ZERO CARBON HUB

CLOSING THE GAP BETWEEN DESIGN AND AS-BUILT PERFORMANCE

NEW HOMES

INTERIM PROGRESS REPORT

July 2013

The Zero Carbon Hub was established in 2008 to support the delivery of zero carbon homes from 2016. It is a public / private partnership drawing support from both Government and the Industry and reports directly to the 2016 Taskforce.

To find out more, or if you would like to contribute to the work of the Zero Carbon Hub, please contact:
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Foreword

The Zero Carbon Hub should be congratulated. Firstly, for assembling the large number of industry specialists who have volunteered their time to contribute to the Work Groups and secondly, for bringing the wide range of opinions and experiences together in this report. In any housing development, even a modest infill of two or three houses, there will be a long sequence of transactions, decisions, processes and approvals, from the initial acquisition of land to the final hand-over of homes to the customer. At each stage of this process there is potential for the intended performance to be compromised, creating a 'performance gap'. This report highlights the significant role that bodies, who both directly and indirectly influence housing supply, can play in minimising the performance gap. These bodies include policy makers, client and commissioning organisations, designers, builders, developers and product suppliers.

The report describes how the Work Group structure has examined particular stages in the house building process, looking at the activities of both small and large developers, and shows how the likely risks in each sphere of house-building activity have been prioritised. The focus will now move on to gathering the evidence that will either confirm or allay the suspicion that a particular aspect of the process is repeatedly undermining performance. The published academic studies point towards the single conclusion that there can be a wide discrepancy between the envisaged ('as designed') and 'as-built' performance of a home, but this evidence applies to a relatively small sample. The focus of the Work Groups has, therefore, been directed towards gathering evidence that exists outside these academic studies, for instance field trials, product manufacturers' test data and the post-occupancy evidence of the Energy Efficiency Best Practice Programme, and from housing associations that have been pioneering low-carbon designs. For the evidence gathering stage to be effective we must also devise suitable investigations and on-site audits that can give some confidence of the extent and impact of the problem and enable us to monitor improvement over time. Further relevant evidence is essential to establish proportionate remedies and to identify where the industry as a whole can operate more efficiently.

Although the Work Group consultations have unearthed a wide range of viewpoints and interests, there is consensus on the challenge we face. The house-building industry must increase supply in a time of acute need and at the same time respond to increasingly demanding technical standards. We are moving to an era where performance will need to be demonstrated through verification, assurance and testing, rather than prediction alone but we are not yet equipped with all of the means to establish this task. The future work stages charted in this report set a measured and robust course towards this aim and we recommend that they are supported to the full by all of us, in our endeavours to deliver what we intended.

Richard Partington & Nigel Ingram
Steering Group Co-Chairs

Executive Summary

This interim progress report provides a summary of the work carried out to date within a collaborative industry project, led by the Zero Carbon Hub, to investigate and help close the gap between the design and as-built energy / carbon performance of new homes. This report presents initial findings and explains the next steps for the project.

Background

An earlier review by the Zero Carbon Hub in 2010, which investigated the energy / carbon modelling regime for new homes, included a detailed examination of the performance gap. That report contains a historical review of evidence from a limited number of sources and found that more evidence was needed to understand the scale of the performance gap and technical issues involved. Since that time more evidence has emerged, but in a piecemeal rather than coordinated manner.

In February 2011, as part of its recommendations to government on Carbon Compliance, a Zero Carbon Hub task group advised that future performance standards for zero carbon homes should be linked to 'as-built' performance (see 'The 2020 Ambition' below). Government has welcomed the opportunity to explore a collaborative approach to achieving this aim.

CLOSING THE PERFORMANCE GAP: THE 2020 AMBITION

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

Introduction

The current work programme considers the complete house-building process, in its broadest sense, from conception through to completion on site. Performance of the completed home, beyond handover to the occupant, is outside the scope of this work, although the significance of building services controls is being considered.

The first phase of the project, concentrating on research and identification of issues, is well underway, with 140 industry experts across 90 companies presently involved as part of the project's Industry Executive Committee, Steering Group and Work Groups. The next phase will focus on the analysis of evidence found to date, and further evidence collection and assessment. This information will play a vital role in moving discussions from opinion to fact-based evidence. The Steering Group will then be able to more robustly prioritise issues to address and identify 'quick wins' within the project period to March 2014, whilst recognising that this journey is to 2020.

Emerging Themes and Issues

Understanding and addressing the performance gap is an industry-wide challenge. Creating a clear overview of the housing delivery process is considered an important task in order to provide a structure for considering the various potential issues.

There are multiple house building delivery routes within the industry, which makes mapping the process a complex task. Varying business model approaches are used by large, medium and small builders, in addition to differing contract types such as 'Design and Build' or 'Materials and Labour'. The potential routes to procure professional services, materials, and products, at varying development scales, add a further layer of complexity.

Considering the entire delivery process at a strategic level has resulted in the identification of a number of cross-cutting issues. Often bridging across professions and timescales these issues fall into four themes; Knowledge, Communication, Responsibility and Skills.

This Executive Summary provides a brief summary of the issues that might influence the performance gap, structured around headings related to the main phases of a development. Further information can be found in the main report.

Concept, Planning and Detailed Design

Decisions made at the very beginning of the development process can have a significant effect, both positive and negative, on the eventual energy and carbon performance of new homes, Local Authorities frequently set energy and carbon targets at the planning stage but there is currently inconsistency in how these are defined and what information is required to demonstrate they have been met.

There is a general lack of understanding across developers, designers and planners about the potential impact they can have on energy performance and buildability. For example, aesthetically driven features, such as dormers and bays, can create complexity for both the detailed design and construction stages.

There are multiple reasons for issues to arise. Information flow from early stage design to the later stages in the process may be limited or ignored, and lessons learnt during construction and the later design stages are not consistently fed back to create a virtuous circle of improvement. There is a lack of suitable energy performance analysis tools that enable designers to easily and routinely check the robustness of their design proposals.

The government's compliance tool, known as SAP (Standard Assessment Procedure), plays an increasing role as developments progress through the detailed design stage. A review of existing research indicates that the core building physics of SAP may be broadly sound but further work is required on the inputs and assumptions to ensure it is a robust tool for the future. Particular aspects of the model itself that need further work include ventilation, thermal mass, hot water and lighting. There is concern regarding the transparency of assumptions and the suitability of some of the inputs currently used if it is to become a more accurate predictor of 'as-built' performance (e.g. laboratory based thermal conductivities, building services component efficiencies). SAP as a whole has been identified by many of the Work Groups as a major area for further detailed investigation to establish its potentially significant role in contributing to the performance gap.

Energy literacy within the detailed design team can be limited, and often an external energy modeller (SAP Assessor) will be engaged for design and specification advice. A lack of ongoing communication between the design team and SAP Assessors can mean that the performance implications of design changes are not fully understood.

Procurement

The materials, components and systems used to create homes clearly have a significant role in their energy performance. Manufacturer performance declarations (e.g. thermal conductivity, heat recovery efficiency) are legally required to be in conformity with harmonised European test standards and further work is required to look at the impact of these on the performance gap. There are concerns regarding the appropriateness of such test data when related to 'as-built' performance. Products and materials are generally tested in isolation, as individual components, not as systems or fabric assemblies constructed on site.

Focus has been on two areas: U-value calculation conventions (BR443) and current testing methodologies. A specially convened workshop has reviewed the existing U-value conventions and highlighted a range of areas requiring revision in the immediate future. The industry's ability to reliably and repeatedly test the 'as-built' performance of both fabric and services is an area of concern. Existing hotbox and heat flux tests are currently unable to replicate 'in-situ' issues (e.g. solar gain, moisture) and whole building co-heating tests face considerable limitations for widespread usage.

The main concerns regarding the influence of procurement on the performance gap relate to product substitution, the level of information contained in tender specifications and, as an overarching issue, the knowledge and skills of those making procurement decisions (be they the procurement team, site managers, contractors, or sub-contractors). Designers typically provide drawings and specification documents which include phrases such as 'or equivalent'. Without enough information as to the critical performance criteria, products chosen or substituted may not meet the original design intent, and these changes are unlikely to be fed back to the design team or SAP assessor to check any potential performance implications.

Construction, Commissioning and Completion

It is at the construction stage that design intent, materials, components and systems combine. It appears that culture and embedded behaviours are not always aligned to enable the delivery of 'as-built' performance. In some cases the design team will not provide sufficiently detailed drawings to explain how junctions should be assembled to achieve the air tightness and thermal performance envisaged. In others, such drawings will have been produced but may not be referred to by the construction teams. Information on unbuildable / uninstallable details may not be fed back to the design or concept team so lessons are not learnt.

Discussions have highlighted the potential for some materials and products to be inadvertently substituted on site, however the extent of this needs further investigation. Once packaging / labelling has been removed it can become very difficult to identify the correct specific product for installation (e.g. between different thicknesses / types of mineral wool insulation). In addition to this some manufacturers only provide limited, if any, installation or commissioning guidance for construction teams. This can result in improvised or 'ad-hoc' approaches being used on site without understanding the energy performance implications.

There are concerns regarding the level of both installation and commissioning skills for building services, especially mechanical ventilation and heat pumps as demonstrated by GHA research, Zero Carbon Hub's Ventilation and Indoor Air Quality reports and EST field trials.

Anecdotal evidence suggests a lack of ownership of verification across the delivery process and many incorrect assumptions and expectations of the part that various parties play in the verification process. For example, Building Control is often incorrectly perceived to be a Quality Control process, but this is not the case as responsibility for compliance remains with the builder. A risk-based approach to building control site inspections has become the norm, which tends to prioritise health and safety related issues. In addition, the specialist nature of regulatory requirements for thermal performance requires Building Control Surveyors to place reliance on the timely and accurate supply of information from specialist consultants and Competent Persons Schemes.

Verification by SAP Assessor Accreditation Bodies currently tends to focus on the calculation procedures themselves rather than a more intensive audit of the information provided at the design and construction phase. This means the differences between the design intent and actual built specification are potentially missed, even though an 'as built' SAP assessment is required by Building Regulations.

Construction Joint Details

Following a specific government request a review is underway of the existing Accredited Construction Details, Enhanced Construction Details and associated thermal bridge calculation procedures. This is particularly pertinent with regards to any possible updates to Part L of the Building Regulations.

A multidisciplinary group has been considering issues including the strengths and weakness of existing details, potential for their revision, the need for any additional details and the ability to accommodate future innovations. In parallel, the future ownership and commercial viability of any such scheme has been investigated and it is the intention to pursue available options for this, including reviewing existing examples from Europe.

Findings to date include the conclusion that the current details need to be updated to reflect improved building fabric specifications, as well as buildability and robustness concerns, and to cover a number of common details currently not included within SAP Appendix K. The current lack of a Competent Person Scheme for thermal bridge modellers is also an area of concern. During their deliberations, the Work Groups considering design and construction both identified standard details as a potential aid to closing the performance gap. The commissioning of a new set of construction joint details is therefore thought to be a useful 'quick win' for the project and additional funding will be sought to achieve this.

Knowledge and Skills

Throughout the initial phases of this project every Work Group has identified that knowledge, skills and working practices within the industry are a serious concern and will have an influence on both the performance gap and the ability to close it. The Steering Group and Industry Executive Committee have supported the intention of the Zero Carbon Hub team in conjunction with HBF (Home Builders Federation) to seek substantial additional funding from CITB (the Construction Industry Training Board) to enable these aspects to be addressed.

Next Steps

The activities carried out so far have revealed the sheer number of issues which have a potential to impact the performance gap. The next phase of this project is the analysis of existing evidence and co-ordinated gathering of new data. It is also recognised that further work is required to identify the issues relating to building services and this will also take place during the next phase.

Evidence collection and analysis

It is recognised that in carrying out the initial identification of issues, the Work Groups relied quite heavily on their own experiences and expertise (which can mainly be classified as anecdotal evidence). Further evidence collection and analysis will be carried out over the summer, with the intention that in the autumn enough information will be available for the Steering Group to make decisions on the prioritisation of issues to be taken forward and tackled, including identification of 'quick wins'.

Due to the cross industry nature of the performance gap there are a number of potentially valid evidence types which are being considered. These include:

- State of the industry (statistical analysis)
- Compliance processes (surveys)
- Field trials
- Academic studies
- "Secret" knowledge (unpublished)
- Anecdotal

A review of the evidence identified to date shows in many cases a willingness to share 'secret' knowledge from within house builders. Some manufacturers are also willing to share similar information about product and system performance. The Zero Carbon Hub team has been in discussions with the Technology Strategy Board to explore how this project can gain access to data from the Buildings Performance Evaluation programme and wider EMBED (Energy Monitoring and Building Evaluation Database) datasets prior to their wider publication, which does not quite tally with the timescales of this project.

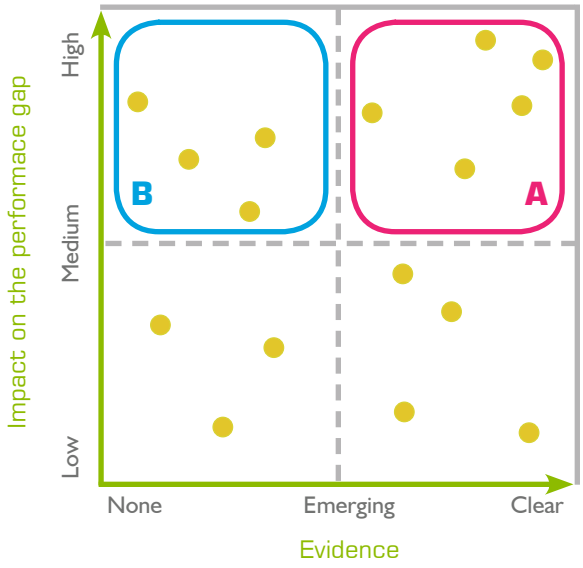
Following an All Member workshop, focussing on cross-cutting issues, a number of additional evidence-gathering exercises are being investigated. For example the Zero Carbon Hub team is in discussions with HBF regarding their offer of making homes available on a number of their members' sites for anonymous testing / trialling and evidence-basing. A coordinated analysis of SAP calculations has also been proposed.

Prioritisation of Issues

The Work Groups have been keen to turn to solutions, but prior to moving to this phase of the project a process of prioritising the issues that impact the performance gap will be carried out. Only activities relating to those issues considered to have a significant impact will be taken forward within the timescale of this funded project.

A matrix has been developed to help prioritise the importance of identified issues. This compares the potential impact each issue has on the performance gap against the sufficiency and clarity of evidence collected for that specific issue (see illustration). Once the placing of the issues has been ratified by the Steering Group, it will be clear which form part of the ongoing work plan for this project and which can be disregarded as they are of relatively low significance or are best tackled at a later date.

Those issues where there is both clear evidence and a high impact will be taken forward by the project, to develop solutions and recommendations (Area A). Those where a medium-high impact is suspected, but clear evidence is not available (Area B), will be investigated by further evidence gathering and analysis to see whether the issues are substantiated (and hence move horizontally to the right of the matrix) or if they turn out to be low impact or unsubstantiated issues (and hence move towards the bottom right of the matrix).



Establishing a baseline

It is recognised that in order to measure progress on topic areas there must be a defined method to clarify whether there is an actual impact on closing the performance gap. This might take the form of establishing 'where we are now' and identifying how much progress has been made over a defined period. Where the initial baseline is impossible to establish, the method of demonstrating a reduction in the performance gap 'by proxy' will be developed.

Defining solutions

The intention is to focus effort around the activities dictated by the issues which fall in the 'clear evidence, high impact' and 'low evidence, potentially high impact' quadrants of the matrix.

These 'activity groups' will set their own programme of work, assisted by the Zero Carbon Hub team, to tackle the prioritised issues and additional evidence gathering. Issues that are identified as 'quick wins' will be progressed with a view that by the end of the funding period of this project there will be activities completed or detailed work plans in progress to deliver the specific solutions identified. Cross-cutting issues such as those surrounding the SAP compliance tool may need additional consideration in relation to defining workable solutions.

A thorough analysis of the potential cost impacts of the Work Group proposals and final Steering Group recommendations will be prepared using a combination of qualitative and quantitative techniques. Impacts will be identified using a structured assessment framework, with the significance of each impact determined using available evidence or other relevant information. The Industry Executive Committee will also aid this analysis and act as the 'commercial oversight' for proposals coming forward.

Areas requiring government support

The project work to date has already identified that government departments may need to be consulted with in order to address potential issues that may inhibit the closing of the performance gap if action is not taken. Areas requiring government support include:

- A serious review of the SAP assessment tool, including inputs.
- The update of construction joint details.
- Supporting industry's ambition to improve knowledge and skills.
- Supporting the development of new test methods.

It is also recognised that there may be particular legislative barriers to certain solutions. For example, harmonised European Standards may be a barrier to 'in-situ' product performance declarations. This may require specific recommendations on revisions to the rules or their application in certain parts of the industry.

A final report to government will be delivered at the end of the project period in March 2014. This will include a more detailed analysis of the issues affecting the performance gap and recommendations for a future programme of work to 2020.

Introduction

Why the Performance Challenge is a priority

There is growing evidence of a gap between the as-designed and as-built energy / carbon performance of new homes. This gap might arise in a number of ways within the overall house-building process and, if significant and widespread, may constitute a considerable risk.

From a government perspective, a gap in a building's performance 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 house builders the fall-out from underperforming new homes could impact on their reputation and business. A performance gap has been recorded on high-profile projects where energy performance has been a focus, so the concern is that it could also be found in typical mainstream home production.

For these reasons, even though the origin, size and extent of the gap have not been precisely identified to date, its investigation is seen as a high priority by government and by a wide spectrum of interest groups across the sector. This project indicates the perceived importance of this agenda: over 140 professionals have come together to explore potential causes of the performance gap and, where convincing evidence is uncovered, to work collaboratively to develop cost-effective and realistic proposals that will help to close it.

Policy development and overall objective

Part of the Zero Carbon Hub's 2010 review of the energy / carbon modelling regime for new homes included a detailed examination of the performance gap[1]. That report contains a historical review of evidence from a limited number of sources and while it concludes that the available evidence provides a cause for concern, it argues that more evidence is needed to appreciate the scale of the gap and also to improve understanding of the technical issues involved. Since that time more evidence has emerged, but this has arisen in a piecemeal way rather than through a concerted or coordinated investigation.

In February 2011, as part of its recommendations on Carbon Compliance, an industry task group led by the Zero Carbon Hub advised that future performance standards for zero carbon homes should be linked to as-built performance[2]. The way to take this forward has been the subject of considerable debate over the last two years. A proposal within the Part L 2013 consultation for an end-to-end Quality Assurance process, incentivised via a 'confidence factor' approach, did not gain favour, although the principle of closing the gap received considerable support.

Instead, government is engaging with and supporting this collaborative Zero Carbon Hub led work programme, bringing together all participants in the design-construction-verification cycle to establish a better understanding of the issue and to formulate any necessary solutions. The 2020 ambition for closing the performance gap, as set out in the 2011 Carbon Compliance report, is repeated below.

CLOSING THE PERFORMANCE GAP: THE 2020 AMBITION

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

[1] http://www.zerocarbonhub.org/resourcefiles/CARBON_COMPLIANCE_GREEN_OVERVIEW_18Aug.pdf and http://www.zerocarbonhub.org/resourcefiles/TOPIC4_PINK_5August.pdf

[2] http://www.zerocarbonhub.org/resourcefiles/CC_TG_Report_Feb_2011.pdf

A new approach

The Zero Carbon Hub established the current work programme on the performance gap, which has initial funding up to the end of March 2014. This is based around a collaborative approach with input from across the wider house building industry. The objectives, structure and operation of the groups set up to undertake this work are summarised below.

THE GUIDING PRINCIPLE OF THE PROJECT HAS BEEN SET OUT AS FOLLOWS:

Develop ideas collaboratively with all relevant parties to ensure support from industry and government throughout the initial funding period and beyond to 2020.

Scope

The programme of work is looking at the complete house-building process, from conception through to completion on site. Performance of the completed home, beyond handover to the occupant, is beyond the scope of this work, although the significance of building services controls is being considered.

Objectives

The overall objectives of the work programme the Zero Carbon Hub has put into place are set out below:

- **Draw together and analyse existing work in this area** (including work by the industry and its supply chain, leading academic institutions, accreditation bodies, etc.). This will lead to a reliable dataset of information that can offer a starting point for identifying the nature of any performance discrepancies, and give some insights into the relative importance of key areas of concern.
- **Identify the gaps** in the existing evidence base and set criteria for further data requirements to ensure all aspects of meeting the desired 'as-built' standard are addressed. This will lead to proposals for additional testing / monitoring work.
- **Agree the programme of work and who is best placed to address the issues** to enable industry to meet the target for 90% of all new homes achieving or exceeding their designed energy / carbon performance from 2020. This may include investigatory, production, testing, dissemination and implementation phases for each main topic area, as deemed necessary.
- **Develop** the information, education / training, guidance, and good practice requirements for the industry to adopt as potential non-regulatory 'quick wins'. These will present practical, cost effective, viable solutions and will consider the potentially differing approaches by small, medium and large house builders.
- **Commission** or carry out, as appropriate, specific agreed work to help close the design vs as-built performance gap – be this further research, testing procedures, quality assurance schemes, etc.
- **Set performance criteria** to monitor and report the success of the group in achieving its aims.

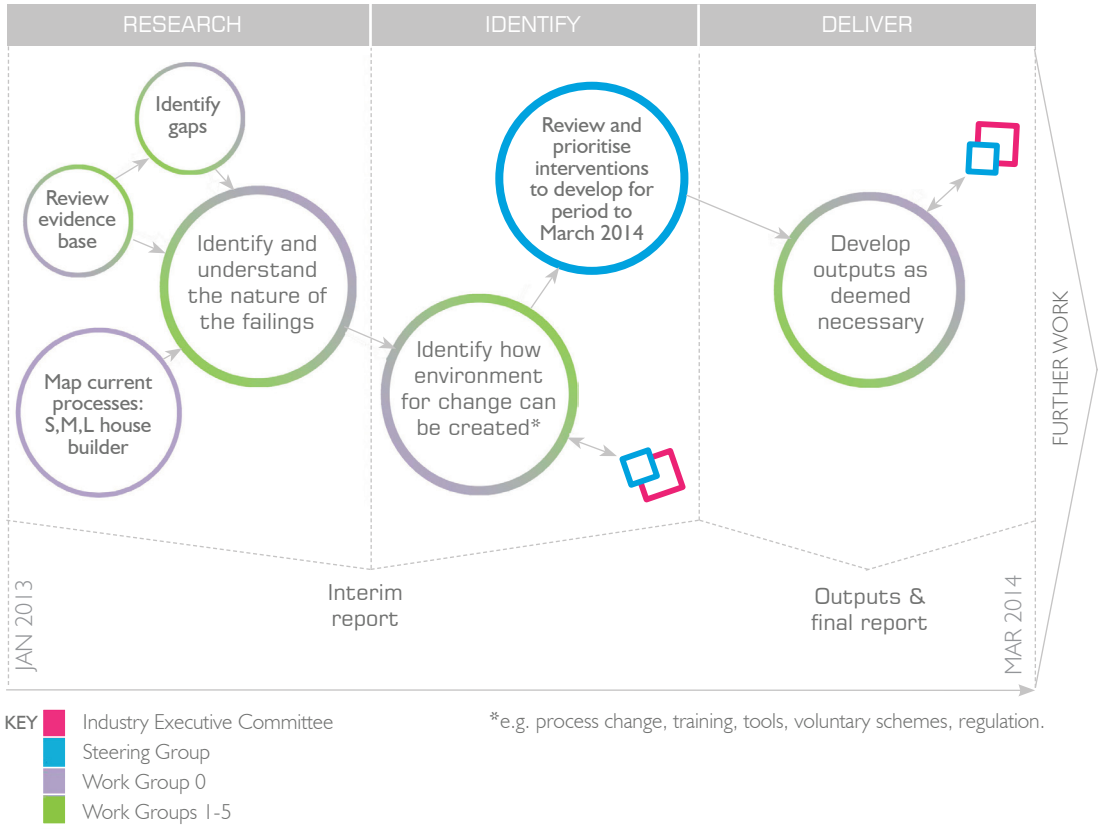


Figure 1 Flowchart of project work stages

Delivery

The project's programme of work for 2013 / 14 is summarised in Figure 1.

Structure and operation

Figure 2 overleaf shows the overall structure that has been devised for the initial 'Research' and 'Identify' aspects of the work programme to enable in-depth thinking in specific areas which were suspected to have relevance to the performance gap.

Industry Executive Committee (IEC)

The purpose of the IEC is to ensure that recommendations for closing the performance gap are based on a sound business footing. This group will analyse and comment on the findings from the Steering Group with a particular focus on cost, viability and impact on the build programme.

The IEC is made up of around 16 senior representatives of the house building industry including house builders, RSLs, manufacturers and others.

Steering Group (SG)

The Steering Group directs and coordinates the Work Groups and has a dialogue with government departments and the IEC regarding potential solutions. Specialist advisors have been appointed on costing proposals and to help manage the evaluation of evidence.

The Steering Group is made up of the Work Group Leads plus seven other knowledgeable professionals including two co-chairs.

Work Groups (WGs)

The Work Groups undertake the bulk of the activities and feed information to the SG for consideration and validation.

Each Work Group has a nominated Lead together with 8-15 members. Some of these individuals are specialists in the area concerned; others are from across industry to give the groups a useful dynamic, the ability to discuss cross-cutting issues when they occur, and to spot interdependencies.

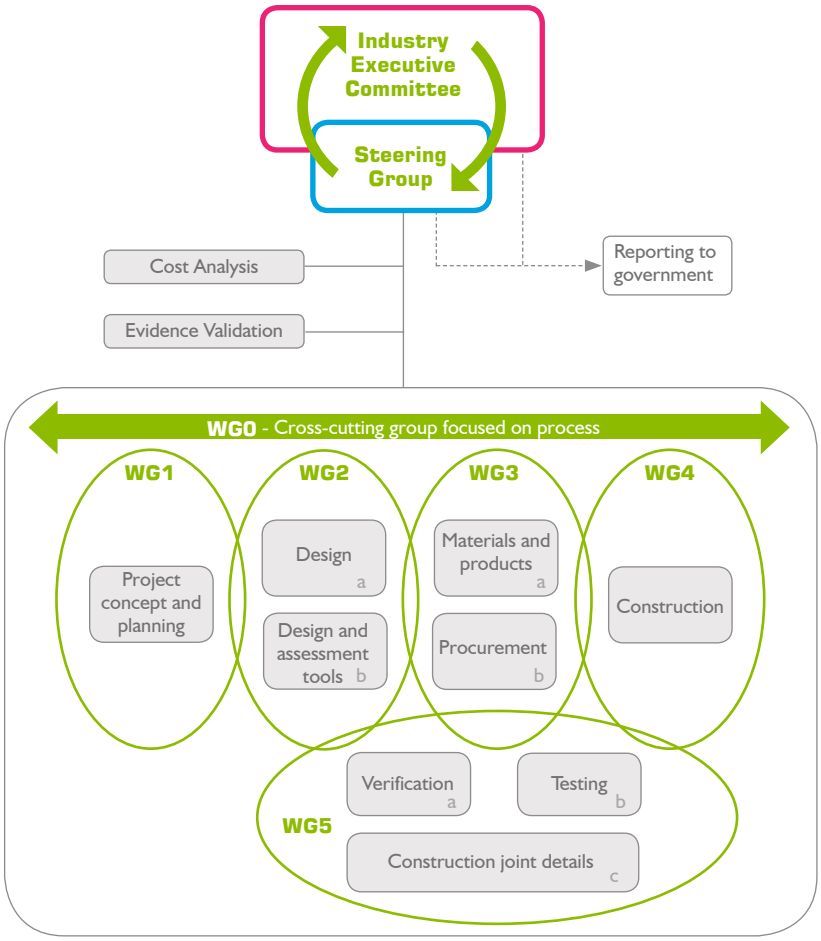


Figure 2 Project structure

Project progress

The first phase of the project, concentrating on the 'Research' and 'Identify' activity areas, is well underway, with 140 industry experts across 90 companies presently involved in the journey. The Zero Carbon Hub team is extremely grateful for the in-kind support of so many businesses, amounting to over 2400 people-hours on the project so far.

The Steering Group activities began with an Enabling Day in January to brainstorm the potential issues that might form part of the performance gap, starting from a list populated from a trawl of published work in this area. It has met on two subsequent occasions to be updated on the activities of the Work Groups and to hear from specialists on cost, evidence and legal aspects.

The activities of the Work Groups began in March with a workshop session for each group to brainstorm in further detail the issues that might form part of the performance gap in the group's particular area of focus[3]. Over the course of two further meetings these have been developed into themes and the process of evidence gathering, to validate the issues, has begun. In some cases this has been more difficult than others, as is explained further in 'Evidence collection and analysis', page 26. A specific additional meeting was held to discuss U-value conventions (BR443), which was attended by 35 members from across the Work Groups and others knowledgeable in this area.

The Industry Executive Committee has met once at the end of May to be briefed on the project, updated on progress, and to outline their responsibilities going forward.

An All Member event was held at the beginning of June to consolidate progress so far in identifying issues and to act as a catalyst for further evidence-gathering activities.

The rest of this report explains in further detail the outputs of the activities carried out to date and the intended next steps. It is important to note that evidence is key to support assertions of where the major issues relating to the performance gap lie, and at the time of writing this report the project is only part way through the process of collecting what is required. The immediate further work to be carried out on the collection, commissioning and analysis of evidence is described in 'Next Steps', on page 33.

[3] A record of these workshops can be found in Appendix G

House Building Process

Understanding and addressing the performance gap is an industry-wide challenge. From the initial stages of this project the Steering Group identified the need for a clear house building process map. Work Group members have supported this viewpoint and expressed a desire to understand how their individual role fits within the wider process. A multi-disciplinary team, ranging from land buyers through to construction experts, is working to create such an overview. Their emphasis has been on activities they considered to be most likely to influence the performance gap.

There are multiple delivery routes within the industry which make mapping the process a complex task. Varying business model approaches are used by large, medium and small builders, in addition to differing contract types such as 'Design and Build' or 'Materials and Labour'. The potential routes to procure professional services, materials, and products at varying development scales, add a further layer of complexity.

Work Group members have provided example process maps for review, but it has been suggested that only a small proportion of the wider industry has such clearly defined processes. A limited number have specific CO_2 and energy efficiency related decision 'gateways', but this is unusual at present. Even within these more advanced developers there are limited formalised feedback mechanisms between design, procurement, and construction teams.

To encourage cross Work Group investigations, complementary to the more specialist discussions, a selection of prototype process maps have been developed. Figure 3 overleaf provides an example of the style currently being refined. The use of a hybrid Gantt and Process chart appears to have the most potential as it allows the reader to understand the key activities and interactions at each stage. Colour coded comments will indicate where issues influencing a performance gap may occur. Key stages will be expanded in greater detail, with assistance from the Work Groups, to help the Steering Group better understand overarching activities such as testing and verification. Separate maps for large and small house builders will be developed, as well as for different contract / procurement routes as necessary.

Cross-cutting issues

Considering the entire delivery process at a strategic level has resulted in the identification of a number of cross-cutting issues. Often bridging across the more focused Work Group discussions, these issues have been deemed to fall into four themes; Knowledge, Communication, Responsibility and Skills.

Examples of the kind of cross-cutting issues suggested to date include[4]:

- Lack of clear processes to ensure communication of performance related issues between concept and detailed design teams.
- Concept, procurement and construction teams not taking responsibility to inform the detailed design team of changes or difficulties on site.
- Frequent site labour changes reducing the industry's ability to increase or retain knowledge.
- Poor building services installation and commissioning skills (e.g. mechanical ventilation).
- Design team devolving responsibility for performance specifications to sub-contractor without proper consultation or contractual explanation.
- Pressure to hit sales or year-end targets compromising communication and planning on site, resulting in trades completing work out of sequence.

[4] Please see 'Emerging work plan' on page 31 for more detail on cross-cutting issues

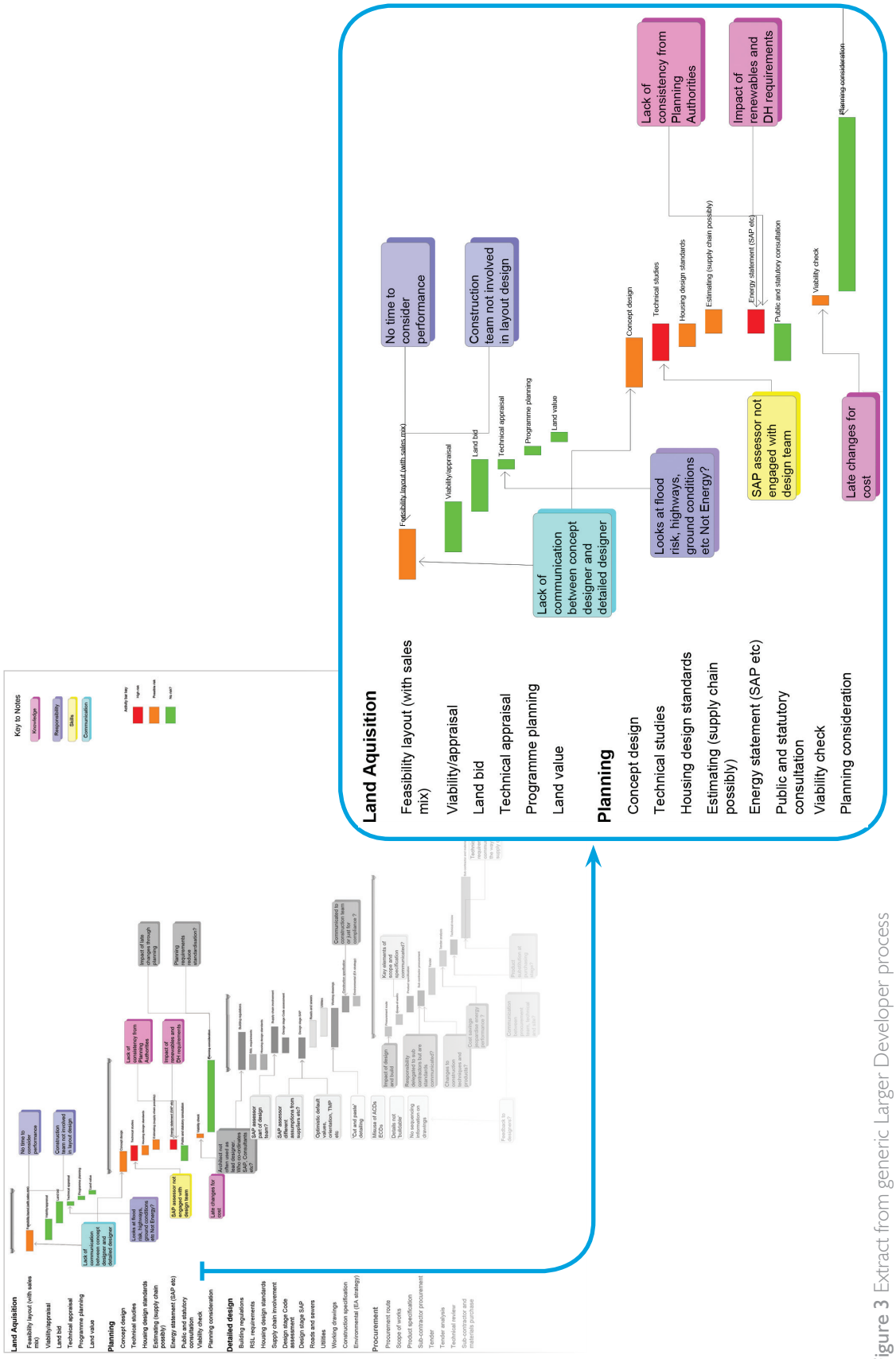


Figure 3 Extract from generic Larger Developer process map showing examples of suggested performance gap related issues at Land Acquisition and Planning stage, illustrating how elements of the final output will support Steering Group conclusions and recommendations.

Emerging themes and issues

Introduction

During the project's initial research and identification phase, Work Groups have been focussing on their areas of expertise. Following several meetings and an All Members Workshop, a selection of issues suspected of affecting the performance gap have been identified. The purpose of this section is to summarise these emerging issues and overlay them across the entire housing development process. This has been broken down into the main development phases, along with specific sub-sections discussing materials and products, verification, testing and the compliance tool, which have influence across the process. Later sections of the report discuss the current evidence base and planned future activities.

Concept and Planning

Decisions made at the very beginning of a development's journey can have a significant effect, both positive and negative, on the eventual energy and carbon performance of new homes. Discussions within the Work Groups have revealed a series of issues at this initial stage.

Local Authorities frequently set energy and carbon targets that must be met at the planning stage but there is a lack of consistency in how they are defined, what information is required to demonstrate they are being met, and how submissions are evaluated. This lack of a consistent methodology may unnecessarily increase the amount of work needed to make an application, adds complexity and uncertainty for developers, and stretches the skills and knowledge of planning officers when evaluating the submission[5].

There is a general lack of understanding across developers, designers and planners of the energy performance and buildability impacts of early stage design decisions and aesthetic preferences. For example, a desire for varied street scenes and references to local vernacular style sometimes implicit in planning guidance (e.g. dormers, bays, parapets, steps and staggers) tend to result in more complex thermal and construction detailing. This can increase heat losses through the fabric junctions and lead to buildability issues, such as making assembly of the air tightness barrier more difficult for site teams.

Energy modelling is not commonly used at this early stage and there is a lack of suitable tools to inform or analyse early stage design to support developers, designers and planners. Energy modelling is usually divorced from the design process and seen as a separate technical issue rather than being integrated into and supporting design decisions.

Best practice lessons from the construction phase are very rarely communicated to the concept and planning team, whose involvement in a project is commonly ceased at the planning stage. Consequently lessons are not learnt about the practical implications of their design decisions on as-built performance. Similarly, if changes to 'standard' house types are not communicated appropriately, this may result in late design changes, out of sequence work, or unbuildable details which require 'ad-hoc' solutions with potentially different energy performance levels than those previously assumed.

Beyond the current focus on energy efficient design there is concern that some planners, developers and designers are paying insufficient attention to issues such as overheating.

In summary, to date, the key issues relating to the performance gap may include:

- Locally defined energy and carbon targets (e.g. Merton rule), which without a single agreed set of metrics increase the complexity of solutions and uncertainty for developers.
- Lack of knowledge and skills of designers, planners and developers to understand the wider performance implications of early-stage design and aesthetic decisions.
- Energy modelling not commonly being utilised, therefore limiting objective performance assessment.
- Best practice construction stage lessons not being communicated to concept and planning teams.

[5] Although the consistency of requirements may be improved by the Housing Standards Review which is due to report shortly.

Design

Following the concept and planning stage, a more detailed design for the development is created. Investigations have highlighted that this is often carried out by a different team, or indeed, even a different organisation in the case of medium and small developers who buy land with planning approval already in place.

Frequently there may be no structured handover of energy performance information and responsibility between teams at this stage. There appears to be a disconnect between conceptual design for planning and more technical design, for construction and delivery. Within many projects there is a lack of integrated design between aesthetics, fabric performance and building services which are considered separately or, in the case of building services, perhaps not at all at this stage.

A common failing of design (except where a 'standard' house type is used) is that energy performance is not dealt with as a key and integrated requirement. This can be due to a lack of clarity at the concept and planning stage, lack of energy literacy on the part of the designer, or lack of specialist support from an energy assessor or building services engineer.

Changes along the design development and procurement route are seldom modelled iteratively to understand energy performance implications. At present there are no design software packages available that have the 'SAP engine' as an embedded element, so this process is undertaken by a third party, the SAP Assessor, which increases the risk of data input errors and misinterpretation. The time required for this process means that SAP calculations are generally infrequent and potentially result in decisions that negatively affect the 'as-built' performance.

There appears to be a tendency for some, predominantly smaller, developers to rely on the SAP Assessor to provide design and specification guidance. These developers are therefore at risk of receiving variable standards of advice, depending on the assessor's capability and expertise. Similarly there is a suspected low level of thermal detailing knowledge across the industry, and thermal bridging and U-value calculations are of varying quality as there are currently no active competency schemes.

The increasing importance of energy and CO_2 performance is also highlighting a lack of communication between some design and procurement teams. It is currently common practice for designers to provide drawings and specification documents that include phrases such as 'or equivalent'. This can lead to lower performing alternatives being substituted with no feedback to the designer / energy assessor. Building Information Management systems which can track such changes are rarely employed. It may also be the case that the designer does not provide sufficient information regarding the performance characteristics of the materials and products envisaged to form the fabric and services of the home.

Continuous Professional Development and education programmes currently have limited focus on as-built performance, thereby reducing a designer's ability to closely correlate energy performance with design outcomes.

In summary, to date, the key issues relating to the performance gap may include:

- Sporadic involvement of designers meaning they are unable to provide continuity of information across the delivery process.
- Lack of design integration of building services which can lead to ad-hoc construction stage 'design' / installation decisions.
- Lack of suitable energy performance analysis tools to enable designers to easily and routinely check the robustness of their design proposals.
- The reliance of some developers on SAP assessors for design advice, the quality of which is variable and dependent on the assessor's capability and expertise.
- Insufficient information on key performance characteristics of materials and products being passed to procurement teams, or use of terms such as 'or equivalent', leading to lower performing alternatives being substituted with no feedback to the designer / energy assessor.

Materials and Products

The materials, components and systems used to create homes clearly have a significant role in their energy performance. Discussions regarding the building fabric have revealed issues surrounding current material testing methods. Manufacturer performance declarations (e.g. thermal conductivity, heat recovery efficiency) are legally required to be in conformity with harmonised European Standards. The manufacturing industry considers the testing regime to be robust and it is subject to significant independent accreditation. In addition, it is a criminal offence if manufacturers do not test or declare in accordance with the requirements of the Construction Products Regulation.

However there are concerns regarding the appropriateness of such test data when it is used as an input into energy modelling tools such as SAP and then related to as-built performance. Products and materials are generally tested in isolation, as individual components, not as the systems or fabric assemblies constructed on site. Whilst testing materials in isolation provides a logical and level comparison between products, it does not allow for issues such as air movement within a wall element, or build tolerances when different products are fixed together[6].

Investigations into the basis of how product performance declarations become an input to energy models have focussed on the U-value calculation conventions, described in a publication known as 'BR443'. Experts from design, manufacturing, energy modelling and construction reviewed the current protocols and identified a number of areas considered to affect the performance gap[7]:

- Lack of a Competent Persons Scheme for U-value calculations, meaning conventions for adjustments are open to interpretation and manipulation.
- The accuracy of adjustments to allow for site tolerances and conditions within calculations, highlighting a need to review default values, conventions and assumptions.
- Lack of clarity on how to model unventilated air spaces, air gaps between insulation layers, fixings or recessed light fittings, and limited adjustments for wind and moisture within the structure.
- Lack of requirement for supporting evidence if modelling a timber frame construction with thermal bridging better than the default, and lack of guidance on how to model Structural Insulated Panels (SIPs) or Cross Laminated Timber (CLT) constructions.

There is also a sense that due to commercial pressures there is institutionalised optimism built into the process. This could lead to dwellings having much better theoretical performance than justified.

Potential issues have been raised with the identification of products on site. Once packaging has been removed from some materials it is very difficult to identify the correct specification to be installed, for example varying thermal conductivities of mineral wool roof insulation. In some cases there also appears to be a lack of installation and commissioning guidance, meaning that contractors may use 'ad-hoc' approaches on site without understanding the performance implications.

In summary, to date, the key issues relating to the performance gap may include:

- Manufacturer performance declarations (legally required to be in conformity with harmonised European Standards) not providing adequate 'in-situ' performance values for input into energy modelling software.
- The fact that products and materials are generally tested in isolation, as individual components, not as the systems or fabric assemblies constructed on site.
- Lack of a Competent Persons Scheme for U-value calculations and the need for a general update of current U-value calculation procedures, including a review of default values, conventions, and assumptions.
- Difficulties in product identification, once packaging is removed on site, resulting in materials with different performance being inadvertently installed.
- Lack of manufacturer provision of product installation and commissioning guidance for site teams.

[6] Further details on this area can be found in the 'Testing' section on page 21.

[7] More detailed output from the workshop which was held to discuss BR443 can be found in Appendix A.

Procurement

Investigations to date have focussed on the procurement of materials, services and labour during construction only. The exact approach is influenced by the size of developer (e.g. large national, small regional), number of homes being built and contract structure (e.g. design and build, materials and labour, labour only). Each of these presents its own potential influences on the performance gap but some common themes have been identified within this stage of the delivery process.

It is clear that the majority of Procurement teams assess a range of criteria beyond capital cost, including quality, value and the suitability of the product for its intended purpose. At present it appears that they have limited knowledge of energy performance related issues, or are not being given adequate information by the design team of the key energy performance criteria that need to be met by the materials and products that are procured. This can result in materials, products and systems being selected that have performance levels outside of those envisaged by the design team.

There is a risk some 'value engineering' processes may misjudge the importance of energy performance resulting in lower specification products or systems being used. Depending on the procurement approach, some projects may leave critical design decisions, such as exact window U-values and glazing solar energy transmittance, to a sub-contractor. It is not uncommon, even on large developments, for small purchases to be made outside of the main procurement process by the contractor or sub-contractor. In some instances this may be due to the design team not providing detailed construction drawings meaning key materials are overlooked.

Discussions have indicated that due to a lack of information from the design team, mainstream tender documentation, such as Trade Specifications and Employer Requirements seldom define the required level of energy performance-related labour skills. For example, without clear definitions of responsibility for air tightness and target pressure test results, there is potential for dry lining and building service contractors to compromise the air barrier. The use of accredited installer schemes is sometimes used as a proxy for installation quality, without understanding the true nature of the scheme or what it might guarantee.

In many cases, there appears to be a lack of feedback to the SAP Assessor and Design Team regarding changes to the materials specified (be they by the procurement team, site managers, contractors, or sub-contractors). This means the SAP Assessor is unlikely to pick these changes up when producing the Energy Performance Certificate, and there is no understanding gained by the team on the energy performance implications of such changes (good or bad).

A lack of training aimed at procurement experts means they often rely on sub-contractors and suppliers for performance related information. This can result in them receiving conflicting data that makes like-for-like comparisons very difficult.

In summary, to date, the key issues relating to the performance gap may include:

- Procurement teams having limited knowledge of energy performance-related issues, and not always being given adequate information by the Design Team on key performance criteria.
- Reliance by procurement teams on sub-contractors and suppliers for performance related information, making objective comparisons difficult.
- The wording of Tender documentation, especially Trade Specifications and Employers Requirements, seldom defines the required level of energy performance related labour skills or definition of responsibilities.
- Lack of feedback to the Design Team and SAP Assessor during procurement selection to help highlight any performance implications between tenders
- Lack of feedback to the Design Team and SAP Assessor regarding changes to materials specified (product substitution).

Construction

Discussions have highlighted a current lack of energy performance-related training, knowledge, and collaborative working on construction developments. It appears that culture and embedded behaviours are not always aligned to enable the delivery of 'as-built' performance. This situation is further complicated by frequent changes in labour resources, which means skills and experience are seldom transferred. Consequently mainstream site teams may be unaware of the role they play in delivering energy performance. An example being the potential, more likely on smaller developer sites, for a site manager to purchase materials locally to maintain build speed, without realising the need to check with the designer for any performance implications.

The lack of feedback between design and construction teams means that a number of known 'unbuildable' or 'hard to insulate' details continue to be specified. Site teams regularly have to adopt different construction sequences and detailing in areas such as ceiling level insulation at wall to pitched roof junctions, resulting in poor insulation continuity and a potential performance gap.

There appears to be considerable variability in developer quality control procedures focussing on thermal performance. It is common practice for time-pressured site managers to delegate quality control responsibilities to their sub-contractors. This may lead to difficulties maintaining focus on energy performance-related issues which are impacted by many trades. For example, whilst air pressure testing has raised awareness of this particular performance issue, its use as an end-of-line 'pass or fail' point has resulted in certain parts of the industry having a culture of short-term sealant fixes rather than more robust overall building design detailing and embedding site cultures to protect the air barrier.

In some cases, due to a lack of integrated design, site teams may be given 'uninstallable' details relating to building services (or in some cases, no details at all), leading to 'ad-hoc' on-site decisions. Within building services there is also concern related to installation and commissioning quality; for example, the increasing use of mechanical ventilation (e.g. whole house extract and heat recovery) demands new skills from contractors. Existing installers are frequently felt to lack the level of knowledge, particularly in terms of commissioning, to ensure efficient system performance and provision of appropriate indoor air quality. Similarly, concerns related to commissioning and performance of both air source and ground source heat pumps have resulted in some developers reverting to more traditional technologies.

Process planning and change control is frequently lacking on construction sites. Other pressures, including achieving specific sales or year-end targets, may compromise communication and planning which can result in trades completing work out-of-sequence. As highlighted in the Procurement section, a lack of clear responsibility between trades can compromise key 'as built' performance elements such as the air tightness barrier.

In summary, to date, the key issues relating to the performance gap may include:

- Lack of construction team training and frequent labour changes meaning individuals have limited knowledge of their role in maintaining the energy performance intent.
- Site culture and behaviours not currently being aligned to deliver 'as-built' performance.
- Lack of communication between site and design teams meaning 'unbuildable' or 'uninstallable' details have to be modified on site.
- Lack of awareness of the importance of particular cross-trade energy performance related aspects by those responsible for quality control on construction developments.
- Building services installers (especially of mechanical ventilation and heat pumps) often lacking the skills to commission systems efficiently.

Verification

A review has been carried out of the elements of verification that currently relate to energy and CO_2 performance and their suitability for assisting the achievement of the '2020 ambition'. The predominant focus of current verification activity is in demonstrating Part L compliance.

The current areas of verification that are relevant include: Building Control; Audit of SAP Assessors and Accreditation Bodies; Audit of Air Pressure Testers; New Home Warranty site inspection.

Anecdotal evidence suggests a lack of ownership of verification across the delivery process and many incorrect assumptions on the part that various parties play in the verification process. Building Control plays a valuable role in the achievement of compliance across the full scope of Building Regulations, including energy performance. However, Building Control is frequently perceived to be a Quality Control process but this is not the case as responsibility for compliance remains with the house-builder. Whilst the breadth and complexity of regulations relevant to new homes has increased significantly over the last two decades, the resource levels and fees received by Building Control Bodies have not, in all cases, kept pace. Where full plans are provided, Building Control carry out a full desk-top assessment of designs for Building Regulations compliance, including that of Part L, whereas a risk-based approach to building control inspections has become the norm, which tends to prioritise health and safety related issues.

The complexity and breadth of modern Building Regulations means that Building Control Surveyors require detailed knowledge across many areas. In relation to Part L compliance, a strong reliance is placed on the timely and accurate supply of information provided by specialist consultants and Competent Persons Schemes to support an informed view of whether compliance has been achieved.

Specific energy-related Quality Assessment processes are considered to be of limited effectiveness. Auditing requirements for On Construction Domestic Energy Assessors (OCDEA) are typically focussed on the calculation itself rather than auditing the data used to produce 'As Built' certificates. Similarly there is a lack of clarity on what documentary evidence is required / acceptable to demonstrate Part L compliance. This lack of verifiable feedback to the SAP Assessor during the construction process, and at completion, can result in the final 'as built' performance calculation not reflecting the actual building.

Building Control Bodies are 'authorised to accept' air pressure testing certificates from both the British Institute of Non-Destructive Testing (BINDT) and Air Tightness Testing and Measurement Association (ATTMA). Experience within the group suggests that there are inconsistencies between the auditing regimes and the rigour with which variations from the norm during testing are recorded (e.g. where additional temporary sealing has been applied). Without a consistent approach to air pressure tests, industry's ability to learn which details and products deliver the most robust as built performance is reduced[8].

In summary, to date, the key issues relating to the performance gap may include:

- Building Control frequently being perceived as Quality Control rather than verification.
- Building Control Surveyors' reliance on third-party information due to regulation, fee income, resource constraints and breadth of the role.
- The commoditisation of third-party schemes and the need to improve audit processes.
- Building Control site inspections being risk-based, which tends to prioritise health and safety related issues.
- SAP related audits which tend to focus on calculation rather than the information audit trail for As Built certificates.
- Air pressure testing generally being undertaken only at completion when it can be too late to affect robust remedial works to the air tightness barrier.

[8] Further details on current verification processes can be found in Appendix B.

Testing

A robust, practical and cost-effective range of testing methodologies will be required to inform industry on the journey towards the '2020 ambition'. However, the current absence of suitable methodologies for particular areas should not impede progress. The main activity within the project so far has been to consider the key needs, reliability and appropriateness of existing test infrastructure. Discussions have started to explore what new test infrastructure might be required to address any gaps and whether there are existing tests in other industries which, through modification, could support the performance analysis of buildings. These aspects will be explored in more detail during the next phase of the project.

A review of the existing testing infrastructure covered the following aspects:

- **Thermal** – Including thermal imaging, hotbox, U-value measurement and co-heating
- **Air** – Including air tightness pressure tests, ventilation flow rates, indoor air quality monitoring
- **Building services** – Including components, systems and controls
- **Feedback** – Linking learning from test data to inform improved design

Despite input from leading experts the full testing landscape from component manufacturing to in-line and end-of-line testing is complex and remains unclear. This is further complicated by the lack of understanding of the uncertainties associated with the application of some of the tests, and inconsistent guidelines on implementation and the interpretation of results. This impacts feedback and learning across industry.

As mentioned in the Materials and Products section, the use of harmonised European Standards for testing procedures, especially relating to inputs for U-value calculations has been reviewed. There is currently limited ability to conduct laboratory or in-situ tests to understand how different weather affects the thermal performance of the fabric. There is a lack of standard practice in applying existing Heat Flux measurements, and Hot Box tests are currently unable to replicate dynamic effects such as solar gain or wind speed. In addition there are no agreed test methodologies to measure heat loss at junctions (Psi values). Further research is required to develop a 'test cell' approach that can replicate 'real' conditions while controlling others (e.g. isolate weather from workmanship).

At the whole building level there are considerable limitations to the widespread uptake and utilisation of co-heating tests (e.g. timescale, reliability, comparability, seasons). Although it has merit as a tool to inform research and development, its use as a single industry wide end-of-line gateway is impractical. There is an even greater capability gap when trying to assess building service efficiencies at the system rather than component level. This highlights the need for investment in the development of new test methodologies and the adoption of existing ones, possibly from outside the house building industry[9].

In summary, to date, the key issues relating to the performance gap may include:

- Lack of clarity on the uncertainty associated with the application of existing tests coupled with inconsistencies in the implementation and interpretation of results from existing component to in-line and end-of-line tests.
- Lack of take-up of existing laboratory capability for test methods that can provide more accurate U-value measurements.
- Limited ability to replicate dynamic effects on fabric thermal performance in the laboratory, and lack of agreed protocols pertaining to in-situ measurement of thermal conductivity.
- The application of protocols used for air tightness testing, and how the results are then used within the energy modelling software.
- Lack of a suitable and practical end-of-line overall energy performance test.
- Limited ability to conduct laboratory or in-situ tests of building services at a system rather than component level.
- Lack of feedback of learning from test data to inform improved design, specification and installation practices.

[9] Further details on the gaps and recommendations regarding the areas above can be found in Appendix C.

Design and Assessment Tools

The main design and assessment tool used for modelling dwelling energy and carbon performance is SAP (Standard Assessment Procedure). Discussions relating to SAP occurred across the board, highlighting the significance of energy modelling tools within the house building process.

In terms of the SAP tool itself, many aspects of the building physics engine have been shown to be robust. For example, previous work by the Zero Carbon Hub[10] has shown that when compared to more sophisticated models such as PHPP (PassivHaus Planning Package) or dynamic models such as IES and Energy Plus, with the same assumptions, the predicted monthly space heating demand are very similar. However, particular areas of the calculation procedure, for example around ventilation, thermal mass, hot water, cooling and lighting, are likely to require further examination.

There is general consensus from across the groups that what is required is a tool that is a better predictor of as-built performance. To this end deliberations have focused on the inputs into the SAP model, conventions, and the verification processes which surround it. In addition to this there have been discussions around how such a tool can be integrated into the concept and planning, and critically, the detailed design phases of a project. Fundamentally this involves designers understanding low energy design and using the energy model as a tool. This may be assisted by developing a 'front end' which fits in to the design process and is focused on the needs of designers.

The diagram below (Figure 4) shows the types of inputs and assumptions that are required in order for the SAP engine to calculate a dwelling's energy and carbon performance, and illustrates the breadth of data that needs to be inputted by the Assessor. This is further discussed in the sections that follow.

[10] http://www.zerocarbonhub.org/resourcefiles/CARBON_COMPLIANCE_GREEN_OVERVIEW_18Aug.pdf

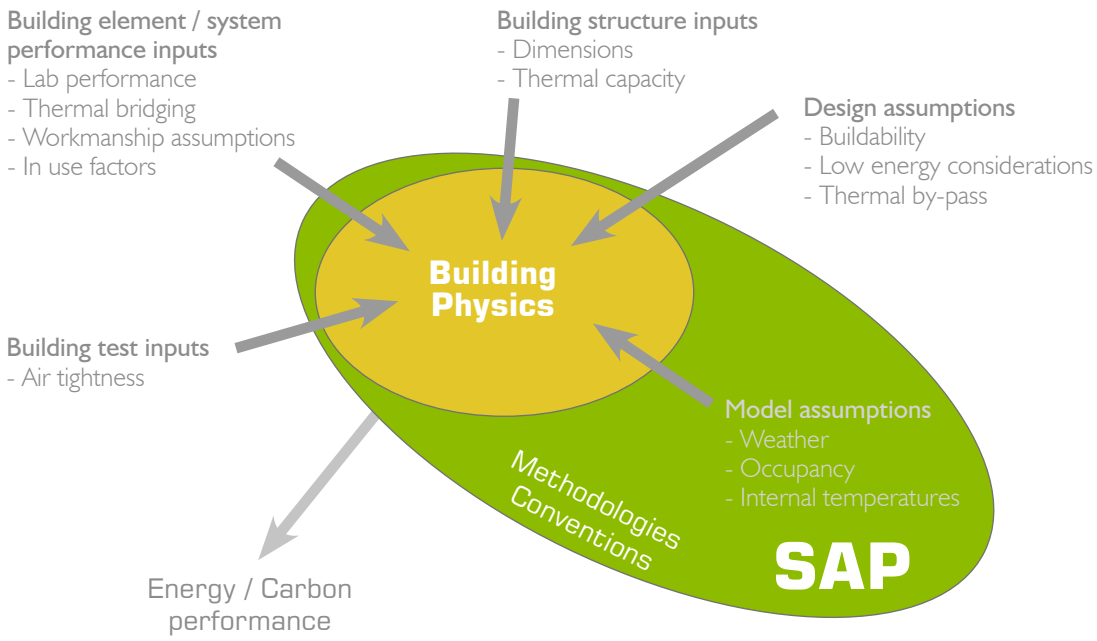


Figure 4 Representation of the SAP model, showing broad input types

Input values / conventions

The validity of the model outputs is critically reliant on the quality and accuracy of the input data, and these inputs need to reflect the in-situ performance in order to avoid adding to the performance gap. Some aspects of this have been highlighted in the 'Materials and Products' and 'Testing' sections and relate to the declared or lab tested performance of individual materials and products compared to their performance when combined as a building element (e.g. wall) or system.

There are a number of common thermal bridges which are not currently required to be accounted for in the SAP model, which will have a direct impact on the prediction of as-built performance. Additionally, site tolerances are not considered and no account is made of differing site practices. There is also a perception that some technologies may be 'over-rewarded' by the way in which they are modelled in SAP, encouraging inappropriate use and leading to inaccurate model outputs.

Assumptions

There has been a general concern over the appropriateness of some of the model assumptions, for example around internal temperatures, heating patterns and weather data.

However, many of these aspects will not directly affect the performance gap because the modelled and 'real' data will both take into consideration the same set of assumptions. Therefore although it might seem sensible for the model to be updated to take better account of low energy building design and use, this should not be a focus for this project. One area which does need further investigation is whether certain assumptions might preclude the benefits of innovative energy saving technologies being taken into account. Worries were also raised over the transparency surrounding some of the model assumptions which have been based on empirical data.

User capability, information flow and verification

There is concern over the competency of Assessors relating to the use of conventions and the accuracy of data input and some evidence that the changes which might have taken place between design and 'as-built' are not being identified and incorporated in the final as-built SAP. It is considered that this may be due, in part, to a lack of competency / adequate CPD framework, compounded by a lack of information flow between the design, procurement and construction teams and the SAP Assessor. Concern was also raised over a potential institutional optimism in U-value and SAP calculations, exacerbated by commercial realities and relative power between the parties involved.

There is concern that the report outputs from the energy model are not 'user friendly' and undermine the ability to clearly communicate the assumptions used; this includes to the designer to enable validation of material performance assumptions, and to Building Control and others to aid in verification procedures.

Other issues surrounding the verification of SAP inputs have been raised, and the fact that SAP related audits tend to focus on the calculation process rather than the information audit trail for as-built certificates[11].

In summary, to date, the key issues relating to the performance gap may include:

- The applicability of current modelling inputs and conventions when attempting to model 'as-built' performance.
- The accuracy of aspects of the calculation model, for example around ventilation, thermal mass, hot water, cooling and lighting.
- Lack of 'in-situ' performance information to use as inputs (e.g. U-value, services efficiency).
- Lack of feedback between the design, procurement and construction teams and the SAP Assessor.
- Lack of a 'front end' to the modelling tool to enable it to be used to aid design decisions from concept and planning stage, through detailed design.
- The capability, knowledge and skills of SAP Assessors.
- The competency of verification procedures in relation to SAP.

[11] Please refer to 'Verification' on page 20 for more details.

Construction Joint Details

Objectives

The Construction Joint Details Work Group is a topic-specific group which was created following a specific government request in anticipation of it arising as a special issue within this project. The reason for this is twofold: it is an area which is often mentioned in relation to potential performance gap issues (arising from current published details and the way in which heat flow through junctions is treated in SAP[12]), and there is also a potential solution in helping to close the gap – by the creation of a functioning construction joint details scheme utilising up-to-date buildable details. This is particularly pertinent with regards to any possible updates to Part L of the Building Regulations in 2013.

Therefore, the objectives for construction joint details are:

- To provide a set of construction joint details and associated psi values which provide a generic foundation for low carbon buildings through good joint detailing..
- To develop an approach where this foundation can be built upon by industry such that improvements to detailing is encouraged.
- To develop an approach whereby industry takes responsibility for the issues involved thus reducing costs for government.

Activity

The group is comprised of builders, manufacturers, building control, energy assessors, architects and junction modellers. The work programme is shown below in Figure 5 below.

[12] For example: indicative results for a semi-detached dwelling with fabric elements at around the level required for 2010 Part L, suggest that if junction heat loss is as described by default values in SAP Appendix K, it would account for around a third of total heat loss. This can be reduced to below 20% with the use of current Accredited Construction Detail Psi values, and to below 10% with the use of Constructive Details. Critically, as the specification of fabric elements and air tightness improves, the proportion of total heat loss through junctions increases. If the theory was routinely replicated in practice this wouldn't be so much of an issue, but the group has concluded that this is not the case.

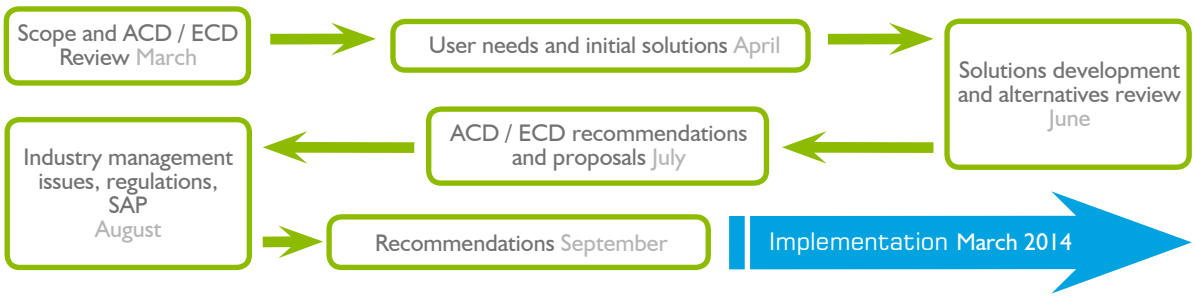


Figure 5 Construction Joint Details group - Work Programme

Findings to-date

The work to-date has concluded the following:

- The existing Accredited Construction Details (ACDs) and Enhanced Construction Details (ECDs) need updating to take account of a number of factors including improving building fabric specifications, buildability and robustness concerns, the need to deal with certain thermal bypass issues, and a number of common junctions not included in the current set of details and SAP Appendix K 2009 (see Appendix D, Section 1).
- The group considers that the amended ACDs / ECDs should allow the construction of a typical dwelling using either timber frame or masonry cavity wall construction. Appendix D, Section 2 contains information from warranty body databases which were used to inform this decision.
- The group has also identified an 'urban' build type with an increased use of clad systems on apartment blocks but it is not yet clear as to whether a simple set of generic junctions could apply to this technique.
- The development of the details should include a process to assess both buildability and robustness (i.e. the effect of site tolerances) such that the psi values used within the SAP calculation have every opportunity to be delivered in practice on site.
- In order to provide a foundation for the development of innovative junction detailing and / or build techniques the protocols used for modelling and buildability / robustness evaluation need to be transparent. Adequate training and assessment of competency needs to be considered if consistency of approach is to be achieved.
- Knowledge about the concept of psi values and the consequent importance of good junction details is generally poor amongst designers and the smaller builders, and consideration needs to be given as to how this is improved.
- Consideration needs to be given to the status of other emerging construction joint 'pattern books' within SAP. There is support for a 'pattern book' approach similar in concept to the Robust Details approach to acoustics (see Appendix D, Section 3).
- A pragmatic approach to costs should be considered such that any updated ACDs / ECDs focus on a sufficiency of important details produced in a way to take account of other design variables. The concepts used in Constructive Details whereby a range of psi values covering variations in elemental U-values would greatly reduce the number of details needing to be published whilst at the same time 'future proofing' them. On a similar theme any emerging pattern book scheme must be financially viable for those concerned.
- In exploring methodologies for dealing with detailing elsewhere in the EU the Austrian 'DataHolz' (www.dataholz.com) concept is being studied as it appears to provide:
  - A financially self-sustaining pattern book of details (both junction and elements) based upon a one scheme multi provider market model.
  - A vision as to how a UK construction joint detailing pattern book scheme similar to that used for Building Regulations Part E could be extended to progressively include information on performance against other regulated requirements (e.g. acoustics).

It should be noted that the terms of reference of this working group are confined to the production of reliable details in a form that can be deployed on site. Whilst the issue of verification that such details were adequately constructed is a recurring topic, this issue is deliberately being left for the Verification Work Group to consider.

Evidence Collection and Analysis

Ian Orme has been appointed as the Evidence Manager for the project and holds a co-ordinating role with regards to the collection and analysis of evidence.

Six evidence types have been identified under which evidence has and will be categorised. These are:

- State of the industry
  e.g. aggregated data from NHBC, LABC, professional institutions, house builders, manufacturers.
- Compliance processes
  e.g. as-built SAP ratings, air permeability test results, use of ACD / ECD, commissioning test results.
- Field trials
  e.g. EST Heat pump trials, TSB BPE Programme.
- Academic studies
  e.g. Stamford Brook, Elmtree Mews, Temple Avenue.
- "Secret" knowledge
  e.g. Manufacturer's field trial data, unpublished academic work.
- Anecdotal

The Work Groups have brought forward a variety of evidence against the issues they have identified as potentially contributing to a performance gap. These have been categorised against the evidence types above and in many cases constitute the release of 'secret' knowledge from house builders regarding their processes and procedures, and actions they have taken to rectify perceived issues with the build process or technologies. Some manufacturers have also voiced willingness to share aspects of their 'secret' knowledge in respect of product and system performance. A list of the evidence brought to the table so far can be found in Appendix E, alongside other key publications.

The 'All Member event' held on 10th June provided an opportunity to focus on evidence assessment and methodologies, and included a presentation by the Evidence Manager, and a facilitated workshop aimed at gathering further information in relation to existing and required evidence against 20 cross-cutting issues.

A review of the workshop outputs has shown limited new sources of evidence beyond those already identified. Much of this is either reports prepared for government in support of Part L reviews; the Zero Carbon Hub in support of developing Zero Carbon Homes policy recommendations; or published field trials by both academic teams and organisations such as the Energy Saving Trust. It was acknowledged that much 'secret' industry knowledge exists, but that the extent of this may not be easily accessed due to commercial sensitivities.

Many ideas were expressed about how evidence may be acquired going forward. Much of this revolved around approaching house builders and compliance organisations for data on specific subjects. It is well recognised that data on the energy performance gap is not readily available and that questions would need to focus on specific fabric, services or thermal comfort issues.

Suggestions were also made for sending a questionnaire to SAP Assessors to collect data on the frequency with which as-built data was provided, and assess if it is consistent with visual examination on-site. In addition, it was considered that a limited sample of dwellings should be investigated to compare design data with the as-built dwelling. It was noted that projects participating in the Technology Strategy Board's Building Performance Evaluation programme would be uploading similar data to EMBED (Energy Monitoring and Building Evaluation Database), but that project completion timescales may mean that only a limited dataset would be available. The Zero Carbon Hub team has been in discussions with TSB as to how this project can gain more immediate access to the valuable insights offered by analysis of the data gathered as part of the BPE programme and expect this to be a valuable addition to the evidence base. Additional scientific data in a number of areas is also required.

A further function required of the evidence accumulated is to help define a baseline to enable progress to be tracked and against which the cost impact analysis of solutions can be referenced.

The immediate next steps for the project relate to evidence collection, collation and analysis and are described further in 'Next Steps', on page 33.

Costing the Impact of Solutions

The Zero Carbon Hub team has appointed Sweett Group as cost consultants for the project. By providing information on potential impacts (quantitative and qualitative) of the issues raised they will assist the Work and Steering Groups in the development of workable solutions for industry. This section outlines the methodology developed for undertaking this analysis.

Summary

A thorough analysis of the potential impacts of the Work Group proposals and final Steering Group recommendations will be prepared using a combination of qualitative and quantitative techniques. Impacts will be identified using a structured assessment framework, with the significance of each impact determined using available evidence or other relevant information.

The costs and / or benefits associated with significant impacts will be quantified using suitable methods that reflect the nature of each impact. Overall impacts for the sector will be assessed together with analysis of the implications for any groups that might be particularly significantly affected. In all the quantitative analysis, particular care will be taken to be explicit about assumptions and the relevant evidence base to support the adopted approach. In presenting the findings the quantification of impact will be used to support (rather than lead) the overall narrative describing the potential impacts and their significance.

Method

Proposals being developed by the Work Groups may have a wide range of impacts on the housing and associated sectors (including construction products, regulators, professional bodies, etc.). To support the proposals developed by each Work Group, and the overall recommendations agreed by the Steering Group and Industry Executive Committee, their financial and other impacts will be assessed to estimate the potential implications for different parties.

Underpinning assumptions / principles

The following assumptions and principles have informed the approach to assessing the impacts of proposals and recommendations generated by this project:

- Impact will cover a broad scope
  Impacts may cover the full value chain of the house building activity and at each stage could encompass changes to processes, methodologies, testing, verification, etc. Depending on the nature of the impact it might be a long-lasting or a short-term adjustment whilst the sector adapts to an alternative approach.
- Incomplete quantification
  Not all of the impacts will be capable of effective quantification or monetisation. Where the impact of a proposal is highly uncertain or there is limited evidence on which to base the assessment, then at least two plausible scenarios will be used to help set boundaries for the potential impact, together with a clear qualitative statement of the possible impacts and associated uncertainties and assumptions.
- **The current system is assumed to be reasonably efficient** i.e. evidence will be required to support the assumption that any new processes can be implemented at low / no cost as a result of theoretical efficiencies in the delivery process.
- Variation within the sector
  The nature and scale of the impacts are likely to vary between larger and smaller organisations and may also be influenced by construction method and type of housing produced (e.g. houses or flats).
- **Wider quality and value benefits will not be quantified unless there is strong evidence to do so**
  In addition to energy savings, there may be quality benefits from new housing adopting the Steering Group's recommendations. Unless specific highly tangible benefits are identified, these will not be incorporated within the analysis. Similarly, it will be assumed that none of the recommendations will have a direct impact on a home's sale price.

Recognising the above complexities and challenges the developed approach follows a process of:

1. Development of an initial review framework that captures the key parties that might be differently impacted by project proposals / recommendations.
2. Definition of assumptions and data for the 'do nothing' baseline against which the impact of the proposals / recommendations will be assessed.
3. Structured qualitative record of potential impacts identified by expert review (within each Work Group and the Steering Group).
4. Collation of the evidence available to support impact assessment (in liaison with the project's Evidence Manager).
5. Qualitative assessment of significance based on scale of impact and confidence that the impact will occur (i.e. a risk / opportunity analysis).
6. Attempted quantification (including uncertainty) of significant impacts including how they impact different parties and any particularly sensitive groups.
7. Assessment of overall aggregate impacts together with supporting narrative to identify key qualitative issues and make clear the associated assumptions and uncertainties.

Each step is described further as follows.

Develop assessment framework

A simple but structured assessment framework will be used for impact capture. This will include the following elements:

- The development of the details should include a process to assess both buildability and robustness (i.e. the effect of site tolerances) such that the psi values used within the SAP calculation have every opportunity to be delivered in practice on site.
- Proposals or recommendations to which the impact relates.
- Description of the impact – e.g. cost, time, risk, 'change', performance, etc.
- Impacted parties - see Table 1 overleaf (it is not expected that impacts will be recorded for all or even the majority of these groups in every case).
- Scale of impacts for different parties and on any specifically sensitive groups - see Table 1.
- Duration .
- Uncertainty.
- Associated indirect or consequential impacts.
- Nature of evidence to support the recorded information.

It is likely that each proposal may have more than one impact. Initially information will be recorded qualitatively with quantification introduced only for those impacts considered to be of significance.

Party	Potentially sensitive groups
Delivery	
Landowners	
Developers includes house builder land and sales arms	Small developers e.g. 50-250 units and <50 units per year Niche developers e.g. all urban, rural, etc
Contractors includes house builder delivery arms	Small contractors e.g. 50-250 units and <50 units per year Niche contractors e.g. non-masonry / timber frame methods
Sub-contractors	
Professional services Planners, architects, engineers, consultants	Small practices
Suppliers	
Manufacturers	Manufacturers of insulation and building services Manufacturers of novel products
Merchants	Small businesses
System manufacturers e.g. MMC	
Technical	
Technical standards and software e.g. SAP	Testing and verification bodies
R+D organisations	
Professional bodies	
Building control and warranty bodies	
Owners and occupiers	
Landlords	Social housing
Households	
Others	
Regulators and policy makers	Mortgage providers
Funders	

Table 1 List of impacted parties

Define baseline

The baseline against which impacts will be assessed will be based on:

- Housing performance.
- Testing regimes.
- Product declarations – e.g. European requirements for declaring and labelling performance.
- Housing numbers and mix – e.g. using government projections.
- Construction costs and other expenditure.

The baseline assumptions and analysis of housing costs and market activity will be tested with the project Steering Group and Industry Executive Committee to ensure that they provide a robust basis for subsequent analysis.

Qualitative record of potential impacts

Working with the Lead of each Work Group the potential impacts of each proposal will be recorded using a consistent pro forma (based on the developed framework). In some cases it may be apparent that the impacts of a proposal would only be realised when the proposal is implemented as part of a package of other measures. Where this is the case, the impacts of proposals will be assessed as a group.

Collate evidence

Working with the Evidence Manager and others, evidence to support the assessment of impacts will be collated. This evidence will be used to assess significance and to put bounds on the quantification of impact. The method will work with evidence of all levels, with the evidence quality used to determine the confidence that can be applied to subsequent analysis.

Where no available evidence can be obtained to substantiate a perceived impact, the impact will still be assessed but with reduced confidence in the nature and scale of the impact. To help support the assessment, evidence relating to other relevant or related activities will be sought.

Assess significance

Significance will be assessed based on scale and likelihood, and specific points on the scale will be determined once the overall schedule of impacts has been identified. It is intended that the significance assessment identifies the top 5-10 impact areas for a particular proposed solution. Analysis will also consider those risks which, although less significant for the sector as a whole, can have a significant impact on specific groups and therefore merit further analysis.

Where a potentially significant risk has little good quality evidence with which to undertake further analysis, this will trigger further work to identify additional evidence or to develop a viable means of impact assessment. These areas will be identified and targeted as priorities for future learning and evidence gathering.

Quantify impacts

The key impacts will be quantified in terms of their cost impact. In many instances it will be necessary to derive a cost impact from other impacts such as time or risk. A quantification method will be developed for each key impact that determines the implications for different affected parties and considers the most important variants (e.g. organisation size, construction type, product type, etc) as appropriate. The method will allow for changes in the nature of any impact over time, e.g. as new working methods / design protocols become embedded.

Applying a simple 80:20 rule (Pareto principle) the quantification will aim to cover the majority of scenarios, together with any specific situations of higher impact, but will not cover all conceivable situations.

Overall impact and reporting

The overall impact of the recommendations will be derived from the key quantified impacts (with supporting commentary to highlight qualitative factors). The assessment will cover all house building in England and will consider both costs and benefits in the short and medium term.

Whilst the output will aim to quantify both costs and benefits, these analyses will be subsidiary to a more nuanced assessment of the range of qualitative impacts believed to arise from the Steering Group's recommendations and taking into account specific feedback from the Industry Executive Committee on the wider commercial aspects of the recommendations.

Emerging Work Plan

Previous sections have detailed a variety of potential issues that could impact the performance gap, which have been raised during Work Group discussions. This section explains how the Steering Group is identifying cross-cutting issues and outlines the initial proposals from the Work Groups for their next steps.

Cross-cutting issues

During Work Group presentations to the Steering Group, and linked to the process mapping exercise, a number of cross-cutting issues have begun to emerge. Capturing these is an important step as information flow and responsibility between the delivery stages is of particular interest.

Loosely based upon the previously presented process map[13], the following diagram (Figure 6) summarises a selection of cross-cutting issues. At this stage of the project's research, and until the evidence based prioritisation is complete, these issues should not be considered of any greater significance to the performance gap than any others. They have primarily been selected due to their appearance across multiple stages of the delivery process. The issues have been categorised into the four key themes identified by the Process group; Knowledge, Communication, Responsibility and Skills. An issue may fall into multiple themes, but one per issue has been chosen for the purpose of the diagram.

Some of these cross-cutting issues may provide a coherent area upon which evidence gathering activities can be co-ordinated. The primary objective is to ensure any interactions with the wider industry (including surveys) are well structured to encourage a positive response.

Work Group proposals

The Work Group Leads, in conjunction with their members, have proposed work plans for the next project phase. These are available in Appendix F and provide an indication of the type of activities that may be undertaken following the evidence-based prioritisation, although it should be noted that these plans are not comprehensive. There are clearly cross-overs between groups and therefore the Zero Carbon Hub team, in discussion with the Steering Group, will draw together the various proposed activities to ensure there will be no duplication of effort and that resources are directed in the most efficient way and towards the activities which will yield the greatest results.

It is important to note that prior to undertaking any of the delivery activities proposed by the Work Groups (as opposed to those relating to evidence gathering), a process of prioritising the issues that impact the performance gap will be carried out. Only activities relating to those issues considered to have a significant impact on the performance gap will be taken forward within the timescale of this funded project. The prioritisation process is explained further in 'Next Steps' on page 33.

[13] For more information see 'House Building Process', page 13.

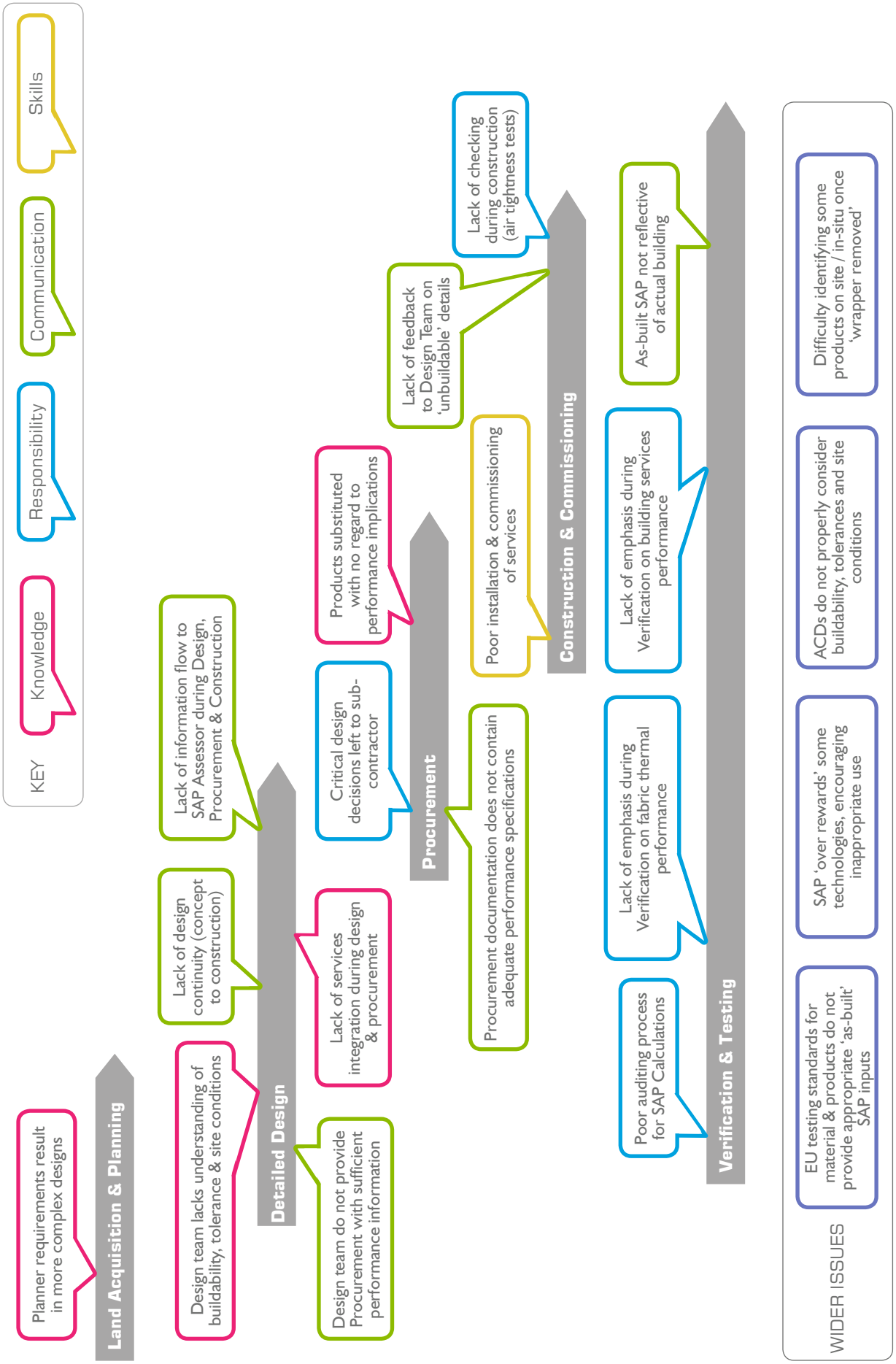


Figure 6 Cross-cutting issues as explored at the All Members Workshop

Next Steps

The activities carried out so far, as described in previous sections of this report, have revealed the sheer number of issues which are perceived to have a potential to impact the performance gap. The next stages of the project will enable these to be prioritised via the evidence gathering and analysis process, and should also reveal those aspects that are not as relevant as might have initially been thought.

The work plan (Figure 7) has necessarily been adjusted from the initial proposal due to the difficulties the group has faced in gathering evidence for some of the issues involved. The decision has therefore been taken to extend the evidence gathering phase in order to avoid making premature assumptions on the impact and hence prioritisation of the issues identified. It has always been acknowledged that this project will not solve all the issues raised and that evidence gathering and development of solutions will need to carry on beyond March 2014.

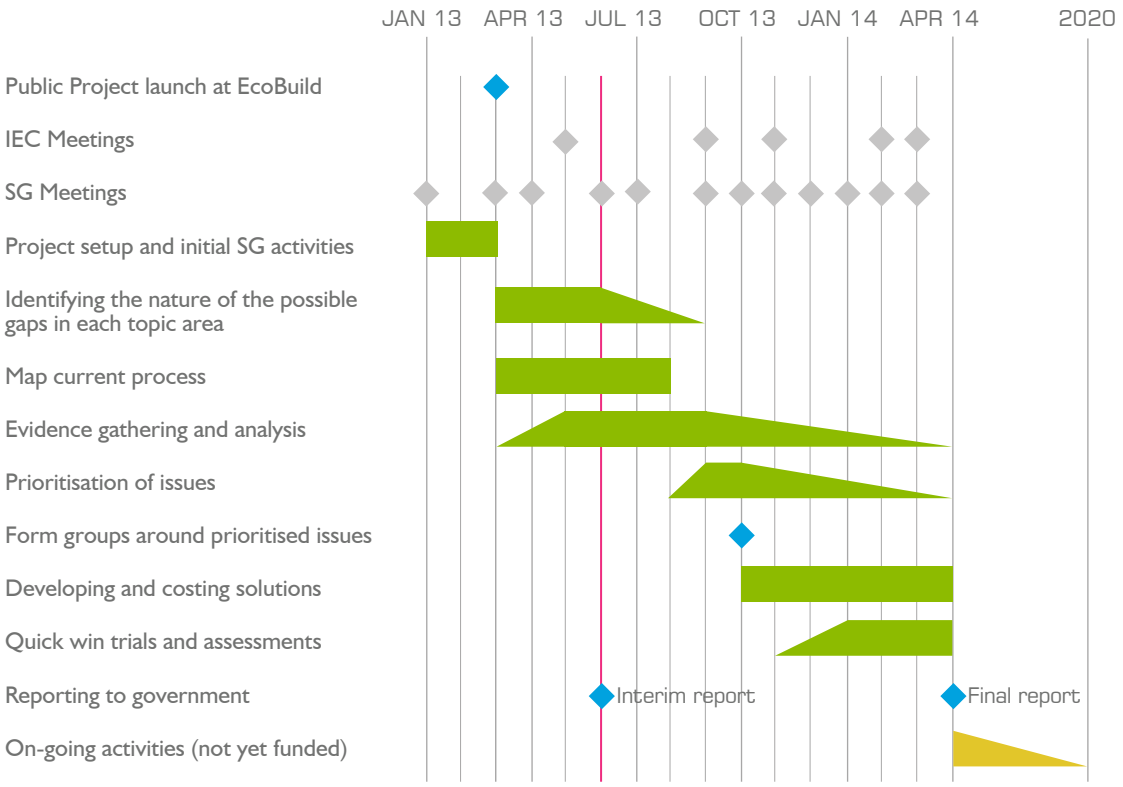


Figure 7 Work Plan

Immediate actions

Evidence collection and analysis

It is recognised that in carrying out the initial identification of issues, the Work Groups relied quite heavily on their own experiences and expertise (which can mainly be classified as anecdotal evidence). Further evidence collection, collation and analysis will be carried out over the summer, with the intention that in September enough information will be in place to enable the Steering Group to make decisions on the prioritisation of issues to be taken forward and tackled, including identification of 'quick wins'.

Options that will be considered for the gathering of additional evidence may include[14]:

- Desktop studies e.g. to assess the issues arising from poor SAP calculations.
- Assessment methodologies such as 'Walk Throughs' to physically inspect materials and products used in construction for comparison against those specified, and to gather information on current site practices.
- Specific discussions with Registered Providers of affordable housing on evidence they may hold from building to advanced standards or employing innovative techniques.
- Potentially commission work to compare and contrast traditional build methods with a system-build approach to see if there are lessons to be learnt.
- Request access to unpublished data held by universities.
- Field trials.
- Physical laboratory tests of 'systems' and 'assemblies' and / or connecting component parts.
- Evaluating the effectiveness of Validation and Verification processes on test sites.
- Independent assessment of a sample of architectural and services drawings for buildability.

Some of these further evidence gathering activities will require additional funding, which will be sought from a variety of places including EPSRC, TSB, DCLG, DECC, industry, and linking with current funding opportunities from existing programmes.

The Zero Carbon Hub team is in discussions with HBF regarding their offer of making available homes on a number of their members' sites for anonymised testing / trialling and evidence-basing. Discussions have also been taking place with the Technology Strategy Board to explore how this project can gain access to data from the Buildings Performance Evaluation programme and wider EMBED[15] data sets prior to their wider publication which does not quite tally with the timescales of this project.

Services

It has been identified that Work Group discussions so far may not have focused sufficiently on the services aspect of dwellings (heating, hot water, ventilation, etc) so in order to rectify this situation a specific group of people, drawn from those involved in the project and any other support deemed necessary, will be convened to discuss the potential performance gap issues arising from the design and installation of services and their manufacture, testing, and performance reporting.

Knowledge and Skills

The issue of knowledge and skills has been raised in all the Work Groups, with some pointing to issues with the general culture within the house building industry. This is an aspect which is already acknowledged to be a major issue in relation to the performance gap, and is thought to stem from a lack of specific training for people coming into the industry coupled with a lack of appropriate continued development of individuals already part of the industry. Therefore, over the next few months a specific group of representatives from the Skills Councils, Further and Higher Education, Professional Institutions, and other industry bodies such as the Green Construction Board Knowledge and Skills Project Group will be drawn together to help the project engage on this issue in a more meaningful way. An application has been made to CITB[16] for additional funding to help develop the training material and dissemination routes that the project may recommend.

[14] A brief summary of evidence gathered to-date can be found in Appendix E

[15] Energy Monitoring and Building Evaluation Database

[16] The Construction Industry Training Board

Prioritisation of issues

A matrix has been developed to help prioritise the importance of identified issues. This compares the potential impact each issue has on the performance gap against the sufficiency and clarity of evidence collected for that specific issue (see Figure 8). Once the placing of the issues has been ratified by the Steering Group, it should be clear which issues should form part of the ongoing work plan for this project and which can be disregarded as they are of relatively low significance or are best tackled at a later date.

Those issues where there is both clear evidence and a high impact will be taken forward by the project, to develop solutions and recommendations (Area A on Figure 8). The impact of the potential solutions on the industry will be analysed by the project's cost consultants prior to being discussed by the Industry Executive Committee.

Those issues where a medium-high impact is suspected, but clear evidence is not available (Area B), will be investigated by further evidence gathering and analysis to see whether the issues are substantiated (and hence move horizontally to the right of the matrix) or if they turn out to be low impact or unsubstantiated issues (and hence move towards the bottom right of the matrix).

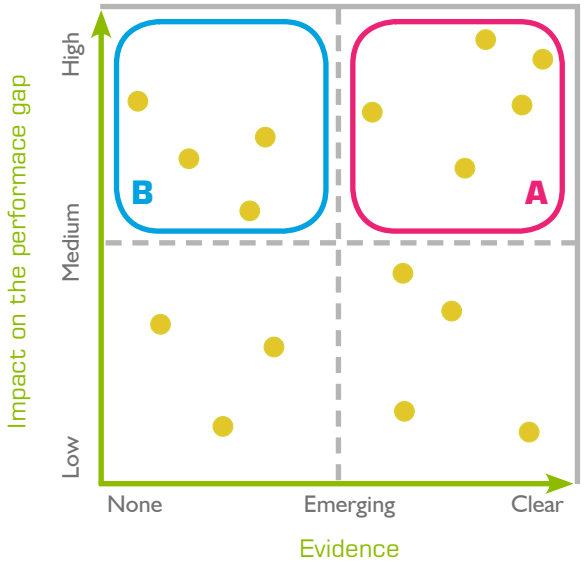


Figure 8 Impact-Evidence matrix to aid prioritisation of issues

Establishing a baseline

It is recognised that in order to measure progress on topic areas there must be a defined method to clarify whether there is an actual impact on closing the performance gap. This might take the form of establishing 'where we are now' and identifying how much progress has been made over a defined period. Where it is not possible to establish a baseline, the method of demonstrating a reduction in the performance gap 'by proxy' will be developed.

For example, whilst it is the case that use of Accredited Construction Details could be said to provide a known baseline, it is not easy to verify whether the details are being implemented successfully in the Construction phase of a development. Therefore unless a 'by proxy' methodology is developed, it will be very difficult to demonstrate whether a new scheme and set of details is an improvement or not.

Establishment of a baseline for the prioritised issues forms part of the next steps for this project.

Defining Solutions

The intention is to re-form the Work Groups, which have so far acted mainly as 'consultation' groups, around the activities dictated by the issues which fall in the 'clear evidence, high impact' and 'low evidence, potentially high impact' quadrants of the matrix. This will be carried out after the further review of evidence, described above, has been undertaken.

The groups will set their own programme of work, assisted by the Zero Carbon Hub team, to tackle the prioritised issues and any additional evidence gathering. This will be communicated to the Steering Group for approval.

Issues that are identified as 'quick wins' will be progressed with a view that, by the end of the funding period of this project, there will be activities completed or in train to deliver the specific solutions identified. This may include 'good practice' documents, revisions to Codes of Practice, on site tool box talks for trades personnel, development of further testing, practice notes, introduction of new LABC / NHBC standards etc. Cross-cutting issues such as those surrounding the compliance tool may need additional specific consideration in relation to defining workable solutions.

Areas requiring government support

The project work to date has already identified that government departments may need to be consulted with in order to address potential issues that may inhibit the closing of the performance gap if action is not taken. Areas requiring government support include:

- A serious review of the SAP assessment tool, including inputs.
- The update of construction joint details.
- Supporting industry's ambition to improve knowledge and skills.
- Supporting the development of new test methods.

It is also recognised that there may be certain legislative barriers to particular solutions. For example, harmonised European standards may be a barrier to 'in-situ' product performance declarations. This may require specific recommendations on revisions to the rules or their application in certain parts of the industry.

A final report to government will be delivered at the end of the project period in March 2014. This will include a more detailed analysis of the issues affecting the performance gap and recommendations for a future programme of work to deliver the '2020 ambition'.

Acknowledgements

The Zero Carbon Hub is extremely grateful to all those involved in the first phase of this project and is looking forward to ongoing support from government and industry sectors. Special thanks go to the Chairs of the Industry Executive Committee and Steering Group, and the Work Group Leads.

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