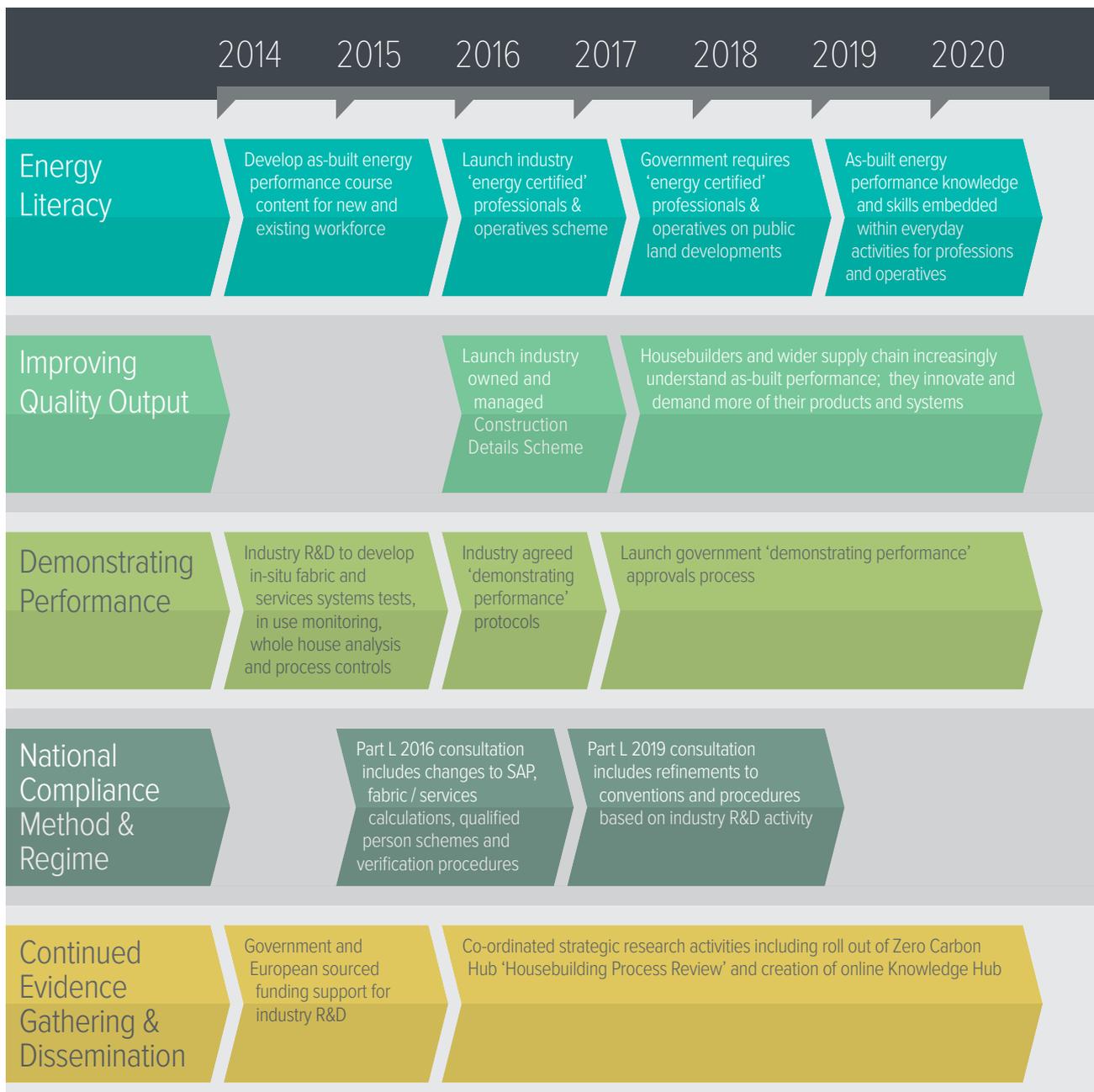
Expansion of the current evidence gathering process is required to increase understanding of the Performance Gap and disseminate findings and feedback to developers, industry and government. In order to drive the cultural change required, it will be necessary to ensure this communication is targeted specifically to the different audiences.

The initial ambition of the project was to undertake research and consider solutions that would, where possible, be cost neutral to industry. Whilst hugely ambitious, the project has indicated that although cost may be incurred in one area it is often offset in others. Certain improvements already undertaken by industry leaders have been undertaken at no cost but will have an immediate effect on the Performance Gap. These changes were instigated as a direct result of their involvement with the project's evidence gathering process.

Next Steps

As the construction industry develops products and processes capable of delivering homes with more predictable as-built energy and carbon performance, it will become essential that the research methods and tools used to assess them are continuously improved. Industry recognises the significant challenge the Performance Gap represents and the corresponding need to proactively address it. Rather than relying on ever more onerous regulatory interventions, industry is very capable of developing innovative, commercially viable methodologies to demonstrate their success.

This requires immediate co-ordinated pan-industry activity to trigger a cultural shift so that as-built performance becomes a core element of delivering high quality new housing. A strategically timed series of actions is therefore needed by industry and government between now and 2020, as set out in the summary Route Map that follows.



Headline Recommendations

The *Evidence Review Report* identified key areas that needed ‘immediate action’ and those needing ‘further research’, but it is clear that actions are needed by both government and industry if we are to close the ‘Performance Gap’ in the short to medium term. Indeed, the 18 months of discussion with experts has highlighted many ‘cross cutting’ themes and the overarching recommendations below should not be assumed to be exclusive and should be read in the context of the full report.

Priority Actions for Industry

To commit to providing the investment for:

1. PERFORMANCE ASSESSMENT R&D

Undertake the research and development necessary to create innovative testing, measurement and assessment techniques to understand the Performance Gap and develop commercially viable methodologies acceptable across industry for ‘demonstrating performance’.

2. SKILLS AND KNOWLEDGE DEVELOPMENT

Ensure that as-built energy performance knowledge, including learning from ongoing research and development, is embedded into training and up-skilling for professionals and operatives.

3. CONSTRUCTION DETAILS SCHEME

Develop an industry owned and maintained Construction Details Scheme providing ‘assured’ as-built energy performance for the most common major fabric junctions and systems.

4. CONTINUED EVIDENCE GATHERING

Support further evidence gathering processes and coordinated feedback to ensure accelerated continual improvement across all sectors of industry.

Priority Actions for Government

To accept the Zero Carbon Hub's recommendations to:

1. SIGNAL CLEAR DIRECTION

Clearly indicate that, in place of immediate additional regulation, it expects the construction industry to act now and have put in place a number of measures to ensure that the energy Performance Gap is being addressed and to demonstrate this by 2020.

2. STIMULATE INDUSTRY INVESTMENT

Signal their long term intent, by funding research and development into testing, measurement and assessment techniques with immediate effect, to support the industry in providing the information necessary to quantify the Performance Gap and create the learning loops required to drive continuous improvement. Additionally, provide pump prime funding to enable industry to develop a Construction Details Scheme.

3. STRENGTHEN COMPLIANCE REGIME

Take action by 2016 to ensure that the Zero Carbon Hub recommended revisions to energy modelling practices, SAP processes and verification procedures, together with a strong regime to ensure that only suitably qualified persons carry out energy modelling and assessment, can be put in place.

4. SUPPORT SKILLS & KNOWLEDGE DEVELOPMENT

Accelerate the demand for industry developed qualification schemes by requiring energy certified operatives and professionals for developments on public land from 2017.

This project has identified a number of key actions that government and industry are required to undertake. There is now a need for a concerted level of activity to implement the many detailed recommendations within this report in order to close the Performance Gap and demonstrate the '2020 Ambition'.

DETAILED RECOMMENDATIONS SUMMARY

A number of solutions, grouped into five key themes, have been proposed to address, in particular, the priority issues identified in the Evidence Review Report. While some may apply across the entire industry, others may only be relevant to certain sectors, professions or organisations.

Energy Literacy

- Training for all new entrants to the industry should emphasise energy performance issues, from site operatives through to planners, designers, procurement staff, assessors, testers and inspectors.
- Training for all current members of the industry is similarly needed in energy performance awareness, skills and knowledge.
- An industry recognised card scheme should be developed to enable operatives and professionals to demonstrate that they have the necessary energy performance knowledge and skills.
- Energy Performance Certificates should include a low / medium / high estimate of total energy consumption.

Improving Quality Output

- Encourage design continuity and feedback:
 - Appoint an 'energy champion' with the authority and responsibility to oversee the energy principles of the design from concept stage to completion.
 - Include 'gateways' within the design and construction process that define specific points at which energy performance requirements are checked.
 - Explore the potential for BIM to act as a 'golden thread' to monitor and control design, quality, change control and performance in respect of energy performance.
- Improve specification, design and procurement of materials and services:
 - Reduce inadvertent product substitution by improving labelling to aid product identification.
 - Improve product design to aid correct installation.
 - Improve manufacturer specifications and installation instructions to focus on correct installation of products and systems to achieve high levels of energy performance.
 - Procurement teams to assign very high levels of importance to ensuring that products and labour meet the necessary energy performance, specifications and competency.
- Responsibility for the provision of 'standard' construction design details should be moved to industry control. This industry owned and maintained Construction Details Scheme should provide 'assured' as-built energy performance for the most common major fabric junctions and systems.
- Improve quality control:
 - Greater importance needs to be placed on controls surrounding energy performance requirements, for example by clients and developers.
 - An increased focus on energy-related checks and assessments is needed across all areas of the building delivery chain, from the design stage to completion on site.
 - Improvements are needed to the commissioning process as a whole, and commissioning should be carried out by independent subcontractors.
- Improve learning and feedback loops so that lessons can be fed back effectively and appropriately to all relevant parties. As part of this, disseminate lessons learnt from the Zero Carbon Hub evidence gathering work, including from the **Housebuilding Process Review** (see also Continued Evidence Gathering & Dissemination section below).

National Compliance Method and Regime

- The SAP process needs to be refined to improve compliance reporting:
 - Introduce a more comprehensive Product Specific Plain Language Compliance Report, with a signed declaration of accuracy of the input information by the housebuilder, to be provided to Building Control at design stage as part of the controlled documents.
 - At the as-built stage, the updated Product Specific Plain Language Compliance Report, with signed declaration by the housebuilder, would be provided to the SAP assessor, Building Control and the occupant.
 - SAP assessors should only be allowed to issue the EPC on receipt of the as-built stage signed Product Specific Plain Language Compliance Report. Accreditation scheme disciplinary procedures must reflect the serious nature of any contraventions.
 - Building Control should only be allowed to issue a completion certificate on receipt of both the as-built stage signed Product Specific Plain Language Compliance Report and the EPC RRN from a full SAP.
- Governance of SAP accreditation schemes and SAP assessors needs to be reviewed:
 - Responsibilities of SAP assessor, housebuilder and Building Control need to be defined in a clear and coordinated manner.
 - The terms of reference of the SAP Conventions Group should be clarified and its membership expanded to ensure an appropriate focus on energy performance issues.
 - Government audits of SAP assessor accreditation schemes need to be tightened and have a strong technical standards focus, and assessor Continuing Professional Development expectations need to be refined.
- The accuracy of U-value and Psi-value calculations needs to be addressed:
 - Improve training and quality assurance for those undertaking U-value calculations.
 - Improve training and quality assurance for those undertaking Psi-value calculations.
 - Formally review BR443 and BR497 (which define the conventions for calculating U-values and Psi-values) with a view to better reflecting in-situ performance.
 - Establish an approval process for all U-value software.
- Undertake a systematic review of SAP methodology and assumptions, particularly focusing on those inputs which have significant impacts on the Performance Gap.
 - Confidence (or 'in-situ') factors should be considered for evaluation to reflect the real performance of the system or combined elements (i.e. the performance of a specific make up of completed walls or entire heating system, including its controls, etc.) implemented in such a way to allow competing systems to innovate and demonstrate their specific as-built performance.
 - SAP default values should be reviewed to ensure they are worst case to encourage product / system specific values to be entered.

- Make changes to SAP software:
 - Require the incorporation of a minimum level of input data validation to identify inconsistencies.
 - Provision must be made to include information to be fed into the Product Specific Plain Language Compliance Report and for the production of the report itself.
 - Establish an online document management and storage system for compliance documents to enable document transfers between clients and SAP assessors, accessible to occupants.
 - Software manufacturers should work with user groups to explore options to improve the usability of SAP software.

Demonstrating Performance

- Further development of diagnostic tests is urgently needed:
 - Refine and standardise protocols of existing tests to make them more useful, usable and consistent.
 - Develop new tests for fabric and services systems, for diagnostic use both in the laboratory and on-site.
- Develop new commercially viable testing, measurement and assessment techniques to demonstrate the '2020 Ambition'.
- Enhance testing skills, knowledge and practices through training and accreditation to ensure consistent interpretation and analysis of results (see Energy Literacy section).

Continued Evidence Gathering & Dissemination

- Continue and develop the current evidence gathering process and improve coordination with a view to providing better evidence of Performance Gap issues and to provide feedback to developers, industry and government.
- Collate and disseminate evidence of findings and examples of good practice, through an online 'Knowledge Hub', building on the work of the *Evidence Review Report* and linking to other communication channels targeted at specific stakeholders in the industry.



1. CONTEXT, FUTURE VISION & DRIVERS FOR CHANGE

In February 2011, a Zero Carbon Hub task group recommended that zero carbon homes policy should be linked to as-built performance.

This proposed future shift in the regulatory framework, known as the '2020 Ambition', influenced the task group's recommended levels for minimum on site carbon reduction levels as it recognised the significant challenge industry faces in delivering actual performance as opposed to simply designed performance.

From a government perspective, the Performance Gap would mean that new housing cannot be relied upon to play its expected, vital role in the national carbon reduction plan. 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 the fall-out from underperforming new homes could impact on their reputation and business.

For these reasons, even though at the beginning of the Zero Carbon Hub Performance Gap project the origin, size and extent of the gap had not been identified, it was set as a high priority by government and by the wider construction industry.

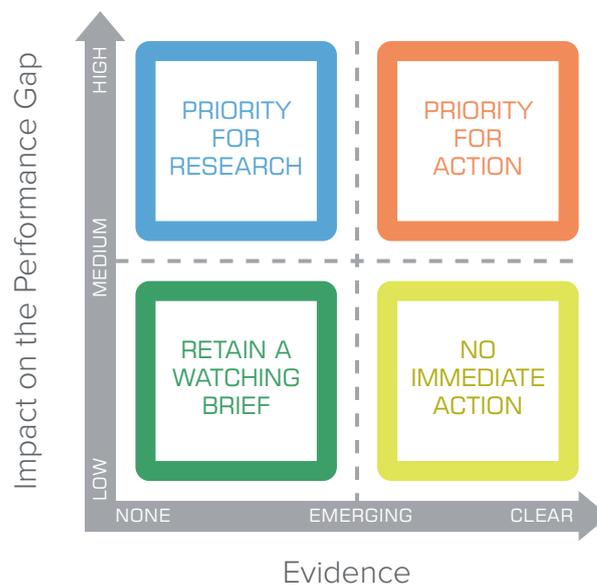
The Performance Gap project commenced at the start of 2013, since which time over 160 professionals from across the building industry have contributed to the project. Initial findings and activities are described in the *Interim Progress Report*, published in July 2013. This identified a list of approximately 60 issues suspected of contributing to the Performance Gap.

CLOSING THE PERFORMANCE GAP: THE 2020 AMBITION

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

There then followed an extensive process of evidence gathering, summarised in the *Evidence Review Report*, published in March 2014. This provided industry and government with a structured review of how and where the Performance Gap occurs within the current housebuilding process. Evidence was gathered from a range of sources: an analysis of published literature and industry research; questionnaires, surveys and audits; and a *Housebuilding Process Review* that gathered evidence from delivery teams, including visits to 21 live construction sites.

Drawing on this evidence, issues contributing to the Performance Gap were categorised using a prioritisation matrix. This was based on the degree of evidence for each issue and the potential impact it may have on energy performance. Fifteen 'Priority for Action' issues were identified, with a strong supporting evidence base and medium to high potential impact on the Performance Gap when they do occur. These appeared across the delivery process from concept design and planning, through to construction and commissioning. There were also a number of issues around verification and testing activities.



A further 17 issues were identified as 'Priority for Research': it is suspected that these have a significant impact on the Performance Gap, but only emerging evidence is available. The remaining issues were categorised as 'Retain a Watching Brief'. A full list of issues is available in Appendix A of this report.

Since publication of the *Evidence Review Report* the industry experts involved in the project have been generating potential solutions, particularly focused on the 'Priority for Action' issues, as well as the cross-cutting themes of communication, responsibility and knowledge & skills. They were also tasked with identifying necessary research to enable activation of the suggested solutions. Alongside the original work groups, five specialist groups were formed with specific tasks:

- Speculative Housebuilder Delivery Approach and 'Design and Build' Delivery Approach Work Groups, considering which solutions had the greatest potential for success within their specific commercial environment.
- An Assured Performance Work Group considering what potential techniques could be used by industry to demonstrate the '2020 Ambition'.
- A Further Research Work Group considering where additional research is required and identifying potential funding routes.
- A Services Work Group considering services-related issues and solutions.

Future Vision

During this project it has become clear that the Performance Gap in new buildings is widespread. Many within industry, ranging from architects and manufacturers to site personnel and Building Control officers, now believe that significant change is needed.

The key recommendations presented in this report are intended to create a competitive environment where companies willing to invest in the R&D needed to rapidly and substantially close the Performance Gap are rewarded commercially, and able to gain significant market advantage within the regulatory environment.

A pan-industry shift in focus is required to create the necessary cultural change to address the issues identified. This will require a similarly systemic process to the embedding of health and safety within the industry consciousness and everyday quality processes.

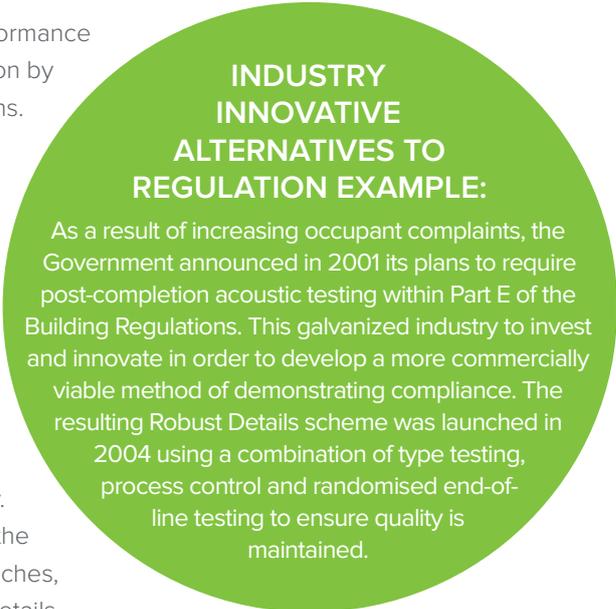
Industry needs to make changes in a number of areas which have been identified and are detailed in the following Section 2 – Areas for Change. Many of these issues, which were highlighted in the *Evidence Review Report*, are comparatively well known but to-date there have not been sufficient drivers to bring about change. The highly cost competitive nature of the industry means that in parallel with their efforts there is a role for limited and appropriate regulatory interventions to allow those delivering a better quality product / service to differentiate themselves, thereby increasing brand value and commercial advantage.

Making Change Happen

To engage the entire industry and catalyse change there needs to be a strong and certain business case for shareholders and executive boards of large organisations and the owners and directors of smaller businesses. Approval for the necessary investment to drive changes in their business practice typically requires the prospect of market advantage via strong consumer demand, increasing risks of consumer dissatisfaction, and / or a clear regulatory path.

Industry is committed to addressing the Performance Gap and would not want to be forced into action by negative consumer feedback or perceptions. Experience from similar periods of change indicate that industry is best placed to create innovate, commercially viable solutions.

However, if a market advantage already existed for delivering high quality, low carbon, low energy cost homes, industry would already be exploiting it. Therefore it is believed that a clear regulatory commitment, appropriately designed, will help catalyse early action across the entire industry. A key aspect of any regulatory driver must be the ability for industry to develop alternative approaches, in a similar manner to the creation of Robust Details.



INDUSTRY INNOVATIVE ALTERNATIVES TO REGULATION EXAMPLE:

As a result of increasing occupant complaints, the Government announced in 2001 its plans to require post-completion acoustic testing within Part E of the Building Regulations. This galvanized industry to invest and innovate in order to develop a more commercially viable method of demonstrating compliance. The resulting Robust Details scheme was launched in 2004 using a combination of type testing, process control and randomised end-of-line testing to ensure quality is maintained.

It is important to consider the challenge these issues represent within the context of the Government's growing demands for increased housing supply and recent actions to positively reduce regulatory burden. Industry is keen to embrace the opportunity to address the Performance Gap in a manner that is commercially viable.

The lesson from Robust Details is that if the regulatory pain is too great, industry will invest and create its own alternative.

– **Stephen Stone, Chief Executive, Crest Nicholson**

The success of such a period of rapid innovation is predicated on industry working together to demonstrate to government that it can improve and maintain quality outputs. Well targeted immediate government funding for R&D, via bodies such as the Technology Strategy Board, is required to accelerate cross-sector innovations.

Significant investment has been and is being made in designing and constructing low carbon homes. There are already sectors of the industry focused on delivering healthy and comfortable homes able to protect people from future fuel poverty. However the current lack of understanding of how to ensure consistent as-built performance means that only a small number of housebuilders are willing to proactively market or guarantee this element of their product.

The current inability to differentiate those companies seeking to deliver the highest quality low carbon homes is limiting industry's opportunity to take full advantage of the investments it is making in innovation. The housebuilding industry is complex, with multiple supply chains, often with varying incentives and therefore a coherent methodology is required to demonstrate current performance and future improvements. It is vital that the knowledge and skills developed during this time are disseminated across the construction industry via training courses and certification schemes. Industry is best placed to develop and deliver such schemes but requires support from government to accelerate early demand within the supply chain prior to 2020.

Building Control has an increasing role to play as buildings become more energy efficient and potentially more complicated. There are already some initiatives seeking to raise awareness of the importance of energy performance through the introduction of training schemes and this is expected to continue.

Those developers who have been involved in the evidence gathering exercise have already taken a huge interest in the findings and have instigated changes to their management processes and businesses, demonstrating that making change happen requires a 'nudge' rather than heavy regulatory control.

This combination of industry actions and careful deployment of appropriately targeted regulatory drivers will promote the learning loops essential to delivering the rapid innovation and improvements across industry, from designers, consultants and manufacturers, to site management, commissioning engineers and Building Control Bodies.



2. AREAS FOR CHANGE

A number of solutions to address the issues identified in the Evidence Review Report have been proposed.

It is important to note that they should not be considered as an exhaustive list and, while some may apply across the entire industry, others may only be relevant to certain sectors, professions or organisations. Icons can be found within each of the following sections that indicate which of the issues¹ are being targeted by the proposals. The solutions can be summarised into one of five key themes:

Energy Literacy

Across the whole construction industry there is limited understanding of as-built energy performance and the existence of the Performance Gap. Consequently there is an urgent need to emphasise energy performance issues in training of new entrants and to provide additional training and Continuing Professional Development for existing members of the industry. This includes clients, planners, designers, architects, engineers, SAP assessors, energy modellers, developers, contractors, procurers, site managers, materials suppliers, operatives, commissioners, testers, verifiers, valuers and insurance bodies.

Improving Quality Outputs

There must be strong actions to improve as-built energy performance by encouraging design continuity, identifying responsibility for championing energy performance, introducing 'gateways' and improving learning loops. There is a need to create a more robust industry-led approach to construction detailing, linked to improved quality control from design through to the construction and commissioning phase.

1. A full list of the issues identified in the Evidence Review Report can be found in Appendix A

National Compliance Method and Regime

The Standard Assessment Procedure (SAP) is a critical element within the assessment of a building's energy and carbon performance. Changes are required to increase the usefulness of the outputs for developers, designers, statutory bodies and occupants. Conventions used for calculating key inputs related to both the fabric and building services need to be reviewed and in some cases linked to qualification schemes to ensure only those with sufficient knowledge provide this service. In a similar manner the governance of SAP accreditation schemes, assessors and role of Building Control needs to be reviewed.

Demonstrating Performance

There is a clear need to refine existing diagnostic tests to make them more useful, usable and consistent, and to develop new techniques. In addition manufacturers need to develop and adopt testing methods that better reflect the performance of their products as 'systems' within actual buildings. There remain conflicting views on the most commercially viable way to demonstrate a building's as-built performance, however the development of appropriate testing, measuring and assessment techniques is urgently required to enable the '2020 Ambition' to be demonstrated.

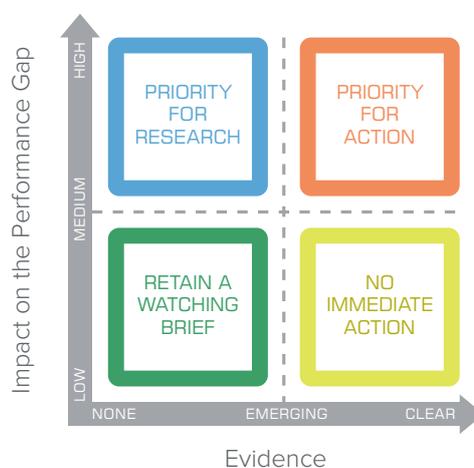
Continued Evidence Gathering and Dissemination

Expansion of the current evidence gathering process is required to increase understanding of the Performance Gap, disseminate findings and give feedback to developers, industry and government. In order to drive the cultural change required, it will be necessary to ensure this communication is targeted specifically to the different audiences.

Within this section of the report, each recommendation has alongside it a symbol, which indicates the issues being addressed. These directly relate to the list of issues presented in the *Evidence Review Report*, the descriptions of which are in Appendix A. The symbols represent the cross-cutting themes of:



The symbol colour represents the quadrant of the prioritisation matrix within which a particular issue falls:



ENERGY LITERACY

Evidence clearly indicates that a lack of knowledge and skills on energy performance across the house-building industry is a significant contributor in causing a Performance Gap. A number of solutions are proposed to address this, including a requirement for new entrants to the construction industry to undertake **energy performance studies which are to be introduced / emphasised on all built environment and associated courses**. Those currently engaged in the industry are to attend **Continuing Professional Development, toolbox talks and other specific training** to enhance their knowledge and skills in areas that affect the energy performance of a building.

A **building performance and energy awareness scheme and qualification** for the whole industry is proposed, with qualification levels ranging from basic to more advanced, depending on responsibility level, potentially providing a means by which developers can help to ensure that their contractors and sub-contractors have the skills required. Professional bodies which accredit courses ranging from architecture to Building Control will need to revise their requirements, and academic institutions and training providers will need to update courses and may need to recruit new expertise. Ultimately, a **cultural shift in awareness of energy performance is needed**, similar to the changes in health and safety that have already occurred in the construction industry. Government could accelerate the demand for industry developed qualification schemes by requiring energy certified operatives and professionals for all developments on public land from 2017.

As well as tackling the energy literacy of those delivering the homes, it is also necessary for **all stakeholders to understand the benefits associated with closing the Performance Gap**. This includes those who commission buildings for construction and clients for the Design and Build sector, who stand to benefit from the Performance Gap being addressed.

To deliver these changes, **further research** will be required to develop an understanding of where improved energy literacy will make the biggest impact, and how challenges in achieving this can be addressed; and to test new ways of sharing knowledge in the field. Existing and ongoing research also needs to be communicated and coordinated more effectively. It is proposed that the **Evidence Review Report** for this project be updated with additional research and converted by the Zero Carbon Hub into an online resource for improving understanding of the Performance Gap. There is also a proposed Building Performance Evaluation network currently under formation by a leading university with which the Hub is working closely. In addition, the research community has a part to play in informing the key content which should be included in energy modules on built environment courses.

TRAINING NEW ENTRANTS

All new entrants to the housebuilding and construction products industry must be trained with the necessary energy skills to understand and reduce the Performance Gap. An appropriate level of energy knowledge needs to be specifically emphasised as part of all relevant courses. It should however be noted that changes to training will be relatively slow to make an impact: it takes time for courses to be updated and for the learning to filter through to change industry practice; other solutions will be needed for those already in the industry. It is also important the demand for this skills and knowledge is created.

I. SITE OPERATIVES



✓ What do we need to do?

There are different routes of entry into the job market for site operatives, so energy training must be designed to reflect this. It needs to form part of all training courses and apprenticeship schemes, requiring the involvement of professional bodies such as Summit Skills, CITB and BPEC to drive demand and set the requirements. Training centres will need to develop their curriculum and resources accordingly.

£ What kind of costs are involved?

The costs of updating existing training should be relatively low however the costs of building and setting up new training facilities would be considerable.

II. PROFESSIONALS



✓ What do we need to do?

Training of planners, architects, surveyors, engineers, building control bodies, building performance assessors, testers and commissioners needs to include energy-related skills and energy modules that can impact on Performance Gap issues. This requires the involvement of the professional bodies that accredit courses, including for example CIOB, Asset Skills, RIBA, RICS, CIBSE, CIAT and ARB, to encourage academic institutions and training providers to amend their courses, using input from the research community.

£ What kind of costs are involved?

The costs of updating existing courses and training programmes should be low but new specialist staff may be needed where the required skills do not already exist within a particular education provider.

The recent UK Build Up Skills Roadmap (2013) made a range of recommendations to address workforce skills and knowledge gaps, including a call for an energy efficiency accreditation scheme which should be promoted to employers and clients. CITB and the Green Skills Alliance are working to address the recommendations of the Roadmap through a programme of work which will seek to establish energy literacy as an integral part of mainstream construction and building services engineering learning. As part of this programme, work is currently planned with industry-recognised card schemes, to provide a facility whereby individuals can demonstrate evidence of aligned energy efficiency learning and achieve recognition for energy literacy.

At Saint-Gobain we have seven dedicated training facilities, teaching site operatives to fit our products to optimise their energy performance.

Stacey Temprell, New-Build Sector Marketing Director, Saint Gobain

www.saint-gobain-technical-academy.co.uk

III. ENERGY MODELLERS

✔ What do we need to do?

More comprehensive training requirements should be developed for modellers of SAP, U-value and Psi-value calculations. This would be driven by changes to Part L and SAP to require the use of qualified U-value and Psi-value modellers (see section on 'National Compliance Method and Regime') and supported by CPD requirements. Training for all modellers needs to provide better awareness of the process and practicalities of construction and potential Performance Gap issues. This increase in technical requirements should be standardised across all accreditation bodies.

Zero Carbon Hub is running toolbox talks for SMEs and small builders over 2015-2016

Rob Pannell, Managing Director, Zero Carbon Hub

★ What are the challenges and opportunities?

More training would, potentially, increase costs, making it more difficult for people to enter the market, and will require strong and positive interest from existing SAP assessors and assessor organisations. This may be addressed by closely involving SAP assessors in the process and clarifying the benefits of additional knowledge.

IV. THOSE CARRYING OUT TESTING

✔ What do we need to do?

A programme is needed to address an expertise gap in the research and testing community, to improve its supporting infrastructure (*for example, the equipment used*), and to increase the value of tests that are undertaken. In addition, those that are interpreting and analysing test results also need training to avoid drawing incorrect conclusions from results of tests such as thermography. For the more established testing techniques, such as air pressure testing, this could be driven by a UKAS accredited Competent Persons Scheme (see section on 'Demonstrating Performance' for more detail).

★ What are the challenges and opportunities?

In the short term training can bring additional cost, which potentially can act as a barrier to those wishing to enter the market. However those involved in testing must have robust training schemes in place to manage these changes.

INCREASING SKILLS OF EXISTING WORKFORCE

In addition to educating new entrants to the housebuilding profession, much of the existing workforce needs to have a far better awareness of energy performance. For site operatives, it may be difficult to incentivise people to undertake this additional training, requiring an industry driver to encourage uptake of training. For other construction professionals, CPDs may provide a route for additional training.

I. SITE OPERATIVES



✔ What do we need to do?

Educating site teams on energy performance skills should have an immediate impact on tackling the Performance Gap, to include specific topics such as: the importance of closely following the details within the drawings and specification feeding information back to the site management team where drawings are inadequate; sequencing the installation of specific materials into difficult areas such as complex roof construction and loft eaves; and helping individuals to understand their role in maintaining items such as the airtight barrier. A range of approaches are needed to try and reach all parts of the industry; this would include Toolbox Talks, directly relating to the Performance Gap, along with graphic examples of good workmanship to display on site. Manufacturers would have a role in training installers, which could be linked to the warranty on the product, which *for example is already the case with boiler manufacturers.*

★ What are the challenges and opportunities?

Existing site operatives need the time and incentive to undergo further training; they need to really engage with understanding the challenge. This may be helped by framing the issue in the right language and through carefully targeted campaigns. A cost may be incurred through the loss of working time, so employers would need to provide the suitable times and easy access to the training. Where there is a high turnover of site personnel, there is a risk that knowledge learnt is lost, both within and across different projects. Finally, training must highlight the importance of all operatives adhering to quality standards, emphasising the extent to which all parts of the build are vital in safeguarding the energy performance of the finished product.

II. OTHER CONSTRUCTION MANAGERS AND BUILDING PROFESSIONALS



✔ What do we need to do?

All stakeholders in the housebuilding industry need to improve their knowledge of low energy design and the Performance Gap, including construction managers, designers, planners, building control and engineers. This training will require to be delivered differently to the various stakeholders to ensure their critical part in the process is highlighted. *For example the procurement team could receive more detailed information on energy performance from suppliers; Building Control need to understand the relevant energy-related items to check on site; and commissioners have an important role in closing the gap.*

One way of delivering this training will be through CPD training, which could specifically address the Performance Gap, as well as broader issues of energy literacy.

It is clear that many issues arise between the design and construction team and specific collaborative planning sessions will be required at which designers and contractors can interact, to enhance one another's knowledge of detail, issues and construction methods and possible solutions. This training will be undertaken by professional associations and certified bodies such as Asset Skills.

★ What are the challenges and opportunities?

Some professionals may not be incentivised to carry out this training, though this could be addressed by changing the CPD requirements. *For example, attendees could be obliged to complete an assessment some time after training to demonstrate competency; or a certain number of important CPD topics could be made mandatory.*

👤 Who needs to do what?

Professional institutions such as RIBA, CIBSE and RICS would need to change the emphasis, requirements and content of their CPD courses.

INDUSTRY RECOGNISED CARD SCHEME



✔ What do we need to do?

An industry-supported scheme is recommended to demonstrate knowledge and skills of energy performance, with different levels of competence to suit different needs. As noted above, in response to recommendations arising from the recent UK Build Up Skills Roadmap, CITB and the Green Skills Alliance are currently planning a programme of work including investigating establishing an energy efficiency accreditation scheme.

★ What are the challenges and opportunities?

Procurers would need to start demanding that the workforce have the necessary certification, which would drive demand for site workers to undergo training and achieve the qualification. Operatives would need to invest time and money, for which they would need to receive some form of incentive and recompense. Investment would also be needed to set up the system, perhaps through a grant scheme.

👤 Who needs to do what?

There is a need for a card scheme provider (or providers) to be identified. Once a scheme is introduced, procurers would be able to specify a requirement for 'card-holders'; this would help to ensure that the necessary energy performance skills are employed on site and to encourage site operatives to undergo the necessary training to achieve the qualification. The scheme could be enabled by government, if they required all publicly funded developments to employ certified professionals and operatives as a pre-requisite within their tender for land sales and developments. This would aim to drive mainstream adoption of the new programmes.

WIDER AWARENESS OF THE PERFORMANCE GAP

✓ What do we need to do?

The existence of the Performance Gap, the risks associated with it and the benefits of closing it need to be clearly communicated. Means of raising awareness within industry are outlined above, but it has been suggested that as a follow-on to this project, work also needs to be done to inform potential occupants who stand to benefit from the Performance Gap being addressed. Communication and marketing of the benefits of new low energy homes would raise awareness and increase demand for such homes by helping to differentiate them.

Registered Providers may also be able to ask for real performance as part of their Client's Requirements, as a means of driving change in the design and build sector.

Some of the organisations involved in this project suggested that EPCs should be updated to include estimates of unregulated energy use (low / medium / high), in order to make them more meaningful to householders.

IMPROVING QUALITY OUTPUT

Solutions to address the Performance Gap by improving quality output span from the earliest concept stage through design, construction and verification. Some of the solutions suggested here may not be appropriate for all businesses, but give an idea of what can and should be done. These fall into a number of themes:

The *Evidence Review Report* emphasised that unless there is **continuity of the original design and energy aspirations** through to the construction phase, unintended changes inevitably happen, which result in part of the Performance Gap occurring. It may therefore be important that an 'energy champion' be appointed who would be responsible for overseeing energy design and implementation through every stage of development. It is also recommended that 'gateways' could be introduced, requiring the design team to undertake certain key actions before progressing to the next work stage to ensure energy performance is not compromised. BIM may also be able to act as the 'golden thread' on which design, quality, change control and compliance are based.

Improvements need to be made to the specification, design and procurement of materials and services. Evidence clearly demonstrates that manufacturing changes could reduce the Performance Gap. *For example, a universal labelling system on difficult to differentiate materials.* Manufacturers should also include details in the specifications of the skills required for optimum installation. Those professionals who are responsible for the procurement of materials and sub contract services also have an important role: they should assign very high levels of importance to ensuring that products and labour meet the necessary energy performance, specifications and competency.

It is strongly recommended that an **industry-owned and maintained Construction Details Scheme be developed for the most common major fabric junctions and systems.** These need to be buildable, flexible, robust, cost effective and capable of being implemented at scale. Clear guidance on thermal bridging should also be provided for house-builders and industry.

There is a need for an increased focus on **energy-related checks and assessments** across all areas of building delivery. Improvements to the **role of commissioning** are also required, and there may be a role for clients in driving a **greater emphasis on quality control in relation to energy performance.**

There is a clear lack of **continual improvement processes** in many parts of the industry. **Learning and feedback loops** are needed right across the housebuilding industry to ensure the necessary knowledge uptake. Clear methodologies need to be developed to make sure this takes place.

DESIGN CONTINUITY & FEEDBACK

I. APPOINT AN 'ENERGY CHAMPION'



✓ What do we need to do?

Appoint an 'energy champion' with the authority and responsibility to oversee the energy principles and performance of the design and implementation, from concept stage to completion. Depending on the project, this could be a SAP assessor with good site experience or an architect with a high level of energy knowledge and awareness, it could be an external specialist, or it could be multiple people who share the role. Whoever takes this role must have sufficient authority and be involved from the earliest stage of the project.

★ What are the challenges and opportunities?

Clear limits would need to be set on exactly what the role entails – *for example, it would need to be built into the company business hierarchy to ensure that there is full accountability.* An unintended consequence could also occur, whereby the rest of the delivery team defer to the energy champion, rather than taking responsibility for their role in delivering the energy strategy. Some multi-disciplinary consultancies already offer this service, which is being driven by market demand. It is recognised that this idea is more difficult for SMEs.

£ What kind of costs are involved?

There would be an added cost to the client for filling this role, either from the increased time and responsibility for existing team members, or from the appointment of an external consultant. Initial estimates from Sweett Group indicate that the costs might be in the region of £100 - £300 per unit.

JRHT have developed a methodology over the years for trying to ensure designs & concepts are delivered effectively. Some might reply this is just good Project Management practice but it boils down to ensuring a collective understanding is arrived at by the key parties at the appropriate stage of a project. This is easy to say but often difficult to actually achieve, as who these key parties are, can be subject to debate - therefore this Performance Gap evidence is critical at it shines a light on who/what these key links in the construction chain are.

–
Nigel Ingram, Director of Development, Joseph Rowntree Housing Trust

II. USE A WORK PLAN WITH GATEWAYS



✓ What do we need to do?

Design continuity could be achieved through using a structure that limits progress beyond given 'gateways' unless certain requirements have been met. This would aim to improve sequencing, ensure better details and construction methodologies, clarify the handover process and define responsibilities. Specifics might include: requiring involvement of an M&E designer at concept stage, demonstrating sufficient handover from concept to detailed designer, fully disseminating the energy strategy or clarifying exactly which design team members need to input to a particular phase of work.

👤 Who needs to do what?

For it to work, all stakeholders would need to familiarise themselves with a new plan and adopt it in full. Organisations such as RIBA clearly have a role in the Performance gap but little of their work applies to the housebuilding industry. However, the latest RIBA Plan of Work 2013 could help inform the underlying structure; the Construction Industry Council has already adopted it, and it has the potential to highlight Performance Gap issues as an 'overlay'. Updates would be needed to the plan to better reflect Performance Gap issues and it would also need to be made applicable for projects that do not involve architects at all stages.

III. INCREASED USE OF BIM



✓ What do we need to do?

Building Information Modelling and Management (BIM) could act as a 'golden thread' to achieving proper design continuity, helping to monitor and control design, quality, change control, performance and compliance. Used in full, it provides a collaborative exchange of information and is arranged around staged outputs, stretching from concept through design, delivery, handover and operation.

★ What are the challenges and opportunities?

Firstly, BIM needs to be fully adopted as part of the housebuilding process to be of benefit. There is also a perception that skills are lacking - an NHBC review found only 11% of major housebuilders using BIM - and that existing alliances and competitive procurement could be compromised. BIM would need to provide the necessary feedback loop to benefit skills development and cost optimisation. For small housebuilders, this could be a particular challenge. Some changes may be needed to the BIM process, such as data conformity standards and interoperability of software, and also to allow for the discrete nature of housebuilding workstages and uncertainty in the planning process. The potential role of BIM is explained further in Appendix G.

£ What kind of costs are involved?

Another major barrier is the additional up-front cost: the additional resources and skills required to adapt to using BIM. This may be reduced through a growing library of BIM-ready content: a platform has been developed by NBS which is being populated by manufacturers. Larger housebuilders constructing standard house-types may be better positioned to provide the necessary resources and skills. Savings should also be accrued through the use of BIM: the BIM Task Group¹ has found that it saves 8-18% on design fees and 8-10% on construction costs.

👤 Who needs to do what?

There is already a clear signal from government that they wish the industry to make more use of BIM: they have committed to using it for central government building procurement contracts in the UK from 2016. Clients and contractors need to adapt, with clear requirements enshrined in the execution plan from the outset, stating the inputs needed from each project contributor. Project staff will need to undergo additional training and housebuilders may need to employ a BIM manager.

SPECIFICATION, DESIGN & PROCUREMENT OF MATERIALS & SERVICES

I. IMPROVED PRODUCT LABELLING



✓ What do we need to do?

The very simple suggestion has been made that where it is difficult to distinguish between two products, a universal labelling system be introduced. This would be a coding system particular to product families, such as mineral wool insulation, to ensure that once the packaging is removed, site operatives are still able to identify the materials and ensure they are fitted in the correct location. Material manufacturers are already coming forward with several effective solutions.

👤 Who needs to do what?

This would need to be coordinated by organisations such as insulation trade associations, suppliers, installers and housebuilders. It would then be for the manufacturers to develop and adopt a finished scheme.

1. www.bimtaskgroup.org

II. PRODUCT DESIGN CHANGES



✓ What do we need to do?

There may be other opportunities for manufacturers to make small changes to their products, resulting in a positive impact on the Performance Gap. For example, certain housebuilders have recently requested that their window manufacturers put a 'stop' on the windows to make certain that they are fitted at the right point in the window reveal and minimise thermal bridging. This would address a problem repeatedly witnessed during the *Housebuilding Process Review*.

After reading the Evidence Review Report, at Barratt Developments we are working with our suppliers to pilot providing window formers fitted with a stop, ensuring that windows are correctly located to reduce the risk of thermal bridging.

—
Michael Finn, Group Design & Technical Director, Barratt Developments

III. SPECIFICATION CHANGES



✓ What do we need to do?

Improvements to manufacturers' specifications could help their materials and products to be properly fitted, focusing on how to achieve performance and providing clear information on actual performance. This could link to the previous suggestion on product labelling, with individual codes on each component or material to confirm its performance.

★ What are the challenges and opportunities?

Manufacturers would need to be incentivised, and it would need to be adopted across the industry to avoid any commercial disadvantages. It may therefore require regulation to create a level playing-field.

£ What kind of costs are involved?

There should be negligible additional cost for improving specifications; however, if regulation was needed, it could become a more time consuming and costly process, requiring a full training programme and roll out.

IV. PROCUREMENT TO FOCUS ON PERFORMANCE



✓ What do we need to do?

A cultural shift is needed for procurement teams to prioritise actual material performance in their list of considerations. It is important that the labour resource procured has the necessary competence and that products meet the performance specification. For example, using an elemental approach to material procurement often leads to a risk of a Performance Gap occurring which could be overcome by adopting a 'total cost' approach.

★ What are the challenges and opportunities?

Further research is needed to understand how this fundamental change to procurement could be achieved. The limited knowledge of procurement teams in relation to the importance of specific product performance requirements is a barrier to change, however those companies involved in the *Housebuilding Process Review* are already taking positive steps to resolve this issue.

✓ What do we need to do?

Develop a set of up-to-date construction details, as envisaged in Part L1A of Building Regulations 2006, to provide best practice details covering the major fabric junctions and systems for current standard construction types (masonry, timber and concrete frame). These need to be buildable, flexible, robust, cost effective and capable of being implemented on a significant scale. These details should be developed by people who fully understand the technical challenges around air tightness, U-values, thermal bridging and the practicalities of construction. Once submitted, performance calculations need to be independently verified for robustness and accuracy.

The details can then be listed on a publicly available database, similar to the not-for-profit DataHolz database in Austria, although the priority should be to improve industry understanding, competency and consistency. It is expected that in addition to the technical drawings, additional guidance and other material would be provided to site operatives to enable them to build the details. The scheme structure could be further enhanced through a more robust auditing process based on actual site practice and quality. Alongside this, developers and manufacturers should continue to collaborate in reviewing best practice and publishing new details, so that advances in detailing are openly available.

Uptake of this may require an increased use of IT and BIM, as well as better guidance for thermal bridging in various parts of industry to address a gap in knowledge and skills.

There is an important link to recommendations made in the section on the 'National Compliance Method and Regime' for improving U-value and Psi-value calculations, to ensure that the details are based on robust inputs. This is with regard firstly to the technical aspects of reviewing BR443 and BR497, and secondly to the more comprehensive training required for modellers.

★ What are the challenges and opportunities?

Identified problems include: the cost of developing the system, the lack of appropriate assessment process and the lack of skills to develop and understand the details. These would need to be overcome by demonstrating an appropriate balance of risk and reward. Consideration would be needed of verification processes to demonstrate the successful build of specified details, and of processes to ensure information flow from design to build stage and vice versa. Further information on these proposals can be found in Appendix E.

👤 Who needs to do what?

Government needs to provide pump prime funding to enable industry to develop a Construction Details Scheme. Industry needs to commit to creating an industry owned and maintained Construction Details Scheme, match funding the investment from government, to provide 'assured' as-built energy performance for the most common major fabric junctions and systems.

Robust Details has shown how the industry can deliver cost effective and demonstrably high levels of compliance and performance for sound in Part E. We believe we can do the same for Part L given a similar framework.

—
John Tebbit, Managing Director, Robust Details Limited

Some modelling has already been undertaken by various manufacturers and developers, who also have experience of the buildability of such junctions, the findings of which could be contributed to the industry scheme. Once operational, the scheme would be run by industry through a not-for-profit organisation, which would oversee its running and maintenance. This would require extensive involvement of manufacturers and other industry experts. In addition, organisations such as CITB and RIBA should be engaged in the process of improving knowledge and understanding of construction details, *for example through inclusion in site work training courses and CPD.*

QUALITY CONTROL

I. THE ROLE OF CLIENTS & DEVELOPERS



✓ What do we need to do?

The construction industry already has many quality controls in place for the design and construction phases but there is a clear need for the 'clients' who commission a development or construction project and housebuilders/developers to place a greater importance on controls surrounding the energy requirements. Therefore, specifications, design guides and Employers Requirements should contain certain requirements – *for example, carrying out in line tests (such as air pressure), quality control checks and/or the introduction of 'gateways'.*

★ What are the challenges and opportunities?

Barriers to adopting this practice include the additional time required of designers and site personnel to carry out these checks. If it were considered necessary, penalties (e.g. in SAP or by employers) could be introduced for failure to perform proper checks, though it should be noted that this approach did not receive consensus. It may be preferable to instead encourage best practice, *for example by identifying and rewarding individuals for good practice, perhaps in a similar format to NHBC Pride in the Job and LABC Excellence Awards.* This links to certain 'Energy Literacy' concepts, particularly around on-going training of designers and site personnel.

At Lend Lease, to ensure we are achieving the high quality we expect, we already do a staged process of audits on all our builds. This approach could be used on more developments throughout the industry.

—
Richard Cook, Head of Residential, Lend Lease

II. INCREASED ENERGY FOCUS FOR VERIFICATION AND QUALITY CONTROL



✓ What do we need to do?

There is a need for an increased focus on energy-related checks and assessments across all areas of building delivery including at the design stage and on site. This could be carried out either on all dwellings or on a proportionate basis. Reference should also be made to the 'Demonstrating Performance' section.

★ What are the challenges and opportunities?

There are various issues to be considered including who would carry out these energy performance related checks and assessments, how this would fit with existing responsibilities, and how to avoid conflicts of interest. Additional site visits would increase the time, resource and cost involved in the build process, particularly as multiple visits would probably be required, *for example in order to be able to see insulation when it has just been installed, particularly for smaller sites.* Additional costs would be involved in upskilling and good guidance would also be required (see 'Energy Literacy' section). However, the process could help to increase and share knowledge across industry and provide a quick win. It could also help to pick up on general quality issues, as well as improving the accuracy of the As-Built SAP calculation by highlighting where changes have taken place compared to the design.

👤 Who needs to do what?

Industry and government need to further develop and appraise options for energy-performance focused site checks. There may be ways of including more rigorous energy performance checks as an element of Building Control assessments and inspections. Housebuilders and construction companies need to decide if their current business model fully addresses the management of energy performance.

£ What kind of costs are involved?

The costs are likely to be low after the initial investment of 'change'.

III. THE ROLE OF COMMISSIONING



✔ What do we need to do?

Commissioning is a vital process to ensure that the building's systems are fully functional at construction completion. In particular the commissioning of services, whilst already established, needs to be made more structured and delivery assured. It is also important that buildings are commissioned as a whole.

★ What are the challenges and opportunities?

Tick sheets are often an ineffective way of ensuring commissioning has been completed properly, if indeed at all, therefore other means need to be developed that are effective. There may be opportunities to link an enhanced commissioning process with information provided to the building occupant, *for example utilising the BSRIA Soft Landings approach.*

BSRIA work with the Construction Industry to 'make buildings better' by the provision of authoritative guidance on improving the performance of the building and its services. Soft Landings provides a process and a set of principles for the successful delivery of an operationally ready building. BSRIA looks forward to working with the house building industry to ensure all homes achieve a Soft Landing.

—
**Ian Orme, Business Manager,
Sustainable Construction
Group, BSRIA**

Who needs to do what?

Designers and suppliers need to ensure they provide full commissioning data; manufacturers need to supply appropriate commissioning approval protocols for complex systems, such as communal heating; and generally a more holistic approach needs to be taken to the commissioning process by all professions. It is strongly recommended that commissioners should be independent from the sub-contractors whose work they are commissioning.

What kind of costs are involved?

Extra cost should be off-set through the reduced scope of the sub-contractors works. However, some additional cost will be incurred initially whilst systems and procedures are put in place.

LEARNING & FEEDBACK LOOPS



What do we need to do?

Feedback is needed right across the housebuilding industry throughout the supply chain to ensure the necessary learning. This could be aided by processes such as the RIBA Plan of Work 2013 Stage 7, which specifically schedules a feedback process. An increased role for developers and others in undertaking energy-performance related site checks should also help with feedback and communication. Feedback to government is also required to ensure that the '2020 ambition' is being met.

What are the challenges and opportunities?

The challenge is to ensure that feedback takes place at an appropriate time and level. Clear methodologies need to be developed to make sure this takes place. The opportunities are extensive as improved feedback loops would allow the processes linked to energy to also cross-fertilise other areas, strengthening the construction sector's resilience and the quality of the products produced.

Who needs to do what?

Businesses will need to change their processes by implanting new procedures and strengthening current ones. Building Control should also take the opportunity to review and improve their feedback processes.

NATIONAL COMPLIANCE METHOD & REGIME

The *Evidence Review Report* identified various issues relating to the current national compliance method and regime which contribute to the Performance Gap. Many of these related to the Standard Assessment Procedure (SAP), the methodology and tool which is used to check compliance with Building Regulations Part L1A, and the processes surrounding it. In particular, the evidence review found that As-Built SAP assessments are often not reflective of the actual built dwelling; that there are issues around the use of U-value and thermal bridging calculation procedures; and that verification procedures are not sufficiently robust when it comes to energy performance.

There is a need for **refinements to the existing SAP process** in the short term to help ensure that SAP assessments are accurate and that the inputs are easier for developers, Building Control and others to check. The adoption of a Product Specific Plain Language Compliance Report signed by the house-builder is strongly recommended to help in this regard. **Improvements to the governance of SAP assessor accreditation schemes and assessors** are also recommended, to help clarify the responsibilities of those involved in the assessment process - including developers, assessors and Building Control Bodies as well as the governance bodies aiming to ensure high quality, consistent assessments, such as the SAP Conventions Group and those involved in accreditation scheme moderation.

Changes to U-value and thermal bridging calculation procedures are needed, including introducing new modeller competency requirements and changes to improve robustness and better reflect in-situ performance. More generally, a systematic **review and update of the SAP methodology and assumptions** has been suggested, particularly focusing on those areas which potentially have significant impacts on the Performance Gap. This review is likely to be informed by the testing proposals outlined in the 'Demonstrating Performance' section of this report which could potentially allow verification of the accuracy of SAP or of particular assumptions and inputs. It is recommended to include changes to **better reflect system-level performance**, as opposed to individual product performance, and amendments to how default input values are used. To deliver these changes, **further research and consultation may be required**, in particular to develop the evidence base for medium-term changes to the SAP methodology and to consider the potential implications for the regulatory regime. **Changes to software** are also proposed to improve data capture and validation and to provide approved U-value calculation software.

Some of these proposals will require changes to SAP and the management around it, and others may require changes to Building Regulations. As government has responsibility for both, it will need to be involved in all of these activities, including various teams across DECC and DCLG. **Government will need to take action by 2016 to ensure that the recommended revisions to energy modelling practices, SAP processes and verification procedures, together with a strong regime to ensure that only suitably qualified persons carry out energy modelling, can be put in place.** Stakeholders from across industry will also need to be strongly involved.

REFINE THE SAP PROCESS: IMPROVED COMPLIANCE REPORTING



✓ What do we need to do?

A standardised, more comprehensive, Product Specific Plain Language Compliance Report is proposed to help ensure that the Design Stage and As-Built SAPs are accurate and that the inputs are easier for developers, Building Control Bodies (BCBs) and others to check. This should provide a comprehensive summary of the product-specific fabric and services specifications that have been inputted to SAP assessments. The compliance report should include appendices with U-value calculation data sheets, certificates or statements, and details of other calculations such as thermal mass.

👤 Who needs to do what?

At the design stage, the Product Specific Plain Language Compliance Report would be signed by the housebuilder to declare its accuracy and would then be provided to BCBs as part of the controlled documents to use for checks during construction. At the As-Built SAP stage, the SAP assessor would confirm back to the developer all individual items that had changed since the Design Stage assessment. The updated Product Specific Plain Language Compliance Report would then be signed by the housebuilder and provided to the SAP assessor and to BCBs, as well as to occupants via lodgement on the EPC register to reinforce the importance of accuracy. BCBs must not be allowed to issue completion certificates before the signed compliance report had been lodged and received by them along with the EPC generated in full SAP. SAP assessors must also not be allowed to issue EPCs without it and should face disciplinary procedures if they did so.

Government would need to change the requirements in Building Regulations Part L and in SAP documentation and would need to instruct the SAP assessor accreditation organisations and software providers. Regulatory powers should be reviewed to ensure that BCBs have the power to require the information. SAP assessors, assessor accreditation organisations and BCBs will need to be aware of the changes and update their processes. As part of their audit processes, SAP assessor accreditation organisations should include sample checks that valid developer signed declarations have been provided.

It is believed that this recommendation should be acted on in the short-term. Note also that it links to the 'Improved Quality' theme suggestion of increased focus on energy-performance related checks on site, which might be undertaken by SAP assessors, BCBs or others.

If we are to address any performance shortfall then it is critical that the SAP Assessment tool and the SAP verification process is both robust & auditable. Those undertaking U-value & Psi-value calculations need to be subject to improved training & rigorous accreditation to ensure accuracy & consistency of those details. We strongly endorse the Report's recommendations in this regard and for the development of robust Construction Details to underpin such improvements in performance.

–
**Michael Black, Group
Development Director,
Bovis Homes Ltd**

GOVERNANCE OF SAP ASSESSOR ACCREDITATION SCHEMES AND SAP ASSESSORS

I. DEFINITION OF SAP ASSESSOR RESPONSIBILITIES



There needs to be a clear definition of SAP assessor responsibilities set out and publicised by government in SAP documentation, along with a summary of the responsibilities of housebuilders and BCBs, so that assessors understand what they are and are not responsible for.

II. DEFINITION OF SAP CONVENTIONS GROUP RESPONSIBILITIES



The SAP Conventions Group has a key role in bringing consistency to the decisions made by SAP assessors. The Group's Terms of Reference need to be updated and the membership expanded to ensure an appropriate focus on energy performance.

III. CROSS-SCHEME MODERATION AND SCHEME AUDITS



Government moderation of the SAP assessor accreditation schemes needs to be tightened, ensuring different schemes apply SAP consistently. Government audits of the accreditation schemes need to be improved to have a strong technical standards focus - ensuring schemes are adhering to their operating requirements, are consistently applying the SAP conventions, have consistent CPD requirements, and are auditing their assessors properly.

IMPROVE U-VALUE AND PSI-VALUE CALCULATIONS

I. IMPROVED TRAINING AND QUALITY ASSURANCE FOR U-VALUE MODELLERS



✓ What do we need to do?

Improved training for those undertaking U-value calculations is required to drive up standards. Current training is usually limited to a short module in the SAP assessor (DOCEA) qualification. Some form of competency scheme could also help to drive up quality. Whilst BBA already provides such a scheme, clear incentives or requirements are needed to motivate modellers to undertake additional training or join a scheme.

Training needs to be made more rigorous and should aim to provide a strong understanding of building physics, good construction practice and likely Performance Gap issues. Ongoing CPD requirements should be set, and regular audits of the calculations should be undertaken, with ongoing support for modellers. Guidance on ensuring calculations are robust will need to be agreed (see the 'Review of calculation procedures' recommendation below).

Who needs to do what?

The U-value training could continue to be provided as part of the SAP assessor qualification, but could also be delivered separately as it will need to be available to those who are not SAP assessors. Government needs to support the implementation of the recommendation to only allow assessors to accept calculations from appropriately qualified modellers, which is likely to require changes to Part L and SAP.

When do we need to do it?

Improved training is required in the short term and government needs to amend regulations around the competency of U-value modellers at the next Building Regulations Part L review.

II. IMPROVED TRAINING AND QUALITY ASSURANCE FOR PSI-VALUE MODELLERS



What do we need to do?

A qualification or scheme for Psi-value modellers is needed to address the current variability between results and to drive up standards. Current training courses are generally fairly limited and often only provide teaching in how to use modelling tools and do not sufficiently cover the building physics behind the calculations, good construction practice, and likely Performance Gap issues.

A Psi-value competency/accreditation scheme is strongly recommended to provide ongoing quality assurance of calculations, ensure consistent and effective CPD, and to provide a forum for modellers and a vehicle for agreeing guidance on ensuring calculations are robust. A similar approach to the BFRC scheme for windows could be used, balancing technical rigour with cost.

There is a vital link between the requirements on improved competency of those undertaking U-value and Psi-value calculations and the recommendation to develop a set of robust Construction Details in order for such a scheme to be successful (see the 'Improving Quality Outputs' section of this report).

Who needs to do what?

Training might be added to the SAP assessor qualification, but it is likely that a separate qualification will be needed due to the extent and complexity of training required. Therefore a competency scheme provider needs to be identified and funding may be needed to help with

up-front development costs. Government needs to support the implementation of the recommendation to only allow SAP assessors to accept calculations from appropriately qualified modellers, which is likely to require changes to Part L and SAP.

When do we need to do it?

Improved training and scheme setup is required in the short term and government needs to amend regulations around the competency of Psi-value modellers at the next Building Regulations Part L review.

BBA already provides a U-value competency scheme aiming to raise standards in this important area, but clear incentives are needed for modellers to join such schemes. We are also exploring providing a similar scheme for Psi-value modellers, and would be able to set this up fairly quickly should funding be provided to get the project underway.

–
Fanoula Ziouzia, BBA

III. REVIEW OF CALCULATION PROCEDURES & THEIR OWNERSHIP

What do we need to do?

It is recommended that BR443 and BR497, the documents setting out the conventions that govern U-value and Psi-value calculations, should be reviewed through a formal process. This should be either by implementing a formal standard or through full Building Regulations consultation, to reflect the fact that any change to the treatment of different products can have significant impacts. The review should consider how the calculations could be changed to better reflect in-situ performance at scale, as well as 'systems-level' performance based on entire elements, such as a wall. This would be informed by in-situ testing, though some changes surrounding in-situ system level performance may be best made in SAP itself.

It is also felt that the calculation procedures should have a wider ownership than at present; *for example government with industry input (such as through the use of an advisory group like the Building Regulations Advisory Committee)* or another body that represents all of industry.

These recommendations are also strongly linked to the proposal to develop robust Construction Details (see section on 'Improving Quality Output') because it is these recognised calculation procedures which the scheme would need to use. There is also a link to proposals to develop testing methods, which are outlined in the 'Demonstrating Performance' section.

Appendix A to the *Interim Progress Report* of this project contains a summary of recommended changes to BR443 in aid of closing the Performance Gap.

What are the challenges and opportunities?

Challenges include the costs of developing BR443 and BR497 or transferring their ownership; the need for evidence to support calculations of real system performance; and the commercially sensitive nature of changes. However, there appear to be significant potential benefits to the Performance Gap from improving U-value and Psi-value calculations by ensuring that calculated figures are more closely aligned with in-situ performance.

Who needs to do what?

Government needs to support an industry-led review of the standards for calculating U-values, and the conventions for using those standards, with a view to updating the requirements of the approved document for Part L. It is understood that BRE are currently reviewing BR497, but wider industry involvement is required. Manufacturers and testing and research experts will need to be involved to input into changes which affect product performance assumptions, to ensure changes are equitable and to evolve products as needed. U-value and Psi-value modellers will need to keep up-to-date with any changes made. As the data may not be available at present to provide the evidence required to change calculations to better reflect in-situ performance, there is a need for more research into in-situ U-values and Psi-values and how to measure these (see also the 'Demonstrating Performance' section). Research processes should be formalised so that outputs are comparable, generating robust information to improve the reliability of calculations.

When do we need to do it?

It is important that these recommendations are acted on in the short term.

IV. APPROVED U-VALUE CALCULATION SOFTWARE



An approval process needs to be established for all U-value software to ensure consistency and quality.

REVIEW OF SAP METHODOLOGY AND ASSUMPTIONS



What do we need to do?

A systematic review and update of the SAP methodology and assumptions is recommended, particularly focusing on an analysis of those which potentially have significant impacts on the Performance Gap.

The review should include changes to SAP to better reflect system-level performance and interactions (e.g. performance of a completed wall or entire heating system), as opposed to individual product performance, and potentially reflecting this in SAP's Product Characteristics Database to also help provide designers and specifiers the information they need to make more informed choices. The introduction of confidence (or in-situ) factors should be considered more widely in SAP. If implemented, a robust, equitable process would be needed for determining and updating the factors which have the confidence of developers, manufacturers and the wider industry and would allow competing manufacturers to innovate and demonstrate the as-built performance of their systems. The need for the use of confidence factors will depend to a large degree on the scope and ability to make appropriate amendments to U-value and Psi-value calculation procedures described above.

The review should also include amendments to how default values are used, making these worst case to encourage the use of product/system-specific information. The SAP Conventions should be changed to require defaults to be used when no documentary evidence is provided.

The review is likely to be informed by the testing proposals outlined in the 'Demonstrating Performance' section of this report, which could potentially allow verification of the accuracy of SAP or of particular SAP assumptions and calculation procedures.

Who needs to do what?

Government will need to be involved as the owners of SAP and BRE will need to be involved as the current government contractor delivering SAP. Industry and research experts will need to be engaged in and consulted on changes, as well as providing evidence to support the review, and ensuring that changes which affect product performance assumptions are fair.

When do we need to do it?

These recommendations need to be acted upon immediately such that any proposed changes to SAP methodology can be consulted upon at the next available opportunity and implemented as soon as possible.

CHANGES TO SAP SOFTWARE

Changes are required to SAP software in the short term to improve the quality of SAP assessments:

I. DATA VALIDATION



Government and software providers should ensure that all SAP software has a standard minimum level of data validation on inputs into the software to identify any inconsistent data and improve the quality of SAP assessments. *For example, increased validation could pick up errors such as incompatible components.*

II. SPECIFICATIONS MORE CLOSELY LINKED TO DATA INPUTS



Software providers need to make provision for including information to go into the Product Specific Plain Language Compliance Report, and for the production of the report itself. This would help deliver the requirements set out in ADL1a 2013 Appendix C Section 4 which states that 'an important part of demonstrating compliance is to make a clear connection between the product specifications and the data inputs required by the compliance software'. Government needs to ensure these changes happen.

III. DOCUMENT MANAGEMENT



It is recommended that all compliance documents, including the proposed new signed Product Specific Plain Language Compliance Report, should be made accessible through an online document management and storage system which enables document transfers between clients and SAP assessors and is accessible by occupants.

IV. SOFTWARE INTERFACES



Various suggestions have been made for improving the usability of SAP software, *for example some supported the creation of a 'SAP app' to allow the impact of specification changes to be tested by developer teams, and some wanted SAP software to be able to interface with other software such as 3D modelling packages to improve its accuracy.* Software manufacturers should work with user groups to explore these possibilities.

Further detail on all these recommendations, including an illustrative example Product Specific Plain Language Compliance Report, can be found in Appendix C.

DEMONSTRATING PERFORMANCE

Some of the issues that contribute to the Performance Gap are obvious and actions can be taken to address these immediately. Other issues are more complex or may not yet be apparent. The full significance of the various issues, and the Performance Gap as a whole, requires further investigation. However, the existing techniques to measure and assess as-built performance are not fully developed and tend to be expensive, and in-situ tests are often disruptive of the build process.

Therefore **in order to close the Performance Gap it is critical that real performance can be assessed, measured, tested and demonstrated.** This information is vital to inform robust designs; products and systems that deliver 'what they say on the tin'; accurate construction; and good commissioning. Without the ability to measure and assess energy performance, sufficient action to address the Performance Gap and sustain that improvement is unlikely to happen.

Diagnostic tests are needed to investigate why a finished home, system or element does not meet the design intent. **Existing diagnostic tests need to be more useful, useable and consistent,** through standardising the application of tests and the interpretation of results. In addition, research organisations and commercial groups need to **develop new and emerging diagnostic test methods for both services and fabric, particularly at system level** and to improve industry's ability to assess in-situ performance.

It is vitally important that an approach be developed to demonstrate the '2020 Ambition', to enable industry as a whole to firstly ascertain the baseline position and then be able to show progress towards closing the Performance Gap. Good process control and quality assurance checks can also provide some of the feedback required but some form of testing is needed to demonstrate whether these measures are working effectively. Approaches used to demonstrate as-built performance would help to provide feedback on the capability of the housebuilding process (design, product and systems manufacture, construction, commissioning and verification) to produce homes that perform. If the results are worse than expected, questions can be asked as to what may be going wrong with the process.¹

Government needs to signal their long term intent to support the industry in providing the information necessary to quantify the Performance Gap and create the learning loops required to drive continuous improvement, by funding research and development into testing, measurement and assessment techniques with immediate effect.

Industry needs to commit to undertaking the research and development necessary to create innovative testing, measurement and assessment techniques to understand the Performance Gap and develop commercially viable methodologies acceptable across industry for 'demonstrating performance'.

1. It is important to note that for an individual building, this type of as-built performance analysis would not form part of Building Regulations 'compliance' checks.

FURTHER DEVELOPMENT OF DIAGNOSTIC TESTS



✓ What do we need to do?

Diagnostic tests are needed by industry to understand why a finished house, system or element might not be achieving the designed performance. These are particularly beneficial for housebuilders wanting to investigate where problems may be occurring and feed back to manufacturers, suppliers and contractors when problems are indicated; and for manufacturers wanting to analyse the in-situ performance of their products and systems.

The *Evidence Review Report* and feedback from industry during this project has identified a lack of consistency in the application of existing diagnostic tests and interpretation of results, as well as limitations to the fabric and services tests currently available. To address this, it is suggested that protocols of existing tests be refined and standardised to be more useful, useable and consistent in assessing the energy and carbon performance of homes. New and emerging test methods also need to be developed by research organisations and commercial groups, for both services and fabric, both in the laboratory and in-situ. A better understanding is needed of inconsistencies in results and the impact that building methods and different combinations of products have on test results. To help with this, data informing and arising from tests should be made available at a suitable scale for analysis.

Fabric tests cover a range of techniques to evaluate the thermal performance of the building fabric. Existing assessment methods, such as thermography, heat flux testing and elemental laboratory tests, need refining and standardisation of protocols to improve consistency and robustness of results is urgently needed. The air pressure test is well established, but some refinements are needed to make it more robust and consistent, and it could also be used more commonly as a diagnostic tool in combination with other test methods such as smoke tests and thermography. Other less well developed fabric tests need to be progressed: *for example, improved in-situ testing (e.g. using environmental chambers) would help industry to understand site specific impacts on the performance of products and systems, perhaps supplemented with better testing and recording of the impact of site tolerances and practices in laboratory conditions, and the ability to test whole system U-values and thermal bridging.* These tests could help reduce the risk of an associated Performance Gap occurring.

The majority of currently available tests on building services are laboratory based, and focus on individual components rather than the entire system. In-situ tests need to be developed, as do system-level services tests, both laboratory and in-situ, and more systems-level field trials need to be undertaken. For installed services, simple checks and tests and better commissioning guidance could make a significant impact. This would require a collaborative effort from stakeholders including suppliers,

Willmott Dixon has been evaluating the performance of the zero carbon housing development Greenways Drive, working in collaboration with our client Catalyst Housing. We undertook a detailed energy specific design review, regular site visits by energy performance specialists, and various forms of testing on a sample of dwellings together with on-going in-use monitoring. This understanding is feeding into future design choices and influencing construction practices to help narrow the Performance Gap.

—
David Adams, Technical Director, Willmott Dixon

National compliance methods need to be adjusted if we are to address the performance gap in the UK. Appropriate measurement is vital in determining performance and requires further research. We need to move our thinking away from simply assessing efficiencies of individual components and towards system performance; we should be looking at in-situ measurements next to lab-based measurements – but how will these new tests work? More practical research into this is needed and government support is crucial.

—
Marieke Beckmann, Research Lead, National Physical Laboratory Centre for Carbon Measurement

manufacturers and commissioning experts. Commissioning requirements may also need to change to include better checks on the performance of the system as a whole.

An analysis of the strengths and weaknesses of current test and assessment methods has been carried out and details can be found in Appendix D.

Whole house or whole system tests are unable to pinpoint exactly where a problem is occurring, but can provide an indication that something is wrong and of the broad area(s) where further investigation is needed. They may therefore have a place alongside the use of diagnostic tests described above.

Process control and testing skills and practices within the industry need to be improved through additional training, and quality assured through accreditation. This recommendation is discussed in more detail in the section on 'Energy Literacy'.

★ What are the challenges and opportunities?

The development of specific tests comes with specific challenges. These might be technical, *for example complications of testing apartments rather than individual houses, or limits to the times of year at which tests can be undertaken; or strategic, for example, attributing fault when testing a combined services system.* There may also be resistance from certain parts of industry to introducing new tests or changing existing test methods and protocols.

Broadly speaking, industry needs a range of approaches to diagnostic testing to provide effective options for understanding performance. These need to be able to be consistently carried out at scale and available for a reasonable cost. This will require significant investment in research and development. Supply chain issues need to be addressed, including the limited availability of testers and testing equipment, such as environmental chambers and hot boxes. If mechanisms are put in place to motivate industry to address the Performance Gap on a mass scale, then it could be expected that the supply chain would respond.

Knauf recognise that there is a competitive advantage of being able to guarantee the robustness of our product performance in use. Our challenge is to make enough commercial benefit to reward early innovators so that the sceptics do not win out.

We are at the limits of our current testing capabilities, which is a challenge for the entire supply chain.

—
John Sinfield, Managing Director – Northern Europe, Knauf Insulation

👤 Who needs to do what?

Testing experts and research organisations will need to be involved in developing existing and new tests and assessment methods, working with developers to ensure commercial viability. Academia, manufacturers and industry bodies will need to be involved. Funding will be required from a range of sources including Government, developers, manufacturers, and research programmes such as Horizon 2020 and those run by EPSRC and TSB. As new and existing tests are developed, there may be potential implications for the national compliance method and regime which need to be considered by government and industry.

📅 When do we need to do it?

It is crucial that tests are developed in the short term, to enable industry to better understand the extent and magnitude of where Performance Gap issues are occurring, such that the necessary action can then be taken. Real progress needs to take place prior to 2017.

DEVELOPING APPROACHES TO DEMONSTRATING PERFORMANCE

Understanding real performance of completed homes provides the impetus for continuous improvement. It drives designers to ask searching questions beyond the standard system and product performance data sheets, as well as to consider specifying systems that are more robust to install. Product and system manufacturers are motivated to test their products in real life (not just under EU standard laboratory conditions) because otherwise their products may not be selected. Construction teams are driven to follow the correct installation processes and to pay attention to detail, because eventual performance will be demonstrated in some form.

While the market currently delivers products that comply with regulations, there is an increasing awareness of the need to deliver based on performance, with competitive pressures brought to bear on delivering this real performance (of products, systems and buildings) at the lowest cost. This will provide occupants with a home that performs and housebuilders with the confidence to actively market their homes as low energy.

✔ What do we need to do?

We need to be able to measure as-built performance at an industry level in order to determine the size of the Performance Gap, understand the effectiveness of solutions, and demonstrate progress in achieving the '2020 Ambition'. At present, on an industry-wide level, the size of the Performance Gap is unknown and the existing techniques to measure as-built performance are not fully developed and tend to be expensive and disruptive of the build process. Currently the only as-built test routinely undertaken is the air pressure test, and there is currently a lack of a suitable 'in-line' or 'end-of-line' test which covers fabric and services energy performance (in contrast to the test that can be undertaken to demonstrate acoustic performance, *for example*).

Furthermore, whilst the **Evidence Review Report** identified a significant range of issues causing the Performance Gap, these are only the known issues; there are likely to also be unknown issues that may be significant. At both an individual housebuilder level and at an industry level as-built performance feedback is needed to determine where further effort is required and where performance is good.

Approaches discussed as part of this project that could be used to demonstrate the '2020 Ambition' include:

- Extrapolating data from type testing and process control;
- Sample construction completion assessments;
- Deriving as-built performance from smart meter gathered metadata; and
- Deriving as-built performance from statistically significant sample in-use measurement.

Type testing and process control involves undertaking detailed diagnostic tests on a particular dwelling type (i.e. a house with a particular combination

CLOSING THE PERFORMANCE GAP: THE 2020 AMBITION

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

of fabric and services systems), and using this to inform design changes and process control measures for other dwellings of the same type, with quality control processes put in place to ensure that improvements are maintained. 'Process drift' can occur so there is likely to still be a need for some ongoing testing. Data could be extrapolated from this process and collated to provide an industry-wide measure of the Performance Gap.

Sample construction completion assessments may include in-line / end-of-line performance tests which could be used to directly demonstrate the Performance Gap. Looking at populations of whole house or whole systems tests can identify patterns of better or worse performing combinations, *for example correlations based on particular systems or build techniques may become apparent*. Whilst at a certain level this statistical data is useful for developers, it is also likely to be of interest to suppliers, designers, researchers and government.

Deriving indications of as-built performance from smart meter metadata gives less detailed data and so is less useful for identifying causes of a Performance Gap (and hence less useful for individual developers). However, it could be useful at a larger scale to demonstrate the '2020 Ambition'. Sample in-use monitoring provides a step between construction completion assessments and smart metering metadata, as more specific data can be measured at an individual dwelling level making it easier to derive 'normalised' building performance information.

More research is required to develop each of the approaches, including development of suitable construction completion assessment techniques, and ways of 'normalising' in-use monitoring data or smart meter metadata gathered at scale to enable the impact of individual occupant behaviour to be removed from the data.

Who needs to do what?

Work will be needed to gain cross-industry agreement on the suite of testing, measuring and assessment protocols considered acceptable to demonstrate performance, resulting in proven methodologies that are robust and commercially viable at scale. Government needs to signal their intent to support the industry in doing this.

What are the challenges and opportunities?

The approaches outlined above, to varying levels of granularity, can be used to show how well a population of homes 'perform'. The different approaches have different levels of cost, levels of time required, delay to the handover process, associated data privacy issues, and further research requirements. The strengths and weaknesses of the different approaches are explored in more detail in Appendix F.

When do we need to do it?

It is crucial that approaches to demonstrating performance are agreed in the short term, to enable industry as a whole to firstly ascertain the baseline position and then be able to show progress towards closing the Performance Gap. Industry agreement on the suite of testing, measurement and assessment protocols considered acceptable to demonstrate performance is required prior 2017.

We are concerned that proposed pre-occupation testing might have unintended consequences, for example as a Registered Provider and Developer, if we are developing for sale on public land we may find that consent to sell may be withheld if acceptable results data is not provided.

–
Hazel Warwick, Asset Management Director and Deputy Chief Executive, First Wessex

At Kingerlee Homes, we market our homes for sale based on real energy performance, rather than just designed values, as evidenced by our preparedness to monitor the performance of our completed and occupied new homes. In use monitoring should be supported by industry as the essential means of understanding the performance of the completed new home, for the designer, the builder and the occupant alike.

–
Tony Woodward, Managing Director, Kingerlee Homes

CONTINUED EVIDENCE GATHERING & DISSEMINATION

The *Evidence Review Report* published in March presented the results of the evidence gathering process undertaken in the first phase of the current project which aimed to understand issues that contribute to creating the Performance Gap. It identified 15 'Priority for Action' issues, 17 'Priority for Research' issues and 23 'Retain a Watching Brief' issues, all of which to varying degrees will require further evidence to be collected.

Whilst a number of the 'Priority for action' issues have been quantified it is, at this time, difficult to assess the size of the impact they will individually have on the Performance Gap. Therefore a **coordinated programme of ongoing work to collect and evaluate more evidence** is now required. This will provide data to fully understand the scale and nature of the issues' impact on the Performance Gap, in particular focusing on the less well evidenced 'Priority for Research' and 'Retain a Watching Brief' issues. This programme will need to take place in the short term to ensure that industry and government are aware of and understand the different issues which need to be tackled.

Improved communication of the findings of existing and ongoing evidence gathering will also be vital to ensure that the housebuilding industry learns from and responds to these. A regularly updated online resource is proposed, to bring together a range of evidence sources, allowing the issues identified as part of the current project to be monitored. This resource could also be further developed to communicate potential solutions to the various issues. Alongside this, it is proposed that regular symposiums and events be held to disseminate the evidence gathered by the current project, particularly from the *Housebuilding Process Review*. It is recognised that these should be in the context of the journey to Zero Carbon Homes and specifically the importance of addressing the Performance Gap in the context of 'Carbon Compliance'.

This programme of evidence gathering will need to involve stakeholders from all parts of the industry, including academics and researchers, developers, manufacturers and other participants, as well as government. Funding will be needed from both national and international governments and from other organisations, and some potential sources have already been identified.

The Zero Carbon Hub has been collecting further evidence from a variety of sources since the *Evidence Review Report* was published in March 2014, which has reinforced the findings contained therein. A summary of findings is provided in Appendix B.

✔ What do we need to do?

Current evidence gathering processes need to be developed and continued, and coordination needs to be improved. An evidence ‘mapping’ process is proposed which would help to understand what research is currently existing, ongoing and planned. Building on this, the development of a route map to forward-plan research is recommended.

This research should include the further implementation of the current project’s *Housebuilding Process Review* as a formalised method, rolled out to a broader range of housebuilders, and reporting on a regular (bi-annual) basis. Although this would aim to better evidence some of the Performance Gap issues, it should also specifically aim to provide feedback to developers, industry and government to help develop and implement ways of continually improving housebuilding and reducing the Performance Gap. It is intended that different versions of the *Housebuilding Process Review* be developed by the Zero Carbon Hub, tailored separately for particular audiences, *for example Registered Providers commissioning new developments; Building Control officers inspecting sites; and speculative housebuilders seeking to embed best practice within their design and procurement teams.*

The programme should also include regular reviews of newly available literature and collate and analyse research external to that presented in the *Evidence Review Report*. This will draw on other streams of the continued evidence gathering programme: *for example new desk studies, field trials, manufacturer research and site visit / assessment projects.* It will also include other evidence gathering tools used as part of the current project, such as surveys of practitioners and SAP audits to gather evidence on, and gauge the state of practice in, different parts of the industry.

This evidence gathering should help to determine the scale and potential impact of the ‘Priority for Research’ and ‘Retain a Watching Brief’ issues, common underlying causes of these issues, and potentially also other issues that have not previously been identified. The evidence gathering process is likely to be informed by developments in testing, measurement and assessment methods which are discussed separately in the ‘Demonstrating Performance’ section of this report.

It is also important that more evidence is gathered to further strengthen our understanding of the ‘Priority for Action’ issues; however it is suggested that the primary focus for these should be on developing solutions and on the research to inform these.

★ What are the challenges and opportunities?

Evidence gathering needs to be better coordinated and planned across the industry. The proposals outlined below on improving dissemination of evidence would help better understand where research is most needed and what research has already been undertaken.

The Housebuilding Process Review and site walk throughs carried out for this project have helped inform NHBC’s vision of how verification might work in the future and have provided valuable input to further research being carried out into the causation of defects in new homes.

—
Mark Jones, Head of House-Building Standards, NHBC

Suggestions for this research are presented in the other themed sections of this report, and include:

—
research to support the development of testing, measurement and assessment techniques to demonstrate the 2020 ambition

—
to develop protocols, methods and measurement techniques to ensure that evaluation takes place in a consistent manner

—
to address the need for a business case for tackling the Performance Gap to be made for different housebuilding models

—
to test solutions

—
and to embed learning from research and development into training and up-skilling industry to enable the Performance Gap to be tackled.

When do we need to do it?

Evidence needs to be gathered in the short term to support the identification of issues and development of solutions, but also continuing to 2020 and beyond.

What kind of costs are involved?

The scale of the costs will depend on the extent of the research programmes. EU funding streams such as Horizon 2020 may be used (Horizon 2020 has a specific call for projects developing methodologies and tools to reduce the Performance Gap and to monitor and assess actual building energy performance), along with industry funding, Technology Strategy Board and government funding. However individual companies and those Institutes and Associations representing the different sectors of the industry will also need to step up to the challenge and invest in energy performance research themselves.

COMMUNICATION OF EVIDENCE FINDINGS

ALL ISSUES 

What do we need to do?

It is recognised that the biggest challenge to reducing the Performance Gap will be informing large sections of the industry, firstly that it exists and secondly that it is part of the Zero Carbon policy and must be addressed by 2020. It is therefore intended to hold a major campaign of dissemination with a series of seminars and events targeted at manufacturers, consultants, developers and local government together with Building Control to raise the profile of the Performance Gap.

It has been identified that research is not always well communicated and so improved dissemination of evidence findings is required. The development of an online resource or 'knowledge hub' is proposed. This will directly help those involved in the housebuilding industry to understand and address key issues contributing to the Performance Gap. It would perform two key functions: firstly, pooling and communicating findings from the growing body of Performance Gap research and helping to review the less well-evidenced issues; and secondly, providing practical resources to help industry address the Performance Gap, including a portfolio of good practice, exemplar projects and solutions. It would include a full update of the evidence gathered by Zero Carbon Hub since the publication of the *Evidence Review Report* (a summary of which is included in Appendix B).

More widely, improved dissemination is also needed through various channels such as knowledge transfer networks, seminars and publications. The Zero Carbon Hub will be holding a symposium later in 2014 to communicate the detailed findings from the evidence gathering that has been ongoing since the publication of the *Evidence Review Report*. Other organisations are already developing dissemination strategies for their research in this area, *for example the results of the TSB Building Performance Evaluation programme*.

This work has proven to be really valuable and should benefit both the industry and homebuyers. The engagement process delivered a raft of suggestions, directly from the industry, for reducing the Performance Gap. Importantly it also identified some very achievable savings can be achieved now by looking at procurement and site practice. These savings are very cost effective and will help reduce the cost of owning a new home.

—
Adam Mactavish,
Operations Director,
Sweett Group

★ What are the challenges and opportunities?

There is now a massive opportunity to provide more consistent and targeted messages to industry, which can help to inform solutions to address the Performance Gap and also contribute to improving knowledge across the industry. However, ongoing management and communication of data will be a significant task. There will be a need to ensure that data is held securely and consistently, making it available to future research projects.

Often research is kept secret due to confidentiality and efforts need to be made to encourage appropriate sharing of anonymised data, *for example through review and dissemination by a trusted body (the role performed by the Zero Carbon Hub in the current project)*. Cross-industry groups and organisations can help to improve coordination.

Various presentational formats and styles are likely to be required for the communication of evidence as the information will need to be targeted at a range of audiences, including housebuilders, Design and Build clients, architects and design teams, SAP assessors, energy consultants, site managers and operatives, Building Control Bodies, researchers and policymakers. It is recognised that this is a major task and will require 'continuous' effort for all sectors of the industry including those institutes, associations and training bodies whose members will need to be upskilled (*for example CPA, HBF, FMB, RICS, RIBA, CITB, Summit Skills and Asset Skills*). The success will be down to the commitment of these organisations in meeting this challenge.

📅 When do we need to do it?

Communication of evidence needs to be an immediate priority, but will also need to continue to 2020 and beyond. The development of an online resource or 'knowledge hub' would be created during 2014-2015 and regularly updated over the period to 2020.

£ What kind of costs are involved?

The Zero Carbon Hub has already started to scope out in more detail what work would be needed to develop a useful online resource. Funding will be sought from the TSB, the European Horizon 2020 platform together with applications to all Institutes and Associations. The CITB has indicated that it would support applications to enhance the knowledge and skills of those sectors it represents.

A group of experts in building performance is being established, to share knowledge and further improve the vital work being done in this area to provide evidence on the Performance Gap and to help identify solutions. The group will include leading and upcoming academics and practitioners, as well as the companies who rely on their information.

—
Dr Will Swan, School of Built Environment, University of Salford



3. NEXT STEPS

As the construction industry develops products and processes capable of delivering homes with more predictable as-built energy and carbon performance, it will become essential that the research methods and tools used to assess them are continuously improved.

Industry recognises the significant challenge the Performance Gap represents and the corresponding need to proactively address it. Rather than relying on ever more onerous regulatory interventions, industry is very capable of developing innovative, commercially viable methodologies to demonstrate their success.

This requires immediate co-ordinated, pan-industry activity, to trigger a cultural shift so that as-built performance becomes a core element of delivering high quality new housing. A strategically timed series of actions is therefore needed by industry and government between now and 2020, as set out in the Route Map that follows.

Priority Actions for Industry

To commit to providing the investment for:

1. PERFORMANCE ASSESSMENT R&D

Undertake the research and development necessary to create innovative testing, measurement and assessment techniques to understand the Performance Gap and develop commercially viable methodologies acceptable across industry for 'demonstrating performance'.

2. SKILLS AND KNOWLEDGE DEVELOPMENT

Ensure that as-built energy performance knowledge, including learning from ongoing research and development, is embedded into training and up-skilling for professionals and operatives.

3. CONSTRUCTION DETAILS SCHEME

Develop an industry owned and maintained Construction Details Scheme providing 'assured' as-built energy performance for the most common major fabric junctions and systems.

4. CONTINUED EVIDENCE GATHERING

Support further evidence gathering processes and coordinated feedback to ensure accelerated continual improvement across all sectors of industry.

Priority Actions for Government

To accept the Zero Carbon Hub's recommendations to:

1. SIGNAL CLEAR DIRECTION

Clearly indicate that, in place of immediate additional regulation, it expects the construction industry to act now and have put in place a number of measures to ensure that the energy Performance Gap is being addressed and to demonstrate this by 2020.

2. STIMULATE INDUSTRY INVESTMENT

Signal their long term intent, by funding research and development into testing, measurement and assessment techniques with immediate effect, to support the industry in providing the information necessary to quantify the Performance Gap and create the learning loops required to drive continuous improvement. Additionally provide pump prime funding to enable industry to develop a Construction Details Scheme.

3. STRENGTHEN COMPLIANCE REGIME

Take action by 2016 to ensure that the Zero Carbon Hub recommended revisions to energy modelling practices, SAP processes and verification procedures, together with a strong regime to ensure that only suitably qualified persons carry out energy modelling and assessment, can be put in place.

4. SUPPORT SKILLS & KNOWLEDGE DEVELOPMENT

Accelerate the demand for industry developed qualification schemes by requiring energy certified operatives and professionals for developments on public land from 2017.

Route Map to 2020

The priority actions are designed to stimulate an intense period of R&D significantly increasing industry's understanding of how to assess, test, model and monitor as-built energy performance. These innovations will raise awareness of the Performance Gap across the industry, so that by 2016, housebuilders will be able to work with a more informed supply chain.

It is within this emerging industry mind set, and a climate of government support for industry-led R&D, that an early statement regarding the '2020 Ambition' should be included within the Building Regulations Part L 2016 announcements. This should include a commitment from government to have in place, by 2018, an approval process by which industry can submit their methodologies for 'demonstrating performance'. If, by 2018, government considers proposals by industry are unlikely to meet the '2020 Ambition', they may need to explore additional regulatory interventions within the 2019 Part L consultation process.

The reporting by industry on progress in relation to the '2020 Ambition' is only intended to be used to gauge performance across the industry and provide confidence that regulations are delivering the intended energy performance and carbon emission reductions. It would not be used as a method of deciding whether a particular building complies with Building Regulations Part L.

From 2019 onwards it is envisaged that the methodologies being used at scale by industry to demonstrate performance will provide knowledge to drive a further phase of rapid innovation, responding to the realities of as-built performance in a variety of development scales and construction types. Information gathered in subsequent years would inform continuous improvement cycles.

The following diagram presents a 'Route Map to 2020' summarising the key industry and government activities considered critical over the next six years.

This project has identified a number of key actions that government and industry are required to undertake. There is now a need for a concerted level of activity to implement the many detailed recommendations within this report in order to close the Performance Gap and demonstrate the '2020 Ambition'.

2014

2015

2016

2017

2018

2019

2020

KEY

Energy Literacy

Improving Quality Output

Demonstrating Performance

National Compliance Method & Regime

Continued Evidence Gathering & Dissemination

INDUSTRY-LED INNOVATIONS

Development & implementation of energy content for NVQ, BTEC, BSc & BA courses

Development of 'energy certified' professionals & operatives, linked to existing scheme providers

Zero Carbon Hub & BCB Toolbox Talks for SME sector

Develop industry owned & managed Construction Details Scheme

Include as-built energy performance content within all new entrant and existing workforce courses (e.g. via organisations such as ARB / RIBA / CIAT / CIBSE)

'Energy certified' professionals and operatives scheme live

Site management and operatives adopt scheme as normal practice

Construction Details Scheme live

Industry refines solutions and develops innovative alternatives as lessons are learned

Leading housebuilders increasingly seek to understand the as-built performance of their homes and demand more from their designers and supply chain

INDUSTRY R&D:
In-situ test protocols for fabric and services systems
Demonstrating as-built performance methodology trials
Whole house test & in-use monitoring protocols
Manufacturer investigations into their product & system performance

Industry agreement on demonstrating performance protocol(s)

Refine, prove and submit commercially viable as-built performance methodologies for government approval by 2018

Refine industry wide performance data analysis

Industry demonstrates the 2020 Ambition

As-built Performance Symposium

Roll-out of Zero Carbon Hub 'Housebuilding Process Review'

Co-ordinated research strategy delivered by industry, academia & government

Triggers industry investment

Government and European sourced funding supports industry to develop commercially viable methodologies to demonstrate performance process controls (e.g. Technology Strategy Board & EU Horizon 2020)

GOVERNMENT SUPPORT

PART L 2016 CONSULTATION TO CONSIDER:
Revised U-value & Psi-value conventions linked to qualified person scheme
In-situ factors for fabric & services as systems
SAP Assessor & Building Control responsibilities
Developer 'signed' Product Specific Plain Language Compliance Report

Unlocks further industry investment

Part L 2019 Consultation inc. Nearly Zero Energy Buildings

Public land developments require 'energy certified' professionals and operatives (e.g. HCA)

Part L 2016 statement – industry to demonstrate as built performance via government approved methodologies from 2020

Government approval process for industry as-built performance methodologies live

Lessons drive continuous improvement cycles

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Abbreviations & Glossary

ACD	Accredited Construction Detail	HHIC	Heating & Hotwater Industry Council
ARB	Architects Registration Board	Horizon 2020	EU research and innovation funding programme
BBA	British Board of Agrément	LABC	Local Authority Building Control
BCB	Building Control Body	M&E	Mechanical and electrical
BFRC	British Fenestration Ratings Council	MCS	Microgeneration Certification Scheme
BIM	Building Information Modelling/Management	NBS	National Building Specification
BPE	Building Performance Evaluation	NHBC	National House Building Council
BPEC	British Plumbing Employers Council	Operatives	The term operatives has been used throughout this report to refer to trades and those individuals involved in technical applications of construction elements, such as groundworkers etc.
BR443	The document setting out the conventions that govern U-value calculations	Part L	In the context of this report, this refers to Part L1a of the Building Regulations, which deals with the energy efficiency requirements for new dwellings
BR497	The document setting out the conventions that govern Psi-value calculations	Psi-value	A measure of heat loss associated with non-repeating thermal bridges at junctions between different element types (measured in W/mK)
BRE	Building Research Establishment	QA	Quality Assurance
CIAT	Chartered Institute of Architectural Technologists	R&D	Research and development
CIBSE	Chartered Institution of Building Services Engineers	RIBA	Royal Institute of British Architects
CIOB	Chartered Institute of Building	RICS	Royal Institution of Chartered Surveyors
CITB	Construction Industry Training Board	Robust Details	A scheme offering an alternative to pre-completion sound testing for meeting Part E requirements
CPA	Construction Products Association	SAP	Standard Assessment Procedure, the methodology and tool which is used to check compliance with Building Regulations Part L1A
CPD	Continuing Professional Development	SMEs	Small and Medium Enterprises
DCLG	Department of Communities and Local Government	TSB	Technology Strategy Board
DECC	Department of Energy and Climate Change	UKAS	United Kingdom Accreditation Service
DER	Dwelling Emission Rate	U-value	A measure of heat loss through a building element (measured in W/m ² /K)
DOCEA	Domestic On Construction Energy Assessor (SAP assessor)		
DPC	Damp Proof Course		
EPC	Energy Performance Certificate, required when a home is sold or leased		
EPSRC	Engineering and Physical Sciences Research Council		
FETA	Federation of Environmental Trade Associations		
HBF	Home Builders Federation		
HCA	Homes and Communities Agency		

APPENDIX A: ISSUES LIST

REF	WHAT MIGHT BE HAPPENING TO CREATE THE PERFORMANCE GAP?
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.
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).
P3	Inconsistent setting of standards and targets between local authorities (methodology and/or level) leading to increased complexity of solutions.
P4	Limited guidance, modelling tools and standards available to evaluate and review issues associated with energy performance at early design stages, including overheating.
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.
D2	Lack of integrated design between fabric, services, renewables and other requirements, e.g. due to lack of specialist input.
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.
D4	Lack of suitable design tool that incorporates compliance check.
D5	Design team not communicating sufficient information regarding critical energy performance criteria of components to procurement team.
D6	Insufficient design information provided for building fabric, potentially leading to critical decisions being left to contractor/sub-contractor at construction phase.
D7	Insufficient design information provided for building services, potentially leading to critical decisions being left to contractor/sub-contractor at construction phase.
D8	Product and system design issues, e.g. concerns about robustness of product design, systems design issues.

REF	WHAT MIGHT BE HAPPENING TO CREATE THE PERFORMANCE GAP?
PROCUREMENT	
PR1	Manufacturer information lacking critical energy performance detail, relating to either building fabric or services.
PR2	Inadequate consideration of skills and competency requirements at labour procurement (fabric & services).
PR3	Product substitution at procurement without due regard for performance criteria.
PR4	Procurement team lack of understanding of critical energy-performance related criteria.
PR5	Tender documentation not containing up-to-date requirements or trade specifications.
CONSTRUCTION AND COMMISSIONING	
C1	Lack of designer input available to site if issues arise, e.g. due to type of contract.
C2	Sales or year-end/interim build targets driving programme delivery - putting labour out of sequence and potentially compromising construction quality.
C3	Frequently changing site labour limiting ability for lessons to be shared or learnt.
C4	Construction responsibilities for energy performance unclear, lack of collaborative working, e.g. services penetrating air barrier.
C5	Product substitution on site without due regard for impact on energy performance.
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.
C7	Lack of understanding in sales team of impact of changes, e.g. customer add-ons which affect SAP.
C8	Lack of ability to identify some products on site/in situ, e.g. by operatives or for QA or audit purposes.
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.

REF	WHAT MIGHT BE HAPPENING TO CREATE THE PERFORMANCE GAP?
-----	--



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



Full design information or installation guidance produced but not available on site.



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



Lack of site team energy performance related knowledge and skills and / or care.



Accredited Construction Details 'tick box' culture, i.e. recorded in SAP but not built on site.



Poor installation of fabric, e.g. due to installation guidance or design drawings not followed.

VERIFICATION



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



Lack of robust energy-performance related verification, reliance on third-party information (e.g. by Building Control or warranty providers).



Commoditised third-party schemes not independent or checks not adequate (including Competent Persons Schemes).



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



Lack of clarity over documentary evidence required or acceptable for Part L and Part F compliance.

TESTING



Limited tests and agreed protocols available for in-situ fabric performance measurement.



Limited tests and agreed protocols available for in situ services performance measurements, including for system performance.



Concern over consistency of some test methodologies and interpretation of data and guidelines.



Limitations of air-pressure testing methodology (QA, robustness of third party certification, protocols).

REF	WHAT MIGHT BE HAPPENING TO CREATE THE PERFORMANCE GAP?
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Lack of suitable end-of-line overall performance test to validate energy calculation models, products and building fabric.



Tests not replicating or accurately taking into account dynamic effects, e.g. solar gain, microclimate, wind speed, weather effects.



Limited tests and agreed protocols for innovative/less mainstream products and services.

ENERGY MODELLING TOOLS AND CONVENTIONS



Commercial pressures leading to optimistic SAP input assumptions.



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.



SAP conventions not adequate, comprehensive or reflective of site conditions.



As-Built SAP not reflective of actual build.



Lack of transparency and clear outputs for verifiers to check modelling assumptions (including designers to verify material performance assumptions, BC and others).



Infrequent or insufficient audits of SAP assessors by licensing organisations.



Concern over competency of SAP assessors (accuracy of data input, following of conventions, validation of assumptions, provision of design and specification advice).



Issues surrounding use of calculation procedures in BR443 (U-values) and BR497 (Psi-values) or associated Standards.



Limited as-built test data used in SAP calculations (only air-pressure testing).



Limited ability to include new technologies in SAP calculations.



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

APPENDIX B:

EVIDENCE UPDATE

Since the publication of the Evidence Review Report in March 2014, further evidence has been gathered and analysed.

This Appendix summarises the findings, with a full update planned later in 2014. The new evidence includes:

- A continuation of the *Housebuilding Process Review* presented in the *Evidence Review Report*, with an additional 12 sites reviewed, taking the total to 21 sites. The focus of this update is on the findings from the additional sites. It also includes further assessment of some of the sites in the form of:
 - Further SAP Audits of 18 plots across 10 of the sites, taking the total to 26 plots audited across 14 sites. Updated findings are presented, covering results from all of the sites.
 - Costing analysis undertaken to estimate the impact of correcting some common errors observed on site, based on SAP modelling estimates of the potential energy savings.
 - Testing: ‘forensic’ airtightness testing undertaken in combination with thermal imaging and smoke tests on 20 plots across 10 of the sites to assess the impact of variability in air pressure testing methods. Along with further thermal imaging undertaken on 10 plots across five sites, this also provided supporting evidence for some of the *Housebuilding Process Review* findings. A ‘round robin’ airtightness testing assessment was undertaken on six plots across two sites, with tests being carried out by up to five companies on each plot to investigate the impact of variability between testers.
- A SAP Sensitivity Analysis investigating the impact of potential variation in SAP inputs. The summary presented here updates and provides more detail on the initial results presented in the *Evidence Review Report*.
- Further analysis of eight of the TSB Building Performance Evaluation Domestic Phase 1 projects, which were included in the Literature Review in the *Evidence Review Report*.

Housebuilding Process Review Update

A '*Housebuilding Process Review*' has been undertaken to identify and gather evidence on issues occurring on housebuilder development sites that may contribute to the Performance Gap.

In total 21 sites have been reviewed, with approximately 200 plots assessed. Evidence from the first nine sites reviewed was presented in the *Evidence Review Report* and supporting appendices.¹ This Appendix includes the results from the additional 12 sites which have been reviewed since. These additional sites include a wider range of construction methods, with concrete and steel frame construction, as well as timber and masonry. In addition there was also an increase in the variety of insulation types used, with rigid board insulation used less commonly on the additional sites and both blown insulation and mineral wool batts being used. More smaller-sized sites were included than in the initial review. The additional sites also included greater use of bespoke designs. All sites were built under 2010 Building Regulations, some with additional planning requirements.

Evidence was collected by a review team in three stages: interviews with design teams, SAP assessor, procurement team and construction team; a design review to provide an understanding of the design and construction methodology; and finally a site visit to review plots at each stage of the build process where possible. The review team recorded their findings in pre-prepared assessment sheets covering key assessment items that could contribute to the Performance Gap.

It is important to note that the findings given below are based on preliminary analysis and that a more detailed assessment will be carried out and disseminated at a later stage. The findings have been presented in the same format as that used in the *Evidence Review Report* to allow easy comparison with findings from the initial sites.²

Summary Update of Housebuilding Process Review Interview Findings

Planning and Concept Design

All of the issues observed in the *Evidence Review Report* at this stage were supported by findings on the additional sites. This included a lack of feedback to concept design teams on the potential impacts of their decisions on the detailed design stage and on buildability. However, confusion about energy targets was not mentioned to the same extent as on earlier sites. On sites using bespoke designs, the lack of specialist and site team involvement at this stage and lack of effective handover also generally seemed to be slightly less problematic as there was often more focus on maintaining continuity, *for example through use of the same team at concept and detailed design, concept design teams being given a 'watching brief' role, and involvement of specialists and site teams at an earlier stage.* However, further analysis needs to be carried out to investigate the impact of this.

1. Zero Carbon Hub, *Closing the Gap Between Design & As-Built Performance: Evidence Review Report, March 2014.*

2. For more information on the findings for the initial nine sites and on the methodology used please see the *Evidence Review Report* appendices.

Detailed Design

Many of the issues that were noted in the *Evidence Review Report* have been substantiated by the interviews for the additional sites reviewed. *For example, interviewees commented on SAP assessors not being informed of changes to the design, lack of feedback from site teams, timescales for the design process being too short, and a lack of consideration of overheating.* Some issues that were flagged up in the *Evidence Review Report* were felt to be less of an issue on the additional sites, although it is important to note that there were more bespoke sites visited and the differences were found primarily on these sites. In common with concept design teams, on several sites interviewees reported less problems with handover though some still noted significant issues; and several of the bespoke sites had more SAP assessor involvement and some had site team involvement at the design stage, though again further analysis needs to be carried out to investigate the impact of this.

SAP Assessment

The *Evidence Review Report* noted potential issues with how assessors were verifying the information used to calculate the As-Built SAPs, with many assessors accepting a sign-off from a technical manager or member of the design team rather than a site manager or equivalent. This theme was also found on the additional sites visited with some assessors suggesting that changes made on site would generally not be fed back to the technical team and on to them, and that not enough time is given to correctly update the SAP inputs at the As-Built stage. On the additional sites it was also found that most assessors used default values for window g-values, corroborating the findings in the *Evidence Review Report*. The *Evidence Review Report* also identified the competency of some assessors as a potential issue contributing to the Performance Gap - *for example, their ability to recommend compatible components and their rigour in checking assumptions.* It was found that the checking of information relating to both U-values and Psi-values remained an issue on the additional sites although lack of information provision may have also contributed to this.

Procurement Review

Overall the findings on the additional sites visited correlated quite closely with the findings in the *Evidence Review Report*. One of the most prevalent issues was the g-value not being used by the purchasing team to procure the windows. Possible causes might include a lack of full information from design teams, or the procurement team not understanding the importance of the value and so disregarding it when making purchasing decisions. Other issues noted in the *Evidence Review Report* were further substantiated to varying degrees on the additional sites, including some instances of unclear or limited communication and handover, and evidence of limited consideration of energy-related skills. As on previous sites, there was a lack of awareness of schemes such as BPEC and MCS. Most procurement teams again said that they would always report product substitution proposals - either directly to the technical team or at meetings.

Construction

The findings for the additional sites reviewed quite closely reflect the findings outlined in the *Evidence Review Report*. Issues commonly raised included site teams not being involved in signing off specifications for As-Built SAPs, site managers feeling that their job was to overcome problems on site rather than to refer them to the technical team, and

design information missing on site or not fully complete before the start on site. Potential issues were noted during the interviews relating to a lack of energy-related knowledge, varied levels of understanding of the 'air barrier' and a lack of feedback and interaction with the design team, as was found on the previous sites. However on two of the additional sites where bespoke designs were used the site managers were involved early in the design process, though more work needs to be done to investigate the impact of this. Interviewees provided fewer comments on the QA process than in previous interviews though it was found that a few sites did not have a written log book on site.

Summary Update of Housebuilding Process Review Site Visit Findings

Build Stage 1: Sub-Structure

The additional sites reviewed further substantiated all the issues highlighted in the **Evidence Review Report**, including trench block substitution, insulation missing below the DPC and door thresholds bridging cavities. The types of issues occurring tended to be consistent across sites and build types; with some new examples including a timber frame not fitting correctly on top of the foundation block work, creating an overhang to the cavity.

Build Stage 2: Oversite

Very few differences were found on the additional sites when compared to the findings of the **Evidence Review Report**. The sealing around services at this stage was again generally fairly good at this stage. Proprietary insulated floors were generally found to be poorly installed (*for example with gaps at the perimeter and between blocks of insulation*), perimeter insulation was often the incorrect material and/or was poorly installed, and screed was often noted to 'bleed over' the perimeter insulation as well as in several cases bridging the cavity. The installation quality of horizontal floor insulation was also a more prevalent issue than found on previous sites. These findings were supported by the thermal imaging carried out as part of this project, where heat loss was indicated around the perimeter of the ground floor.

Build Stages 3 and 4: Oversite to Joist, Joist to Roof

On all the sites where timber frame construction was used, the findings again supported those found previously. *For example, it was found that the incorrect timber fraction was used in U-value calculations on all the sites where this could be checked, with the default being assumed but significantly more timber being used on site.* In some cases poorly installed or missing sole plate insulation and damaged low-emissivity breather membranes were also observed.

On the sites where masonry construction was used, the issues observed also tended to be similar to the sites included in the **Evidence Review Report**, including dirty cavities and cavity closers not fitting tightly (often as a result of inconsistent cavity widths). As on previous sites, it was found that where joists were not on hangers they were often not fully pointed up; and thermal imaging testing indicated heat loss around joists which is likely to be due to air leakage.

Some of the additional sites reviewed included blocks of flats which used different construction methods than those on the sites included in the *Evidence Review Report*: concrete frame and steel frame. The cavity wall issues noted above for masonry sites were also observed on some of these sites, but additional issues were also found. Often these related to the U-value and Psi-value calculations. In particular, it was observed that the use of Metsec was not reflected well in the U-value calculations – *for example, double sheets of Metsec were used on site but not included in the calculations, or the amount of concrete observed on site was not accounted for.* On one site, Accredited Construction Detail (ACD) Psi-values were assumed for a concrete frame and Metsec construction, although ACDs do not exist for this construction method. Steel beams creating unaccounted for thermal bridges were also commonly observed on these sites, and in one case a thermal bridge was noted where floor slabs were continued through walls to create balconies.

Whilst the majority of the previous sites used rigid insulation, this was used less commonly on the additional sites – where it was used, there were examples of good practice but also some issues with gaps between boards and around openings, as seen on previous sites. A different issue was observed on the additional sites where blown insulation was used: it was observed that drill patterns were not always consistent or likely to allow insulation to be installed around difficult to access areas such as cavity closers and meter boxes. This was also observed at later build stages.

For all types of construction, issues were observed on the majority of the sites relating to party walls: in particular the insulation was often not tightly packed in the cavity and edge seals were often of the wrong type or incorrectly installed. During thermal imaging testing heat loss was indicated through the edges of party walls. As found on previous sites, substitution of lintels was common, and problems with delivering bay window and internal garage detailing were also observed. Heat loss at complex details was also indicated by the thermal imaging testing.

Build Stage 5: Roof to Weathertight

The three main issues highlighted in the *Evidence Review Report* for this build stage have been well supported on the additional sites reviewed: windows and doors being installed forward from their design position resulting in insufficient overlaps with cavity closers leading to greater heat loss from thermal bridging, the tolerances around windows and doors being considerably out which would lead to increased heat loss from thermal bridging, and installed doors and windows varying from the design (most commonly, window g-values varied, but window or door U-values also commonly varied). Where thermal imaging testing was undertaken it also highlighted heat loss around windows and doors.

Build Stage 6: First Fix

Generally all the issues found in the *Evidence Review Report* at this build stage were found on the additional sites reviewed: service penetration sealing was often not done well and staircase strings were not always packed out and sealed. Thermal imaging testing also showed heat loss around some external services, indicating air leakage.

Build Stage 7: Drylining

At this build stage again there were few differences noted on the additional sites compared to those included in the *Evidence Review Report*, with instances of plane ceiling insulation not being correctly fitted or matching the design, insulated boards on the soffits of openings missing and external penetrations not being fully sealed. A continuous ribbon of adhesive was not generally being achieved around plasterboards, with gaps commonly occurring at internal corners and around openings – this was also found on previous sites. The air tightness ‘forensic’ testing also indicated significant air leakage from behind the plasterboard on the majority of sites where testing was carried out. The thermal imaging also indicated heat loss which is likely to be associated with the poor installation of the roof insulation that has been observed on several sites.

Build Stage 8: Second Fix

The additional sites reviewed further substantiated the issues described in the *Evidence Review Report*, in particular missing skirting and inconsistent sealing behind kitchen and bathroom units were observed and these were also highlighted as areas with a high degree of air leakage during the air tightness ‘forensic’ testing. Analysis of the air tightness forensic testing results suggested that the second fix installation may be disturbing the air barrier. As on the earlier sites, on some of the additional sites it was found that there were differences between the mechanical and electrical system designs and the installed systems, including changes to ducting layouts (with excessive bends and length and supply inlets and extract outlets installed too close together) and different or missing heating controls.

Build Stage 9 and 10: Finals and Build Complete, Testing and Commissioning

As was found on earlier sites, plane roof insulation was commonly observed to have been disturbed post-installation leaving some gaps, and the insulation was also not always properly cross-lapped. Other issues further supported by the additional sites included doors not being trimmed to match the ventilation design requirements, Domestic Ventilation Compliance Guide checklists not being available on site, the misuse or poor application of mastic, and customer extras not being accounted for in As-Built SAP calculations.

Summary of SAP Audit Findings

For 26 plots across 14 of the sites visited as part of the *Housebuilding Process Review*, the SAP assessment has been reviewed, based on design information and observations recorded during the site visits. The draft results from four of the sites were included in the *Evidence Review Report*. The updated findings including results from all of the 14 sites audited are described here.

It was not possible to undertake audits for all the sites visited as part of the *Housebuilding Process Review*, as some sites were not sufficiently far progressed at the time of the site visits – this has meant that the majority of the sites for which SAP Audits were undertaken are larger developments where plots close to completion could be seen. Most of the plots audited were semi-detached or detached houses, with some mid-terraced houses and flats. In addition, most were of traditional masonry construction, but

some timber and concrete frame plots were included. Seven of the plots included photo-voltaic panels; 17 were naturally ventilated, seven had mechanical extract ventilation (MEV) and two had mechanical ventilation with heat recovery (MVHR). All plots had a gas heating system, the majority with regular condensing boilers and hot water cylinders.

Two stages of audits were undertaken for each plot:

- **Stage 1:** A review of the original SAP assessment done by the developer's SAP assessor.
- **Stage 2:** A SAP assessment based on site visit observations, compared to the corrected audit from Stage 1.

Differences found during both stages of the audit were evaluated in terms of the change to the DER in absolute percentage terms (i.e. no matter whether the change was positive or negative). Where available, original As Built SAPs were used (12 plots) but construction on some of the sites was not complete, so in these cases (14 plots) Design Stage SAPs were used instead. The **Evidence Review Report** should be referred to for more detail on the methodology used and the assumptions made.

Stage 1 of the SAP audit found errors in the original SAP assessments in all cases. The errors found are summarised below. On average across all the plots audited, an absolute DER deviation of 14% was found.

SAP ENTRY AREA	FREQUENCY OF DEVIATION (% OF PLOTS)*	AVERAGE ABSOLUTE DER DEVIATION (%)	ERROR EXAMPLES
Orientation	15%	0.7	Orientation incorrect by 45°
Sheltered Sides	38%	0.8	Incorrect by 1 sheltered side (usually 1 too many)
Measurements	92%	6.1	Storey height and wall areas; wall, floor, roof type, window/glazed door identification; total floor area
U-values	100%	1.6	Wall, floor, roof type, window/glazed door identification errors; corrections not applied
g-values	42%	1.0	Use of SAP defaults instead of specified values; specification missing g-values; use of incorrect sources for values
Thermal Mass	88%	1.6	Incorrect calculated values; use of incorrect default; differences between default and calculated values (thermal mass usually higher when calculated than default 'low' value assumed). Note that defaults are allowed by SAP Conventions so this latter finding is not an 'error' as such, but perhaps highlights an area where Conventions could be updated.
Linear Thermal Bridging	88%	2.7	Not accounting for different constructions for a particular junction; errors in treatment of dormers and bay windows; inappropriate use of sets of Psi-values for constructions they do not apply to.
Ventilation	38%	1.1	Incorrect number of extract fans
Heating System	58%	2.9	Incorrect boiler size/type/efficiency; incorrect cylinder type; incorrect controls; omission of secondary heating
Low and Zero Carbon Technologies	14%	1.2	Incorrect PV pitch

* Note: the percentage of plots is out of the total 26 plots in all cases except for low and zero carbon technologies present where it is out of the total plots with these technologies present (seven).

Stage 2 of the SAP Audit found that in all instances changes were occurring in constructed dwellings that were not reflected in the SAP assessments. The discrepancies found are summarised in the table below. On average across all the plots audited, an absolute DER deviation of 14% was again found. It should be noted that given various constraints of the project, it was not possible to check all parts of the SAP assessment when on site.

SAP ENTRY AREA	FREQUENCY OF DEVIATION (% OF PLOTS)*	AVERAGE ABSOLUTE DER DEVIATION (%)	ERROR EXAMPLES
Measurements	27%	1.5	Storey height and wall area errors; door/window identification errors
U-values	92%	3.8	Incorrect opening U-values; window/door errors; corrections not applied; incorrect timber frame fraction; reduced roof insulation found on site; party walls not correctly fully filled / sealed (biggest impact); floor block substitutions
g-values	96%	1.3	Incorrect g-values (usually default used but value lower on site, i.e. worse)
Thermal Mass	19%	0.4	Substitution of dense block in party wall increasing thermal mass
Linear Thermal Bridging	92%	7.1	Lintel substitution; lack of continuity of insulation at eaves/wall junction and between joist and gable walls; inner leaf block substitution and insulation missing/bridged at wall/ground floor junction; change in opening overlap with cavity closer; missing cavity closers
Ventilation	4%	2.3	Additional flue for secondary heating found on site
Lighting	19%	4.0	Incorrect low energy lighting percentage (e.g. 100% assumed but 75% found on site)
Heating System	35%	1.7	Weather compensator missing on site; incorrect cylinder heat loss; primary pipework not insulated; secondary heating added
Low and Zero Carbon Technologies	14%	9.9	Incorrect PV overshadowing (none assumed but overshadowing found on site)

When the combined errors from Stage 1 and Stage 2 are taken into account (i.e. Stage 2 findings are compared to the original uncorrected SAP assessment), the deviation becomes even more significant: on average an absolute DER deviation of 26% was found.

Summary of Costing Assessment

Information from the site visits and SAP audits was used to identify some common examples of errors and differences observed between designed and as built dwellings which could be modelled in SAP. This modelling was undertaken to provide a rough indication of the relative impact of each item on energy performance, as assessed by SAP.

This was used to inform an assessment of the estimated financial, energy and carbon savings that might be expected if these differences or errors were corrected. The results from the modelling are presented in the table below.

ERROR/DIFFERENCE	SAP VARIABLE	FUEL	ENERGY SAVING (KWH/YR)	CARBON SAVING (KGCO ₂)	FINANCIAL SAVING (NPV £)	ANNUAL SAVING (£/YR)
Block substitution in inner leaf of wall at ground floor (dense block instead of aircrete)	Ground floor/wall junction Psi-value	Gas	110	440	80	5
Window overlap	Window/wall junction Psi-values	Gas	65	260	50	3
Lintel substitution (continuous perforated instead of split)	Lintel/wall junction Psi-value	Gas	140	550	100	6
Weather compensator	Excluded / included	Gas	120	470	85	5
Lighting substitution (high energy instead of low energy)	75% instead of 100% low energy	Electricity	100	1025	225	14
		Gas	-20	-80	-15	-1
Window substitution	g-value	Gas	210	835	155	10
Timber frame fraction (36% instead of 12%)	U-value	Gas	520	2055	375	23
Party walls not fully filled and sealed	U-value (0.2 assumed)	Gas	660	2620	480	30
Partial fill insulation poorly installed	U-value (air-gap correction level only)	Gas	325	1275	235	15
Roof insulation specification change (100mm less insulation)	U-value	Gas	285	1135	210	13
PV overshadowing	Overshading level 'modest' not 'none/very little'	Electricity	155	1625	350	22

It is important to note:

- The energy saving estimates are based on the estimated impact in SAP and a 'typical' scenario based on the site visit findings.
- The energy saving modelling was constrained by data availability, and the variables that could be changed in SAP or in U-value calculations were limited without undertaking detailed analysis to assess the impact of changes – so it is unlikely that the full impact of the changes are reflected in the modelling carried out.
- The base case model used was the Zero Carbon Hub's standard semi-detached house type, 2010 compliant with a gas boiler and natural ventilation.
- A 20 year timeframe and a discount factor of 3.5% have been used for the financial assessment. The discount factor was chosen as this is the standard value used by government to conduct financial analysis.
- Energy savings and carbon factors are assumed constant over time.
- Future energy price predictions were based on DECC central projections.
- No changes to capital or labour costs have been assumed. Though some of the changes modelled may have capital or labour cost implications, *for example where one product is substituted by another or omitted entirely, it was considered that the costing of the development should be assumed to have allowed for what was included in the design specification.*
- Figures have been rounded to avoid a false impression of accuracy.

Summary of Testing Findings

'Forensic' Air Pressure Testing

'Forensic' air pressure testing was undertaken to investigate the potential impact on results when the air pressure test is conducted in different ways. 10 sites were included in the analysis with two dwellings tested per site.

Air pressure tests were undertaken for each dwelling with four variables examined to determine their impact on the test results: closing / opening of trickle vents, sealing / unsealing of ventilation systems (trickle vents and extract fans), front/back door positioning of equipment, and use of pressurisation / depressurisation method. The current approved test procedure for Building Regulations requires trickle vents and other controlled ventilation systems to be closed and sealed, but allows either option to be chosen for the other variables.

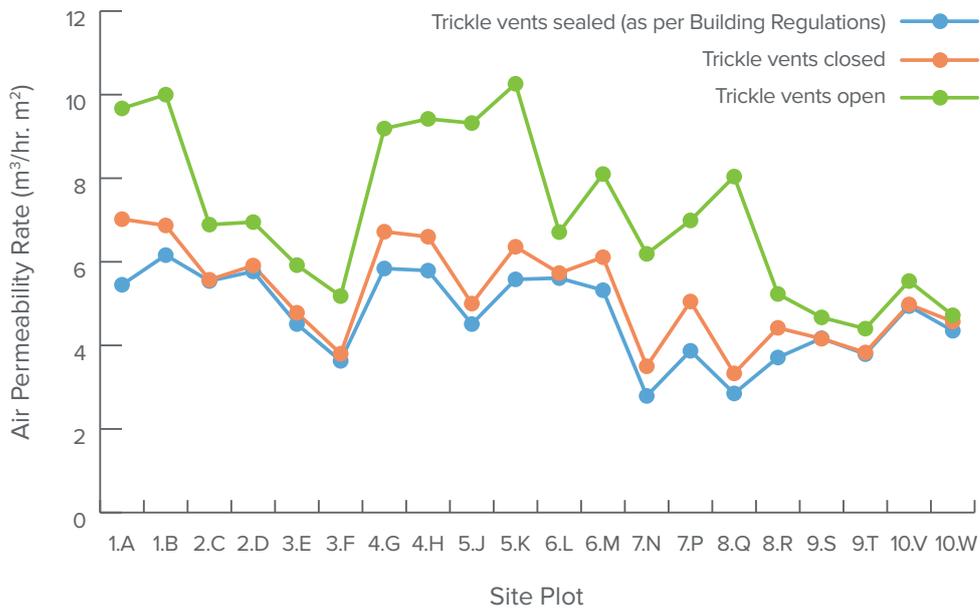
In addition, air leakage paths in the test dwellings were investigated using thermographic surveys, smoke pencil tests and full dwelling smoke tests – some of the findings from these tests are included under the 'Site Visit' section.

The design air permeability rates of the sites under assessment ranged from 4.5 to 6.0 m³/hr.m²@50 Pa (with one site with a target of 7 when including provision for the plus 2 penalty for not testing all units). The results of the forensic testing showed that nearly all units were below their design air permeability rate, with results between 2.8 and 6.2 m³/hr.m²@50Pa and with only one instance of a test result above the design rate. However, there were a number of instances where dwelling test results were significantly lower than their target, *for example with one site achieving a result of 2.9 against a target of 5.5*. The test dwellings were all naturally ventilated and units with air permeability rates below 3.0 m³/hr.m²@50 Pa with significantly higher design targets may be at risk of being under-ventilated.

The study found that the biggest variance from the standard Building Regulations test procedure was with trickle vents open, with 75% of the dwellings seeing an increase of over 1 m³/hr.m² air permeability rate – as shown in the graph below. At the extreme end three of the properties recorded an air permeability rate that was double the rate recorded under the standard test procedure, with increases of around 4 m³/hr. m²@50Pa. It should be noted that leakage associated with trickle vents and other forms of controlled ventilation is not included in the Building Regulations approved procedure as they are not considered background ventilation. SAP calculations do include trickle vents in the form of a default effective ventilation rate, which is based on typical user behaviour. If tests were undertaken with the trickle vents open, in contravention of the approved procedure, it would have a significant impact on results.

The effect of unsealing the ventilation system and unsealing closed trickle vents was considered to be less significant, with increases in air permeability rates for each case generally below 0.5 m³/hr.m². The differences between measuring from the front and back door were, as a percentage, less than 10%, and generally less than 5%. This would indicate that the choice of test doorway does not have a significant effect on the result obtained. The results also indicated that for the dwellings tested the choice of using a de-pressurisation or a pressurisation method was also not significant. However, it should be noted that at higher or lower air permeability rates than those of the sample the impact may be more pronounced.

Figure 1. Air permeability rates for Trickle vents open, closed and sealed



Note that Site/ Plot designation does not relate to notation used in other sections of this Appendix.

'Round Robin' Air Pressure Testing

A 'round robin' assessment was undertaken to investigate potential variation in Building Regulations air pressure test results, undertaken at the same stage on the same dwelling by different companies. Two development sites each provided three plots to test, with up to five companies performing a Building Regulations air pressure test for each plot. The assessment replicated a standard air test as the developers' organised the tests in the usual way – the only instruction was to complete a test for Building Regulations compliance. The testing companies were not aware that the plots had been tested by other companies and the results were compared to the original air pressure tests for each site which had actually been used for Building Regulations compliance. All the 'round robin' tests on the same units were carried out when the dwelling was at the same stage of completion/finish and within the space of eight days on one site, and 15 days on the other.

The round robin assessment recorded significant differences in air permeability values measured on the same test unit. The largest variation recorded was between 4.7 and 7.1 $\text{m}^3/\text{hr.m}^2@50 \text{ Pa}$; another plot (on the other site) had a similar magnitude of variation, ranging from 3.7 to 5.6 $\text{m}^3/\text{hr.m}^2@50\text{Pa}$. Whilst some variation in results is to be expected it is felt that these differences are outside acceptable limits. Due to the nature of this exercise it is not possible to ascertain which of the results is closest to the actual air permeability. However, the fact that there are such large differences in the recorded results is concerning.

The tests were undertaken in close succession and so it is felt that the differences due to ageing effects are unlikely to be significant. External conditions can impact on results, and the level of information provided by the testers on this varied considerably and would not account for all effects, making it difficult to draw conclusions. It is noted that testing companies are no longer required to record the wind speed experienced during air pressure tests. Equipment error is another possibility and whilst testing companies are required to calibrate their equipment each year in order for it to be compliant, not all companies provided the full information on equipment calibration. A more probable cause of the differences in results observed could be the assumptions made by the testers: *for example one company in particular recorded significantly different measurement assumptions from the others.* The information provided by the testers on measurements necessary to calculate the air permeability ranged from the floor area, surface area and volume all being provided to no measurements provided at all. The majority of testers reported the total surface area only.

In relation the choice of testing under either depressurisation or pressurisation, the favoured approach of the testers in the 'Round Robin' assessment was to test under depressurisation, with all companies who provided testing methodologies choosing this method. Whilst the 'Forensic' testing showed relatively small differences in the air permeability between these methods (less than 0.3 m³/hr. m²) the rates were generally lower under depressurisation than pressurisation in the sample. This might suggest that commercial testers may prefer the depressurisation approach as it is more likely to give a 'favourable' result.

A summary of some of the key results from the testing is included in the tables below.

Site A

PLOT	COMPANY	AIR PERMEABILITY (M ³ /HR.M ² @50PA)	ENVELOPE AREA (M ²)
1	1	4.4	330
1	2	6.0	348
1	3	4.2	Not Supplied
1	4	6.0	347
2	1	4.6	330
2	2	5.0	348
2	3	4.0	Not Supplied
2	4	6.1	347
3	1	4.7	292
3	2	7.1	305
3	3	4.9	Not Supplied
3	4	6.9	291

Site B

PLOT	COMPANY	AIR PERMEABILITY (M ³ /HR.M ² @50PA)	ENVELOPE AREA (M ²)
A	A	5.2	378
A	B	4.7	384
A	C	5.1	375
A	D	3.9	526
A	E	5.3	370
B	A	4.1	315
B	B	3.7	306
B	C	3.9	303
B	D	5.6	313
B	E	4.1	301
C	A	6.0	197
C	B	5.5	197
C	C	5.3	199
C	D	5.5	210
C	E	5.4	204

Thermal Imaging

Thermal imaging surveys were undertaken on 10 plots across five sites. It is important to note that thermal imaging is not a quantitative assessment method. However, by analysing the thermal imaging surveys in the context of the observations made on the site visits and findings from the air leakage path investigation undertaken as part of the forensic airtightness testing, confidence can be gained as to where problems are occurring.

Issues corroborated by the thermal imaging surveys included:

- Lack of continuity of insulation, in particular when fitting loft insulation and when insulation has not been well installed at the junction between walls and ceilings. These issues are compounded as they allow cool air to flow over the uninsulated areas;
- Air leakage around joist ends and at service penetrations such as boiler flues and pipes;
- Thermal bridging around lintels and other window details and at the perimeters of ground floors;
- Party wall heat loss potentially indicating an opportunity to improve party wall detailing including air tightness.

Similar issues have been identified in many other projects where building performance evaluation has been undertaken, indicating that specific design and construction improvements need to be identified for these common details.

The Sensitivity of SAP to Input Discrepancies

Description of analysis

Analysis has been undertaken to consider the impact on the Dwelling CO₂ Emission Rate (DER) when a SAP input is used that does not match what is built. Several important limitations of this study should be noted:

- Not every possible input discrepancy could be considered, so some may be under-represented or omitted completely.
- Certain discrepancies will affect a larger proportion of new homes, so are of more importance at a national level. This proportion was based on the expert opinion of the Design & Assessment Tools Work Group, but universal agreement was not reached.
- An 'importance score' was calculated for each discrepancy (DER impact multiplied by proportion of new homes affected).
- Individual results depend on specific assumptions which in practice may vary greatly, so this analysis should be treated as a series of examples.

Key Findings

The three most important SAP input discrepancies appear to be:

- 1. Community Heating Distribution Losses:** Tabulated values and default assumptions were considered to be too generous, providing little incentive for assessors use a more carefully derived figure. The impact on DER of a discrepancy can be huge; with documented cases where well over half of the heat from boilers is lost en-route to homes.³
- 2. Wall U-Values:** DER is very sensitive to wall U-value and there was judged to be a high chance of a discrepancy between the wall U-value input and the as-built value. If there are gaps large enough to allow cold air to circulate behind insulation, a nominally insulated wall could perform similarly to an uninsulated one, potentially resulting in a rate of heat loss several times worse than calculated.
- 3. Thermal bridges:** Thermal bridge input discrepancies are likely to be both multiple and very common; *for example, accredited values may tend to be used where in fact default values should be.* In combination, these can make a significant difference to the DER and therefore this is seen as another important area of potential discrepancy.

Other areas found to be important were inputs relating to window performance, over-shading, roof U-values, proportion of low energy lights, air permeability and photovoltaic power rating. It is also clear that discrepancies relating to dimensions, especially those which affect floor area, can have a large impact on DER. In combination, the input discrepancies identified have the potential to approximately double the DER of a dwelling. In attempting to close the performance gap it is therefore critical to ensure these SAP inputs match what is actually built.

More detail on this work can be found in Appendix H.

3. E.g. www.pam.ealing.gov.uk/PlanNet/documentstore%5CDC11123716-107-1_AF_A.PDF

Summary of TSB Building Performance Evaluation Project Analysis

The *Evidence Review Report* included a Literature Review which, alongside other publications, covered all the available reports from the first phase of the Technology Strategy Board's (TSB) domestic Building Performance Evaluation (BPE) programme. Since the *Evidence Review Report* was published, the Zero Carbon Hub has been further analysing eight of the TSB BPE Phase 1 projects, to better understand the issues which contribute to creating a Performance Gap.

The findings from the reports have been assessed against the issues identified in the *Evidence Review Report*, which include problems potentially arising at all stages of the development process. This approach has provided a structure for comparison across the projects that could also be used for future building performance evaluation, both for informing evidence-gathering, and for evidence analysis by providing a means of identifying and categorising common themes.

Analysis is still underway and initial findings demonstrate examples of both good and bad practice, providing very useful current information on Performance Gap issues. Some initial findings included:

- **Planning** - Most projects had specific environmental performance targets set for them at the initial planning stages and these were dealt with at a preliminary stage by the initial design team. Their successful translation was significantly dependent on the continuity of this team into detailed design stages.
- **SAP assessment** - The role of the SAP assessor and the degree of their influence and involvement varied significantly across the projects.
- **Detailed design** - The contract type for projects significantly determined the cohesion with which the design team members worked. Where several sub-contractors were appointed there was a greater need to identify a designated person with responsibility for ensuring that the energy requirements were not undermined due to changes in design and specification. There were examples of good understanding of the specialist knowledge and skills needed to incorporate innovative processes and systems.
- **Procurement** - Several anomalies were observed between the specific systems designed and those procured. This was due to a combination of lack of adequate ownership of ensuring the energy efficiency of the product and a lack of familiarity within the team to meet the design intent.
- **Construction and site coordination** - Projects where the initial environmental targets were tied in with a critical control over the construction processes, like those targeting Passivhaus standards, were the ones where there was more effective site management. These also generally tended to be smaller scale projects.
- **Modelling and testing** - There was significant variation between tested and monitored energy performance indicators and modelled performance.

The detailed information from these developments will contribute to the full evidence review update later in 2014.

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