LowCarb4Real: Developing Low Carbon Housing, Lessons from the Field.

Draft Final Report

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LowCarb4Real is a collaborative knowledge exchange project undertaken by Leeds Metropolitan University, University College London, The Good Homes Alliance and the University of Leeds. The project is funded by the Urban Buzz programme coordinated and facilitated by University College London and the University of East London. Urban Buzz is designed to foster the exchange and development of the knowledge required to develop sustainable communities.

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Introduction

1. The LowCarb4Real project, funded through the UrbanBuzz programme (project No. 388), lies in the UrbanBuzz target area “Energy efficiency and sustainable housing: harnessing academic understanding”. As is recognised in the Urban Buzz programme, the contribution made to sustainable communities by reducing carbon emissions from housing is considerable. It is recognised also that low carbon housing is highly dependant on design and construction that reduces to a minimum energy demand through improved energy efficiency. However, the findings of the Stamford Brook field trial have demonstrated overwhelmingly that there is a gulf between designed performance and measured performance. The extensive action research programme at Stamford Brook has shown that fabric heat loss (independent of user interaction) can be more than twice as great as design calculations would predict. Other smaller scale studies going back to the 1980s have provided evidence to indicate that the findings from Stamford Brook are likely to hold good for most mainstream new housing. The problem is not widely understood either in industry or in government, the LowCarb4Real project attempted to identify why this situation exists and how it should best be addressed.
2. It appears likely that the specific technical findings at Stamford Brook represent a class of potential mechanisms by which design performance of future dwellings will be degraded. Underperformance, currently masked by cheap energy and oversized heating systems, will become more noticeable and less acceptable as energy prises rise and target emission rates are reduced. The carbon emission limits of Code Level 3 and beyond are likely to entail increasing complexity, less redundancy, faster rates of innovation and unfamiliar low and zero carbon technologies. Unless academia and industry are able to develop systems and a culture capable of managing these challenges, underperformance is likely to increase in relative and possibly even absolute terms. The rapid pace of change is likely to mean that some technical solutions may have a short useful life. The key to managing the process is likely to be the transformation of successful construction companies into learning organisations. The LowCarb4Real project provides initial steps for this transition towards a much closer partnership between industry and academia.
3. This report sets out the main messages and technical materials used to stimulate debate in the LowCarb4Real workshop programme, and describes the outcomes from this knowledge exchange process. The project was designed to develop the knowledge necessary to make Low & Zero Carbon housing a reality, where it matters, “on the ground”. It sought to set up a knowledge exchange programme based on the lessons from the Stamford Brook housing field trial and the experience of those developers seeking to build beyond current building regulations. The project also sought to provide a model for industry-based research and knowledge exchange.
4. Throughout this project the approach was designed as one in which the project team and workshop participants were seen as contributors to the development of learning in a spirit of knowledge exchange. The lessons from the Stamford Brook research project are as significant in the areas of process development and industrial cultural change as they are in the detailed understanding of the application of Low Carbon design and technology in new housing. This project provided an ideal opportunity to hold the sort of participatory, action learning, exchange with the industry that is required if progress is to be made in improving the housing design and production processes and in framing regulatory and other policies needed to provide support.
5. In addition to the dissemination of the learning outcomes from the Stamford Brook field trial and experiences of GHA members, a key objective of the project was to facilitate knowledge exchange based on two key areas of learning:
    - The application of main stream construction technology and the key technical issues in the design and construction of Low Carbon Housing.
    - The development of improved housing procurement and building processes designed to ensure that Low Carbon performance is reliably achieved.

In each area, the programme developed not only the specific lessons from the research but also teased out the underlying lessons that will enable technology and processes to be adjusted and redesigned as the industry moves towards the goal of Zero Carbon Housing.

6. Rather than follow a traditional route based on a process of one way dissemination through industry road-shows and seminars, the LowCarb4Real project sought to foster a two way knowledge exchange. The Stamford Brook team partnered with the Good Homes Alliance in an attempt to broaden the relevance and appeal of the findings from Stamford Brook and then progress through a programme of two-way industry workshops designed to develop skills, knowledge and insights within developers and developer groupings, and between them and academia. Through discussion of change and change planning as part of the main workshops, it was envisaged that both industrial and academic partners and participants would be equipped to influence change in the practices within their organisations.

7. The partnership with the Good Homes Alliance was of particular importance since it is made up of small to medium size developers building to standards similar to and often in advance of the standard used at Stamford Brook. Crucially, the GHA provided access to a developer group at the other end of the scale from the major housebuilders participating in the Stamford Brook development. The GHA represent some of the leading practitioners for delivery of energy efficiency within the SME sector and are directly responsible for 1.5% of the UK new build housing. They have a significant impact as professional advisors on many other projects and, through their policy influence and leadership positioning in the UK, are able to provide direction and learning from which both industry and academia can benefit.

8.

9.

LowCarb4Real Process

10. The LowCarb4Real project commenced in January 2008 with the immediate task of establishing an advisory/steering committee comprising of representatives from the project team, UrbanBuzz, Government, academia, industry and other influential stakeholders. The group assembled at regular intervals to oversee the development and evolution of both a knowledge exchange plan (Appendix 1) and an evaluation plan (Appendix 2).

11. The LowCarb4Real knowledge exchange programme was based around 6 interactive workshops attended by people from all levels within the industry. Table 1 details the workshop programme, with a pilot workshop held in June 2008 used to examine the effectiveness of the proposed workshop format, this format was subsequently adjusted to increase participant input and feedback for later workshops. The final evaluation workshop took the format of a strategic forum, with initial outcomes from all previous workshops leading the discussions This was designed to gain initial feedback on some of the difficulties of achieving deep rooted change and to provide an opportunity for a stronger involvement by influential stakeholders and policy makers.

Table 1 LowCarb4Real workshop dates and locations

	Date	**Location**
Pilot Workshop	19th June 2008	Leeds Met
Workshop 1	22nd July 2008	UCL
Workshop 2	24th July 2008	Leeds Met
Workshop 3	11th September 2008	Leeds Met
Workshop 4	16th September 2008	UCL
Strategic Forum	30th October 2008	UCL

12. As set out in the project's knowledge exchange plan (Appendix 1), the key messages and other technical material disseminated to workshop participants were contained in a series of project "posters" that were easy for the audience to digest and provided enough understanding of the principles to enable workshop participants to engage in

more detailed study following the workshops. The posters were based on the main findings from the Stamford Brook field trial and a number of case studies undertaken by the Good Homes Alliance. In addition to posters, the workshops were introduced with presentation sessions on the findings from Stamford Brook and Case Study material from GHA projects. The poster collection is included in this report in Appendix 3, and together with most of the presentation material, is available on the LowCarb4Real project web page held on the Leeds Metropolitan University website[1].

13. Although the project advisory group members had planned to recruit participants from each of their relevant sectors of government, industry or academia as outlined in the workshop participant matrix (table 2), this was not always forthcoming. As a result many of the workshop attendees came as a direct consequence of invitations from the project team. Efforts were taken to ensure that a diverse delegate list representing a broad spectrum of professions and skill levels.

Table 2 Workshop participant matrix (from the knowledge exchange plan)

Workshop participants	**Workshop Dates**						**Total**	
Month	**June**		**July**		**September**			
Day	**17**	**19**	**22**	**24**	**16**	**11**		
Location	**London**	**Leeds**	**London**	**Leeds**	**London**	**Leeds**	**No.**	**%**
S-Mgt Const.	3	3	3	3	3	3	**18**	10
S-Mgt Des/tech	3	3	3	3	4	4	**20**	11
Mid - Mgt Const..	4	4	4	4	5	5	**26**	15
Mid - Mgt Des/Tech.	4	4	4	4	5	5	**26**	15
Consultants	5	4	5	4	5	4	**27**	15
Sub - mgt.	2	2	2	2	2	2	**12**	7
Sub - site.	2	2	2	2	2	2	**12**	7
Const Train	1	1	1	1	1	1	**6**	3
Sup chain	3	3	3	3	3	3	**18**	10
Policy	2	2	2	1	2	3	**12**	7
Total	**29**	**28**	**29**	**27**	**32**	**32**	**177**	**100**

14. Although a diverse mix of participants was planned and invited to each of the workshops, due to participants dropping out and non-attendees this was not always achieved. Table 3 shows the actual participant mix realised for the 3 workshops held in Leeds. Whilst a similar participant mix to that desired was attained at the September workshop, participant representation for the July workshop consisted only of developer staff (senior and middle management), design staff, inspection & services professionals and supply chain representatives; with no voicing of opinions from site staff, training staff, or from those directly involved in policymaking. As a result some of the initial workshop outcomes put forward to the strategic forum may have been biased towards the sectors most highly represented throughout the workshop programme. The participant mix at the 2 London workshops displayed a comparable under-representation of subcontractor/site staff.

Table 3 Workshop participant mix at workshops held in Leeds

		Jun-19		**Jul-24**		**Sep-11**		**Leeds Totals**	
Role	**Sub-group**	**Number Attending**	**%**	**Number Attending**	**%**	**Number Attending**	**%**	**No.**	**%**
Site Staff	Operative	3		0		0		**3**	
	Supervisory	1		0		2		**3**	
	Total	4	22	0	0	2	7	**6**	10
Developer Staff	Technical	1		6		6		**13**	
	Managerial	6		4		5		**15**	
	Total	7	39	10	56	11	41	**28**	44
Design Staff	Architecture	3		3		3		**9**	
	Services	1		1		0		**2**	

[1] http://www.leedsmet.ac.uk/as/cebe/projects/lowcarb4real

	Total	4	22	4	22	3	11	**11**	17
Inspection & Services		1	6	2	11	3	11	**6**	10
Training Staff		1	6	0	0	3	11	**4**	6
Supply Chain		1	6	2	11	2	7	**5**	8
Policy		0	0	0	0	3	11	**3**	5
Total		**18**	**100**	**18**	**100**	**27**	**100**	**63**	**100**

15. Presentations and breakout sessions concentrating on technical issues at the workshops explored the lessons for design, construction practices and production processes. Ensuing discussions relied on a mix of participants in each group to deliver outcomes representative of the industry as a whole rather than opinions provided by a limited sector. Breakout groups were designed to include, wherever possible, such a range of skills and experiences to provide consideration of the issues from a variety of perspectives. One of the achievements of the LowCarb4Real knowledge exchange process was in getting these diverse groups to enter into round table discussions, in many cases with participants of a level they would not normally discuss such issues with. Participants gained awareness of what others within the industry could offer them and developed an appreciation of what effect their actions and decisions could have on others at different stages of the design/construction process.

Workshop Methods

16. The workshops consisted of presentations to start each morning and afternoon session after which the audience would divide into smaller breakout groups, re-assembling with a plenary discussion to culminate the days' activities, an example of a typical workshop schedule is shown in figure 1. The morning presentation concentrated on the lessons learnt from Stamford Brook and awareness of the gap between as-designed and as-realised energy performance, the afternoon presentation took the form of a case study from a GHA member. A number of simultaneous morning breakout sessions each approached different technical issues; either robust thermal design (including thermal bridging and thermal bypassing), airtightness or systems performance. For the afternoon breakout sessions, groups were re-assigned to achieve a mix of skills and contain representatives from all the morning breakout groups. The afternoon breakout groups underwent a brainstorming exercise with the lead question, "What do designers and constructors need in order to be able to design and construct low carbon housing that is effective, robust and works every time?". Emerging ideas were discussed, and the main themes written onto flipchart sheets to be presented to the plenary session by a group member prior to the general discussion of "Developing a Road Map to 2016".

Workshop Structure – 11th September 2008		
Time	Room	
09:30 – 10:00	118	Registration
10:00 – 10:15	118	Welcome & Introduction to the Day
10:15 – 11:15	118	Overview of Stamford Brook Key Messages
11:15 – 11:30	118	Coffee Break
11:30 – 12:30	G13 G14 119 221	Breakout Groups – Session 1 *Technical Issues*
12:30 – 13:15	118	Lunch
13:15 – 13:45	118	Overview of Good Homes Alliance Key Messages
13:45 – 15:00	G13 G14 119 221	Breakout Groups – Session 2 *"Needs" of designers & constructors*
15:00 – 15:30	118	Coffee Break
15:30 – 16:30	118	Plenary Discussion – Developing A Road Map to 2016
16:30		Close

Figure 1 Example workshop schedule

17. Figure 2 illustrates the LowCarb4Real process and forms the basis of the "*Methods; Converting Inputs into Outcomes*" poster, one of the Workshop Collection series of posters in appendix 3. The initial inputs into the LowCarb4Real workshops came from the Stamford Brook field trial, case studies from GHA members and additional examples of the performance gap observed by the project team. These were introduced to the workshops through presentations and poster material, and fed into the breakout sessions where additional comments and arguments put forward by the workshop participants provided further contributions. All of this was carried forward into the plenary session discussions. Analysis of the outputs from the plenary sessions and from material produced during the '*Needs*' breakout sessions shaped the primary inputs into the strategic forum.

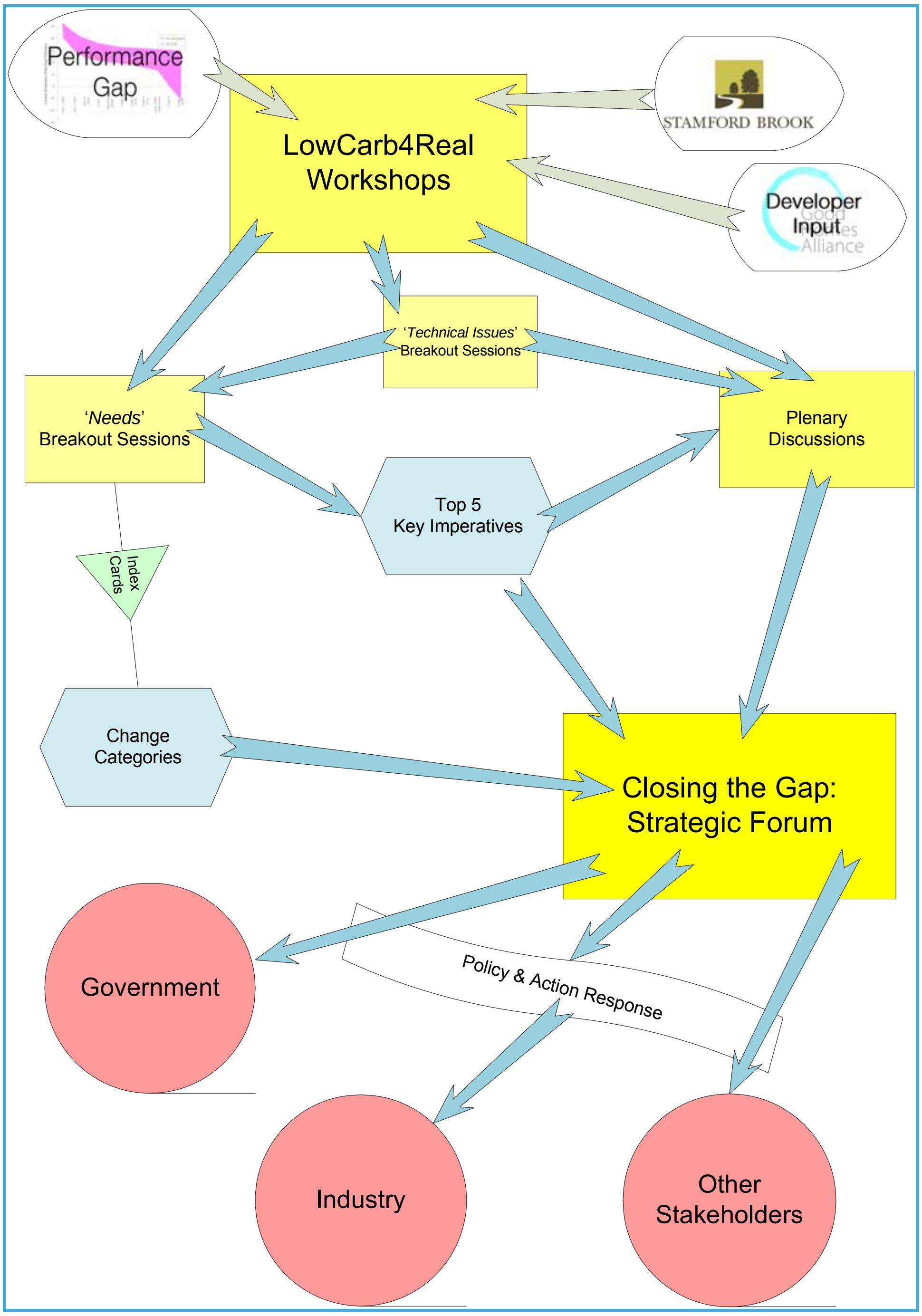


Figure 2 LowCarb4Real process diagram

18. As a culmination of each workshop, all participants took part in the final plenary session. Designed to build upon the day's activities, this took the format of 2 lead questions:

    - What do we need to make the changes?
    - How do we improve performance and close the gap?

    Breakout Session 2 groups presented the outcomes of their brainstorming sessions on the '*Needs*' of designers and constructors to produce Low Carbon Housing to the plenary session audience for general discussion and comment. The discussion was then opened up to the floor, and the topic of discussion moved to more general policy issues of developing a road map to the Government's broad aims of meeting the Zero Carbon target for new build housing by 2016 and how to address the issue of the gap between theoretical "as designed" performance and what is achieved "as built" in reality.

19. The proposed final evaluation workshop developed into "Closing the Gap: A Strategic Forum on the Energy Performance of New Housing". As performance targets get increasingly more stringent, the potential for the gap between predicted and measured energy performance of dwellings is likely to increase proportionally - unless action is taken immediately. The LowCarb4Real project sought to increase awareness of this concern and gain feedback from workshop participants on how best to develop solutions, the strategic forum took understanding and addressing the performance gap as it's main theme, and used preliminary outcomes from the previous workshops as a starting point in tackling the problem and identifying the potential resolution paths.

20. With an invited audience of representatives from Government, industry and other prominent stakeholders, The purpose of the Strategic Forum was to inform, and influence where possible, key stakeholders in each of these sectors. As with the previous LowCarb4Real workshops, the event centred around knowledge sharing. Presentations from the project team and previous workshop participants lead into breakout sessions asking:

    - What is required in order to initiate and embed the required change?

    Breakout Session groups each debated 2 of the Change Categories, discussed the issues arising and reported back to the Forum (as done in previous workshops). For the Strategic Forum, the report back planned to identify the policy and strategic responses required for action by; Government, Industry and Other Stakeholders.

21. Sense of methodology?

Knowledge exchange

22. The Stamford Brook field trial was an action research project funded by the Department for Communities and Local Government (CLG) and based around a 700 house development undertaken by Bryant Homes and Redrow Homes, on land owned by the National Trust. The 6 year field trial sought to assess, in a comprehensive way, the issues involved in improving the carbon performance of mainstream house building. It has generated an unprecedented amount of learning related to airtightness, envelope integrity and systems performance, at all levels including building physics, dwelling design, site management, workforce training and procurement systems. Given the challenging regulatory targets proposed by government aimed at Zero Carbon new housing within 10 years, it is crucial that the learning from field trials such as Stamford Brook is captured, refined, contextualised and embedded as thoroughly as possible within the house building industry.

23. The LowCarb4Real workshop presentations centred around the "Developing Low Carbon Housing: Lessons from the Field" context, using real experiences, data and observations to highlight the issues needing consideration. The Leeds Met research team presented material to the workshops based on the Stamford Brook field trial; specifically looking at thermal performance, airtightness, thermal bypassing and the construction process, but also approaching the more general issue of the gap between 'as-designed' and realised energy performance. Presentations from GHA members illustrated that some developers are already building to higher standards. Both sets of presentations gave insight not only into their achievements, but also to the pitfalls and barriers encountered on their journeys and how these might be overcome.

24. The "*Technical Issues"* breakout groups provided additional opportunity for dissemination of some of the Stamford Brook key findings, where aspects of potential underperformance were highlighted to participants, actual details re-designed and potential solutions discussed. The robust thermal design breakout groups looked specifically at thermal bridging and thermal bypassing, encouraging participants to identify where these problems existed by using actual examples; explaining the principles and asking participants to re-design details to eliminate or minimise these heat-loss mechanisms whilst considering issues such as sequencing and buildability. The airtightness groups considered air barrier design, continuity and robustness, and were asked to perform pen-on-section tests on actual details, re-designing these

details to eradicate air barrier discontinuities and interruptions and maintain its location adjacent to the thermal layer to diminish the risk of thermal bypassing. The groups examining systems performance sought to estimate the potential for heat loss from primary pipework in real examples and redesign dwelling layouts to minimise the gap between individual component performance and systems performance. In all groups the technical exercises were followed by open discussions of both the problems and of potential solutions.

Feedback

25. The '*Technical Issues*' breakout sessions used input from brief technical presentations and the 'Re-designing the detail' task to stimulated discussion and feedback from the workshop participants. Audio recordings and flipchart notes made by the session facilitators were used to document responses and formed the basis of feedback from these sessions together with the annotated details resulting from the tasks.

26. The 'Needs' breakout session used brainstorming to focus on the requirements of both designers and constructors to build low carbon dwellings that would reliably work in practice. Ideas were written onto individual index cards which were subsequently read out and discussed. Stimulated by the presentations and earlier '*Technical Issues*' sessions and drawing on participants' own broad spectrum of professional experiences, nearly 800 ideas were written on cards during the '*Needs*' breakout sessions. After discussing as many of the developing ideas as possible in the time available the participants in each '*Needs*' session were asked to decide upon their top 5 Key Imperatives necessary to embed the required change from the issues raised, these were written onto flipchart sheets to present as feedback to the Plenary Discussion. Audio recordings of these sessions and flipcharts notes augmented the outputs of index cards and key imperatives lists to chronicle the outcomes from the '*Needs*' sessions.

27. Following the series of workshops both the index cards and top 5 key imperatives outcomes from the '*Needs*' breakout sessions underwent a degree of analysis and were utilised as starting materials for the breakout discussions at the 'Closing the Gap' strategic forum. The index cards were collated and classified into 8 Change Categories, as listed in table 4, with each breakout group at the strategic forum discussing a pair of Change Categories. The 'Top 5's were similarly analysed classified into 13 main set of key imperatives for change. These are described in more detail in the Workshop Outcomes section of this report and form the basis of 2 posters in the Workshop Collection series of posters.

Table 4 Change Categories

Change Categories	**No. of Index Cards**
Process	195
Culture & Environment	138
Knowledge, Skills, Education & Training	177
Communication	49
Resources	54
Tools & Methods	85
Supply Chain	56
Design/Technology Solutions	17

Evaluation Process

28. The LowCarb4Real project evaluation plan (Appendix 2) describes the conceived routes for knowledge transfer anticipated throughout the project. However, as the project evolved it was deemed that knowledge transfer to a potential 200 workshop participants would be too limited an outcome, and the knowledge transfer mechanism was refined to become one of knowledge exchange, utilising the inputs from workshop participants to expand on those of the project team and together propose solutions to the question, how do we produce Low Carbon Housing that performs as designed? The LowCarb4Real project has provided the opportunity to look at this from the bottom-up, through the eyes, opinions and insights of people who work in

the construction industry, as they are confronted with empirical evidence on the performance of new housing. In doing so, teasing open the reasons why things are as they are and what might be done to change them and eventually feeding these back to decision makers and key stakeholders as a guide to action.

29. Figure 3 illustrates the different levels at which the LowCarb4Real project is designed to facilitate the knowledge exchange. Whilst the inputs to the initial workshops shown in figure 2 form the main Level 1 drivers, interactions between workshop participants provided insight and consideration of issues at Levels 1-3. During the workshops, breakout sessions were designed to include a mix of participants of various skills and knowledge levels and a variety of professions to encourage knowledge transfer between different sectors of the industry, primarily at the micro and meso levels. Outcomes from the workshops fed into the strategic forum, where the participants were invited specifically to view potential actions and policy implications of embedding change at the macro level as indicated figure 3.

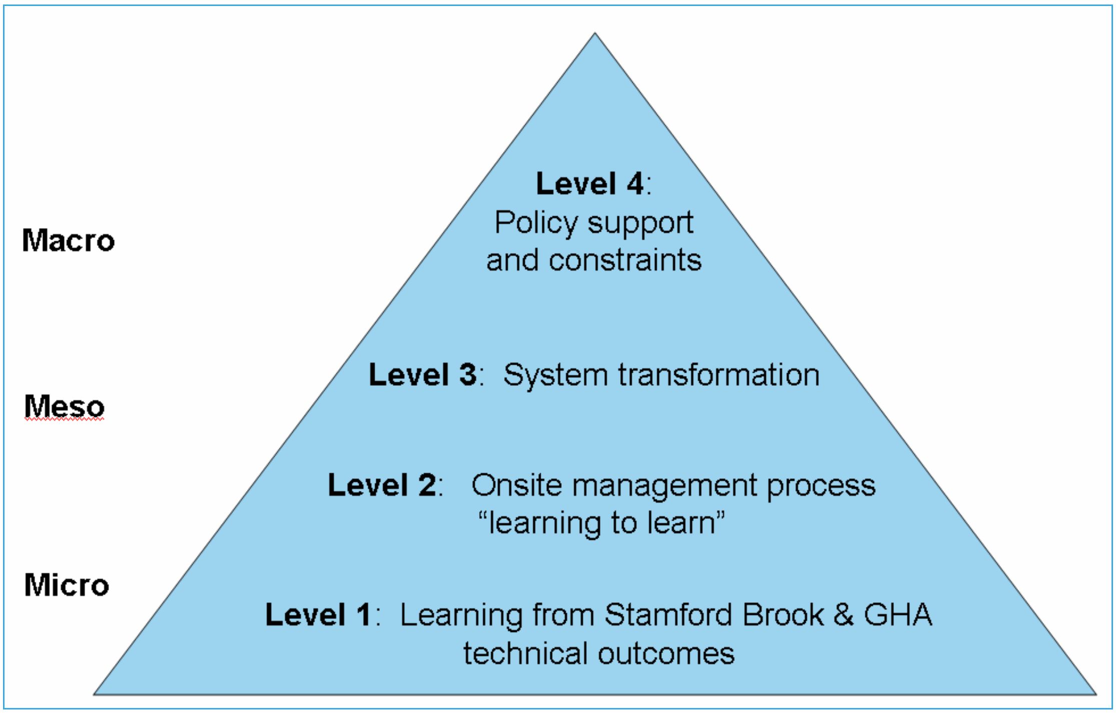


Figure 3 Mapping of learning levels

30. How does this help achieve objectives …

31. The LowCarb4Real project outline set objectives to be achieved in sustainability and knowledge transfer in a number of categories; environmental, social, economic, sound science, governance and knowledge exchange.

32. The environmental, social and economic objectives all revolve around improving the housebuilding industry in the UK to produce Low Carbon, energy efficient dwellings that meet exacting energy performance standards in practice, not just on paper; reducing CO_2 emissions, reducing the risk of fuel poverty and increasing the capabilities of the industry. For these 3 objectives the dissemination of the Levels 1 and 2 learnings from Stamford Brook, GHA and workshop participants meet the objective directly for those attending the workshops through changes in knowledge, understanding and attitudes of individual participants. It is anticipated that the knowledge transfer will continue beyond the course of the LowCarb4Real project through material outputs such as the poster collection and the website, The direct impact on the energy performance of new dwellings may be small due to the numbers involved, but where workshop participants involvement is elemental their awareness of issues such as thermal bypassing and systems underperformance may go some way to addressing many of the problems inherent in UK dwelling design and construction.

33. The findings from the participatory action research approach adopted during the Stamford Brook project formed the initial basis for the LowCarb4Real knowledge transfer programme and satisfy the sound science objective. Additional input from GHA members supplemented the research and dissemination of Stamford Brook by using a firm scientific footing for their case study material. A multidisciplinary project core team and advisory group ensured that workshop materials, posters and outputs were peer reviewed and the sound science objective achieved.

34. LowCarb4Real sought to identify institutional and legislative barriers to change and increase understanding within the policy making fraternity of the implications of more exacting energy performance standards for new housing. By obtaining input from across the broad spectrum of the housebuilding industry through individual workshop participants, a range of perspectives was achieved and fed back to key policymakers and stakeholders through the advisory group and the Strategic Forum, with intentions to maintain this beyond the LowCarb4Real project life.

35. The LowCarb4Real programme has established an effective model for knowledge exchange within the construction industry, with the learning of all workshop attendees extending beyond the lifetime of the project through their active participation. Knowledge transfer through workshop materials, technical issues sessions, posters and discussions was an expected outcome, but the levels of learning and knowledge exchange observed by placing construction industry staff of differing professions and levels of expertise in specific areas into open roundtable discussions was an unanticipated but welcome benefit.

The Poster Collection

36. The poster collection is included in this report in Appendix 1, and is available to download from the LowCarb4Real web page[2]. The initial posters illustrated some of the outcomes of the Stamford Brook field trial and GHA member experiences; these were embellished with relevant details from other projects to enhance the Level 1 learning and knowledge exchange. As the project progressed, the poster collection evolved to include additional material including some of the outcomes from the first phase of the LowCarb4Real workshops and focus more on the Level 2 and 3 issues. The emergence of the idea of using posters both as the prime vehicle for describing the main issues and as a record of the material and themes emerging from the workshops has resulted in the poster collection becoming a live and developing document.

37. During the workshops, A1 versions of the posters are used to provide a backdrop to the day with opportunities for delegates to look at them during breaks and A4 versions are included in the delegate pack. Informal observations of delegates at the workshops suggest that delegates use the posters and the A4 versions in the packs as casual reading and some have made comments on content. In the case of the large posters conversations between delegates and between delegates and the project team have been enhanced by the ability to refer to the illustrative material mounted on the wall. This provided a level of reinforcement of the central messages and a stimulus for discussion of the issues that emerged.

38. In some of the workshops, where space was available blank comment versions were positioned next to each poster and delegates were invited to make comments on the material. The comments are included in the project data set (appendix 3).

39. .

40. The poster collection is made up of the following sub-collections.

The Project Poster

41. The initial project poster entitled " LowCarb4Real: Developing a road Map to 2016" outlined the project, highlighting issues such as knowledge exchange, key stakeholders, the workshop programme, the requirement for cultural change and

[2] http://www.leedsmet.ac.uk/as/cebe/projects/lowcarb4real

introduced the concept of closing the performance gap (the gap between as-designed and as-measured dwelling performance).

The Stamford Brook Collection

42. Two posters, “Developing Low Carbon Housing: Lessons from Stamford Brook” and “Stamford Brook; Publications & Reports” provide a concise overview of some of the learning achieved during the Stamford Brook field trial and how this information is being disseminated to Government, industry and other stakeholders.

The Design Collection

43. This collection of four posters focused on “Thermal Design Principles”, “Airtightness Design Principle”, “Thermal Bridging” and “Thermal Bypassing”, each concentrating on and individual aspect relating to the design of building envelope. Using examples from the Stamford Brook project and drawing on additional materials, the general principles of each of these facets of design was explained and guidelines for consideration suggested

The Construction Collection

44. Focusing on construction issues such as site sequencing, responsibility, training and awareness of critical areas, this poster used the construction of the air barrier to highlight where, how and why some of these issues occur.

The Process Collection

45. One poster, “Construction Planning” specifically examines issues of the construction process, raising issues regarding process, quality control, value engineering and modification procedure, measurement and feedback. “Closing the Loop” contains material on monitoring and testing as part of the process of developing performance control systems, and offers some insight into how and why the gap between nominal and realised fabric performance exists..

The Workshop Collection

46. Following the development of the project plan the function of the poster set was extended to include output from some of the workshop sessions. This enabled the poster collection to capture not only the Level 1 research and other starter material but also the main themes that emerged during the breakout session and plenary discussions. The “Workshop Collection” was added to the poster set in order to do this, with draft posters being fed back to workshop participants and the project team for comment. Three posters from the pilot workshop were exhibited at subsequent workshops to illustrate potential outcomes. Three further posters were developed for the Strategic Forum which provided an initial analysis of the previous workshop outcomes and methodology and highlighted proposed topics for discussion at the forum.

The GHA Case Study Collection

47. This collection contains case study material from members of the Good Homes Alliance, identifying the main features and issues relating to three recently constructed developments. Each case study contains an “Overview” poster providing background to each scheme and outlining some of the key aspects and initiatives taken. Additional posters on “Airtightness”, “Thermal Bridging” and “Thermal Bypassing” provide supplementary technical details and outline some of the barriers that had to be overcome in developing Low Carbon housing.

Workshop Outcomes

48. The primary objectives of the project were to facilitate knowledge exchange based on the application of mainstream construction technology and encourage the development of improvements in process designed to ensure that Low Carbon

performance is reliably achieved. In both areas the project can claim success, but this success only goes so far. The workshop programme teased out a number of underlying lessons that could assist technology and processes to be adjusted and redesigned as the industry moves towards the goal of zero carbon housing. These were introduced to the final workshop, "Closing the Gap: A Strategic Forum on the Energy Performance of New Housing" under the headings below of 'Change Categories' and 'Key Imperatives'.

49. Achieving these primary goals necessitated some priming of the self-selected workshop audience from the facilitators, but care was taken to accentuate the exchanging of knowledge and views rather than attempting to change participants' perceptions. Detailed below as 'Knowledge Shift', a derived measure of the success of dissemination of the Stamford Brook and GHA experiences by the project team through presentations and the 'Technical Issues' breakout sessions is also described below, .

Change Categories

50. The 771 individual index cards which emanated from the '*Needs*' session, have been classified into 8 Change Categories, which in turn fall into 30 sub-categories. A tertiary division (and 4° for 2 larger sub-divisions) indicated even further just how inter-related many of the areas of concern are and how often similar issues arose within differing categories. With all the cards now entered into a database, and appropriate keywords identified and assigned, a statistical analysis of these inputs from the workshop participants is possible.

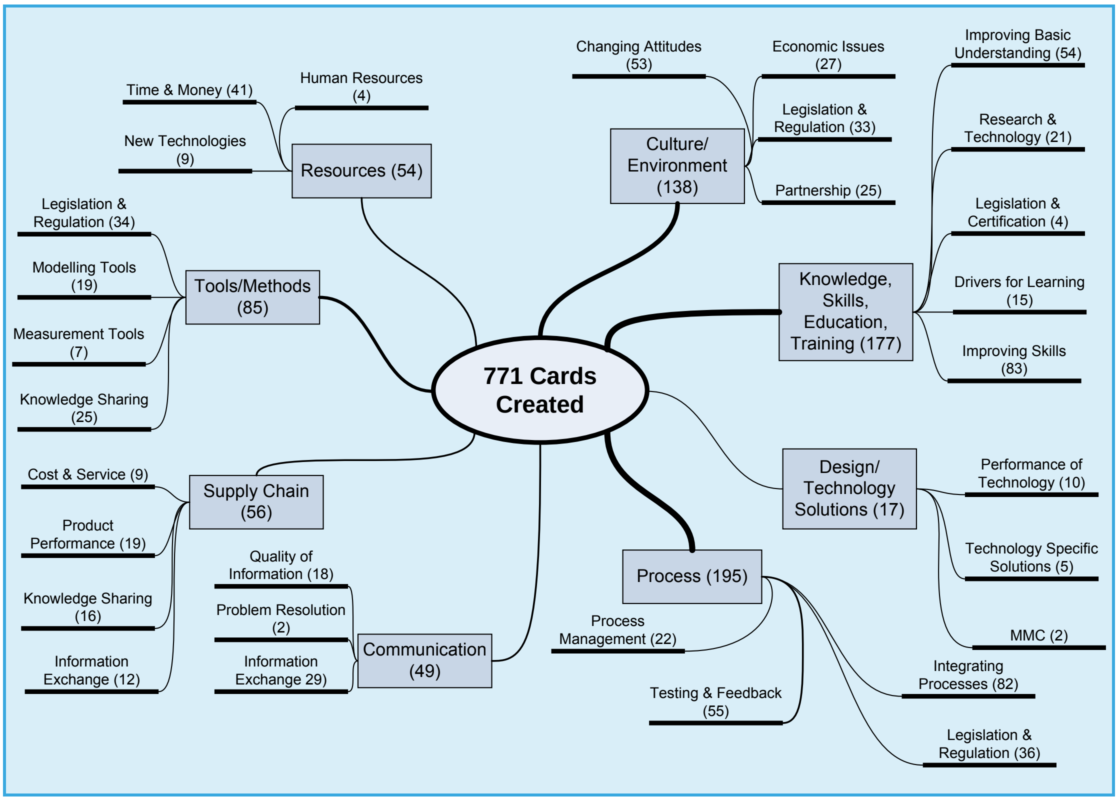


Figure 4 Change Categories

51. The 8 Change Categories were selected by the project team as it was felt that the accumulated index cards could relatively easily be divided into these distinct primary categories. Many of the Change Categories listed contain similar sub-categories such as; legislation, feedback, information exchange, knowledge sharing, but these were considered as secondary concerns, an example is provided in figure 5 where the comment on the card reads:

* Including post-occupancy studies
into ratings

* Actual monitored energy data
widely available
as designed → as monitored

Although this card could be construed in a number of ways, e.g. knowledge sharing due the comment "actual monitored energy data widely available", it was regarded as fitting better into the Testing & Feedback sub-category as part of the Process Change Category, as what is required is a change in the process. Within this sub-category this card was classified into the Monitoring & Feedback 2° subcategory, Compliance/Validation 3° sub-category and finally into a 4° sub-category Post-Occupancy Evaluation with 5 other cards.

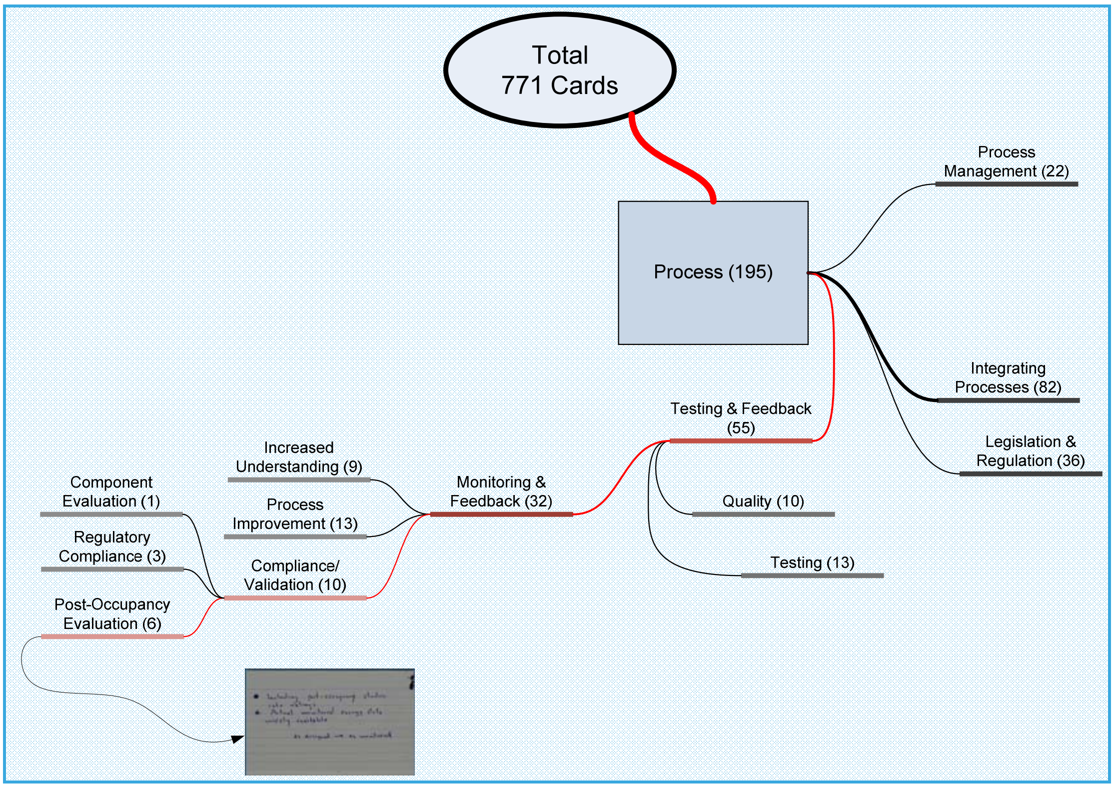
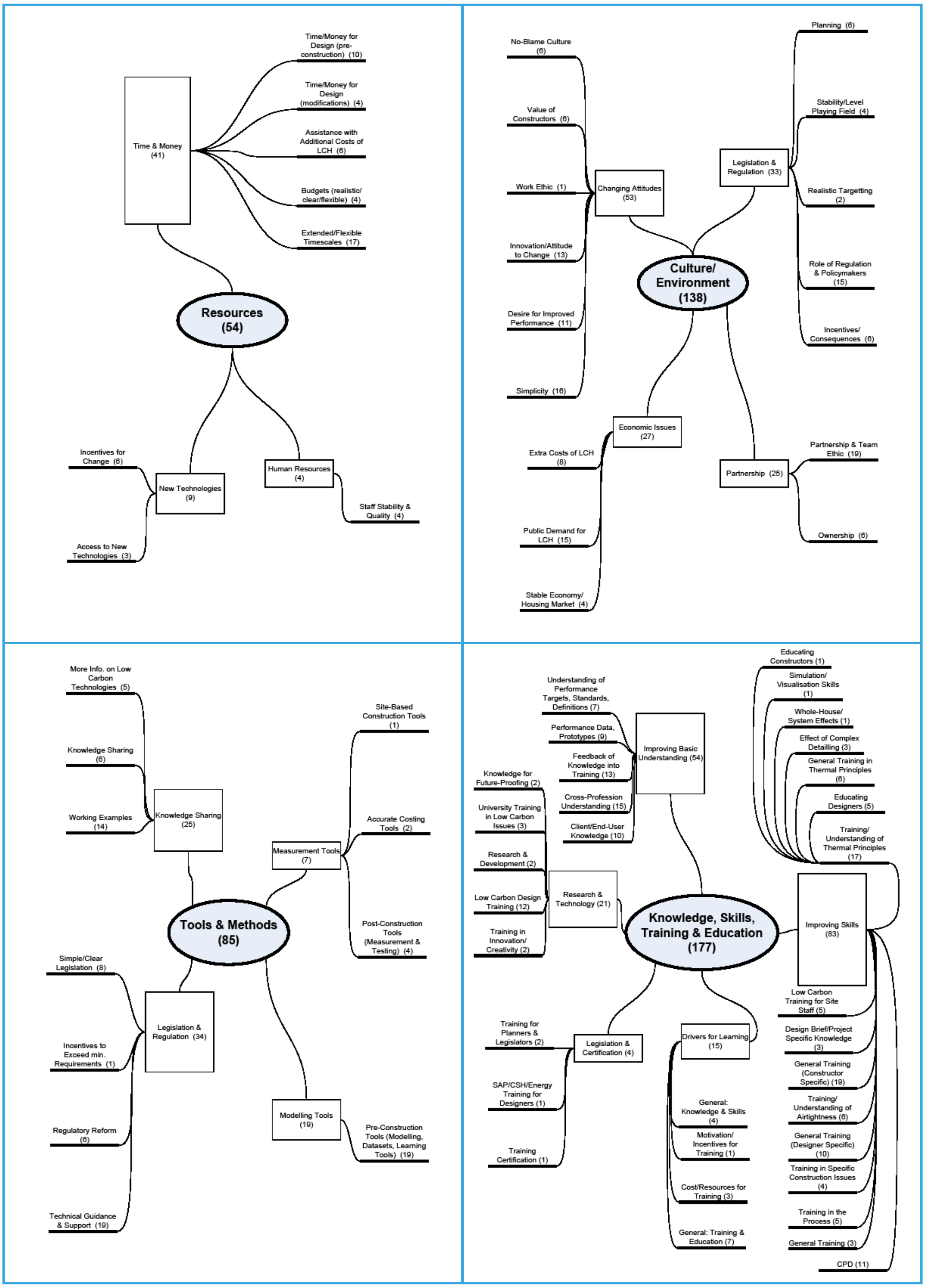


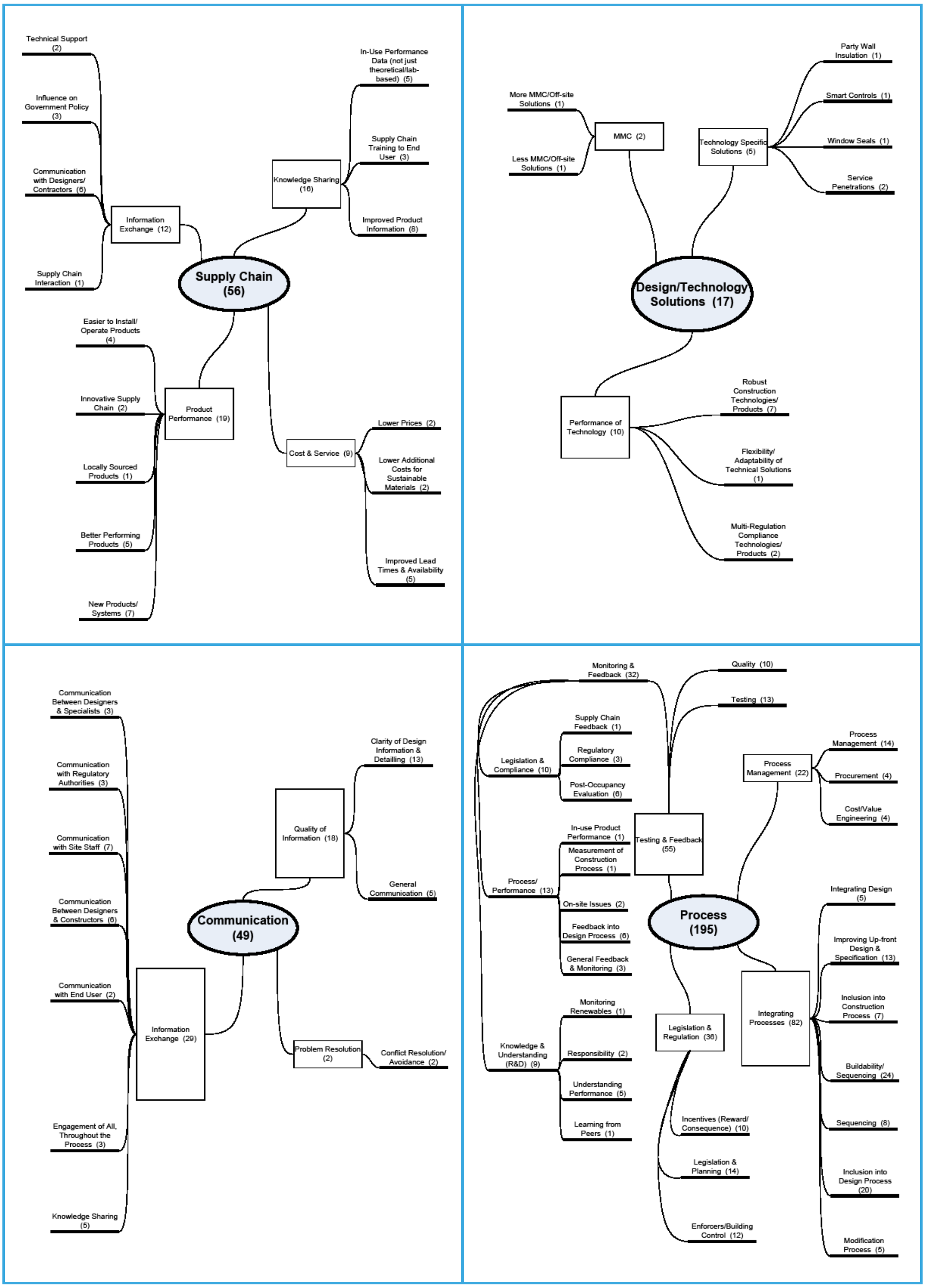
Figure 5 Expansion of Process Change Category leading to an individual index card

52. Each Change Category was partitioned into 1° and 2° sub-categories, with the larger Change Categories (Knowledge, Skills, Education & Training and Process) further divided into a number of 3 and 4 sub-categories in the areas with the most responses as shown in table 5.

53.

Table 5 Change Categories, numbers (in brackets) represent individual index cards.


Resources (54)
Time & Money (41)
Time/Money for Design (pre-construction) (10)
Time/Money for Design (modifications) (4)
Assistance with Additional Costs of LCH (6)
Budgets (realistic/ clear/flexible) (4)
Extended/Flexible Timescales (17)
New Technologies (9)
Incentives for Change (6)
Access to New Technologies (3)
Human Resources (4)
Staff Stability & Quality (4)
Culture/ Environment (138)
Changing Attitudes (53)
No-Blame Culture (6)
Value of Constructors (6)
Work Ethic (1)
Innovation/Attitude to Change (13)
Desire for Improved Performance (11)
Simplicity (16)
Legislation & Regulation (33)
Planning (6)
Stability/Level Playing Field (4)
Realistic Targetting (2)
Role of Regulation & Policymakers (15)
Incentives/ Consequences (6)
Economic Issues (27)
Extra Costs of LCH (8)
Public Demand for LCH (15)
Stable Economy/ Housing Market (4)
Partnership (25)
Partnership & Team Ethic (19)
Ownership (6)
Tools & Methods (85)
Knowledge Sharing (25)
More Info. on Low Carbon Technologies (5)
Knowledge Sharing (6)
Working Examples (14)
Measurement Tools (7)
Site-Based Construction Tools (1)
Accurate Costing Tools (2)
Post-Construction Tools (Measurement & Testing) (4)
Legislation & Regulation (34)
Simple/Clear Legislation (8)
Incentives to Exceed min. Requirements (1)
Regulatory Reform (6)
Technical Guidance & Support (19)
Modelling Tools (19)
Pre-Construction Tools (Modelling, Datasets, Learning Tools) (19)
Knowledge, Skills, Training & Education (177)
Improving Basic Understanding (54)
Understanding of Performance Targets, Standards, Definitions (7)
Performance Data, Prototypes (9)
Feedback of Knowledge into Training (13)
Cross-Profession Understanding (15)
Client/End-User Knowledge (10)
Research & Technology (21)
Knowledge for Future-Proofing (2)
University Training in Low Carbon Issues (3)
Research & Development (2)
Low Carbon Design Training (12)
Training in Innovation/ Creativity (2)
Legislation & Certification (4)
Training for Planners & Legislators (2)
SAP/CSH/Energy Training for Designers (1)
Training Certification (1)
Drivers for Learning (15)
General: Knowledge & Skills (4)
Motivation/ Incentives for Training (1)
Cost/Resources for Training (3)
General: Training & Education (7)
Improving Skills (83)
Educating Constructors (1)
Simulation/ Visualisation Skills (1)
Whole-House/ System Effects (1)
Effect of Complex Detailling (3)
General Training in Thermal Principles (6)
Educating Designers (5)
Training/ Understanding of Thermal Principles (17)
Low Carbon Training for Site Staff (5)
Design Brief/Project Specific Knowledge (3)
General Training (Constructor Specific) (19)
Training/ Understanding of Airtightness (6)
General Training (Designer Specific) (10)
Training in Specific Construction Issues (4)
Training in the Process (5)
General Training (3)
CPD (11)



54. The diagrams of each Change Category shown in table 5 were reproduced on A1 for use at the strategic forum, with 2 separate Change Categories being used for each of the 4 breakout groups to discuss. The level of sub-categorisation illustrates the complexity of some of these categories, and if change is to occur in each, just how many different areas that change needs to relate to and how many different areas of concern need to be addressed.

55. In the Resources Change a substantial majority of comments received were for time and money to implement change in 2 major areas, for design and for amended

construction periods. Another significant need identified was for resources for new technologies and particularly Low Carbon technologies, through incentives, assistance with access and assistance with the perceived increased costs of introducing greener technologies (although index cards prescribing specific technological solutions were included in the Design/Technology Solutions category)..

56. Culture/Environment represented the 3rd largest Change Category with its major sub-category calling for a concerted transformation in the attitudes of the whole housebuilding industry and its traditional values, with a large proportion of cards seeking to change mind-sets and see a real desire for, and appreciation of, improved performance throughout the industry and also from the general public. Legislative change was another well represented area, many comments being related to the similar sub-category in the Process Change Category but considering disparities and inconsistencies in the ethos and tradition of legislation and regulation rather than its technical and practical aspects. Given the current market conditions it is unsurprising that comments on the economic environment were also abundant.

57. Legislation and regulation also featured heavily in the Tools & Methods Change Category, although here the call was for improved technical guidance and support, better clarity of legislation and possible regulatory reform. More accurate and more accessible measurement and modelling tools were sought after, as was the desire for better knowledge sharing, including working examples of Low Carbon dwellings that are available and accessible to all.

58. Many of the cards in the Knowledge, Skills, Training & Education Change Category suggested a need for improvement in basic understanding of the whole build process and an up-skilling of the industry in general. The high number of comments advocating additional training, education and understanding on technical issues such as thermal principles, system effects, airtightness and Low Carbon issues may reflect on those issues being raised earlier in the workshops and being fresh in participants' minds, but these still only represented half of the cards in the improving skills sub-category. Other significant sub-categories included a desire for more research (particularly into Low Carbon considerations) and incentivising learning.

59. Ideas developed in the Supply Chain Change category regarding price, performance and availability were heavily outweighed by a desire for better communication between the supply chain and both designers and constructors. Although information exchange and knowledge sharing also fall into other Change Categories, those classified into this category dealt primarily with how the supply chain needs to adapt to effect the required changes, through proposed improvements in guidance, technical support, training and in-use performance data as opposed to theoretical or laboratory test data.

60. The Design/Technology Solutions Change Category represents cards detailing specific technological solutions, e.g. more (or less) MMC solutions, and comments on the performance of new technological or proprietary solutions. This was the smallest of the change categories in terms of number of cards, possibly due to it being so specific, but it contained comments which did not fit naturally into any other categories as many of the cards on low carbon technologies did.

61. Although much of the response in the Communication Change Category concerned the quality of information and its clarity, the majority sought improvements in dialogue and engagement of different sectors of the construction industry, from end-users to constructors to designers, planning departments and regulators; with many comments stressing a need for specific sectors of the industry to communicate better with other specific sectors appeared to come from the personal experiences of the individual participants.

62. The Process Change Category was the largest category, the largest sub-category of which was integrating processes. It was expressed in many cards that integration and inclusion (principally of designers into the construction process and constructors into the design process) were seen as necessary steps to eliminate many of the sequencing and buildability issues that exist in the housebuilding industry. Improvements in testing regimes and feedback mechanism were also widely called for; whether for quality control, regulatory compliance, process measurement or just

to increase understanding. Although process management was allocated its own sub-category, numerous cards in the testing & feedback sub-category sought for measurement and testing to be fed back to help manage the process.

63. Links between sub categories

64. expansion

65. The index card database contains all the comments made on the index cards in the '*Needs*' breakout sessions, assigned to Change Categories, 1°, 2°, 3°, and 4° sub-categories and each individual index card record assigned up to 4 keywords from a list of 143 (full list in appendix 4), the top 15 occurring keywords are listed in table 6. The number of occurrences of each keyword may indicate to some extent a derived quantification of concerns developing from the brainstorming sessions, however it may also reflect on the presentations and discussion of concerns that had taken place earlier in each workshop, as these very much resemble some of the key issues that had been raised throughout the earlier workshop sessions. All the keywords listed in table 6 had been issues approached during the Stamford Brook and GHA presentations, and most had been significant themes in the each of the '*Technical Issues*' breakout sessions.

Table 6 Index Card Keywords – Top 15

Keyword	No. of Index Cards
Design	95
Understanding	72
Low-Carbon	57
Performance	55
Training	48
Communication	46
Details	46
Knowledge	43
Feedback	41
Education	39
Time	38
Evidence	37
Process	36
Simplicity	36
Guidance	35

66.

67. Summary & comment

68.

Key Imperatives

69. Whereas the change categories indicated the thoughts and concern of the workshop participants, asking them to draw up lists of their Top 5 Key Imperatives added a degree of prioritisation. When posed with the question of which were the most important areas discussed in the '*Needs*' session the answers received did not always tally directly with the numbers of index cards received in the related change category. Additional analysis of all the responses may illuminate the matter further.

70.

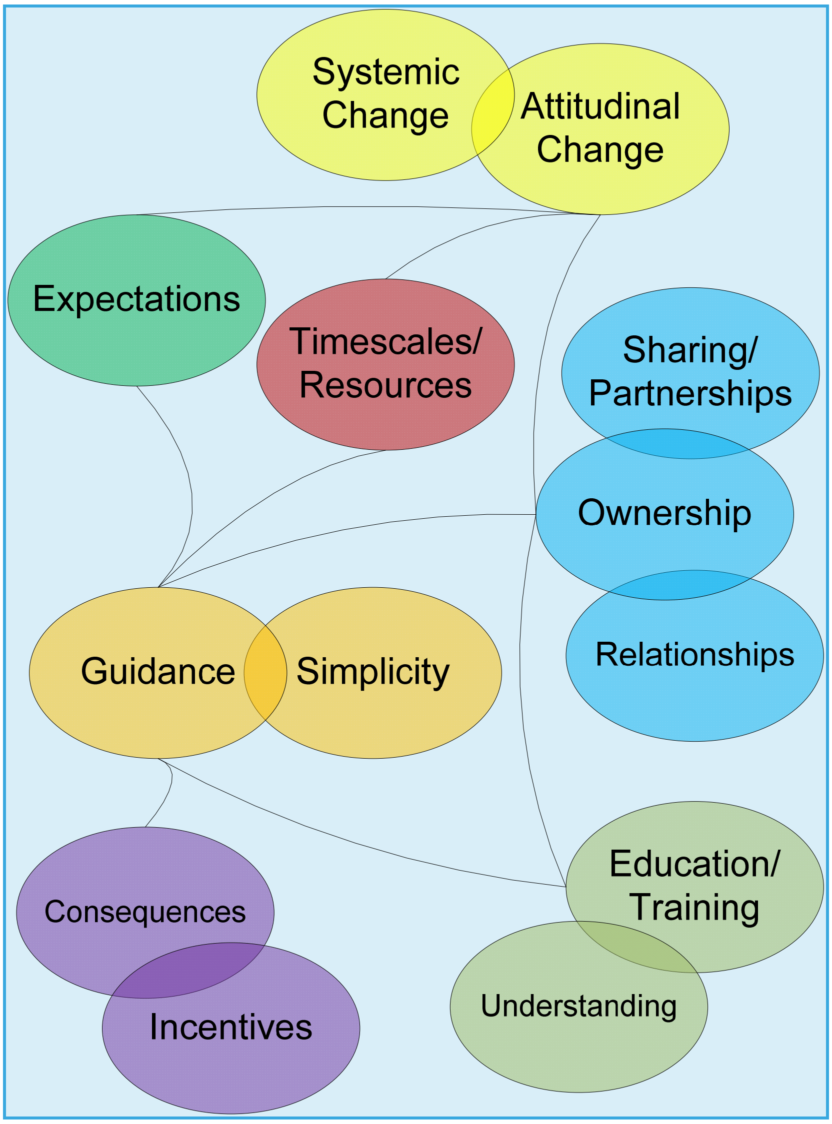


Figure 6 Key Imperatives

71.

Knowledge Shift

72. On registration at the workshops participants were invited to complete a prior knowledge questionnaire to establish their level of understanding of a number of key issues relating to Low Carbon Housing. Some of the questions relating to specific issues to be addressed during the days' sessions. These questionnaires were returned to participants at the end of the workshop for them to re-assess their understanding of these issues and provide the project team with an indication of the knowledge shift resulting from the workshops.

73. [Laifong – you may wish to fill this out from your detailed analysis]

Plenary Session Discussions

74. The final event of each workshop consisted of a plenary discussion under the broad title "Developing a Roadmap to 2016". This was introduced by a brief address by a member of each '*Needs*' breakout group introducing the main points from their session. Audio recordings were made of both the presentations from each plenary session and the subsequent discussions, these were transcribed for circulation to the project team for review and possible future analysis.

Strategic Forum Outcomes

75. The final evaluation workshop was held at UCL on 30th October 2008 in the grandiose setting of the Old Refectory, under the UCL Portico. Titled “Closing the Gap: A Strategic Forum on the Energy Performance of New Housing” an invited audience of policymakers, industry professionals and other influential stakeholders evaluated the implications of the outcomes from the previous workshops for the development of policy for re-engineering the industry and its regulatory framework in a Low Carbon world.

76. The Strategic Forum took a similar format to the workshops, Presentations from the LowCarb4Real team drew on some of the outcomes from the previous workshops, and were augmented by reflections on the workshops from previous participants; a small builder, an architect and a major developer. Breakout groups discussed potential actions for a way forward in a number of change categories, their main points were presented to the plenary discussion to highlight potential policy and action responses that could be taken by Government, industry and other stakeholders to reduce the gap between as-designed and as-built performance. This resulted in only partial success, with a continuation of the analysis of the problems but only limited achievement in developing potential solutions. This re-framing of the solution may have been a consequence of the nature of the forum, reflecting a possible lack of drivers, resources and incentives for implementing change.

Participant Reflections

77. At the “Closing the Gap: A Strategic Forum on the Energy Performance of New Housing” held on 30th October 2008, 3 participants from previous workshops were invited to present their reflections on the LowCarb4Real project. The participants were selected to represent different perspectives, those of a major volume housing developer, a designer and a small housing developer.

78. Next section needs trimming…

Volume Housebuilder

79. Joe Isle is Strategic Development Director for Taylor Wimpey UK Ltd., he attended the 11th September workshop in Leeds.

- “When you end up with evidence, good quality evidence, then the decisions you make in the future are evidence based decisions that we can all respect and build on.”
- “This industry thinks energy efficiency is easy, the reality is once you get into the thermal bypasses, the cold bridges, the air barriers, it suddenly becomes quite complex.”
- “Generally, in the major house builders there is no real accountability through the process for energy efficiency. If you build a house and you make no money the financial director gets a real kicking; if it’s flood risk and the house floods then the technical director gets booted out; if it’s a commercial problem and the houses aren’t built on time then it’s the commercial director; but what about energy efficiency? Who cares? There needs to be a way of bringing accountability into this process. I do believe that the building envelope can be sorted out, can be improved, based on all the work that’s been done. But we as an industry have a lot to do. We’ve got to make people accountable.”
- “At the moment a lot of the industry’s going forward with people guessing, politicians’ aspirational, planners making supplementary planning guidance when they have no idea what’s going on.”
- “Who sets the standards? If we’re going to go to low carbon housing we have to have a rigorous standard. The people who set standards have to understand what they’re setting and then monitoring has to back that up. It’s an area that greatly concerns me. That’s why the work that’s been done on this project needs to be embedded in the industry as soon as possible. Because we are running

before we can walk. The aspirations of the politicians, in terms of renewables, and planners in terms of their SPG's, are just putting things in that they do not know if they're going to work at all. We don't want to be doing that, we want some sound evidence."

- "I think Anthony really has touched on a bit of a nerve in the industry, that we all operate at the minimum levels, which is absolutely true because that's the nature of the animal. I think the big house builders have a long way to go, just like everyone else really. I think it's got to be a little bit of a stick as well as a carrot. As a bigger company we do have the checklists and we do get people around the table, but the key thing is do we do it with regards to energy efficiency? And that's the difference. I think it's the understanding, the guidance. I don't think there's one place where the guidance comes, it's a bit of a mess really. That's why responsibility, accountability needs to be somewhere to bring it into that process."

Designer

80. Richard Partington is a Director of Richards Partington Architects, he attended the 16th September workshop in London.

    - "What struck us enormously from what has been done is the level of detail and rigour and robustness of the method. To us, in a world that is seduced by imagery, that seemed to be in stark contrast with the kind of outcomes that we're seeing from, for instance, the BRE Innovation Park, which is really something that showcases technology and products without disseminating the essential information that we need in order to design. It seems to me that the real let-down from the BRE projects is that there simply aren't the robust measured outcomes of what's been built. There isn't the rigorous testing, and that applies right through the industry."
    - "The research has thrown up some very unexpected outcomes. For instance, the issue of heat loss through a cavity party wall. For us as designers that raises questions about the way we legislate and the way we prescribe for certain standards."
    - "In our organisation there is an anxiety about the route of having robust details, accredited details, enhanced details, because they're firstly designed to a lowest common denominator and secondly they're being applied in a very selective way. So that heat loss through the cavity wall is a direct result of somebody saying this is a way of isolating one dwelling from another for sound. So the whole process of seeing design, construction, inhabitation, procurement, existence as one thing that needs to be thought about globally seems to be lost."
    - "If you follow the logic of good thermal design, good airtightness, it leads you inevitably to simple volumes. It's much easier to control on site, it's much easier to control in design terms. But my clients are saying to me I want something that really sets me out from the rest, I want something that's distinctive, I want something that reflects its context. Our response to the workshops has been, how can we change our processes to try and make sure that we still have responsibility for energy (I would use the word responsibility rather than accountability, as accountability immediately has connotations of blame)? And what we've tried to do is think about how these things happen simultaneously and to start to model, think about thermal bridging, think about airtightness. Involve the builder, with the architect, with the environmental advisor, with the academic, in the same workshop environment so the theory, which we don't necessarily understand, is imparted directly to the guy who's going to build it who has much better insights into the practicality of what's being suggested."
    - "Our reaction has been how do we make the process different? How do we engage people at different levels and incorporate their expertise? That, in a way, is prompted by scepticism in the way that standards are being implemented, and by an enormous scepticisms around what technology can provide."

- "What we're really interested in is the heat loss, not the theoretical performance, and industry is stepping back from that. They're very nervous. I think we need more projects like Malcolm and Rob's that actual test what's happening and get to the nitty-gritty that my profession is also stepping away from."
- "It fills me with fear that a sliding screen or an external louvre is connected to a building management system and it moves across the façade at the right time or at the right season. It seems to me that in Mediterranean countries the has been for years an efficient system of external louvers that can be adjusted from the inside and the neat thing is not that it's connected to the building management system, it's the fact that you can pull your shutters closed in a storm or on a hot afternoon and still have some ventilation. I think this is where the emphasis needs to shift towards something which is much more considered in a passive way. This idea that technology will solve these problems is completely wrong, it's a lifestyle change that has to be promoted as part of an overall package for living with a lower carbon footprint."
- "I think there is a fundamental, cultural difference in the way that houses are developed here and the way that other parts of the construction industry work. If you're developing an office then the likelihood is that your client is going to have a long-term interest in the way that that project runs so you're going to have some commitment either as a landlord or somebody who's managing common areas, so there is much more engagement with how the building will operate once its been completed. Historically, a house builder can't wait to get away once it's been handed over, cheque in bank, thanks, that's the end of it. So there is a slightly different way of setting up and long-term expectations of how the building will run. 5 years ago property developers wouldn't have been bothered about whether their houses met certain energy targets in-use, they would to get through the regulatory regimes, but they wouldn't in the long term. Of course the house builders have to build in a very, very competitive market where the whole of their supply chain, every small element, is built into the process. It's something that they would like to control and like to understand. There is a tendency to have internal expertise in detail design which slightly divorces the theoretical, higher level ambitions of design from the execution. I think the house building industry needs to adjust slightly and there needs to be some mechanisms in place for ensuring that there is a kind of demand, and things are beginning to happen. There are management agreements, there are commitments that developers make to the long term sustainability of a project, but I think there is a cultural difference."

Small Developer

81. Anthony Rodgers is the Managing Director of Huntington Homes, a small housing developer based in York, he attended the the 24th July workshop in Leeds.

- "In my company there's 2 of us, me as an MD and a project manager, and we just don't have the resources in-house to do a lot of the things we've been talking about. We out-source everything. Our designs and architects are out-sourced, our contractors are out-sourced and we rely upon some strong relationships. It's trust in those relationships that will help us going forward in terms of delivering the sustainability we're looking for."
- "It's important that the designers understand and contribute to all facets of what we're trying to achieve in a sustainable development. I'm in this to make money, I'm a businessman, and therefore I have to rely upon the trust I have in my chosen designers to give me what you guys as professionals are going to give me. Because without that we're left high and dry. What that means in reality is that basically we deliver our product to minimum regulatory levels. So the architect says it meets building regs, it meet the requirements of LABC and our guarantor NHBC and I'm happy; I can't get any more money for anything else so that's what I do."
- "I feel a bit guilty having been to these sessions, should I be testing more? If I've got to sit down and as part of my development checklist I've got to consider are

we taking on board considerations of whatever code it might be, whatever buildings sustainability issue we're talking about, are we taking it on board? So I've got to test my professions, my contractors, and they're going to say "well we thought about it, and the implications if you were to do it would be pounds, time, change of design, couldn't do this, couldn't do that" but I think, as a responsible human being, that's what I've got to start doing. We've got to test our profession."

- "If I don't sell my £355,000 house, I don't get paid this month. So if the customer says I want my boiler there, the boiler gets moved. Well hang on Mr Customer, do you realise that by moving your boiler 100 yards down the corridor you're going to cost yourself a fortune? So we've got to take on board customer choice, and we've got to bring the customer in as a stakeholder."
- "It's all very well at Stamford Brook or big projects saying to the customer we'll give you £1000 a year if you'll let us keep this monitoring equipment in – I can't do that, I can't afford to do it. So how can we do it easily? Who's going to do it? There's 2 of us, me and a project manager, we haven't got the time and the resource to do that. Given the size of the organisations with which I tend to work, in terms of designers and builders, for them to invest time and money and resource they would like to think that there's going to be some reward for that investment and that would unfortunately reflect in pounds. So where's that going to come from? Somebody somewhere has got to put money into the kitty to pay for that."
- "One stakeholder we haven't talked about is the landowner. If you've got a discerning landowner, like the National Trust for argument's sake at Stamford Brook, who says we'd love to do this, if we can do this, that and the other and all get brownie points, if we could all look good on it, then let's do it. I'm looking at a site at the moment with a private landowner, and because I'm saying to him actually with these 2 big ones we could put a green emphasis on it and that could help us get planning. How can we get these things? We can get these things if the planners say we'll fast-track you, we'll give you reduced planning costs, if you reach certain levels. That's something I'm sure we're going to come across this afternoon, the impact of building control fees, of planning fees, of CML providers and guarantor costs, all of those things which are a commercial issue in terms of both time and money, if we can get some adjustment or benefit from that by taking on board what we've all been talking about then that's going to make more sense for everybody."
- "I did actually speak to my contractor before I came today. What he said is simplicity, consistency and a degree of longevity. He's doing one project for us, and that's his job for 18 months. In 18 months time he's onto the next job and the building regulations have gone through 2 cycles. In that time he's working for himself, not for one of the big four where he would have been kept up to date continually by some central department. He doesn't know. For him to keep up with the technological improvements, some of the technical changes and regulatory changes, is quite difficult."
- Given the current marketplace, allowing for the audience today, should we stop? Should we stand still for 6 months? Should we say, now we have a dreadful marketplace, now is an opportunity to stand still, get all our thoughts together, and when we come back with a rising market, all the new housing stock can be built to a regulatory level that we're all happy with, and it would mean that the majority of that stock would be enabling us to achieve the targets that we're all setting out to.

82.

Analysis of 'Breakout Group Main Points' Flipcharts

83. At the Strategic Forum the participants were divided into 4 breakout groups, each group was assigned a pair of Change Categories for discussion: Knowledge, Skills, Education & Training with Communication; Process with Culture/Environment; Supply Chain with Design/Technology Solutions and Tools/Methods with Resources. Each

breakout group was asked to consider the Key Imperatives for change that also emerged from initial analysis of the workshop outcomes, and how they integrated into their assigned Change Categories to identify the policy and strategic responses required for action by Government, Industry and Other Stakeholders. As in the previous workshops, the main points were written on flipcharts to be presented, by breakout group members, to the forum plenary.

Table ? Strategic Forum Breakout Group Flipchart comments - Government

Breakout Group	**Comment**
Knowledge/Communication	Insist on an acceptable level of knowledge within Government itself (PPS1)
	Simplification of Standards & Procedures
	Conformity of Guidance
	Building Regulations need better policing - Upskill building control
Process/Culture	Leadership from Government - In solutions / evidence / cost precedent - e.g. Government subsidised housing etc. (enhanced policy) - Robust evidence & dissemination
	Legislative stick versus incentive carrot: - Give real financial consequences so that industry focuses on outcomes, not avoidance.
Supply/Tech. Solutions	Clarity of message
	Stop & think for a while
	Certainty
	More money to gear up => Grants => These should be tied to performance
Tools/Resources	Role of Government: - Delivery agent or regulator?
	Leadership: - Contractual obligation to help - Focus on evaluation
	Standards: - Part L, Code for Sustainable Homes, etc. - Should there be more simplicity/integration? - Should the Regulations be more facilitating?
	Resources: - Should be made more available for training, assisting, leading and regulating.

84. Summary & comment

85.

Table ? Strategic Forum Breakout Group Flipchart comments - Industry

Breakout Group	**Comment**
Knowledge/Communication	Eco-Options: Awareness, knowledge, communication, uptake - Must be led, by who?
	Concentrate on fabric performance - Incentivisation
	Prioritise performance regarding energy more than is currently done - through quality / testing / measurement - through self-regulation / self-testing - through stimulating Government action
	Quality Control needs improving - Accountability & Responsibility
Process/Culture	QA System: What to measure & how - "In-Use" performance measurement - Industry to inform to suit process (to give robustness/effectiveness)
	Feedback & knowledge bank - SPEED! - Real time metering is effective now! (Swedish post occ. consumption) - Fair
Supply/Tech. Solutions	Joined up thinking - How?
	Certifications / Approvals of <u>systems</u> that work

	+ Warranties
	Drivers to use approved products & systems
	Tried & Tested Systems
	Pre-approved "packages" from a range of suppliers - fundamental change of approach
Tools/Resources	More responsibility for actions: - Self-certifying compliance/Quality Control - Internalise QC procedures
	Educate more within industry itself: - Take more notice of case studies, both Good & Bad - (No Blame Culture)
	Proactive involvement (with Government) in regulation & setting standards
	Supporting learning: - To address "the gap" - Get to standards we have now, before updating them - Measurement is essential

86. Summary & comment

87.

Table ? Strategic Forum Breakout Group Flipchart comments – Other Stakeholders

Breakout Group	Comment
Knowledge/Communication	End Users: Must learn how to use Low Carbon Housing - Social Housing: Simple Controls? - Private Housing: Smart Controls? - A Code for Sustainable Homeowners? - Increasing awareness of Energy Use
	Appliance Manufacturers: labelling and display (red/amber/green to show energy usage)
	Finance Companies: Insurers & finance providers should provide preferential terms/conditions/guarantees for low energy design & USAGE.
Supply/Tech. Solutions	How to incentivise demand? From… - Customers - Constructors / Contractors
	Getting housebuilders to understand the benefits of system approach - transparency of information
	How do customers know that what they are getting is working? - Smart meters? - Comparators - Post Code metering data?
Tools/Resources	Need to improve both up and down transfer of information between Government/Industry/Consumers
	Shifting limits of acceptability - Moving public opinion
	Incentivisation & empowerment of the consumer
	Involvement of all stakeholder groups in the process - Utility Companies, Housing Associations, etc.

88. Summary & comment

89.

90.

Conclusions & Recommendations

91.

92.

93.

94. The outcomes from the project reinforced the findings from the Stamford Brook field trial and experiences of GHA members and throw considerable light both on immediate technical issues and on the broader problems of implementing change in production processes and industry cultures, all of which reinforce the need for the establishment of durable and effective learning partnerships.

95. Cultural issues were highlighted at all stages of the project. There is no tradition of energy performance measurement or of design and production processes that follow sound manufacturing principles, in which measured performance is fed back to create system improvements. This issue was identified also in the Egan report almost 10 years ago.

96. There appears to be inadequate knowledge and understanding at all levels throughout the industry. The principles of effective thermal envelope and systems design and construction are not well understood or prioritised within design or construction.

97. Regulatory implementation remains a major issue. Although standards have improved, it is widely recognised that energy standards are neither well enforced nor measured, a point made in the recent forward thinking paper on energy efficiency regulation.

98. Although the project was able to identify many of the strategic process issues and to postulate a number of solution tracks it was not in a position to develop clear solutions that took into account the difficulties inherent in the industry context.

99. The analysis of all the workshop outcomes should assist in highlighting the areas where changes are considered most necessary, most urgently and what actions are needed to successfully facilitate the required changes.

Appendix 1

Knowledge Exchange Plan

LowCarb4Real

Knowledge Exchange Plan

Malcolm Bell, Robert Lowe, Jez Wingfield, Dominic Miles-Shenton, Jon Bootland, Simon Corbey & Lai Fong Chu
May 2008

LowCarb4Real is a collaborative knowledge exchange project undertaken by Leeds Metropolitan University, University College London, The Good Homes Alliance and the University of Leeds. The project is funded by the Urban Buzz programme coordinated and facilitated by University College London and the University of East London. Urban Buzz is designed to foster the exchange and development of the knowledge required to develop sustainable communities.

Introduction

The **L**ow**C**arb**4R**eal project is designed to develop the knowledge necessary to make low & zero carbon housing a reality, where it matters, "on the ground". It seeks to set up a knowledge exchange programme based on the lessons from the Stamford Brook housing field trial and the experience of the Good Homes Alliance (GHA), a group of developers seeking to build beyond current building regulations. The Stamford Brook (SB) field trial was an action research project funded by the Department for Communities and Local Government (CLG) and based around a 700 house development undertaken by Bryant Homes and Redrow Homes, on land owned by the National Trust. The 6 year trial, which concluded in November 2007, sought to assess, in a comprehensive way, the issues involved in improving the carbon performance of mainstream house building. It has generated an unprecedented amount of learning related to airtightness, envelope integrity and systems performance, at all levels including building physics, dwelling design, site management, workforce training and procurement systems. Given the challenging regulatory targets proposed by government aimed at Zero Carbon new housing within 10 years, it is crucial that the learning from field trials such as Stamford Brook is captured, refined, contextualised and embedded as thoroughly as possible within the house building industry. The experience of GHA members will be used to extend the range of experience from which the project can draw.

The project recognises that knowledge exchange is a two way and multi faceted process. Valuable though the lessons and insights from Stamford Brook and the GHA experience are, their absorption, adoption and impacts are controlled by the house building industry. To maximise the value of research and experience in the development of low carbon housing it is important that all sections of the house building industry[3] are able to share their knowledge of the industry and the issues and barriers that arise when seeking the sort of fundamental change that is needed to achieve the demanding targets for low carbon housing set by the UK government and the imperatives of climate change mitigation. This project seeks to facilitate an exchange of knowledge and understanding that would support such change.

Objective

The objective of the project is to facilitate knowledge exchange based on two key areas of learning:

- The key technological issues in the design and construction of low carbon housing in the mainstream.

And

- The development of improved housing procurement and building processes designed to ensure that low carbon performance is reliably achieved.

In each area, the programme will develop not only the specific lessons from the research but will tease out the underlying lessons that will enable technology and processes to be adjusted and redesigned as the industry moves towards the goal of zero carbon housing.

In more specific terms, the knowledge exchange programme will be based around 6 interactive workshops with people from all parts of the industry and the different levels of management. The workshops will explore a range of the issues that will focus on change in the development process itself (design, construction practices and production processes) and

[3] It is very hard to characterise the house building industry. Although convenient for the purposes of this report, referring to them as a single entity does not capture the range and diversity of roles, structures and skill sets that exist. At one level the house building industry is made up of developers who manage the development process, their construction contractors and subcontractors, a wide range of operative groups (masons, joiners, electricians, plumbers and the like) and their professional advisors (from wildly different professions). At another the industry is supported by a broad range of other actors such as materials and component suppliers, professional bodies, government regulators (including building control officers), built environment educators and trainers and important client groups such as social housing providers. Overlaying such diversity of role and skill is the influence of scale. Building one or two houses a year is a very different matter from building thousands of dwellings a year across the UK and these differences are reflected in the approach taken to development and the issues that need to be addressed. Thus, although this plan will make reference to the industry it is important not to forget the considerable diversity that exists.

on the implications for the environment (supply chain, regulation, education and skills etc.) in which development takes place. The programme of industry workshops will seek to:

- disseminate the key findings from Stamford Brook & GHA experience,
- deepen understanding of the problems of reengineering development processes through engagement with the house building industry,
- generate solution ideas for addressing the problems and generating change, and
- influence actions for change at all levels;
  - **Micro** – the detailed technological hardware and processes necessary for the construction of dwellings and other buildings
  - **Meso** – the structures and processes that enable development organisations and meta organisations to design and construct low carbon housing that achieves its required performance levels.
  - **Macro** – the policy and cultural environment in which development takes place, this would include such things as skills & understanding, regulatory policy & practice, technological developments within materials & component supply chains and norms of employment & contracting behaviours.

The Workshop programme

The workshop programme consists of 6 one day events held in London and Leeds so as to encourage a reasonably wide geographical spread of participation. Workshop dates and venues are set out in table 1.

	Date	Location
Workshop 1	17 June 2008	London
Workshop 2	19 June 2008	Leeds
Workshop 3	22 July 2008	London
Workshop 4	24 July 2008	Leeds
Workshop 5	11September 2008	Leeds
Workshop 6	16 September 2008	London

Table 1 Workshop dates and locations

An iterative approach to workshop development

Throughout the workshop programme an incremental strategy of continual review of outcomes and modification will be adopted. Following each pair of workshops the project team will reflect on the outcomes and workshop evaluation feedback from participants with a view to making changes to any aspect of workshop design. The spacing of about 4 to 6 weeks between workshop pairs will provide ample time for both the recording of output and reflective team meetings designed to review and reshape workshop design. The nature of the evaluations is set out in the project evaluation plan that accompanies this knowledge exchange plan.

Workshop design

In order to fulfil the objectives set out above the workshops will be structured so as to use the key messages from Stamford Brook and GHA case studies to disseminate the research findings and to stimulate debate around a number of important questions relating to the need for change and the processes by which change can be brought about. With the agreement of participants, all workshop sessions will be recorded on audio tape for use by the project team and some verbatim material may be used in project reports or on posters[4]. The key principles of design are as follows:

[4] The general agreement of participants will include for the anonymous use of verbatim material taken from the tapes. If it is thought necessary to use attributed versions or if there

- A mixed group of participants will be invited to each workshop so as to provide a range of perspectives within each workshop. Appendix 3 contains a matrix of expected participation.
- Stimulate debate with presentation material backed up by the posters
- Work groups will be limited to between 5 and 10 with a mixture of perspectives
- Attention is likely to be focused at micro and meso levels but where ever possible wider macro level issues will be encouraged.
- All activity and discussion will be grounded in the key findings of SB and GHA.

Disseminating key messages
Two approaches will be used to introduce workshop participants to the key findings.

The poster collection: A set of poster style documents will be produced and given to participants either at the workshops or in the joining pack. The posters will be designed so that they can be produced in either A4 or A1 format and will serve as both hand-out material and display material. Each poster will deal with a single key finding from Stamford Brook or a particular aspect from a GHA case study. It is envisaged that the poster collection will be dynamic and will grow as the programme proceeds. As further insights are gained into some of the issues and barriers relating to change, posters will be added and used as a means of communicating the output from workshops as well as disseminating the starter material. This approach will enhance the development nature of the programme as relevant material from one set of workshops is fed into the next.

The posters will be displayed (A1) at workshop sessions in the main workshop room or breakout rooms as appropriate to the detail being discussed. This will provide a back drop to the whole event and enable participants to accustom themselves to the style. Posters will be placed on the project website as they are produced and after each workshop participants will receive copies of posters produced from the workshop. All participants (as contributors to some of the material) will be acknowledged unless they specifically request not to be identified.

An indicative set of posters is set out in figure 1, which uses the notion of the three levels indicated above (micro, meso and macro) as a means of structuring the collection. Those dealing with Design, Construction and Process (blue box in figure 1) will form the core of the starter posters for the first round of workshops in June. Appendix 1 contains an example poster as an illustration of style and tone.

Workshop presentations: In order to engage participants and to focus the workshop the key issues will be discussed during starter presentations at the beginning of the workshops and will last for around 90minutes (60 minutes on Stamford Brook and 30 minutes on material from GHA case studies). The presentations will reinforce and be backed up by the material in the posters. Also, short (10 minute) presentations will be used to begin each workshop breakout session so as to set the scene and identify the critical issues for discussion.

was a significant risk of identification from the context, separate permission would be sought from the relevant participant.

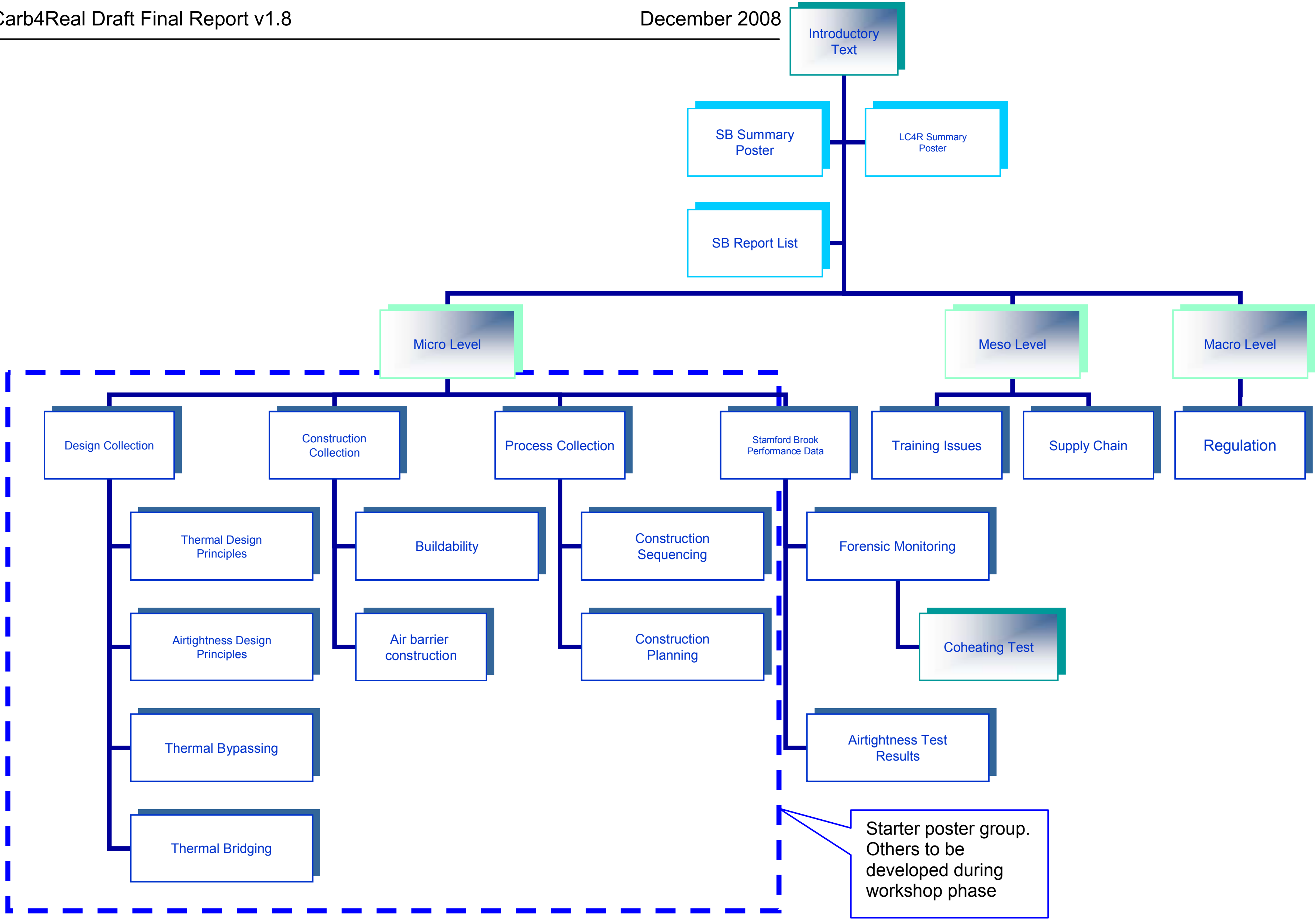


Figure 1 Indicative poster collection for LowCarb4Real.

Workshop breakout group activity
Each workshop will provide some 2 house worth of breakout discussion time in small groups contain between 5 and 10 people depending on attendance and the availability of facilitators. Some 15 group tasks have been defined in draft and it is anticipated that each aspect will be used in at least two groups during each pair of workshops. The tasks themselves together with initial presentation and prompt material are set out in appendix 2. The discussion in each group will be introduced and facilitated by a member of the project team and it is anticipated that each workshop will have up to 6 facilitators available, drawn mainly from UCL and Leeds Met with additional assistance from members of the GHA who will add their experience to the discussion.

The approach of facilitators will be to reinforce the messages from SB and GHA that are appropriate to the task in hand and encourage an open debate. They will seek to balance the need to maintain focus on the task but to ensure that as many contributions and ideas as possible are drawn out. In addition to specific questions at the micro level facilitators will encourage the exploration of other levels as the underlying issues are explored. In particular facilitators will seek to tease out greater understanding of such things as;

- cultures,
- barriers,
- relationship issues between actors,
- approaches to tackling the issues identified, and
- ways of generating change.

Also the facilitator will assume responsibility for recording the main points and ideas on flip charts and for drawing up a summary poster of the group's work. An embryonic version on a flip chart will be used in a short poster presentation session before t he final plenary session. After the even each poster will be drafted and fed back to workshop participants for further comment before placing them on the project website. The key objective of the breakout group posters will be to get the material into the arena as quickly as possible so that there is ample opportunity for those interested in the work to reflect and add comment. This means that the emphasis will be on delivering draft material rather than highly polished text.

The posters will form both a source of data for later analysis and a record of the events. The final evaluation workshop in October will draw on a synthesis of workshop outcomes and debate the key issues raised for policy and practice across government and the industry at large.

Facilitating the group sessions
The key to success of the workshops will be the ability of facilitators to get the most out of the breakout group sessions. In addition to the processes outlined above the facilitators will be required to ensure that all participants remain motivated to engage with the problems discussed. In order for a high level of motivation and engagement to be maintained each participant will need to be;

- be convinced that there is a serious problem to tackle,
- believes that the problem presented is solvable,
- is convinced that they can help to solve it
- and
- gets an emotional buzz out of tackling it on the day and afterwards within their organisations.

The role of the facilitator and rest of the workshop team will be to seek to maintain these key elements of which the most important one will be the element of emotional excitement.

In order to prepare the workshop team a facilitator's seminar will be held facilitated by the project's advisor on participatory methods.

Workshop structure
The workshop day will be structured as set out in table 2. In order to maintain an evaluative thread each workshop will have some evaluation activity built into the programme. Details will be included in the evaluation plan with space made available at the beginning and end of each workshop day.

Workshop Structure	
09:30 – 10:00	Registration & Preliminary evaluative exercise
10:00 – 10:15	Welcome & Introduction to the Day
10:15 – 11:15	Overview of Stamford Brook Key Messages
11:15 – 11:30	Coffee Break
11:30 – 12:00	Overview of Good Homes Alliance Key Messages
12:00 – 13:00	Breakout Groups – Session 1
13:00 – 13:45	Lunch
13:45 – 14:45	Breakout Groups – Session 2
14:45 – 15:15	Poster Presentation and open forum + Coffee break
15:15 – 16:00	Plenary Session – Review and implications for a Road Map to 2016 & final evaluative exercise

Evaluation

Evaluation of the project is the subject of a more detailed evaluation plan that accompanies this knowledge exchange plan. In broad terms the objective of evaluation is to evaluate change in three important areas. The areas are summarised below.

- **Evaluate change in participants**: This will involve seeking to understand the extent to which the workshops develop awareness, understanding and propensity to action in the minds of participants. The use of evaluative assessments at the beginning and end of workshops will play a part in this. Also the receipt of comments and reflections on workshop materials will be used to provide an indication of the extent of engagement with the issues. As indicated below it is expected that the evaluation workshop will play an important part in this process.
- **Evaluate change in collective understanding**: This dimension is aimed as much at the project team as participants since the fundamental ethos of the programme is to ensure that knowledge exchange is a two way process in which everyone learns more about the issues and difficulties of achieving low and zero carbon housing. The discussion at the workshops, reflection on outcomes and formal evaluation at the final workshop and throughout the final reporting process will all play their part in developing change in collective understanding.
- **Evaluate policy & systems change opportunities**: Developing change in policy is not likely to emerge during the very limited life of the project programme. However the programme offers opportunities for engaging policy makers and other key opinion formers and catalistic individuals & organisations. In evaluating the programme the attendance of policy makers at workshops and assessment by and reflections of the project advisory group will add to the range of opportunities afforded by the project. As with other areas this will be assessed during the project evaluation workshop and final reporting process.

Final evaluation workshop
This event will consist of an invited group of participants drawn from policy makers in government and others in the industry with an ability to influence change at a number of levels. It will also consist of selected participants from the main workshop programme. It is hoped that, in this way, we will be able to maintain continuity in the programme and enable participants form the main programme to contribute to the debate about the implications of the outputs from the main workshop programme for government and industry policy and structures.

Appendix 2

Evaluation Plan

Evaluation plan for the LowCarb4Real Project

Robert Lowe, University College London
in discussion with
Laifong Chiu, University of Leeds
20 May 2008

Introduction and background

The LowCarb4Real project is complex and it has taken the Project Team some months to reach a reasonably comprehensive understanding of the task it is engaged in. As a consequence of this complexity, a fairly full introduction to the evaluation plan is needed. Despite the progress that has been made, this plan will remain subject to change in the light of comments from stakeholders, experience with the workshops and resource constraints.

The summary of the LowCarb4Real contained in the original proposal read as follows:

> The objective of this idea is to set up and execute a knowledge exchange programme for low carbon (energy efficient) new housing. It will be based on learning from the Stamford Brook Field Trial, which is an action research project funded by CLG and involving the National Trust, Redrow Homes, Bryant Homes, NHBC, CITB, Vent Axia, and the Concrete Block Association. The 6 year trial, which concludes in November 2007, sought to assess, in a comprehensive way, the issues involved in improving the carbon performance of mainstream house building. The project has generated an unprecedented amount of learning related to airtightness, envelope integrity and systems performance, at all levels including building physics, dwelling design, site management, workforce training and procurement systems. Given the challenging regulatory targets proposed by government aimed at Zero Carbon new housing within 10 years, it is crucial that the learning from field trials such as Stamford Brook is captured, refined, contextualised and embedded as thoroughly as possible within the national house building in general and in London and the south east in particular. This proposal seeks to develop such a programme and to act as a model for industry based research and knowledge exchange designed to make zero carbon housing a reality.

As this makes clear, at this stage, the LowCarb4Real team conceived of the project, in the main, as a knowledge transfer project. This has been modified as a result of development work over the last 4 months, and particularly the realisation that:

- knowledge transfer to a maximum of perhaps 200 individuals[5] would reach around 0.1% of people employed in the house building industry, and support for such a project would be hard to justify economically.
- the housebuilding indusry is now operating in a highly dynamic context – CO_2 emissions limits for new housing[6], which have, on paper, fallen by almost a factor of 2 since 1995, are set to fall to zero by around 2015 (see figure 1). The proposed trajectory for the next 7-10 years implies an unprecedented rate of change within the industry, which is likely to render much of the Level 1 learning from Stamford Brook obselete within a few years.
- the Stamford Brook Project shed unprecedented light on the technical performance, and technical origins of this performance, of dwellings designed to a standard roughly 15% better than the 2006 Building Regulations[7]. But it shed rather less light on how better performance might be achieved, other than to observe that it would require a revolution in culture, organisation and practices within the construction industry.

[5] The project is currrently planning to run 6 knowledge exchange workshops, with a target attendance of 30 at each.
[6] …excluding emissions associated with electricity use by appliances.
[7] This is roughly midway between Code for Sustainable Homes Levels 1 and 2.

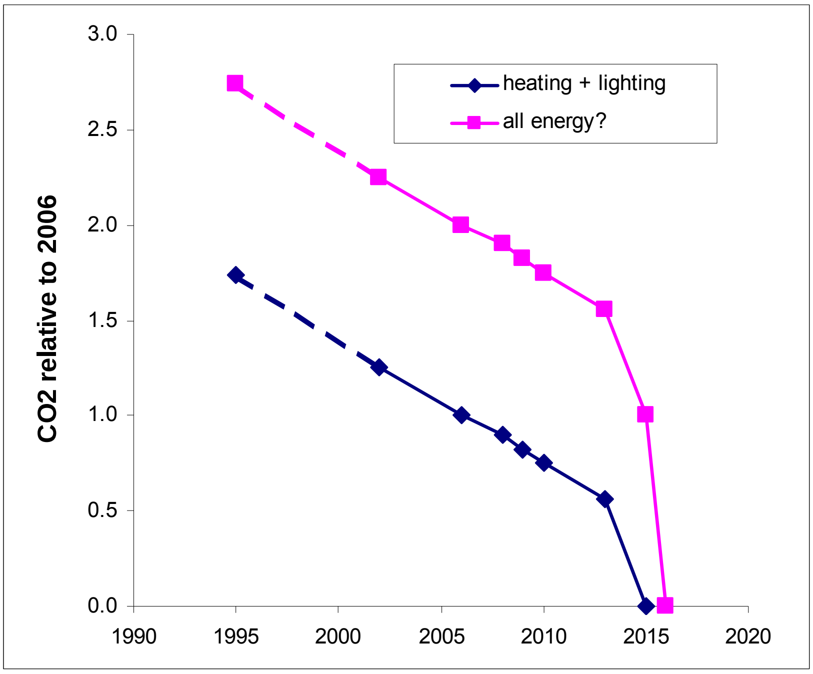


Figure 1. Formal CO_2 limits for new housing based on DCLG 2006 a&b. Emissions from electrical appliances and the projections backward to 1995 are estimated.

The response of the LowCarb4Real team has been to refocus the project on knowledge exchange and to place more emphasis on interactions between participants as shown in Figure 2 below. We expect that most interaction will take place on levels 1-3, but that issues and insights at level 4 will emerge through collective reflection in workshops and the advisory group.
We expect the project to facilitate learning at two main levels[8]:

- Level 1 refers to learning that is specific, context bound and concrete. The importance of and possible solutions to the party wall bypass are an example of learning at this level.
- Level 2 learning – "learning to learn" increases the ability of individuals, systems, research groups and companies to learn and to apply learning at level 1.

Ultimately for the housebuilding industry, it is the fruits of level 1 learning that are built into houses and determine their performance. For academia, level 1 learning would include specifications and protocols for various types of investigation. As noted above, the purpose of level 2 learning is to increase the ability of individuals, systems, research groups and companies to learn and to apply learning at level 1. What was established at Stamford Brook was an environment and a process within which learning could and did take place. The key questions at level 2 are, how did we achieve this, how might we repeat it, and how might we improve upon it?

[8] These learning levels are based on Bateson (1973) *Steps to an Ecology of Mind*, London: Paladin. We realise that we are using the word "level" in two distinct senses here, and that the terminology needs refinement.

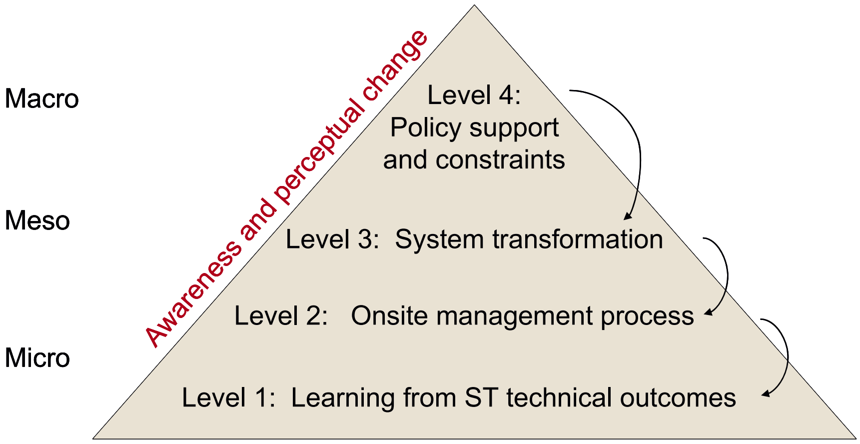


Figure 2. Mapping the potential impacts of the LowCarb4Real Project.

One of the most immediate impacts of this re-thinking on the organisation of the workshops is a move from separate workshops for separate functional groups of participants, to integrated workshops with invitations to people representing all 4 levels in figure 2 to each workshop. This also has the effect of making the project more robust against the inevitable uncertainties in recruitment, since it will still be possible to run the later workshops, albeit with some modifications to programme, in the absence of any particular group.

Sustainability evaluation

This project does not aim to engage with the community as a whole, but primarily with the community of practice formed by the construction industry and secondarily with the policy making community. This community of practice breaks down into smaller communities, operatives, management and supervision, and board level.

This project will address the first four sustainability principles set out in figure 3, as follows:

environmental, by increasing the housebuilding industry's capacity to deliver on energy performance targets for new homes;

economic, by supporting all levels of the construction industry through the revolution in performance standards described earlier;

social, through its direct and indirect impacts on skills and job satisfaction;

governance, by increasing the understanding of policy makers of the implications at all levels of the housebuilding industry, of the proposed energy performance standards for new housing.

The fifth principle, *sound science*, will be addressed by:

- providing a dissemination route for technical and procedural findings from Stamford Brook and other recent and on-going projects to participants and stakeholders. These findings are based on scientific work of the highest standards.
- adopting a rigorous approach to documenting and reflecting on workshops, and to reporting on the project as a whole.

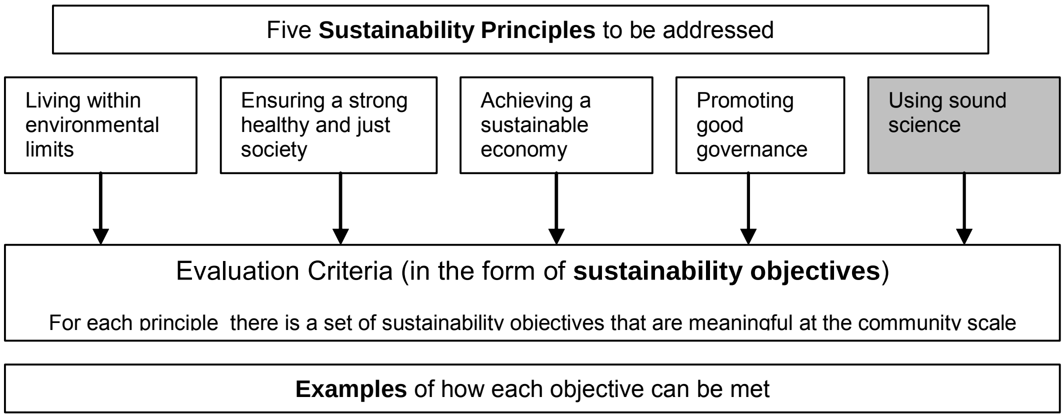


Figure 3. Sustainability Principles, from *OISD Independent Evaluation Notes for Participants in the UrbanBuzz Programme*.

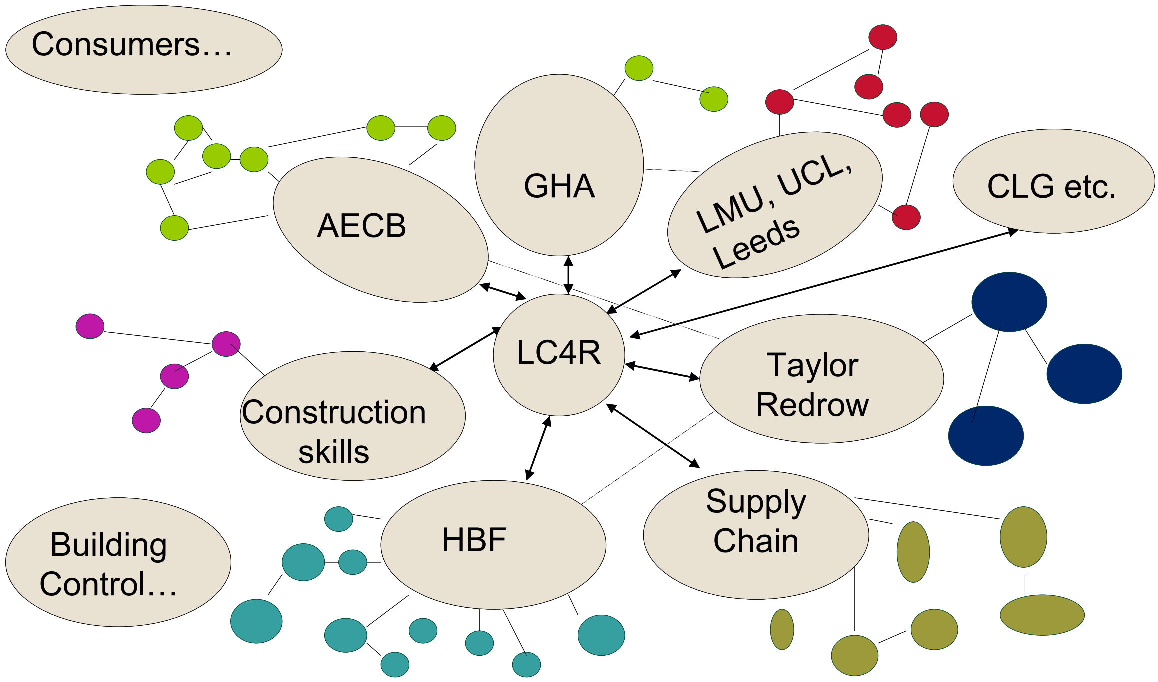
Our sustainability objectives are to:

1. improve the understanding of the Level 1 and 2 learnings from Stamford Brook among all workshop participants. We expect the direct impact of this on energy performance of new dwellings to be modest and probably impossible to measure directly, because of the relatively small numbers of participants involved. However, impacts on knowledge and attitudes of individual participants in LowCarb4Real workshops will be measurable.
2. to achieve a better understanding of what is needed to achieve objective 1 among much larger groups of participants in Knowledge Transfer projects that we hope will follow LowCarb4Real, through reflective interaction with workshop participants, and to communicate this to stakeholders through the Project Advisory Group[9], the Final Review Event in October and the final project report.
3. to achieve a better understanding of the management and organisational implications of the findings from Stamford Brook and other projects, through through reflective interaction with and between workshop participants, through further reflection in successive meetings of the Project Advisory Group, and through the Final Review Event in October.
4. to begin to explore the implications for policy of the above, once again, through reflective interaction with and between workshop participants, through further reflection in successive meetings of the Project Advisory Group, and through the Final Review Event in October.

Stakeholder analysis

The complexity of the system that LowCarb4Real is dealing with is illustrated in the figure below. As well as showing the main stakeholders, this figure identifies two constituencies not currently included in the project.

[9] Two recent insights from the formative phase of the project are: first, that the meetings of the Project Advisory Group constitute an additional series of workshops, and second, that the Project Team will be partipants in as well as organisers and facilitators of the workshops.



The above figure is based on an initial stakeholder analysis undertaken during and shortly after the Project's kick-off meeting in February, and the thinking, reflected in the composition of the Advisory Group, has already moved on. The intention is to update this stakeholder analysis at intervals through the project.
The construction industry consists of a wide variety of organisations and interests. This variety is reflected in the partners and stakeholders in the LowCarb4Real Project . Understanding the different perspectives and interests is essential to the task of transforming the Construction Industry.

Evaluation
The structure of the LowCarb4Real Project comprises four learning cycles:

- three blocks of 2 workshops followed by joint reflection in team and advisory group meetings;
- the Final Review Event and evaluation workshop.

This structure provides the opportunity for significant learning and development (objective 2 above). The evaluation plan is set out in detail in the following tables.

Sustainability or Knowledge Transfer **Objective**	**How your project is meeting this objective** (What action will you take to meet this objective? There may be a number of ways (activities))	**Indicator** (what sort of information will provide a measure of progress in meeting the objective through the activity you are doing)	**Evidence** (Supporting information evidence to demonstrate (measure) progress on each activity - include strategies or changes made or planned to overcome any barriers encountered)
Environmental			
To reduce energy use and CO_2 emissions from new housing	Through improved understanding of the Level 1 and 2 learnings from Stamford Brook among all workshop participants.	Improved energy performance of new dwellings.	Likely to be small and probably impossible to measure directly, because of the small numbers of participants involved and short time-scale and restricted resources.
		Indirect indicator – change in knowledge and attitudes of individual participants in LowCarb4Real workshops.	Before and after questionnaires to be completed by workshop participants. Analysis of reflections of workshop participants based on notes and audio recordings. Discussion and reflection in advisory group meetings, based on recordings and minutes. Email traffic.
Social			
To improve the physical infrastructure, reduce future risks fuel poverty associated with instability of the energy market, To maintain the notion of the construction industry as a skilled industry	Directly, through improved understanding of the Level 1 and 2 learnings from Stamford Brook among all workshop participants.	Direct impact on energy performance of new dwellings	Direct impact likely to be small and probably impossible to measure, because of the small numbers of participants involved and short time-scale and restricted resources.
		Indirect indicator – change in knowledge and attitudes of individual participants in LowCarb4Real workshops.	as above

	Indirectly through dissemination within 'community of practice' (Wenger, 1999).	Indirect impact depends on production and refinement of dissemination tools through workshop cycles effective dissemination, harnessing of stakeholder networks	Posters, final report. Analysis of feedback from stakeholders through Advisory Group.
Economic			
Supporting all levels of the construction industry though the on-going revolution in energy performance standards. Ensuring that the UK has a construction industry capable of delivering the energy and carbon efficient dwellings needed following the peaking of global oil and gas production.	Directly, through improved understanding of the Level 1 and 2 learnings from Stamford Brook among all workshop participants. Indirectly, through dissemination of project outputs to industry. Directly, through improved understanding of structural implications of learnings from Stamford Brook and GHA among all workshop participants.	Change in knowledge and attitudes of individual participants in LowCarb4Real workshops. Discussion and reflections of industry partners in workshops and advisory group meetings.	Before and after questionnaires to be completed by workshop participants. Notes and audio recordings of workshops Recordings and minutes of Advisory Group meetings.
	Indirectly, through dissemination of project outputs to industry.		Posters, final report. Analysis of feedback from stakeholders through Advisory Group.

Governance			
Increase the understanding of policy makers of the implications at all levels of the housebuilding industry, of the proposed energy performance standards for new housing.	Involvement of official in CLG Sustainable Buildings Division on Project Advisory Group. Involvement of senior representative of Housing Corporation.	Discussion and reflections in workshops and advisory group meetings.	Analysis of notes and audio recordings of workshops. Analysis of Advisory Group minutes and email traffic.
Identification and exploration of institutional and legislative barriers to change.	Interactions between all participants in workshops and Advisory Group.	Views emerging from individual participants in LowCarb4Real workshops, discussion and reflections of industry partners in workshops and advisory group meetings.	Qualitative analysis of notes and audio recordings of workshops (using NVivo or equivalent software). Analysis of Advisory Group minutes.
Promotion of future learning networks.		Intentions of Stakeholders to maintain network beyond the life of the project.	Intentions measured using feedback questionnaire and expressed at Final Review Event
Sound Science			
Base the KT programme on best available scientific knowledge	Use of findings from Stamford Brook Project as basis for workshops		Posters, final report, journal publications. Evaluations by stakeholders and workshop participants.
	Use of Participatory Action Research Approach as basis for LowCarb4Real project.	Multidisciplinary core project team, supported by AR expert. Documentation and evaluation of process and outcomes. Use of reflective techniques.	Workshop plan, and project evaluation plan. Stakeholder analysis. Notes from workshop facilitation training workshop. Audit trail of decisions and documents, event log and discussion papers.

Knowledge Exchange			
To establish an effective model for knowledge exchange within the construction Industry.	Iterative learning through workshops, Final Review Event. Support for facilitation.	Evaluation of workshops by participants and stakeholders. Views and reflections of all participants.	Before and after questionnaires to be completed by workshop participants. Notes from workshop facilitation event. Notes and audio recordings of workshops and Final Review Event. Recordings and minutes of Advisory Group meetings.
To encourage the intention of participants to establish effective and durable learning network.	Learning of all participants in LC4R Project. Extent of Level 2 learning to be retained beyond life of Project.	Significant learning of project team, advisory groups and participants Active participation of stakeholders through Advisory Group.	Stakeholder analysis , attendance and minutes of Advisory Group meetings, email traffic. Issues debated at advisory meetings The extent of contributions of stakeholders to the project.

References

Bateson (1973) *Steps to an Ecology of Mind*, London: Paladin.
Wenger, E. (1999) *Communities of Practice. Learning, meaning and identity*, Cambridge: Cambridge University Press

Appendix 3

Posters

Project poster
LowCarb4Real: Developing a Road Map to 2016

Stamford Brook collection
Developing Low Carbon Housing: Lessons from Stamford Brook
Stamford Brook Publications & Reports

Design collection
Thermal Design Principles
Thermal Bridging
Thermal Bypassing
Airtightness Design Principles

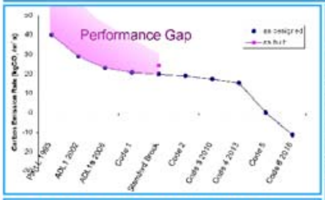
Construction collection
Air Barrier Construction

Process collection
Construction Planning
Closing the Loop

Workshop collection
Needs of Designers & Constructors
Airtightness - Technical Issues
Airtightness - Wider Implications
Methods; Converting Inputs into Outcomes
‘Needs’ of Designers & Constructors; Change Categories
‘Needs’ of Designers & Constructors; Key Imperatives

GHA case study collection
Bladon - Overview
Bladon - Airtightness
Bladon - Thermal Bridging
Bladon - Thermal Bypassing
One Brighton - Overview
One Brighton - Airtightness
One Brighton - Thermal Bridging
Stawell – Overview
Stawell – Airtightness
Stawell – Thermal Bridging

LowCarb4Real: Developing a Road Map to 2016



Closing the Performance Gap

The findings of the Stamford Brook field trial have demonstrated that there is a gulf between designed performance and measured performance.

The challenges and barriers to closing this gap are considerable:

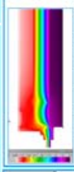
- Cultural – there is no tradition of energy performance measurement or of design and production processes in which measured performance is fed back to create system improvements.
- Knowledge and understanding – the principles of effective thermal envelope and systems design and construction are not well understood or prioritised . Improvements are required at all levels, from developers & designers to site operatives.
- Regulatory implementation – although standards have improved, it is widely recognised that energy standards are neither well enforced nor measured.

The findings from Stamford Brook and experiences from GHA members throw considerable light both on immediate technical issues and on the broader problems of implementing change in production processes and industry cultures, all of which reinforce the need for the establishment of durable and effective learning partnerships.

Knowledge Exchange in Partnership

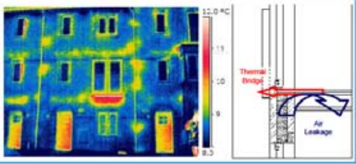
Working with industry to make low & zero carbon housing a reality, where it matters, "on the ground".

Using lessons from the Stamford Brook sustainable housing field trial and the experience of the Good Homes Alliance (GHA) LowCarb4Real is engaging with industry to seek ways of improving the performance of new house building.



Stamford Brook provides lessons about:

- Design processes
- Construction processes
- Technology
- Building physics
- Skills and training



Objectives

To facilitate knowledge exchange based on two key areas of learning:

- The application of construction technology and the key technical issues in low carbon design and construction.
- The development of improved housing procurement and building processes.

In each area, the programme will develop not only the specific lessons from the research but also the underlying lessons and barriers to change so that technology and processes can be adjusted and redesigned as the industry moves towards the goal of zero carbon housing.

Key Stakeholders

- Housebuilders and developers
- Social landlords and local authorities
- Policymakers
- Architects, designers, planners and building service engineers
- Academic institutions and research establishments
- Training organisations and professional bodies
- Supply chain and trade associations
- Inspection services and building control
- Building environmental and sustainability professionals

Workshop Programme

The LowCarb4Real project seeks to foster two way knowledge exchange designed to develop skills, knowledge and understandings within all the stakeholder groups.

The programme is based around 6 interactive workshops with people from all levels within the industry. Workshops will explore the lessons for

- design
- construction practices
- production processes

The implications for industry structures & cultures, government policy and education & training will be drawn out towards the end of the project in an evaluative workshop aimed at influencing key stakeholders.

Cultural Change

The carbon emission limits of Code Level 3 and beyond are likely to entail increasing complexity, less redundancy, faster rates of innovation and unfamiliar low and zero carbon technologies. Unless the wider industry is able to develop systems and a culture capable of managing these challenges, underperformance is likely to increase.

The key to managing change is the transformation of successful construction companies into learning organisations. This will necessitate a closer partnerships between industry, academia and government. Tackling the problems now will contribute significantly to building sustainable communities in the future.

Developing Low Carbon Housing: Lessons from The Field

Project Value: £121,785 UrbanBuzz grant plus £232,972 in-kind contributions

Lead Organisations: University College London, Leeds Metropolitan University

Project Partners: Good Homes Alliance, National Trust, Taylor Wimpey, Redrow, University of Leeds

Contacts: Prof. Malcolm Bell, Leeds Metropolitan University (m.bell@leedsmet.ac.uk)
Prof. Bob Lowe, Bartlett School of Graduate Studies, UCL (robert.lowe@ucl.ac.uk)
Jon Bootland, Good Homes Alliance (info@goodhomes.org.uk)

The Stamford Brook Project Partners

Developing Low Carbon Housing: Lessons from Stamford Brook

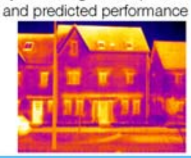
Background to the Stamford Brook Field Trial

Stamford Brook is a development of over 700 cavity masonry dwellings being constructed on part of the National Trust's Dunham Massey Estate near Altrincham under a partnership agreement between the National Trust and the developers, Redrow and Bryant. The implementation and assessment of the advanced EPS08 energy standard being used on the development formed the basis of the Stamford Brook field trial carried out by the Centre for the Built Environment at Leeds Metropolitan University.

Nominal versus Realised Performance

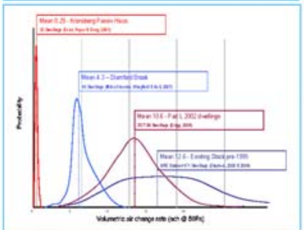
Measurements showed a significant discrepancy between the energy performance of a dwelling, as designed and that realised, as constructed and in use, typically around 20% higher than predicted by modelling. It was possible to account for the difference between measured and predicted performance by taking into account factors such as:

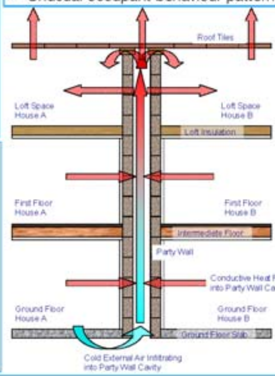
- Thermal bypasses
- Heating system inefficiencies
- Higher than predicted thermal bridging
- Real fabric U-values higher than nominal
- Unusual occupant behaviour patterns



Airtightness

- Mean air permeability of 44 tested dwellings at Stamford Brook was 4.5 $m^3/(h.m^2)$@50Pa versus the target of 5 $m^3/(h.m^2)$@50Pa
- This is significantly better than existing UK practice which is typically of the order 10 $m^3/(h.m^2)$@50Pa
- Analysis and construction observations indicate that low levels of air leakage are possible with cavity masonry construction as long as sufficient consideration is given to the design and construction of the air barrier





Thermal Bypassing

Coheating tests showed that:

- Whole house heat loss coefficients were up to 100% higher than predicted
- Analysis showed discrepancy mainly due to thermal bypass via the party wall cavity
- Effective *U*-value of the party wall was found to be of the order 0.5 W/m^2K

Key Lessons from Stamford Brook

- Design to optimise thermal design principles
- Raise awareness of thermal bypasses
- Improve detailed design and heating system design
- Integration of building services into designs
- Design for inspection and testing
- Continuous improvement in design and construction
- Better communication between design and construction teams
- Enforce change control procedures
- Improve buildability of details
- Reduce design complexity
- Ensure build sequencing is logical and consistent
- Reduce construction variability
- Improve process mapping
- More comprehensive design documentation
- More performance measurement and feedback
- Collaborate with supply chain and subcontractors
- Improve training and education at all levels

Process Issues

The root causes of the measured gaps in energy performance are more complex than a simple list of design and construction characteristics and system inefficiencies would suggest. They relate much more to the interrelationship of the various parts of the whole process from design, construction and training through to completion and occupation. We have identified a range of process issues including:

- Failures in the system of regulatory advice
- The need for more integration between different parts of building regulation
- Problems with levels of understanding within the design and construction process
- Inadequate design tools and modelling protocols
- Poor training of designers and building physicists
- A lack of comprehensive performance testing and prototyping of designs and details
- A lack of feedback of performance data into the design process
- The need for significant changes in planning and executing the construction process

As energy performance targets approach Zero Carbon standards, even small inadequacies in the construction process can result in significant levels of under performance in terms of carbon emissions. There is now therefore an imperative for the UK housing industry to learn from the Stamford Brook experience, rethink the whole construction process and to embrace modern process improvement tools and systems thinking.

Knowledge Exchange

The Stamford Brook project has generated an unprecedented amount of learning. Given the challenging regulatory targets proposed by government aimed at Zero Carbon new housing within 10 years, it is crucial that the key lessons and messages are captured, refined, contextualised and disseminated as widely as possible within the UK house building industry.

UrbanBuzz Project—Developing Low Carbon Housing: Lessons from The Field

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The Stamford Brook Project Partners

leeds metropolitan university · THE NATIONAL TRUST · REDROW · Bryant Homes · Communities · UCL · Vent-Axia · NHBC

Stamford Brook Publications & Reports

Leeds Metropolitan University: Stamford Brook Field Trial Interim & Final Reports

http://www.leedsmet.ac.uk/as/cebe/projects/stamford/index.htm

Deliverable 1: St Nicholas Court Final Project Report (April 2003)
This report describes the EPS08 energy standard, its first application on the St Nicholas Court housing development in York, as well as a detailed description and analysis of the design process and costings for the St Nicholas Court project.

Deliverable 2: Interim Report: Design Process (April 2004)
This report documents the progress of the Stamford Brook project up to spring 2004. This includes the drafting of environmental and energy standards, design team assembly, site layout and dwelling design.

Deliverable 4: Interim Report: Construction Process (July 2005)
This report describes site observations from the early stages of construction at Stamford Brook.

Deliverable 5: Interim Report: Post-Construction Testing and Envelope Performance (July 2006)
This report details the results of a range of dwelling performance tests carried out on completed dwellings at Stamford Brook.

Deliverable 6: Interim Report: Airtightness Monitoring, Qualitative Design and Construction Assessments (July 2007)
This report describes the results of detailed construction observations and airtightness tests on nine dwellings at Stamford Brook. A critical analysis of the data is given in relation to the design and construction of airtight dwellings.

Deliverable 7: Interim Report: Coheating Tests and Investigation of Party Wall Thermal Bypass (May 2007)
This report describes coheating experiments designed to explore the mechanism and magnitude of the thermal bypass via the party wall cavity between semi-detached and terraced dwellings and to investigate methods of blocking the bypass.

Deliverable 8: Final Report: Lessons from Stamford Brook - Understanding the Gap between Designed & Real Performance (October 2007)
The final report summarises the results and conclusions of the interim project reports. Also discussed are the results of intensive in-use energy monitoring of four occupied dwellings at Stamford Brook. The implications of the data obtained during the project are discussed in the context of issues such as building regulation, future energy standards, design, construction processes, training and occupant behaviour patterns.

National Trust, Bryant & Redrow Report: Volume - Delivering Sustainable Housing

http://www.nationaltrust.org.uk/main/w-stamford-brook.pdf

"Volume - Delivering Sustainable Housing" has been published by the National Trust, Redrow Homes and Bryant Homes. Based on the experience of Stamford Brook, the report highlights the major obstacles which need to be overcome to make high environmental standards on volume housing building standard practice across the UK and ultimately reach the target of zero carbon new homes by 2016.

Leeds Metropolitan University: Stamford Brook Journal Articles

http://online.sagepub.com/

LOWE, R.J., WINGFIELD, J., BELL, M. & BELL, J.M. (2007) *Evidence for Heat Losses via Party Wall Cavities in Masonry Construction*, Building Services Engineering Research & Technology, Volume 28, Part 2, pp 161-181

ROBERTS, D., JOHNSTON, D. & ISLE, J. (2005) *A Novel Approach to Achieving Airtightness in Dry-lined Load-bearing Masonry Dwellings*, Building Services Engineering Research & Technology, Volume 26, Issue 1, pp 63-69

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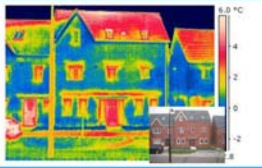
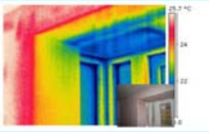
LowCarb4Real; Design collection: Thermal design principles

Understand thermal performance

- Thermal Bypasses can occur where:
  - Air barrier and/or insulation layer are not continuous around the external envelope
  - Air barrier and/or insulation layer do not continue across junctions between attached buildings
  - Air barrier and insulation become separated
  - There are poorly designed cavities that penetrate the air barrier/insulation layer
- Thermal Bridging can occur where:
  - Materials of higher thermal conductivities allow greater flows of heat than the surrounding area
  - The geometric design creates disparities between internal and external heat loss areas





Ensure details are thermally efficient

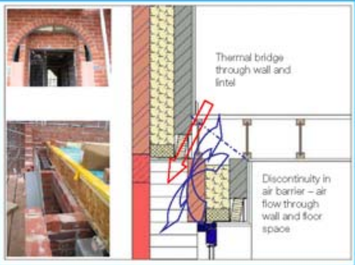
- Thermal inefficiencies can occur where:
  - There is insufficient consideration of thermal/airtightness issues in both design & construction
  - There is no clear thermal fabric performance strategy
  - The heating and/or cooling system capacities are incorrectly specified
  - Insulation is omitted, misplaced, or positioned where its benefit is compromised
  - Inappropriate products/materials are specified

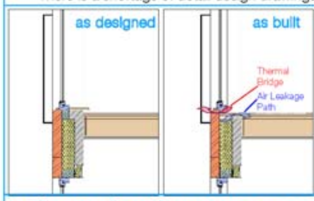
Allow for buildability

- Sequencing issues can occur where:
  - The build sequence is inflexible and not included in the designs
  - Build sequence is dictated by operatives presence on site rather than planned timings
- Design complexity issues arise where:
  - There are insufficient skilled or appropriately trained operatives
  - "Simple" designs are replaced for aesthetic purposes

Compel site teams to look at design information

- Failure of design communication systems can occur where:
  - Different trades work from different sets or versions of drawings
  - Operatives work from "experience" rather than from designs
  - Third party drawings lack details not directly related to their specific trade
  - Staff are incorrectly trained or inducted, or miss staff briefings
  - There is a shortage of detail design drawings available on site





Minimise design modifications and material substitutions

- Check changes are thought through and approved:
  - Avoid on site *ad hoc* designs
  - Design modification approvals process needs to be robust
  - Specification changes need recording and new documents issued immediately
  - Alterations to designs and product substitutions require the same rigorous vetting procedures as original designs and material choices
- Where details rely on the work of more than one trade:
  - If one trade makes an alteration to a design, ensure this is disseminated to all other trades
  - Introduce procedural instructions into the design and construction notes

Is thermal performance measured routinely?

- Persevere with a rigid testing regime:
  - Physical testing or quality control checks on all materials and components
  - Air permeability tests, test on completion of the air barrier (when problems can easily be rectified) as well as on completion
  - Thermal imaging and physical measurement of heat movement when conditions permit
  - Coheating tests, if practicable
  - Post-occupancy monitoring

Use measurement to provide feedback on performance

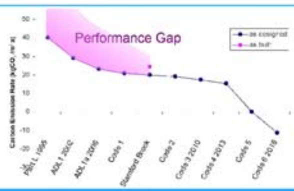
- Analyse data from testing and monitoring, then act on it:
  - Identify areas of under-performance and notice trends developing
  - Establish where maximum benefit can be obtained with future investment
  - Amend designs accordingly

Learn from mistakes

- Repeating the same mistakes costs time, effort and money:
  - If operatives have to work around problems, ensure this filters back to design staff.
  - Eliminate the wasteful practise of "design, build, break-into, install, repair"
  - Amend designs accordingly

Are regulation standards being achieved on the ground?

- How do you know how your dwelling performs?
  - Ensure inspections occur when the element being checked is visible or accessible
  - Don't assume, measure
  - If monitoring, be as comprehensive as practicable to isolate occupier effects as much as possible
- How do others know how your dwelling performs?
  - Can you guarantee your dwellings' performance? If not, why not?
  - How do you get to the next level if you don't know where you are at right now?
  - If you are building to a higher standard than the UK norm, let people know and show them that you can prove it



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LowCarb4Real; Design collection: Thermal bridging

What is a thermal bridge?

- A thermal bridge is created when materials that are poorer insulators than surrounding materials come in contact, allowing heat to flow through the path created.
- Insulation adjacent to a bridge is of limited help in preventing heat loss (or gain) due to thermal bridging; the bridging has to be eliminated, re-built with a reduced cross-section or with materials that have better in-sulating properties, or with an additional insulating component (a ther-mal break).

Types of thermal bridge

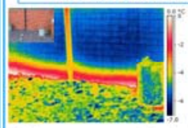
- Repeating: where bridges occur following a regular pattern, such as that made by wall ties penetrating a cavity wall or timber studs in a timber frame external wall..
- Non-repeating: where bridges occur that are detail specific, such as the bridging of a cavity wall by a combined lintel or at a door thresh-old.
- Geometric: at the junction of two or more planes, such as at the corner of an external wall or at the eaves.

Repeating thermal bridges

With a higher level of insulation, the relative importance of thermal bridges in-creases in the energy balance. With this in mind, repeating thermal bridges which may have been acceptable in the past need to be designed out to achieve the en-ergy performance standards required in today's lower carbon emission dwellings. Timber studwork in standard timber frame construction, and in pre-manufactured insulated panels (left), may create repeating thermal bridges that will need to be de-signed out; most commonly by the addition of a supplementary layer of insulation.

At Stamford Brook (right), traditional stainless steel wall-ties would have significantly in-creased the heat loss through the masonry-cavity external walls, effectively bypassing much of the 142mm of retro-filled blown-fibre insulation. The use of Kristiansen Refust 250mm glass-filled thermoplastic polyester wall-ties (with a thermal transmittance well below that of steel) went some way to re-ducing the repeating thermal bridging.

Geometric thermal bridges

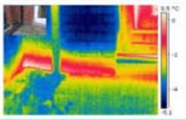


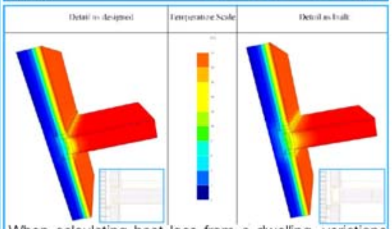
These can be either 2-dimensional (where 2 planes intersect) or 3-dimensional (at the junction of 3 or more planes).

Geometric thermal bridges are due to the shape of the building or, more specifically, due to the shape of the thermal envelope. An increase in the complexity of the building geometry is liable to increase the occurrence of junctions that display a degree of geometric thermal bridging.

3-D junctions offer a level of complexity that is often difficult to visualise from 2-D drawings alone and frequently require changes in material as well as in direction.

Designs must ensure that such issues are not left to site operatives to solve but are addressed fully at the design stage, considering such concerns as continuity of insulation, buildability, build sequence and procedural issues.





When calculating heat loss from a dwelling, variations between as-designed and as-built details can have a significant on the overall result.

The example illustrated here shows the difference made by omission of the intermediate floor perimeter insulation in a timber framed dwelling.

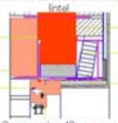
Designs need to ensure that the likelihood of such errors occurring are minimised.

Non-repeating thermal bridges

SAP Table K1 value for combined lintel: Ψ = 0.30 W/mK

Original separate lintel design at Stamford Brook: Ψ = 0.016 W/mK

Steel toe added to inner leaf lintel



Compromise 42mm gap: Ψ = 0.068 W/mK

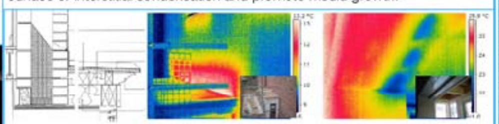
Worst case, 20mm gap: Ψ = 0.18 W/mK

Non-repeating thermal bridges are intermittent and often caused by disconti-nuities in the designed thermal envelope. These may be constructive or ma-terial thermal bridges, frequently observed around openings and other in-stances where materials of different thermal conductivities form the external envelope.

Thermal bridges can be quantified by calculating the linear thermal transmit-tance (Ψ-value), measured in W/mK. This is the additional heat loss (or gain) through the building envelope per metre length of that detail, and can be cal-culate by using software such as the freely available THERM package from LBNL (http://windows.lbl.gov/software/therm/therm.html) and the resultant values fed back into SAP to establish the DER rather than use the default values for ac-credited construction details (see left).

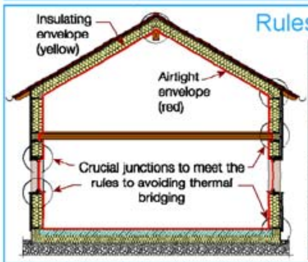
Design changes, whether in the design or construction phases need to be re-viewed and thermal bridging re-calculate to avoid potential problems (below).

In more extreme cases thermal bridging can significantly increase the risk of surface or interstitial condensation and promote mould growth.



Thermal bridge at the Stamford Brook bay window head, the design included an insu-lated head liner which was omitted in the construction phase for aesthetic reasons.

Rules to assist in the avoidance of thermal bridging



Design Rule	Description
Prevention Rule	Where possible, do not interrupt the thermal envelope.
Penetration Rule	Where an interrupted insulating layer is unavoidable, thermal resistance in the insulation plane should be as high as possible.
Junction Rule	At building element junctions, insulating layers should meet without any gaps. Insulating layers should join without interruption or misalignment.
Geometry Rule	Design edges to have as obtuse angles as possible.

Adapted from CEPHEUS (Cost Efficient Passive Houses as European Standards) - Projectinformation No. 36 (Feist, Peper & Gorg, 2001).

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LowCarb4Real; Design collection: Thermal bypassing

What is a thermal bypass?

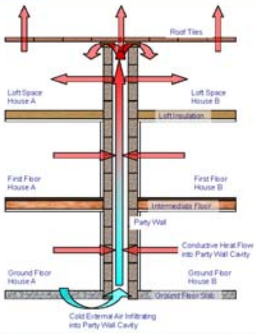
A thermal bypass is set up whenever air movement is able to take place in such a way as to reduce the effectiveness of an insulation layer.

Two types of bypass

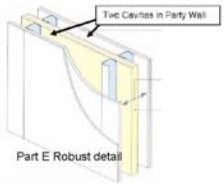
- TYPE 1— Air movement in construction cavities
- TYPE 2— Air movement within and around insulation

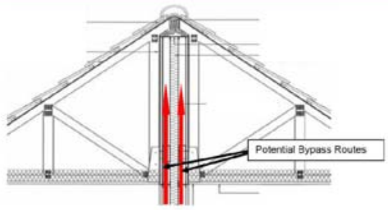
Type 1 The party wall bypass

Most party walls in dwellings have a cavity to reduce sound transmission. This creates a potential air path that wicks heat away from the dwellings on either side. Heat is lost to the loft space via conduction through the leaves of the wall or more directly via the movement of air from the cavity to the loft space or direct to outside.

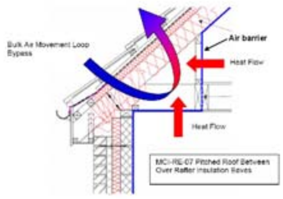


Masonry Construction





Steel frame Construction



Other Type 1 bypasses can exist in all forms of construction

Wherever there is a cavity where air can pass to the outside or transport heat across an insulation layer a bypass exists. In this "room-in-the-roof" knee wall the air barrier is separated from the insulation allowing cold outside air to circulate in the void taking heat away and reducing the effectiveness of the roof insulation.

How large can the heat loss be?

Measurements in masonry dwellings at Stamford Brook in Cheshire indicate that heat loss is increased from the assumed figure of zero to over 0.5 W/m^{2}K (U value) from each dwelling. On this development the loss is twice that from the insulated external walls.

Type 2 Examples — air movement around insulation at cavity insulation boards and at cavity trays

Gaps around insulation allow air to circulate around the insulation taking heat from the warm side to the cold side. This reduces the effectiveness of the insulation.

How large can the heat loss be?

Laboratory measurements suggest that heat loss can more than double depending on the size of the gaps around the insulation.

Avoiding bypasses - Some guiding principles

1. Ensure that the air barrier and insulation layer are in contact with each other at all times
2. Fit insulation tightly to its supporting structure and to each insulation element
3. Ensure continuity of the insulation layer and air barrier
4. Design details that make it easy to accommodate tightly fitting insulation
5. Make allowance for material tolerances when designing joints
6. Minimise the geometric complexity of the thermal envelope

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LowCarb4Real; Design collection: Airtightness design principles

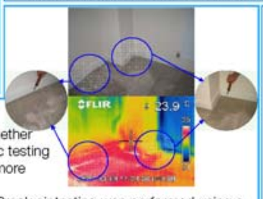
Airtightness IS a design issue

- Airtightness needs to be addressed at every stage in the design process. Designers should identify a continuous line through the envelope of the dwelling where the primary air barrier will be: a *pen-on-section* test.
- Designers need to ensure that information is available at the appropriate level of detail and that this information is communicated effectively to all construction staff, subcontractors and their operatives.
- Design information should include procedural specifications which clearly define the primary air barrier and treatment of it.
- It is the designers responsibility to ensure that components forming part of the air barrier can guarantee adequate airtight performance.
- Where sealants are used it should be ensured that they are of the correct specification, compatible with adjoining materials and that they have the required elasticity, or proprietary sealing products considered.
- Changes to design information (dwelling designs, products or procedures) should be communicated quickly, consistently and clearly. These should be recorded and appropriate design documentation reissued immediately.

Primary air barrier - design it with CARE

CARE - Continuous, Accessible, Robust, Explicit.

- Continuous: Air leakage may occur anywhere where there are discontinuities in the air barrier. Care must be taken at junctions of building elements and at penetrations to ensure its integrity is maintained.
- Accessible: The air barrier must be observable for inspection and reachable for maintenance and repair.
- Robust: The air barrier needs to be robust enough to withstand subsequent construction and to last the lifetime of the building.
- Explicit: There must be conceptual clarity for all staff (whether design or construction based) on what constitutes the air barrier, where it is positioned and how its continuity is to be maintained.



Complexity

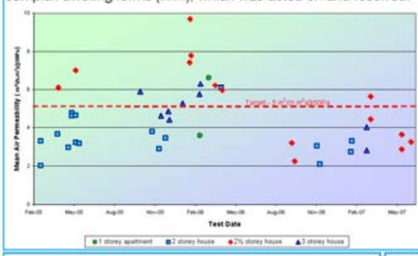
Increasing the design complexity also increases the number junctions and details where continuity of the air barrier may be awkward.

It is simpler to design an uncomplicated geometric structure with a very basic airtight and thermal barrier in contact to avoid thermal bypassing.

Any additional architectural detailing can be supplemented to this basic airtight design, with due consideration given to airtightness, thermal bridging and thermal bypassing.

Measurement and feedback

Regular measurement of the airtightness of dwellings is necessary to establish whether problems are occurring and if any trends develop. At Stamford Brook a systematic testing regime highlighted an upward drift in test results and possible problems with the more complex dwelling forms (below), which was acted on and resolved.

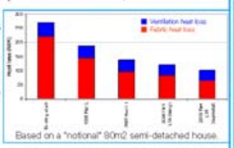


At Stamford Brook air testing was performed using a blower door with leakage detection carried out by smoke detection, thermal imaging (when possible) or preferably both (above). Results were discussed immediately with site staff and fed back to the design teams so that appropriate remedial action could be initiated.

Without adequate measurement and analysis it is impossible to determine how designs are performing and what additional measures need to be taken. A regular testing regime also heightens the awareness of all staff involved regarding airtightness issues.

Airtightness and emissions

Airtightness is crucial to improving the energy performance of dwellings. Air leakage is uncontrolled background ventilation additional to the purpose-provided ventilation, and can dramatically increase the dwelling's heat loss. This has resulted in the CO_2 emissions from air leakage becoming increasingly important over time as building fabric has improved to meet regulatory standards.



Based on a "notional" 80m2 semi-detached house.

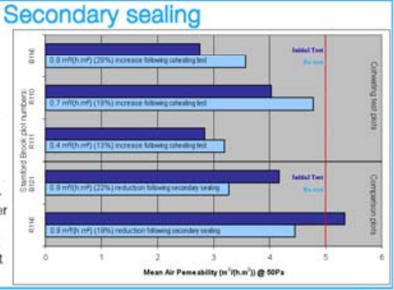
With designers striving to achieve the lowest possible DER's, it is imperative that an airtightness strategy is included in the designs with a target that is attainable, and enough information included to enable it to be achievable.

Secondary sealing

Secondary sealing involves plugging gaps in surface finishes using mastics, caulks and foams in an attempt to limit air movement, in the hope that this will inhibit overall air leakage.

The coheating tests at Stamford Brook provided a unique opportunity to quantify this by providing accelerated drying and shrinkage, causing partial failure of the secondary sealing. The difference being comparable to that observed in other dwellings before and after sealing.

Historically, guidance has placed an over-importance on secondary sealing, which is only beneficial in the very short term (i.e. for an individual test) but is not a robust long term solution.



Designing airtight dwellings - Some guidelines for consideration

1. Ensure that design prioritises the identification and location of the primary air barrier and that there is no reliance on secondary sealing.
2. Avoid complexity and minimise the number of service penetrations. Where complex details are unavoidable, provide additional detail specifically identifying how continuity of the air barrier is maintained.
3. Ensure that all drawings prepared by third parties include information on the air barrier and treatment of penetrations through it.
4. Simplify the primary air barrier by avoiding or minimising changes of plane and the number of different materials used.
5. Minimise gaps by addressing different construction processes varying tolerances, ensuring that conflicts are resolved before construction.
6. Multiple components, particularly where a higher specification single component would suffice, create detailing difficulties where they penetrate the air barrier.
7. The air barrier needs to be capable of inspection and robust enough to repair prior to being covered by later construction.
8. Performance testing of airtightness both during and after construction should be undertaken to provide formative feedback as well as being part of a formal quality control process.
9. Specify a ventilation strategy flexible enough to cope with the entire range of likely levels of airtightness.

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LowCarb4Real; Construction collection: Air barrier construction

Airtightness IS a construction issue

- Airtightness needs to be addressed at every stage in the construction process. Waiting until completion places a misconceived reliance on secondary sealing.
- Operatives need to know what they are required to achieve and what constitutes an acceptable standard.
- The importance of high levels of workmanship in hidden areas should be stressed and quality control should be capable of verifying the standard achieved.
- Sealants should only be applied in a controlled way based on effective joint design. Operatives need to know the type of sealant required and the requirements for surface preparation.
- The number of service penetrations should be minimised by coordinating service routes and synchronizing trades.
- At times of increased or accelerated production management processes should provide additional resources and training to ensure that airtightness performance does not suffer.

Dangerous misconceptions

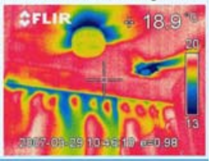
Much historical guidance focussed on secondary sealing and less-robust options such as relying on continuous ribbons of plasterboard adhesive to form the air barrier. Modern guidance now concentrates on a designed-in air barrier. Still, many operatives (and other building professionals) seem unaware of this. However, **If the primary air barrier on the walls, floor and ceiling is continuous and complete, secondary sealing and continuous ribbons are superfluous.**

Maintaining the air barrier's integrity

- Awareness: All construction staff need to be aware of what constitutes the air barrier, where it is positioned and how its continuity is to be maintained.
- Workmanship: Just because you can't see it doesn't mean it's not important; workmanship should be of an equally high standard throughout.
- Accountability: All staff are accountable for airtightness, not just those trades whose work directly impinges on the air barrier.
- Responsibility: If anyone damages the air barrier, it is their responsibility to repair it.
- Effort: Airtight dwellings don't just happen, they require a conscious effort by all concerned.

When you seal and inspect the air barrier can be as important as how you do it. In this example the electrical penetration (upper left) has been sealed at the 1st fix stage, with a suitable mastic, and looks airtight. However, somewhere between then and the 2nd fix (lower left) the sealant has become dislodged and not been replaced.

The thermal image of the detail (right), taken under depressurisation, illustrates the air leakage at this point, as well as showing cold air being drawn in from the loft around gaps in the "continuous" plasterboard dabs.



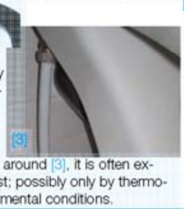
Hidden air leakage paths

Typically for UK new build housing, the vast majority of air leakage occurs through indirect or "hidden" leakage paths, via the network of interconnected voids throughout the dwelling.

Air may exit the dwelling at a point far removed from where smoke detection revealed it leaving the habitable space.

Example 1 (right) shows a Ø150mm hole carefully drilled for a Ø110mm soil pipe, leaving a gap around the pipe of over 8000mm^2 [1].

The tiles are fitted with no attempt to seal these gaps at the air barrier [2], allowing air to move freely between the cavity and the void behind the plasterboard. As this void is linked to all other voids throughout the dwelling, air from anywhere within the property could escape through these holes.



Once the tiling is complete and the soil pipe sealed around [3], it is often extremely difficult to tell that these "hidden paths" exist; possibly only by thermography and even then relying on favourable environmental conditions.

Sequencing

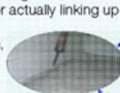
A change in sequence from partitioning-first to ceilings-first dramatically improved airtightness for Bryant Homes at Stamford Brook.

The build sequence adopted can present problems of accessibility when constructing the air barrier and maintaining its continuity. The lack of detailed planning of work sequences can lead to a completed detail being constructed then damaged for a subsequent installation, before being repaired. This "build – damage – install – repair" approach is both inefficient and unnecessary.

- The primary air barrier should be completed before it is obscured and its accessibility compromised.
- Where possible services penetrations should be fitted with sleeves and sealed as construction proceeds to avoid the need for breaking out new construction.
- Sealing of services penetrations should be robust enough to enable later fitting work to be carried out without damage to the seal.

Drilling the penetration for a waste pipe after the kitchen units have been installed is a common practice. However, once the pipe is installed it becomes extremely difficult to seal at the air barrier.

Example 2 shows a simple "hidden" path, with air leakage detected at the junction of the skirting board and the intermediate floor actually linking up to a gap at the jamb/sill junction, through the void behind the dry lining, as shown by the thermal image (right) and photograph taken during the construction phase (left).



Constructing airtight dwellings - Staff training and awareness

1. Developers should ensure that training materials are readily available and of a desired quality. All staff should be encouraged to utilise the training materials.
2. Site and trade specific training on airtightness should be a compulsory part of the site induction, with explanations of what happens when things go wrong.
3. Training should be targeted, for all site staff, rather than just creating a general awareness of the issues.
4. Refresher courses should be regularly scheduled to maintain focus.

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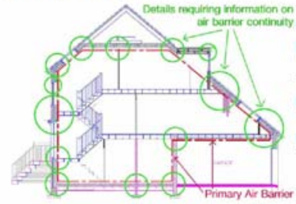
LowCarb4Real; Process collection: Construction planning

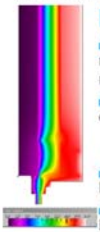


Airtightness

- Any scheme must have a clearly defined strategy for airtightness; a clearly designated air barrier in the design of all dwelling types (including variations) with all drawings showing the location of the air barrier with notes on specific airtightness measures such as sealing and taping.
- There should be a clear understanding of the airtightness strategy by the client, design and construction teams and subcontractors.
- Routine pressure testing of dwellings should be undertaken throughout, ideally including pressurisation testing of each dwelling at a point at which the air barrier is complete and exposed so defects can be readily identified and rectified.

Ventilation

- The design of the ventilation system needs to be considered in conjunction with the airtightness strategy. It is likely that the energy requirements for future developments will require very low levels of air permeability. Hence the ventilation strategy will be one based on mechanical ventilation, increasingly with heat recovery.
- The ventilation strategy should also consider the risk of summer overheating. This might include an option for overnight purge ventilation combined with exposed thermal mass.
- The requirement for a mechanical ventilation system would place additional requirements for dwelling design to ensure that duct runs and space provision for fans and vents are an integral part of the building design.



Fabric Design and Performance

- The design of the thermal envelope must be addressed very early in the design process with realistic estimates of U-values and thermal bridging effects. This is crucial since there are compromises that may have to be made between thermal performance and aesthetic design.
- Design culture is inclined to minimise the problems of detailed design at concept and master planning stage. It is crucial that this does not happen to avoid subsequent compromises in detailed design and thermal performance.

Process, Production and Quality Control

- These issues are deep-seated and difficult to address in a single development, they should be considered as longer-term goals for any developer or associated organisation.
- Both initial work and contracts for later stages need to ensure that design and construction teams are capable of demonstrating how they intend to verify performance.

Cost Engineering

- The cost engineering process must be designed to fully consider the effects and risks of any proposed changes in products, materials or processes on thermal performance, airtightness, ventilation, buildability, maintainability, condensation risk, thermal comfort and any other performance factors.

Training

- The training programme should involve a review of existing processes so that they can be used as training materials, as well as using material from other sources such as Stamford Brook, GHA members and the Passivhaus programme.
- Initial training programmes should be planned from the start and incorporated into budgets.
- Training should be continually reinforced, refreshed and updated to ensure that messages are not forgotten and that all teams are able to learn from each other as work progresses.

Design Changes

- Design change and production substitution processes must be set up to fully consider the effects and risks of any proposed changes in design, products, materials or processes on thermal performance, airtightness, ventilation, buildability, maintainability, condensation risk, thermal comfort and any other important performance variables.
- Training of construction teams and sub-contractors should highlight the potential problems of uncontrolled *ad-hoc* design changes and product substitutions.

Inspectability, Compliance Measurement and Performance Checking

- The choice of construction processes and detailing should take into consideration ease of inspection.
- The development of the required inspection methods and compliance checking protocols should be part of the overall construction plan. A similar approach to measurement and testing should also be taken.
- As with training, the development budget should take into account the need for enhanced inspection and testing processes.

Feedback and Continuous Process Development

- A formal procedure of continuous process development should be used to ensure that process and product improvement become an integral part of the overall design and construction process.
- A range of tools are available around which to form a framework for continuous process development, most of which are based on some form of PDCA cycle (Plan, Do, Check, Act).
- All of the above criteria are vital to the development of an effective feedback process. Maximum benefit will only be achieved by planning the entire construction process holistically, in addition to developing each individual significant area listed above.

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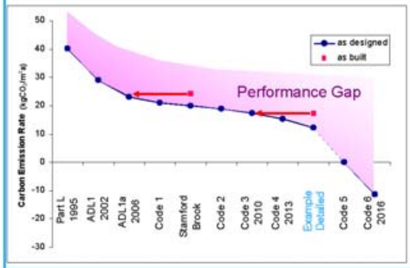
LowCarb4Real; Process collection: Thermal design - Closing the Loop

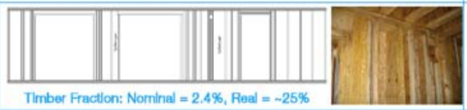
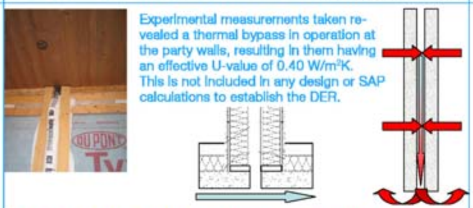
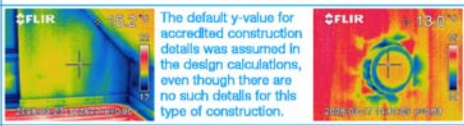
Nominal vs Realised Fabric Performance - An MMC Example



The Stamford Brook field trial showed that even in dwellings considered well-constructed by UK standards, fabric performance may be well below that designed.

The gap between nominal and realised fabric performance is not limited to traditional methods of construction, but can occur in any type of build. The example detailed below is a mid-terrace property, constructed using a closed panel timber frame structure, with a high degree of manufacture performed off-site.

In this case, a dwelling designed to between Code For Sustainable Homes levels 4 & 5 actual performed as a level 3 property based on fabric alone (the Stamford Brook value also included system inefficiencies).

Detail	Design Value	Observations from site	Realised Value	Increase in Heat Loss
Floor U-value	0.20 (W/m²K)	Floor construction completed prior to research team involvement	0.20 (W/m²K)	0.0
Wall U-value	0.18 (W/m²K)	 Timber Fraction: Nominal = 2.4%, Real = ~25%	0.30 (W/m²K)	+3.8 (W/K)
Roof U-value	0.13 (W/m²K)	 • Increased timber fraction • Settlement of cellulose insulation in transit in sloping roof sections • Incomplete fill of mineral fibre insulation in flat roof sections	0.15 (W/m²K)	+1.5 (W/K)
Window U-value	1.50 (W/m²K)	Original design had a "whole window" U-value of 1.5 W/m²K. The installed windows had a "centre-pane" U-value of 1.5, a whole window value of 2.0. 	2.00 (W/m²K)	+9.1 (W/K)
Party Wall U-value	0 (W/m²K)	 Experimental measurements taken revealed a thermal bypass in operation at the party walls, resulting in them having an effective U-value of 0.40 W/m²K. This is not included in any design or SAP calculations to establish the DER.	0.40 (W/m²K)	+55.2 (W/K)
Thermal Bridging y-value	0.08 (W/m²K)	 The default y-value for accredited construction details was assumed in the design calculations, even though there are no such details for this type of construction.	0.15 (W/m²K)	+11.3 (W/K)
Total Fabric Heat Loss	64.9 (W/K)	Additional thermal bypasses were identified but not included in these calculations. 	145.8 (W/K)	+80.9 (W/K)

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LowCarb4Real; Workshop collection: Needs of designers and constructors

19 June 2008 — Breakout session 1, an investigation of designer and constructor needs

This session used brainstorming to collect ideas about what is required for those involved to be able to design and construct robust thermal envelopes reliably. Two starter questions were posed and addressed separately

Starter questions:
1. What do designers need to enable them to design robust thermal envelopes?
2. What do constructors need to enable them to construct robust thermal envelopes?

Interpretation of "Need"
This was defined very loosely and participants were asked to consider as wide a definition as possible and examples were given of types of need such as — Personal —Technological — services from others etc.

Classification of responses

44 responses to each question were recorded from 8 participants (including facilitators) and discussed. These were classified as below (numbers in brackets are numbers of ideas).

Design needs

- Knowledge & Understanding (13)
  - Base knowledge
  - Guidance & training
  - Standardisation of knowledge
- Cultures (11)
  - Client cultures
  - Professional cultures
  - Industry cultures
- Processes (7)
  - Planning & sequencing
  - Flexibility & change
  - Des/const interface
  - Process tools
- Communications (4)
  - Project based
  - General skills
- Tools (4)
  - Predictive design tools
  - Testing capability
- Supply chain (5)
  - Product/service quality
  - Appropriate products/service
  - Relationship & control

Constructors' needs

- Processes (10)
  - Planning & sequencing
  - Clear modification processes
  - Performance control & testing
  - Reward incentives
- Construction/Design relationship (11)
  - A good design
  - Good design information
  - Involvement in design
  - Good communication
- Supply Chain (7)
  - Product/service quality
  - Reliable supply
  - Availability
- Knowledge & understanding (6)
  - Base Knowledge
  - Guidance and training
- Cultures (5)
  - Client cultures
  - General public
  - Constructor cultures
- Resources (5)
  - Time and money
  - Effective staff
  - Weather management

Quotations from discussion during the session:

"We do not do it that way on this site" - A lack of consistency of process in the same organisations and same building types.
"Designers should be builders and builders designers" - A need to have much greater cross-over, understanding between the roles.
"Communication is about knowledge, status and relationships" - Referring to the power of status & knowledge modified by relationships.
"Too much information clogs up communication" - Information (supply chain and others) is not well focused and needs to be controlled.
"So who owns what bit?" - Ownership of the different aspects is often confused and hinders the overall process.

Project Partners: Leeds Met, UCL, GHA, National Trust, Taylor Wimpey, Redrow, University of Leeds. .
Contacts: Prof. Malcolm Bell, Leeds Metropolitan University (m.bell@leedsmet.ac.uk), Prof. Bob Lowe, Bartlett School of Graduate Studies, UCL (robert.lowe@ucl.ac.uk) Jon Bootland, Good Homes Alliance (info@goodhomes.org.uk)

LowCarb4Real; Workshop collection: Airtightness - Design & Construction 1

19 June 2008 - Topic C - Airtightness; design & construction

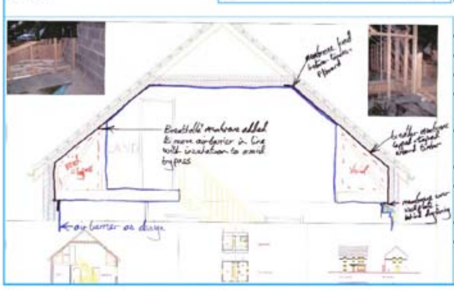
This session used a short presentation and video clip of a dwelling pressurisation test and leakage detection to lead into the main question: *Why does it appear to be so difficult to design and construct an airtight dwelling?*

- In session 1 participants used a range of sample products and design details to look at some of the technical difficulties of designing and constructing an airtight dwelling whilst still ensuring adequate ventilation.
- In session 2 the discussion moved to the wider implications of issues arising from session 1; including policy, inspection, communication and process issues.

Breakout Session 1- Technical Issues

Task - pen-on-section test:

Workshop participants were provided with section drawings of actual dwellings and asked to conduct a pen-on-section test - drawing a line around the dwelling at the primary air barrier to illustrated its continuity, and then discuss the issues that arose.



Issues arising relating to the airtightness task:

- Air barriers are seldom marked on drawings
- Design complexity rarely considers airtightness
- Build sequence can inhibit air barrier continuity
- Designers are not fully knowledgeable regarding standard site practices
- Value engineering often has an impact on designed performance
- Lack of detail design available on site – particularly for subcontractors
- Questions of culpability and responsibility - both on site and in the design process
- Role of accredited construction details
- Communication between manufacturers, specifiers and tradesmen
- Cost of design alterations is often hugely underestimated
- Airtightness and ventilation is often an "after-thought" in the design process
- Some trades seem oblivious to many design characteristics not related to their own field
- It is hard to check areas which are hidden from view
- If the site operatives don't have all the necessary details, why are they expected to build it correctly?
- How can 2D designs be translated to 3D structures more easily?
- Higher-spec products are readily available but rarely used due to the envisaged extra cost

Additional Topics Discussed

Following on from the pen-on-section task, a number of discussion topics not directly related to airtightness ensued:

- What is "deemed to satisfy", and who offers guidance to, takes responsibility over and polices the entire construction process rather than just individual sections?
- Product manufacturers research and development is often dismissed as sales and marketing and under utilised. Training of specifiers and operatives could be undertaken better through manufacturers, to ensure that their products get specified correctly and used correctly to gain maximum benefit.
- If extra policing is required who is qualified to perform it, and who will pay for it?
- All adaptations to standard house designs need assessment which is not always considered in terms of time and cost, and often not considered until the design goes into production - by which time the original designer is often no longer included in the chain
- How much can be learnt regarding process issues from looking at how other industries cope with stratified production processes?
- The possibility of manufacturers integrating their designs to come up with effective system designs; rather than leaving it to architects and other agents to combine individual details into a "patchwork-quilt" of a house design.
- The "quality" of workmanship and the trades' skill levels appear to have decreased significantly over the last 30 years

Airtightness Breakout Session 1 - Summary

- There is a general lack of understanding throughout all sectors of the industry regarding airtightness and ventilation.
- There are severe breaks in communication, especially between designers/specifiers and site staff. Many problems could be averted by better and quicker information transfer and feedback.
- Pattern book approach has changed the mass-housing design mindset from one of first principles to one of "detail-shopping".
- No one is an expert in every field, but there is often a general reluctance within the industry for people to seek professional advice and instead adopt a "that should do" approach.

UrbanBuzz Project - Developing Low Carbon Housing: Lessons from the Field - LowCarb4Real

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LowCarb4Real; Workshop collection: Airtightness - Design & Construction 2

19 June 2008 - Topic C - Airtightness; design & construction

Both sessions used a short presentation and video clip of a dwelling pressurisation test and leakage detection to lead into the main question: *Why does it appear to be so difficult to design and construct an airtight dwelling?*

- In session 1 participants used a range of sample products and design details to look at some of the technical difficulties of designing and constructing an airtight dwelling whilst still ensuring adequate ventilation.
- In session 2 the discussion moved to the wider implications of issues arising from session 1; including policy, inspection, communication and process issues.

Breakout Session 2 - Wider Implications

The implications of the issues discussed in breakout session 1 on the wider industry were considered in greater detail in this session. These fell loosely into 3 categories:

Implications for Designers & Manufacturers

Designers and manufacturers have a vested interest to their stakeholders and cannot be expected to act purely altruistically. Given this, what drivers exist for developers/ manufacturers to provide incentives for higher performance?

- Virtually no prototyping of new designs exists, how does prototyping get included into pricing of developments?
- Designers are actively discouraged from attending some sites.
- Training is often done for commercial or CPD reasons and not necessarily in the areas where skills are lacking.
- Pattern Book design is seen as a quick and easy fix, but does not encourage innovation or continual improvement. Hence, much design basically becomes "detail shopping".
- Design roles are often segmented and lack continuity.
- Design changes can require huge amounts of time and money which nobody budgets for, with ownership of changes issues.
- If designers & manufacturers put their research data and knowledge bases into the public domain they may lose their competitive advantage - so what incentive is there for them to share their expertise?
- Design and build projects traditionally are specifically designed to a fixed price, not a fixed level of quality.
- Who shoulders the extra expense of increased quality and performance?
- Too often designers are directed to web-sites and literature and then make assumptions, rather than talk to the technical staff at manufacturers and suppliers.

Implications for Constructors

Developers pay for a professional service from contractors and subcontractors, are promised it and expect just that. Why is perfection not regularly achieved?

- Lack of continual training - once trades are qualified there is little facility for re-training or refreshment.
- Lack of understanding of 1st principles - especially in buying/ procurement departments, which constructors work around it.
- Expense of "green" issues can be small compared to cost of planning, structural or fire compliance, but seen as an easy option for cost savings.
- Cost or Value engineering? Money is often saved but at what cost? Again, constructors work around it.
- Information from designers and manufacturers often doesn't filter down to operatives.
- Designers, specifiers, manufacturers need to spend more time on site - communication needs to improve, in both directions.

Implications for Policing Bodies / Regulators

What standards are people working to, Code for Sustainable Homes, Building Regulations? Who checks this, at what stage and at whose expense?

- In-house testing and inspection could be done; with independent inspectors regulating the in-house teams where necessary for regulatory compliance.
- BCOs can only see so much, and can only be expected to know so much. Are BCOs that specialise in a particular area required?
- Critical appraisals of designs need to be performed prior to any work starting on site.
- What are the consequences of failure? Are they stringent enough to have an impact? A greater cost for failure to comply may equate to a greater degree of compliance.
- Understanding of issues from 1st principles is often limited, many issues such as thermal bridges should be seen in the design process or picked up during the build, but are only detected after completion when problems start occurring.

Comments from other workshop participants

Draft versions of the posters resulting from the Airtightness breakout sessions were distributed to all workshop participants, the following comments were received:

- "Only thing I'd add is the general issue of airtightness being an indicator of good quality in construction, and the benefits of promoting this in order to get contractors to be proactive about achieving airtightness, demonstrating it by testing, and promoting it through marketing."
- "As with our sessions, it seems that better communication is the key to improvement."
- "Currently we only test on completion for compliance purposes. I will suggest additional testing to see more easily where improvements can be made."

UrbanBuzz Project - Developing Low Carbon Housing: Lessons from the Field - LowCarb4Real

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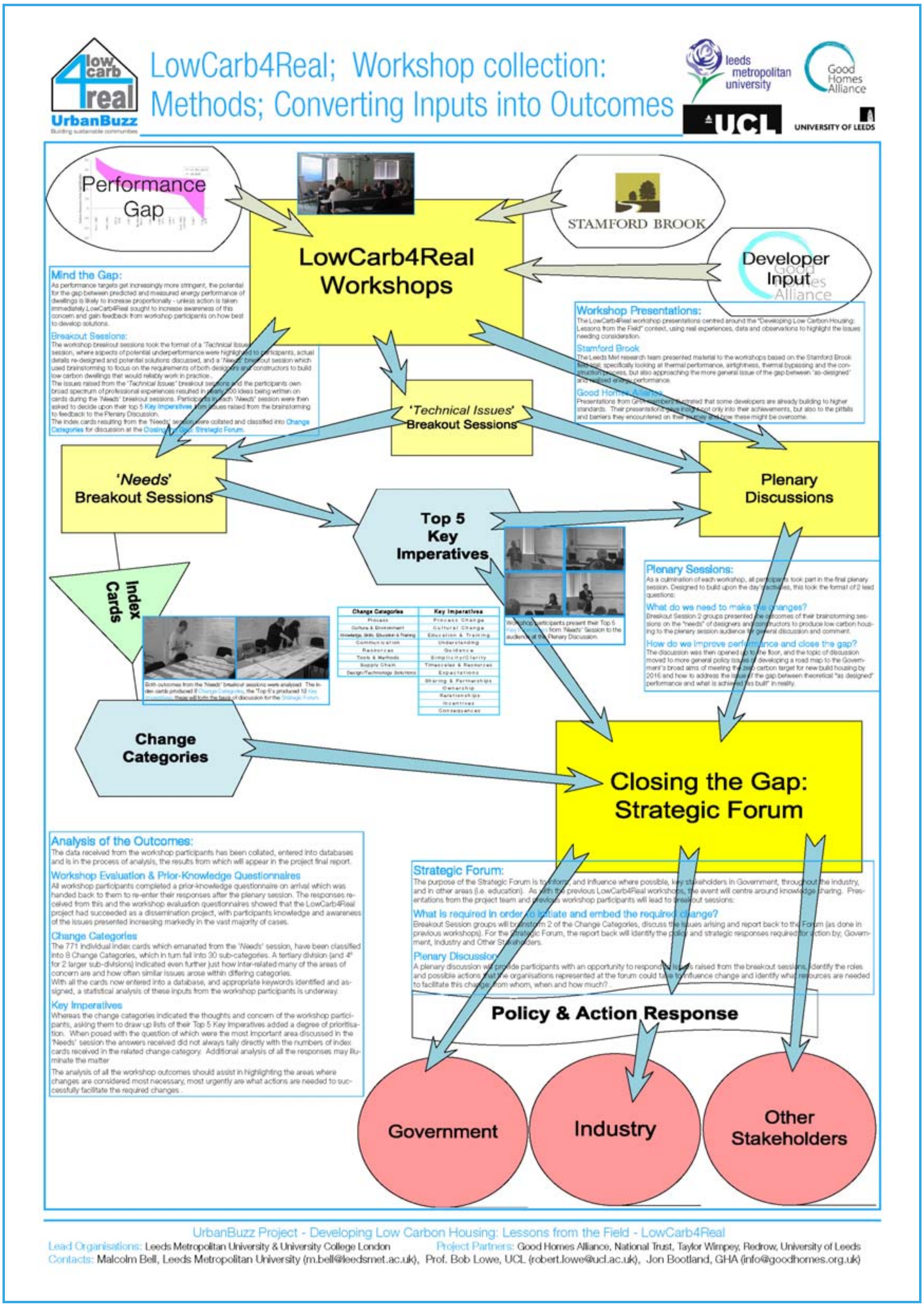
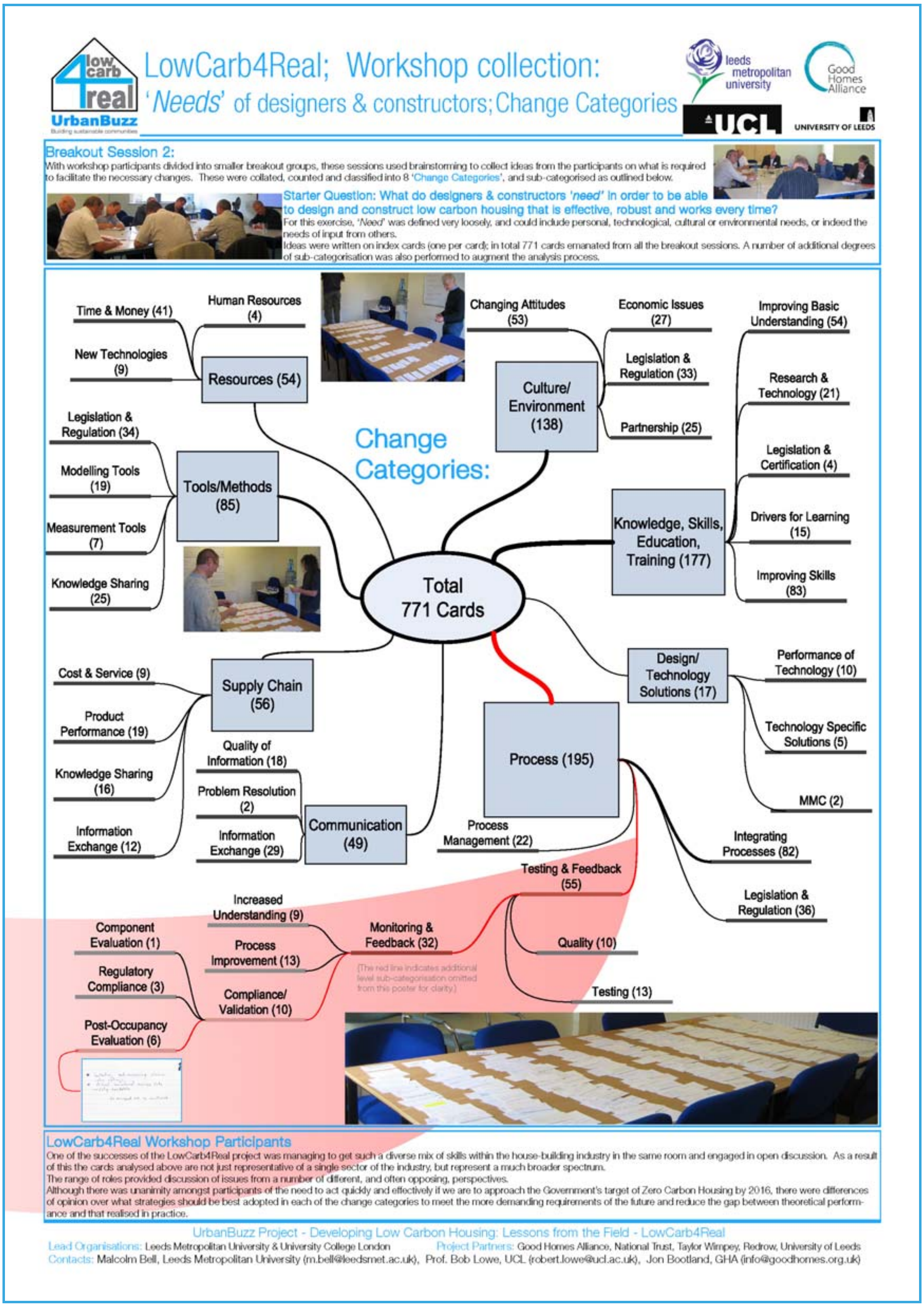


Change Categories	Key Imperatives
Process	Process Change
Culture & Environment	Cultural Change
Knowledge, Skills, Education & Training	Education & Training
Communication	Understanding
Resources	Guidance
Tools & Methods	Simplicity/Clarity
Supply Chain	Timescales & Resources
Design/Technology Solutions	Expectations
	Sharing & Partnerships
	Ownership
	Relationships
	Incentives
	Consequences



low carb 4 real
UrbanBuzz
LowCarb4Real; Workshop collection:
'Needs' of designers & constructors; Change Categories
leeds metropolitan university
Good Homes Alliance
UCL
UNIVERSITY OF LEEDS
Breakout Session 2:
With workshop participants divided into smaller breakout groups, these sessions used brainstorming to collect ideas from the participants on what is required to facilitate the necessary changes. These were collated, counted and classified into 8 'Change Categories', and sub-categorised as outlined below.
Starter Question: What do designers & constructors 'need' in order to be able to design and construct low carbon housing that is effective, robust and works every time?
For this exercise, 'Need' was defined very loosely, and could include personal, technological, cultural or environmental needs, or indeed the needs of input from others.
Ideas were written on index cards (one per card); in total 771 cards emanated from all the breakout sessions. A number of additional degrees of sub-categorisation was also performed to augment the analysis process.
Change Categories:
Total 771 Cards
Resources (54)
Time & Money (41)
Human Resources (4)
New Technologies (9)
Culture/ Environment (138)
Changing Attitudes (53)
Economic Issues (27)
Legislation & Regulation (33)
Partnership (25)
Knowledge, Skills, Education, Training (177)
Improving Basic Understanding (54)
Research & Technology (21)
Legislation & Certification (4)
Drivers for Learning (15)
Improving Skills (83)
Tools/Methods (85)
Legislation & Regulation (34)
Modelling Tools (19)
Measurement Tools (7)
Knowledge Sharing (25)
Design/ Technology Solutions (17)
Performance of Technology (10)
Technology Specific Solutions (5)
MMC (2)
Supply Chain (56)
Cost & Service (9)
Product Performance (19)
Knowledge Sharing (16)
Information Exchange (12)
Communication (49)
Quality of Information (18)
Problem Resolution (2)
Information Exchange (29)
Process (195)
Process Management (22)
Integrating Processes (82)
Legislation & Regulation (36)
Testing & Feedback (55)
Quality (10)
Testing (13)
Monitoring & Feedback (32)
Increased Understanding (9)
Process Improvement (13)
Compliance/ Validation (10)
Component Evaluation (1)
Regulatory Compliance (3)
Post-Occupancy Evaluation (6)
(The red line indicates additional level sub-categorisation omitted from this poster for clarity.)
LowCarb4Real Workshop Participants
One of the successes of the LowCarb4Real project was managing to get such a diverse mix of skills within the house-building industry in the same room and engaged in open discussion. As a result of this the cards analysed above are not just representative of a single sector of the industry, but represent a much broader spectrum.
The range of roles provided discussion of issues from a number of different, and often opposing, perspectives.
Although there was unanimity amongst participants of the need to act quickly and effectively if we are to approach the Government's target of Zero Carbon Housing by 2016, there were differences of opinion over what strategies should be best adopted in each of the change categories to meet the more demanding requirements of the future and reduce the gap between theoretical performance and that realised in practice.
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LowCarb4Real; Workshop collection: *'Needs'* of designers & constructors; Key Imperatives

UrbanBuzz
Building sustainable communities

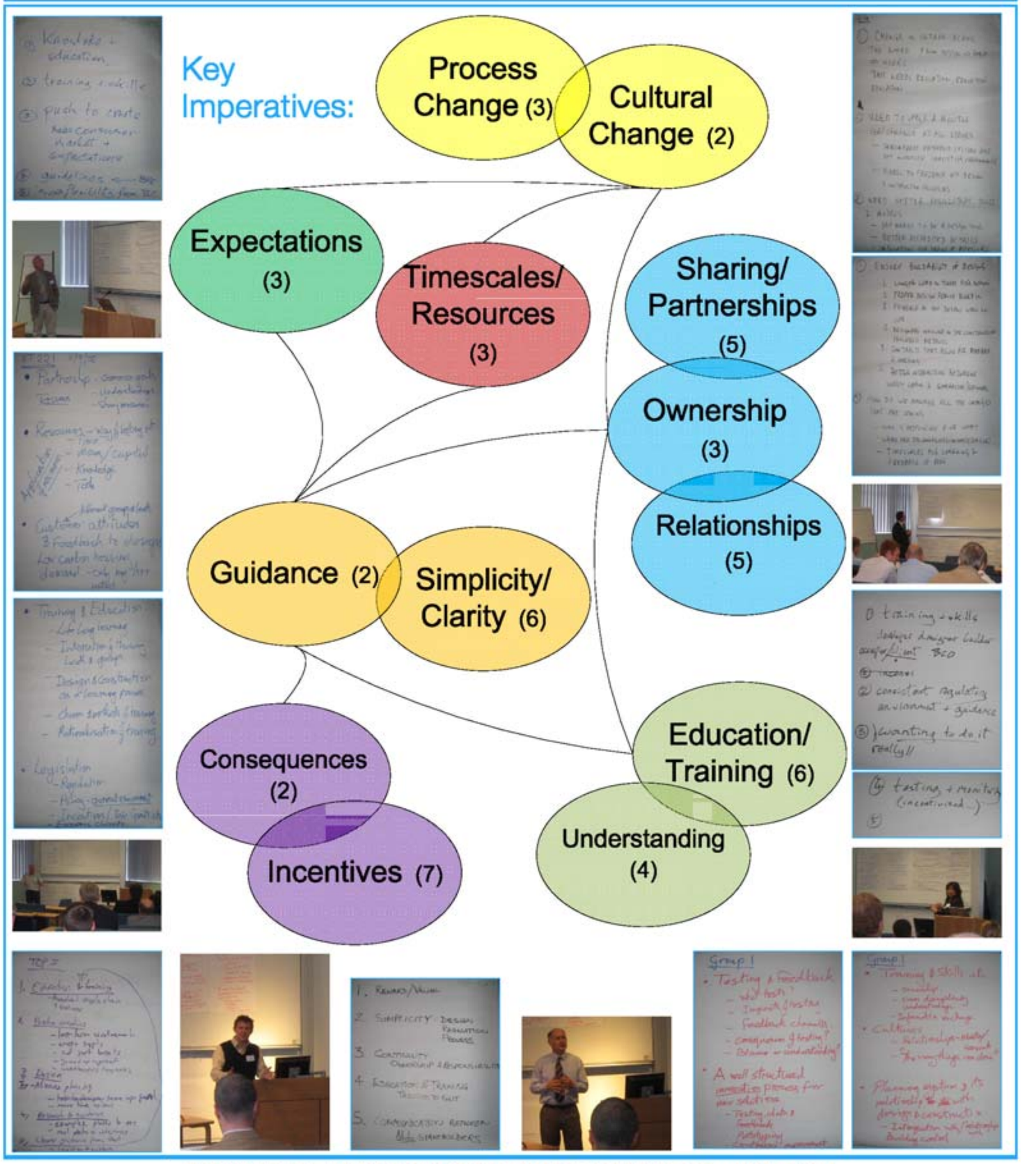
Feedback from Breakout Session 2:

With workshop participants divided into smaller breakout groups, these sessions at the 3rd, 4th and 5th workshops used brainstorming to collect ideas from the participants on what is required to facilitate the necessary changes.

Each group were asked to decide upon the top 5 'Key Imperatives' from their discussions of these ideas, which they subsequently presented to the plenary discussion. These 'Top 5s' were written on flipcharts (a selection of which is shown below) and presented by a breakout session group member, rather than by one of the LowCarb4Real project team.

The 13 key imperatives illustrated below were established through analysis of the flipcharts presented to the plenary sessions (right). It must be stressed that over-laps and linkage lines between individual key imperatives are purely representative, and only a small amount of the interactions between them are shown below.

The numbers (in brackets) indicate how many times each key imperative appeared in the lists of 'Top 5s', from a total of 10 breakout groups.



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LowCarb4Real; Design collection: GHA: Bladon Overview

Background

Lincoln Grove is a development of 9 x 2 and 3 bed homes near Woodstock, 9 miles from Oxford, constructed in 2007. The homes were awarded EcoHomes excellent, scoring 77 credits, the same as BedZED. The homes have been subsequently re-assessed under the Code for Sustainable Homes and achieved level 3

Thermal Design

- The shortcomings and complexity of standard cavity wall construction were clear to the developers Kingerlee Homes, so after considerable research, they specified NBT Thermoplan blocks - a single skin load-bearing wall system. The honeycombed blocks are planed top and bottom, enabling them to be laid to produce a single skin, robust, weather and air-tight structural wall, which is vapour permeable (air-tight and breathable). The blocks interlock on the vertical face and require no vertical mortared joints and the thin horizontal mortar joint increases the overall fabric performance. The wall, whose insulation value is entirely due to the block, is simply constructed without cavities, membranes or additional insulation. A thermal design checklist was drawn up and every junction detailed, to ensure continuity of air barrier and minimise thermal bridging and bypassing . Final airtightness tested at 3.8 – 4.8 m/h@50Pa.
- With **Thermal bridging:** calculated to an exceptionally low y-value = 0.024
- The design changed many times and it was hard for the whole team to keep up. In the end, there was a lack of ownership for the thermal checklist and it was not strictly adhered to.

Construction

- **Roof:** 300mm of Warmcell insulation blown in between 250 mm I-beam rafters with 35mm wood fibre insulating sarking board
- U-value: 0.11 kWh/m^{2}k (0.15) y of 0.04
- **Floor:** Concrete planks with 150mm Kingspan insulation under a 50mm screed with 50mm edge upstands;
- U-value: 0.12 kWh/m^{2}k (0.20)
- **Walls:** 365mm Thermoplan single skin cellular insulation monolithic clay blocks with stone or render facing
- U-value: 0.26 kWh/m^{2}k (0.28) y = 0.05

Ease and Speed of Construction

The developers had been impressed at the speed of construction of the Thermoplan system in Germany and the general understanding of the importance of thermal performance across all the site operatives. The construction system led to vastly reduced build times in Germany, potentially halving build times.

Materials

Kingerlee wanted to adopt a build system that was simple and effective, with lower embodied energy and with more sustainable materials. The Thermoplan system has very low embodied energy and environmental impact compared to conventional masonry building methods, which is recognised in their 'A' rating in the BREEAM Green Guide. Warmcel is also rated A in the Green Guide and FSC timber was used throughout

Process

- The integrated thermal design and detailing was a collaborative process between the developers and the material suppliers NBT and their consultancy arm NBT consult. The entire team – developers, architect, contracts manager, investors , QS and site manager visited sites in Germany to see the system in action and how quickly the build can progress. They also visited the Thermoplan factory.
- The QS was impressed with his findings and much more confident about costs and timelines
- Onsite training was delivered to the in house construction team and their main subcontractors and the site manager was suitably inspired by his trip to Germany. NBT Consult compiled a check list and details of junctions. Inspections were made by the teams at crucial stages of the build, to ensure the detailing was adhered to and effective, before work continued

Sequencing

- The render finish on the inside of the single skin block walls provides the bulk of the airtightness, so it was essential to ensure a cohesive shell - the render had to follow round the inside and form a continuous unbroken layer, which included rendering behind fitted kitchen cupboards and appliances, before fit out. If walls cannot be plastered before fit out then they should be parged whilst still accessible.

Planning

- There were issues with scaffolding, which took longer to erect than the Thermoplan walls and delayed the build process. The access was very tight for the crane.

Management and Supply chain

- Kingerlee made a Board level decision to move away from standard cavity construction and adopt the principles behind MMC.
- Working closely with NBT, the Thermoplan suppliers on the design for thermal efficiency ensured the forming on an effective collaborative team at an early stage

Post-Construction Monitoring

Kingerlee have understood that air tightness testing and thermographic imaging are essential tools during the build process. They also tested at a number of stages in the construction process which allowed easy remedial action at an early stage – much cheaper in the long run and help give better final results.

Post Occupation Monitoring

- Heating costs from the SAP Predicted Energy Assessment, based upon May 2007 fuel costs, are in the region of £150.00 per year, depending upon the size of the units
- On the same basis, the total fuel cost for heating and hot water will be approximately £200 per year including standing charges.
- Early indications from monitoring appear to confirm the performance anticipated in the SAP predictions.
- At Bladon, a whole house monitoring system allows both occupiers and the developers to access energy use across the 8 electricity circuits, the gas, the water and internal and external temperatures and internal humidity.
- Monitoring shows that radiators have been turned off upstairs, the wood burners have not been used, and the passive ventilation system is ensuring comfortable temperature and humidity throughout the homes.
- Kingerlee are also working with Oxford Brookes, who are monitoring the occupants behaviour, to understand better how occupants use their homes and how this behaviour reflects in consumption patterns - the links between energy use and occupancy behaviour will be made clearer

Cutaway of Typical House

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LowCarb4Real; Design collection: GHA Bladon: Airtightness IS a Design Issue

Primary Air Barrier — Design it with CARE

Kingerlee had understood the importance of good thermal design and were aware of some of the early findings from Stamford Brook. Their search to maximise their own build quality took them to Germany to understand their systems better. They wanted a system that could consistently deliver air tightness performance twice as efficiently as demanded by Building Regulations – so they targeted 5m/h ach@50Pa

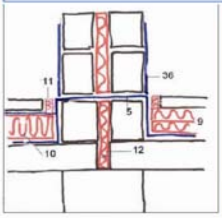
This research and learning on thermal design was fed through to the entire design team and the site operatives. Indeed the whole design team visited Germany and when the new site manager started, he also was taken over.

Further training at NBT for sub contractors laying the blocks on site helped improve understanding of good thermal design and helped ensure the design was actually constructed with this in mind as a priority.

The architects ALP also received training on the principles of good thermal design and airtightness. Complex areas like junctions, steel bedding and wall junctions and openings such as doors, windows and balconies were fully detailed and discussed and drawn – drawings were also annotated with EcoHomes credits . Detailed drawings referred to how continuity of the air barrier would occur on site. Complex detailing was removed where possible and complex areas like junctions and wall junctions and openings such as doors, windows and balconies are fully detailed and drawn – if you can't draw it you can't build it.

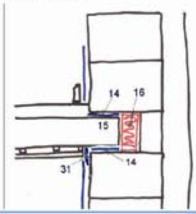
Working with Peter Warm and NBT consult, an airtightness schedule and 37 point checklist was devised to make sure that detailed checks on all complex junctions were made at the following stages of the build

- Completion of radon barrier
- First joist of the first floor construction
- First purlins
- Final membrane roof sealing



Airtightness around DPM/Radon barrier
1. Check seal around service entries - stove air (B)
2. Check seal around service entries - Electrical & BT incomer duct(s) (B)
3. Check seal around service entries - Drains (B)
4. Check seal around service entries - Water incomer duct (B)
5. Check continuous and sealed through insulated party wall (A)
6. Check seal to external wall/DPC (B)
7. Check seal where dropped around external doors (B)
8. Check under slab ventilation present to external air for Radon and combustion air (B)

Continuity of insulation
9. Either: uses 2 sheets 75mm polystyrene and offset joints (A)
10. Or: use 150mm polystyrene and extra DPM over top to prevent screed filling gaps (A)
11. Check 25mm polystyrene Edge insulation correctly installed before screed pour (A)
12. Check cavities filled with 75mm acoustic insulation, no snots or ties bridging (A)



Measurement and Feedback

Lesson - Test for air tightness at an early stage in the construction process – remedial action is cheaper AT THIS STAGE– and testing more than once will lead to better final figures

1) Completion of shell
Air tightness testing at this stage when the walls and roof were completed but before the render gave a result at Bladon of 22 m/h@50Pa. The tests showed that there was an unexpected significant air loss under the timber window sills, where the dpc was rounded off under the window sill, allowing air movement in the small gap between the dpc and the blocks. Testing at this stage allowed this problem to be easily solved at an early stage.

If you can't easily trace your finger around the air barrier on the plans, then you will have problems with thermal bridging

2) Once the thermal envelope has been completed and services are in
The plaster finish on the inside will provide the bulk of the airtightness so need to ensure that you have a cohesive shell which includes rendering behind fitted kitchen cupboards and appliances. The render has to follow round the inside and form a continuous unbroken layer. If walls cannot be plastered before fit out then they should be parged whilst still accessible.

Punctures in walls from service runs are the most common form of air leakage. Careful attention should be given to all service layouts and pipe runs minimised, but remedial action may be required to improve these figures. At Bladon, it was also noted that there was some leakage externally, where the dpc was dressed into the block joint, and so a polystyrene seal was placed over the joint

Testing at this stage revealed that air tightness was a range of 6.2 – 7 ach

3) Final testing
The above remedial action ensured that the final figures at completion showed a figure of 3.8 – 4.8 m/h@50Pa, comfortably within the target of 5

General testing
Acoustic testing at an early stage also showed that any penetrations through party walls rapidly reduces acoustic performance. This resulted in ensuring that electrical sockets were placed on external walls where possible and any sockets on party walls were surfaced mounted

Kingerlee have invested in a **thermographic camera** as a quick and easy way to understand how buildings are operating and which areas of the building are performing and which aren't.

Designing Airtight Dwellings– Guidelines

- Understand the subject area and train your design team
- If you can't draw it, you can't build it.
- Ensure the design and construction team, including sub contractor, understand the importance of good thermal design
- Help make energy visible by explaining about CO_2 emissions and homes

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LowCarb4Real; Design collection: GHA: Bladon, Thermal bridging

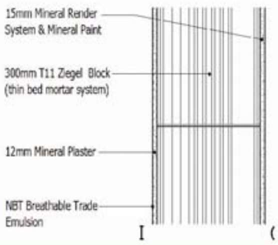
Bladon—Thermal Bridging

The first designs for this site reflected Kingerlee Homes' progressive approach with a modern design. The Planners were supportive of this and recommended the initial contemporary scheme for approval but the Planning Committee however wanted the scheme to be '*more like Bladon*', and were keen to mark the heritage of the site as a stone quarry for the adjoining Blenheim estate, and so the initial designs had to be significantly changed and then modified again. Planning restrictions on height meant the roof lines became complex as they were refined and the aesthetics and design constraints reduced the flexibility and potential for good, simple thermal design and resulted in an unwelcome level of complexity to the final design. Extra complexity leads to extra junctions and therefore lower performance.

The thermal design of the homes was based on a well insulted slab and 365mm Thermoplan single skin cellular insulation monolithic clay block walls with stone or render facing with U-value: 0.26 kWh/m^{2}k (0.28) y = 0.05

The roof is slated over low timber content I-beam rafters, supported by timber trusses and steel purlins. I-beam timber joists also form the first floor. Warmcel recycled insulation is used throughout the roof and first floor.

Careful attention was given to selection and use of a complete build system design that reduced thermal bridging to a minimum. Construction details using ThermoPlan were calculated to an exceptionally low y-value = 0.024

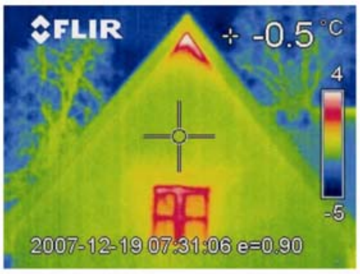


Geometric thermal bridges

The simple shape of the thermal envelope was compromised by the nature of the planning restrictions both on site lines, height and also aesthetics made junctions more complex. This together with a changing design, a structural engineer with no interest or knowledge in thermal design, led to a challenging build.
Junctions and joins were given careful attention to make sure operatives understood they they should be thermally broken

Repeating thermal bridges

The well insulated slab – two slabs of 75mm polystyrene with offset joints and 50mm polystyrene edge insulation – all were checked before pour, and the Thermoplan single skin wall system prevented the most common form of repeating bridge – the wall tie.
Junctions with steels were carefully detailed and extra insulation around the joints - included – thermal breaks
The timber I beam rafters also reduce thermal bridging as the web reduces the flow of heat



Non-repeating thermal bridges

Working with Peter Warm and NBT consult, an airtightness schedule and 37 point checklist was devised to make sure that all the following areas were checked

- Completion of radon barrier
- First plank of first floor
- First steel purlins
- Final membrane roof sealing

Also included on the check list was ensuring the lintels contained the insulation before casting and were cast, at First floor – fully filled bearing, insulated ends of I beams and careful attention to ends and sealing of steel purlins

Rules to assist in the avoidance of thermal bridging at Bladon

- Understand your subject
- Consider a build system or MMC with single skin wall – no additional insulation or wall ties
- Train design and construction staff
- Create a checklist for the development that defines the most likely points and stage in the construction process for loss of thermal performance
- Ensure that contractors take ownership and responsibility for thermal design on site.

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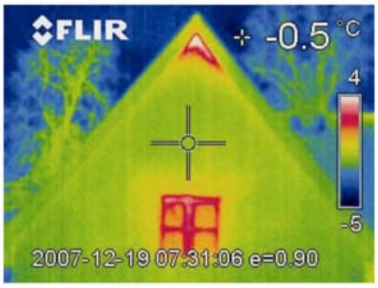
LowCarb4Real; Design collection: GHA: Bladon, Thermal Bypassing

Reducing Thermal Bypassing

Kingerlee were keen to find a solution to the problems being experienced with external cavity walls. They were aware of examples of cavity walls, where examination of the cavity after completion, revealed significant areas with floating or missing insulation. Breaks in the continuity of the insulation layer mean the immediate surrounding insulation is effectively useless.

They were also aware that incorrectly placed insulation batts could actually bridge the cavity and provide a route for damp transfer to the inner wall. Use of the single skin insulation Thermoplan block system at Bladon removed the need for cavities and the need for separately installed insulation.

Thermal bridging can be avoided by simply ensuring that the insulation does not have any cavities on either side and is contained on both sides



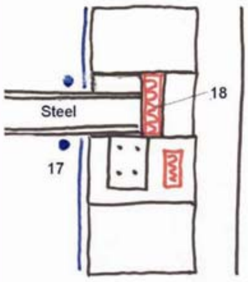
Type 1: Air Movement in Construction Cavities

An early discussion with Leeds Met regarding the early reports from Stamford Brook, warned Kingerlee of the risks associated with cavity party walls, and their ability to become 'chimneys' drawing warm air up through the cavity. At Bladon the Party Wall cavities were filled with 70mm acoustic grade Rockwool, thereby stopping air movement.

This problem was overcome at Bladon by fully filling the cavity

Type 2: Air Movement Within and Around Insulation

The use of the Thermoplan system meant that this problem was removed from the walls. Warmcel 500 was used in the roof and the advantage of this product is that it is blown in under pressure and fills any gaps and cracks, thus reducing any thermal bypassing.

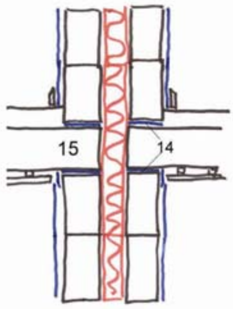


First Floor Plank bearing

14. Ensure fully filled bearing top and bottom for air seal (D,E)
15. Check perps for planks filled especially in built in ends (D,E)
16. Check Insulation strip on external walls on end of plank (D)

Steel Purlins

17. Check pads correct height and insulation block in lintel block (F)
18. Check insulation correctly placed at end of beam (F)



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LowCarb4Real; GHA Design collection One Brighton: Design Overview

One Brighton. Crest Nicholson BioRegional Quintain
Architects. Fielden Clegg Bradley
Main Contractor. Denne Construction
ME Engineers. MLM Ltd
Structural Engineers. Scott Wilson (incorporating Cameron Taylor)
Landscape Architects. Nicholas Pearson Assoc
QS. Jones Lang Lasalle
Planning. Planning Perspectives.
Thermal performance consultants. NBT Consult

Background

One Brighton at Blocks E & F, New England Quarter, is a mixed-use scheme sitting within a mixed-use neighbourhood. The development will offer a range of residential accommodation, community and commercial/office space. Through the design, specification and service provision, One Brighton aims to make sustainable high quality living easy, affordable and attractive. The project is being developed in a joint venture by Crest Nicholson and BioRegional Quintain ("CNBQ") . The development comprises 172 homes (eco-studios, 1-bed, 2-bed and 3-bed units), around 1,000 m^2 of community space, and approximately 1,200m^2 of commercial/office space. The development formed of Block E (up to 11 storeys) and block F (up to 9 storeys) has been designed, specified, and is currently being built under the One Planet Living® principles; and has achieved an EcoHomes (version 2005) 'Excellent' rating.

The development has been designed to be Zero Carbon through a combination of good thermal design and on and off-site renewable generation technologies; including a central biomass boiler to provide space heating and hot water, on-site photovoltaic panels and electricity from new capacity REGO-certified sources. The energy demand has also been reduced with a highly thermally efficient building envelope, energy efficient lights, fittings and appliances.

One Planet Living is a global initiative based on 10 guiding principles, developed by BioRegional and WWF–International. For more information visit www.oneplanetliving.org. For more on the development, please visit www.onebrighton.co.uk

One Planet Living® principles

Design Targets

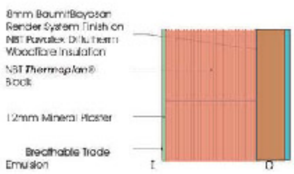
- Net zero carbon development in use
- CO_2 emissions from homes (as defined by EcoHomes) to be 25kg CO_2/m^2
- Space heating demands < 30 kWh/m^2/annum
- Hot water < 45 kWh/m^2/annum
- Electrical consumption < 45 kWh/m^2/annum
- U - values 40% above building regulations
- Walls: U - Value 0.21 W/m^2k
- Windows: Overall U - Value 1.4 W/m^2k
- Glazing area to exceed 0.15m^2 per m^2 of floor area
- Target Air tightness 5m^3/hour/m^2 @50pa
- Low energy lighting and appliances, drying spaces and good daylighting
- Low carbon, low impact concrete frame and infill design
- Monitoring through an established ESCO – energy services company

Materials

Lean concrete frame with an infill of NBT Thermoplan blocks - a single skin load-bearing wall system. The honeycombed blocks are planed top and bottom, enabling them to be laid to produce a single skin, robust, weather and air-tight structural wall, which is vapour permeable (air-tight and breathable).

The blocks interlock on the vertical face and require no vertical mortared joints and the thin horizontal mortar joint increases the overall fabric performance. The wall is simply constructed without cavities.

Where not in the BRE Green Guide for Products, a bespoke assessment for the build up was commissioned from the BRE.



Reducing the embodied energy of the build

Concrete Frame – lean design

The units are designed to be energy and resource efficient in both build and in use. The design is based on a post tensioned concrete slab which reduces the thickness of the slab by up to 15%. The concrete frame uses 100% recycled steel reinforcement, 50% cement replacement (Ground Granulated Blastfurnace Slag – GGBS) and 100% recycled or secondary aggregate. This material is a by-product of the china clay industry and was previously part of the waste stream, but has now found a new market in the aggregate supply industry. The material is being shipped from Cornwall to site to reduce footprint of supply.

Infill

NBT Thermoplan Plus – single hollow core blocks @240mm and insulated externally with 100mm Pavatherm woodfibre insulation and rendered or clad

Reducing CO_2 from the build process

It is calculated that this lean design approach, should decrease carbon emissions associated with the concrete frame by one third. A target of using 25% recycled materials by mass has been exceeded—the estimated recycled content is 47% by mass.

A mix of between 50% and 95% biodiesel (old chip fat) has powered the cranes on site for the last 8 months.

Post-Construction Monitoring

Whole building energy performance and Air tightness testing

NBT consult have been contracted to consult on the thermal performance of the building with special attention to the external walls and air tightness. The first air tightness tests have just been concluded with results of 2.8m3/h/m2@50pa. A report collated the build issues and the team are now confident they can set revised lower targets which will also improve the efficiency in operation of the MVHR.

ESCO

The energy requirements on site are to be managed by an ESCO – an energy services company which includes the boiler supplier who will maintain the system, the feedstock supply companies, energy metering and billing companies.

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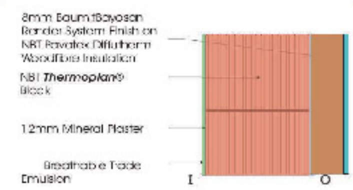
LowCarb4Real; GHA Design collection One Brighton: Airtightness

Air tightness and health

With very low level of air tightness, internal air quality can deteriorate unless there is a viable ventilation strategy. At air tightness levels of less than 3 m3/h/m2@50 Pa, some form of mechanical ventilation will generally be required. One Brighton will benefit from mechanical ventilation with heat recovery. MVHR will operate most efficiently and quietly at air change rates of 1-1.5 and it is now intended to aim for these lower targets at One Brighton. In addition to the MVHR, this build offers a breathable construction and so moisture and condensation can also migrate through the wall to the outside, so helping ensure comfortable internal air quality.



Primary air barrier— Design it with CARE

One Brighton is being built under a design and build contract. The thermal efficiency and airtightness targets of 5 m3/h/m2@50 Pa were set by the developers as part of the extensive sustainability action plan for the site.

The construction is a lean concrete frame , with a single skin infill wall from Thermoplan blocks. These monolithic blocks are extruded with vertical perforations.

Continuous The primary air tightness barrier is provided by the internal parging coat on the Thermoplan blocks.

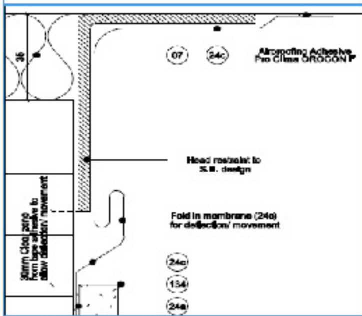
In addition, the frame and infill blocks are wrapped externally with insulation of compressed interlocking T&G 100mm wood-fibre boards and rendered or clad.

Accessible: Sequencing was changed to ensure that all areas to be parged are accessible to prevent discontinuity.

Robust: The parged coat gives a robust and long lasting air tightness.

Explicit: The importance of the continuity of this parging layer has been emphasised to site staff and a first test has been completed and reported and a check list compiled of areas that require particular attention.

Leakage where section of external wall within services boxing remains unplastered.



Detail of expansion joint

Complexity

Although CO_2 savings in the frame build have been significant, it has added complexity to the air tightness detailing. This is because the building's maximum frame deflection is increased to up to 25mm which has required 35mm movement joints at the top of the infill wall to allow for this movement. A bespoke tape had to be sourced, wider than standard, to be able stick onto the soffit, over the movement joint and stuck on the blocks.

Leakage where membrane is poorly sealed around cables use of grommets was recommended

Crack leakage beneath bottom of door frame where membrane seal along base of plaster board is discontinuous.

Measuring, Learning and Improving

The main contractor, Denne, employed NBT Consult (see www.nbtconsult.co.uk) to advise them on detailing for airtightness. A first air tightness test of the show home was completed in July 2008, with encouraging results at just under 2.8 m3/h/m2@50 Pa . An inspection and report was compiled. The construction team had been a little concerned that the target of 5 was already very tough. However, this test allayed their concerns, and the team realised that in fact this target was not only achievable , it could be bettered. They now have the renewed confidence to revise the target downwards, to an average between 1 and 2. Further tests are scheduled for end October 2008.

The report drew attention to several categories of leakage sites:

a) Associated with the membrane system providing the seal between the walls and the concrete slab floor and roof at both low and high level;

b) Around door and window openings, including the boxing-in adjacent to most openings;

c) Around and through the electrical sockets and switches, both on external walls and on party walls to adjacent dwellings;

d) Around pipe penetrations, both vertically and horizontally, where the use of timber pattresses, or similar, was suggested to provide a robust surface against which an effective seal to the pipe penetration can be achieved.

Recommendations:

(1) utilising a more robust membrane system and ensuring that it is fully adhered and properly overlapped at joints, and is mechanically trapped behind plaster(board) or other elements wherever possible;

(2) Ensuring that any foam sealing is cut back and sealed over with mastic to ensure the most effective seal;

(3) Cleaning all surfaces, particularly at low level, to remove dust before mastic or sealant is applied, and ensuring that all mastic joints are tooled in place to give a good finish and the best possible adhesion;

(4) Providing a continuous mastic seal around all window and door frames, including between the slab and the plywood cill, and extending this to include all vertical joints in the boxing in found adjacent to window and door openings. We estimate that Air Permeability values of as low as 1.0 (m3/hr/m2 @ 50 Pa) should be achievable.

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LowCarb4Real
GHA Design collection.
One Brighton: Thermal Bridging

One Brighton—Reducing Repeating Thermal Bridging

The Thermoplan blocks project over the face of the slab by 35mm which helps reduce thermal bridging, as the face of the slab can be insulated . This is then wrapped in 100mm interlocking T&G woodfibre board, fixed to the blocks with thermally broken fasteners.

This structure is not in the accredited details. This means that either:

1. A default "y" value of 0.15 is taken, which effectively increases every U value by this amount, or

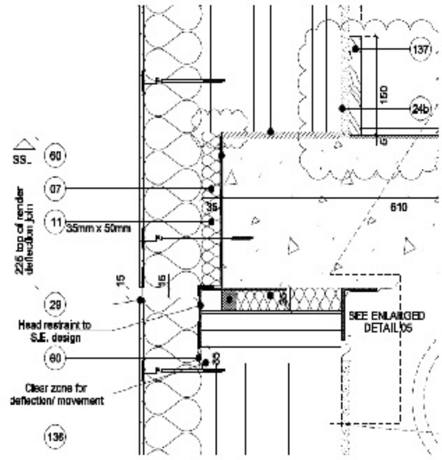
2. A psi calculation is carried out which will result in the calculation of the psi value at this point, and since this is the major thermal bridge, other psi values can be taken from IP 1/06 as reasonable estimates, ie for ground floor and roof, windows, etc.

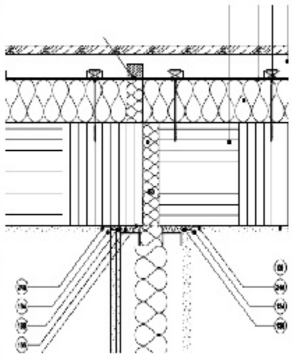
These psi values are multiplied by their length of the detail, to give an additional heat loss in Watts per degree K (the y [illegible] value). This is then added to the fabric heat loss calculated from the areas and U values.

Psi Values (W/Cm)	Thermoplan projection over floor slab (mm)
0.11	0
0.10	20
0.08	50

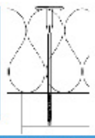
A number of different projections were modelled showing the difference in Psi values at different projections.

Section through slab showing Thermoplan blocks projecting





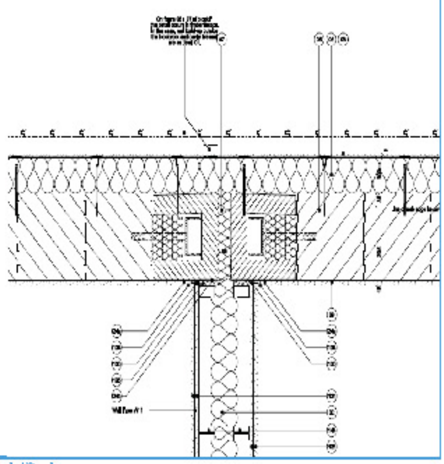
Figures: Fixing the wood-fibre board and the thermally broken fasteners



Geometrical thermal bridging

All junctions with external and internal walls have been carefully detailed to reduce bridging:

Plan detail below: Junction of internal partition to Thermoplan blocks with the windposts.



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LowCarb4Real; GHA Design collection: Stawell Design Overview

Background

- The Old Apple Store is a development of 5 new family homes, with one existing unit retained and completely refurbished. The site nestles within the site of the old apple store in the picturesque village of Stawell in Somerset. The 2 x 4 bed units are nearing completion and work will shortly start on the terrace of 3 bed units: all the new homes are designed to achieve CSH level 5. Following on from their award winning development at Great Bow Yard, Ecos Homes wanted to create a specification that achieved CSH level 5 in a robust solution that provided a thermally efficient shell, could be easily replicated, with reduced build times and with the most sustainable materials on the market.

Thermal Design

OSB pre-formed cassettes manufactured offsite form the walls. These are supplied open-stud and once erected, filled with Warmcel (recycled newspaper) and insulated externally with 100mm woodfibre board and rendered. Together with triple glazed windows and with a well insulated slab and roof, the structure offers very low U-values, designed to require only minimum additional heating. With a target airtightness of 3m/h@50Pa and an overall heat loss parameter of 1.2 W/m2K, the buildings should be very efficient to operate. Top up heating is with wood pellet stoves. Passivent, Solar thermal, rainwater harvesting and PVs are also integrated into the design. All hot water pipe runs are insulated and run through a central service zone and minibore where possible to reduce the volume of water in the system. Ecos have also minimised radiators (none in living space) and located the cylinder as close to the pellet burner as possible to minimise heat loss.

Construction

- **Roof:** Engineered I Beams fully filled with Warmcel with 100mm woodfibre with OSB top and bottom. Internally Proclima Vapour Control Layer Intello Pro to underside of OSB. Finished externally with Sarnafil Single Ply membrane. U-value: 0.12 kWh/m^2k
- **Ground Floor:** Concrete slab with 150mm Kingspan insulation under a 50mm sand binding with 50mm edge upstands; U-value: 0.15 kWh/m^2k
- **Walls:** Engineered OSB cassettes fully filled with 175mmWarmcel and insulated externally with 100mm woodfibre board and rendered with mineral lime render or clad with baked softwood: U-values 0.14 kWh/m^2k
- **Doors and windows:** Triple glazed FSC windows U-values 1.2 kWh/m^2k . Doors U-value 1.1 kWh/m^2k

Materials

A glulam frame with infill OSB cassettes form the structure. OSB (Orientated Strand Board) was selected as the sheathing board as it is manufactured in a process which uses nearly 90% of the log, with the balance used to supply energy. Insulated with recycled newspaper – Warmcel and insulated externally with woodfibre boards (compressed wood fibre with no additional resins) and rendered with a mineral render or clad with baked softwood. Between floor insulation is UK sheep's wool.

Ease and Speed of Construction

Significant resources were used to construct retaining walls to the rear of the site which delayed the build somewhat. The building inspector has been quite amenable to the design but did insist on additional structural steels, which required some redesign and additional detailing. The build itself has been quick but the design of the sloping flat roof and sloping rear walls has added complexity

Process

The Houses are being built by Pippin Properties Limited, a joint venture between the landowners and Ecos Homes Limited with Ecos managing the build.

- The benefits of partial offsite construction were clear
- Thermal mass is provided by the slab
- Reports from Stamford Brook highlighted the need for simple and effective detailing and minimal service punctures
- The design with sloping roofs and walls has added considerable complexity
- Some detailing has had to be worked up on site
- Close attention was given to sealing gaps – 3 operatives for 3 weeks on the first 2 units

Management and Supply chain

- Ecos are managing the build themselves which has allowed problems to be worked through on site
- The supply chain has been stretched but manufacturers such as Passivent have worked with Ecos to provide new solutions. Passivent have supplied the system with a roof outlet for the flat roof, which was a new product

Post-Construction Monitoring

Ecos Homes have learnt from others, especially Kingerlee Homes, the benefits of early air-tightness testing and intend to undertake the first test once the windows are in.

Post Occupation Monitoring

- A whole house home energy hub supplied by Green Energy Options will allow detailed monitoring of energy, water, temperature and humidity. With a touch screen, wireless sensors and live web display, the system is designed to be attractive and engaging, especially for children and will detail how the solar panels and circuits are performing.
- Tenants post occupation studies will also evaluate consumer satisfaction and behaviour patterns

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LowCarb4Real; Design collection: GHA, Stawell: Airtightness IS a Design Issue

Primary Air Barrier — Design it with CARE

Airtightness is essential in order to prevent unnecessary heat loss through the building fabric due to air movement. Any shortcomings in airtightness will increase heating costs, reduce thermal comfort and may cause interstitial condensation. Airtightness was considered a priority at Stawell with a best case target of 3 m/h@50Pa and a fall back target of 5 m/h@50Pa.

Continuous: The primary air barrier in the walls is provided by the dense tongue and grooved woodfibre boards whilst in the roof the Pro Clima Active membrane has variable water vapour diffusion, is reinforced for extra strength and has a minimum 50% recycled content.

Accessible: The air barrier is easily inspected

Robust: These products are protected by cladding or render and will last the lifetime of the building without degrading

Explicit: All site operatives were briefed on the importance of air tightness with a brief introduction to the subject. Punctures to the building envelope were minimised and were carefully sealed

It is intended to conduct the first air tightness tests shortly.

Complexity—Raked walls

When the OSB cassettes were adapted to the plane of the raking wall, Ecos was left with a complicated intersection where the raking wall meets the plinth wall and additionally where the raking wall meets the side walls. The detailing of these junctions was resolved on-site which, although Ecos has the benefit of a committed team who are air tightness aware, is not ideal.

Windows/doors - The original intention was to have the windows in the same plane as the wall but having consulted numerous window manufacturers it was clear that, using standard window designs, their was an unacceptable risk of water ponding and reducing the life of the joinery. Additionally, the U-value of a window is calculated vertically so the on-paper performance of the building would be misleading if they were tilted. The necessity of window linings to insert vertical windows into a raking wall also posed additional design challenges with regard to the continuity of insulation. These were all overcome but, as before, at a considerable time and financial cost. From an air tightness point of view, by adding a window lining you are introducing an additional interface and an additional gap that needs sealing.

Tolerances - Ecos were able to find an excellent local joinery firm who manufactured the window linings and were a great help in overcoming the major design challenges they posed. The tolerances between the linings and the windows were, as a result, very pleasing. The interface that has been the most vexing has been that between the joinery and the frame. The off site manufacture has had the benefit of being extremely quick in comparison with an on site stick build but the elements are still manufactured by people and are thus subject to the same human error and tolerance levels. As Ecos wanted to have a 'breathing' structure and avoid wrapping the building in plastic this has meant a very time consuming process of dealing with gaps between panels and elements. Ecos are now looking at systems that will improve this for the next development.

Secondary Sealing: Considerable effort consiting of a team of 2 over 3 weeks was spent in ensuring all gaps around the windows linings and frames were sealed and all junctions were checked and sealed

Measurement and Feedback

The benefits of measurement and testing is a key part of the GHA, with all developers signing up to testing and monitoring. It is intended to conduct a series of airtightness tests with the first one due when all the windows are in.

A whole house monitoring system will feedback on the efficacy of the design

Designing Airtight Dwellings – Guidelines

- Understand the subject area and train your design team to understand the airtightness implications of complex design and junctions simplify if possible
- If you can't draw it, you can't build it.
- Ensure the design and construction team, including sub contractor, understand the importance of good thermal design
- Help make energy visible by explaining to the teams about CO_2 emissions and homes

UrbanBuzz Project—Developing Low Carbon Housing: Lessons from The Field—LowCarb4Real

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LowCarb4Real; Design collection: GHA: Stawell, Thermal bridging

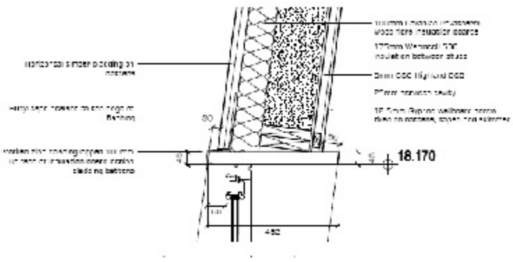
The Old Apple Store—Thermal Bridging

If the thermal bridge coefficient (which is an indicator of the extra heat losses of a thermal bridge) is lower than 0.01 W/mK, the detail is said to be "Thermal Bridge Free". If this criterion of avoiding thermal bridges is fullfilled throughout the thermal envelope, neither the designer nor the builder has to worry about cold and humid parts in the construction - and it will be far much simpler to calculate the heat energy balance. The design at Stawell was carefully worked up to limit thermal bridging to a minimum. The coeffieicnt here is expected to be under 0.03 W/mK

Geometric thermal bridges

The design of the 4 bed units led to complications as the rear walls slope out and the flat roof has a 15° slope. These angles meant that junctions between floors, walls and roof were significantly more complicated. It also meant that steels had to be used as opposed to the preferred glulam beams. The detailing of junctions was occasionally more complicated in reality than represented in the drawings and had to be carefully resolved on-site. This resulted in inevitable time and cost implications.

Where the wall was broken by a door or full height window at ground floor level Ecos also faced the challenge of ensuring the floor insulation accurately followed the buildings footprint to avoid cold spots.



Repeating thermal bridges

The fabric design at Stawell with glulam frame, fully filled insulated casettes insulated externally with 100m tounge and grooved woodfibre boards, reduces repeating thermal bridging to a minimum. Junctions with the steels were carefully detailed and extra insulation added to ensure thermal breaks.

Non-repeating thermal bridges

Balconies

Rear balcony structure to Units 4 and 5 were constructed as part of the frame and supported off the ground with Glulam posts, attached to the stud, with fixings penetrating the minimum amount of the buildings insulation envelope and encased in insulation to restrict thermal bridging to a minimum

Rules to assist in the avoidance of thermal bridging

- Understand your subject
- Consider a build system or MMC with no cavity or wall ties
- Train design and construction staff.
- Create a checklist for the development that defines the most likely points and stage in the construction process for loss of thermal performance
- Ensure that contractors take ownership and responsibility for thermal design on site.

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Appendix 4

Data Output from the LowCarb4Real Workshops

Index Cards Database

The Index Card Database has 771 individual entries, comprising of all the comments and ideas written onto index cards during the '*Needs*' brainstorming sessions performed in the workshops. The database has since been extended to include key imperatives, poster comments and main points from the Strategic Forum breakout groups.

In the database the index cards have been classified into 8 primary Change Categories with up to 3 further degrees of sub-categorisation, the first 2 of which are listed below:

Change Categories with 1° and 2° sub-categories

<table>
<tr><th>Change Category</th><th>1° Sub-Category</th><th>2° Sub-Category</th><th>No. of Cards</th></tr>
<tr><td rowspan="27">Knowledge, Skills, Training & Education</td><td rowspan="5">Improving Basic Understanding</td><td>Cross-profession understanding</td><td>15</td></tr>
<tr><td>Performance data, prototypes (conflicts, limitations, buildability)</td><td>9</td></tr>
<tr><td>Understanding of performance targets, standards, definitions</td><td>7</td></tr>
<tr><td>Feedback knowledge into training (building knowledge base)</td><td>13</td></tr>
<tr><td>Client/End-user knowledge</td><td>10</td></tr>
<tr><td rowspan="10">Improving Skills</td><td>CPD (updating/new technologies)</td><td>11</td></tr>
<tr><td>General training (quality, frequency, etc)</td><td>3</td></tr>
<tr><td>Training/Understanding of thermal principles</td><td>17</td></tr>
<tr><td>Training/Understanding of airtightness</td><td>6</td></tr>
<tr><td>General training (Constructor specific)</td><td>19</td></tr>
<tr><td>General training (Designer specific)</td><td>10</td></tr>
<tr><td>Design Brief/Project specific knowledge</td><td>3</td></tr>
<tr><td>Low Carbon training for site staff</td><td>5</td></tr>
<tr><td>Training in specific construction issues (detailing)</td><td>4</td></tr>
<tr><td>Training in the Process</td><td>5</td></tr>
<tr><td rowspan="5">Research & Technology</td><td>University training in low carbon issues</td><td>3</td></tr>
<tr><td>Low Carbon design training</td><td>12</td></tr>
<tr><td>Training in Innovation/Creativity</td><td>2</td></tr>
<tr><td>Research & Development</td><td>2</td></tr>
<tr><td>Knowledge for future-proofing</td><td>2</td></tr>
<tr><td rowspan="3">Legislation & Certification</td><td>SAP/CSH/Energy training for designers</td><td>1</td></tr>
<tr><td>Training for Planners & Legislators</td><td>2</td></tr>
<tr><td>Training certification</td><td>1</td></tr>
<tr><td rowspan="4">Drivers for Learning</td><td>Cost/Resources for training</td><td>3</td></tr>
<tr><td>Motivation/Incentives for training</td><td>1</td></tr>
<tr><td>General: Training & Education</td><td>7</td></tr>
<tr><td>General: Knowledge & skills</td><td>4</td></tr>
<tr><td rowspan="10">Process</td><td rowspan="7">Integrating Processes</td><td>Sequencing</td><td>8</td></tr>
<tr><td>Buildability/Sequencing</td><td>24</td></tr>
<tr><td>Inclusion into design process</td><td>20</td></tr>
<tr><td>Inclusion into construction process</td><td>7</td></tr>
<tr><td>Modification Process</td><td>5</td></tr>
<tr><td>Improving (up-front) design & specification process</td><td>13</td></tr>
<tr><td>Integrated design</td><td>5</td></tr>
<tr><td rowspan="3">Legislation & Regulation</td><td>Enforcers/Building Control</td><td>12</td></tr>
<tr><td>Legislation & Planning Issues</td><td>14</td></tr>
<tr><td>Incentives (Rewards & consequences)</td><td>10</td></tr>
</table>

	Testing & Feedback	Quality	10
		Testing	13
		Monitoring & Feedback	32
	Process Management	Procurement	4
		Cost/Value Engineering	4
		Process Management	14
Culture	Legislation & Regulation	Stability/Level playing field	4
		Realistic targetting	2
		Incentives & Consequences	6
		Planning	6
		Role of Regulation & Policymakers	15
	Economic Issues	Extra Costs of L.C.H.	8
		Stable economy/housing market	4
		Public Demand	15
	Changing Attitudes	Simplicity	16
		No blame culture	6
		Desire for better performance	11
		Value of Constructors	6
		Innovation & attitude to change	13
		Work Ethic	1
	Partnership	Ownership	6
		Partnerships & Team Ethic	19
Tools/Methods	Legislation & Regulation	Simple/Clear legislation	8
		Technical Guidance & Support	19
		Regulatory Reform	6
		Incentives to exceed minimum requirements	1
	Modelling Tools	Pre-Construction Tools (Modelling, Datasets, Learning Tools)	19
	Knowledge Sharing	Knowledge Sharing	6
		Working Examples	14
		More Information on Low Carbon Technologies	5
	Measurement Tools	Post-Construction Tools (methods of testing/measurement)	4
		Accurate costing tools	2
		Construction tools (site-based)	1
Communication	Quality of Information	Genral Communication	5
		Clarity of Design Information & Detailing	13
	Information Exchange	Communication with Site staff	7
		Communication with end-user	2
		Communication with regulatory authorities	3
		Communication between Designers & Constructors	6
		Communication between Designers & Specialists	3
		Knowledge Sharing	5
		Engagement of all throughout process	3
	Communication Breakdown	Conflict resolution	2
Supply Chain	Knowledge Sharing	Improved product information	8
		In-use performance data (not just theoretical/lab-based)	5
		Supply chain training to end user	3
	Information Exchange	Supply chain interaction	1
		Communication with Designers & Constructors	6
		Technical Support	2
		Influence on Government policy	3
	Product Performance	Better performing products	5
		New products/systems	7
		Easier to install/use products	4

		Locally sourced products	1
		Innovative Supply Chain	2
	Cost & Service	Lower prices	2
		Improved lead times and availability	5
		Lower cost of sustainable materials	2
Resources	Time & Money	Time/Money for Design - pre-construction	10
		Extended/Flexible Timescales	17
		Budgets: realistic/clear/flexible	4
		Time/Money for Design - modifications	4
		Assistance with extra costs of LCH	6
	Human Resources	Staff stability & quality	4
	New Technologies	Incentives	6
		Access to new technologies	3
Design/Technology Solutions	MMC	More MMC / Off-Site solutions	1
		Less MMC / Off-Site solutions	1
	Performance of Technology	Flexibilty & Adaptability of technical Solutions	1
		Robust construction technologies/products	7
		Multi-regulation compliance technologies/products	2
	Technology Specific Solutions	Smart controls	1
		Party Wall Insulation	1
		Window Seals	1
		Service Penetrations	2

Each individual index card entry has been assigned up to 4 keywords from the list below.

List of Keywords in Index Card Database, and number of occurrences

Keyword	No.	Keyword	No.	Keyword	No.
Accreditation	6	Evidence	37	Prototype	7
Accuracy	8	Example	16	Public Opinion	11
Adaptability	7	Existing Stock	2	Quality	28
Aesthetics	5	Experience	14	Realistic	9
Airtight	17	Faults	5	Receptive	4
Aspiration	10	Feedback	41	Regulation	31
Attitude	14	Finance	17	Relationship	7
Authority	6	Flexibility	8	Renewables	4
Barriers	5	Funding	5	Research	6
Behaviour	3	Government	14	Respect	2
Budget	10	Guidance	35	Responsibility	15
Buildability	29	Implication	5	Re-think	7
Building Control	2	Incentive	18	Robust	10
Capability	5	Inclusion	14	SAP	9
Change	18	Information	29	Science	8
Clarity	22	Innovation	15	Sequencing	8
Client	25	Input	14	Sharing	22
CO_2	6	Inspection	3	Simplicity	36
Code for Sustainable Homes	12	Integration	16	Skills	19
Communication	46	Investment	4	Solution	31
Complexity	11	IT	5	Specialisation	3
Compliance	9	Knowledge	43	Speed	2
Component	4	Learning	8	Stability	6
Compromise	3	Legislation	13	Standardisation	12
Confidence	6	Limitations	3	Standards	13
Conflict	5	Low-Carbon	57	Strategy	7
Consequences	7	Management	14	Sub-contractor	6
Consistency	10	Materials	17	Supervision	6
Construction	16	Measurement	9	Supply Chain	33
Constructor	15	Model	12	Sustainable	12
Contractor	14	Modern Methods of Construction	8	System	23
Co-ordination	7	Modifications	7	Target	17
Cost	27	Monitoring	14	Team	19
Culture	6	Motivation	4	Technology	28
Customer	8	Multi-skilled	4	Testing	29
Definition	7	Objective	2	Thermal	27
Design	95	On-site	27	Time	38
Details	46	Openness	2	Tools	17

Drawings	8	Operative	14	Training	48
Early	14	Ownership	17	Understanding	72
Economy	3	Partnership	7	Up-front	4
Education	39	Performance	55	User-friendly	2
Effective	2	Planning	20	Value	14
Efficiency	11	Prediction	4	Value-Engineering	5
End-User	19	Priority	5	Warranty	3
Energy	18	Process	36	Workforce	14
Enforcement	5	Procurement	17	Workmanship	3
Evaluation	4	Programme	3		

The top 5 main points emerging from each '*Needs*' breakout session to be presented to the workshop plenary sessions are tabled below, categorised into a list of 13 Key Imperatives for change.

Key Imperatives groupings

Key Imperative	**Comment**	**Workshop**
Cultural Changes	Customer attitudes & feedback to design (different groups & levels). Low carbon housing demand - only buy A++ rated.	11-Sep
	Change in culture across the board. From Design to Build to Users. This needs education, education, education	11-Sep
Process Changes	Ensure buildability of designs 1. Longer lead in times for design 2. Proper design period built-in 3. Feedback of how details work on site 4. Designers involved in the construction process & methods 5. Contracts that allow for feedback & checking 6. Better interaction between supply chain & contractors/designers	11-Sep
	A well structured innovation process for new solutions - Testing, data & feedback - Prototyping - Continuous improvement	16-Sep
	Design and delivery process improvements fully "engineered" as a manufacturing process	24-Jul
Education/Training	Training & skills: developer/designer/builder/occupier/client/BCO's	16-Sep
	Training & Education: - Life-long learning - Integration of training (levels & groups) - Design & construction as a learning process - Churn & methods of training - Rationalisation of training	11-Sep
	Education & Training: Tailored to suit	11-Sep
	Education & Training: Throughout - from supply chain to end-user	16-Sep
	Knowledge + education	11-Sep
	Training + skills	11-Sep
Sharing/Partnerships	Knowledge Sharing: - Models - Details - Performance - Training - Supply Chains - Across Industry - Project Review	24-Jul
	Share experience with no shame - Both good & bad performance - Serious barriers to doing this	24-Jul
	Partnership Teams: - Common goals - Sharing resources - Understandings	11-Sep
	Learning from other manufacturing industries - trendy, overstated, level of tokenism. Do not need to re-invent the wheel	24-Jul
	Training & Skills etc. - Ownership - Cross-disciplinary understandings - Information Exchange	16-Sep
Timescales/Resources	Skills/Knowledge/Training - Need time to train & learn & feed back - 2010/2013/2016 doesn't help	24-Jul

	Design: - Aligning planning - More up-front design - More time up-front	16-Sep
	Resources (Application of resources) - way of looking at: - Time - Money/Capital - Knowledge - Tools	11-Sep
Relationships/Interaction/Communication	Cultures: - Relationships - Master/servants - "The way things are done"	16-Sep
	Communication between ALL stakeholders	11-Sep
	More flexibility from Building Control	11-Sep
	Communication up & down supply chain through to contractors/designers - Industry forum - A trade body of trade bodies/CPA - There is a common purpose; who can facilitate HBF? or others? - BRE - Need to be what they used to be!	24-Jul
	Planning system & its relationship with design & construction. - Integration with ("relationship with") Building Control	16-Sep
Expectations	Understanding & realistic expectation of planning committees. Sufficient consultation or flexibility on planning.	24-Jul
	Push to create consumer market + expectations	11-Sep
	Agreed & realistic setting of achievable targets across the whole of the UK. - political issues?	24-Jul
Ownership	How do we manage all the changes that are coming? - Who is responsible for what? - Where are the conflicts/inconsistencies? - Timescales for learning & feedback on performance	11-Sep
	Need to take everyone along. - big developers & small housebuilders	24-Jul
	Continuity: Ownership & Responsibility	11-Sep
Understanding	Understanding comfort and other user requirements and the implications for carbon performance.	24-Jul
	Research & evidence: - Examples, places to see - Real data (independent)	16-Sep
	Feedback on performance Understanding building performance as a system	24-Jul
	Durability & research into real performance of prototypes	24-Jul
Guidance/Models	Need better regulatory tools & models - SAP needs to be a design tool - Better accredited details - Implications for training of assessors	11-Sep
	Guidelines (BRE ?)	11-Sep
Incentives/Motivation	Need to check & monitor performance at all stages - subcontract payment system does not incentivise quality or performance - Needs to feed back into design & construction process	11-Sep
	Wanting to do it - really !!	16-Sep
	Incentives	24-Jul
	Reward/Value	11-Sep
	Legislation: - Regulation - Policy - general environment - Incentives - tax/grants/etc - Economic climate	11-Sep
	Testing + monitoring (incentivised)	16-Sep
	Positive incentives: - long-term involvement - energy supply - not just targets - joined-up approach - understanding timescales	16-Sep
Consistency/Simplicity/Stability/Clarity	Simple, buildable, self-checking designs Simple legislation	24-Jul
	Simplicity: - Design - Regulation - Process	11-Sep
	Clearer guidance from Government - legislation & evidence	16-Sep

	Consistent regulatory environment + guidance	16-Sep
	Legislative stability with clear targets & no contradictions	24-Jul
	Keep it simple & solutions that work. (Why does an Eco-House have to be off the wall?)	24-Jul
Consequences	Consequences for under-performance Defirne and measure under-performance & must be fair	24-Jul
	Testing & Feedback: - What tests? - Impacts of testing - Feedback channels - Consequences of testing (under-performance)? - Blame or understanding?	16-Sep

At several of the workshops blank A1 posters were hung adjacent to the A1 project posters for workshop participants to write comments on. Little feedback was obtained via this method, the few poster comments received are tabled below.

Poster Comments

Poster Collection	**Poster**	**Comment**
Design Collection	Thermal Design Principles	It would be interesting to analyse design cost of a house - or housetype - against that for the car you drive - nett cost per house & per car. - There is masses of time spent in housing looking at half baked solutions.
Construction Collection	Air Barrier Construction	Operatives need to know why airtightness is important!
Construction Collection	Air Barrier Construction	It would be nice to see who thinks who is responsible for the design of the example details for junctions of the envelope :- Architect :- Main Contractor :- Sub Contractor :- etc…
Construction Collection	Air Barrier Construction	Design needs to incorporate services & details of junctions & possibly if left to contracts will be ad hoc. All services need to be thought about in detail at design stage.
Process Collection	Construction Planning	If every project has to have a CDM Co-ordinator why not insist on a CLERK OF WORKS?
Process Collection	Closing The Loop	Can designers be involved in quality control on site rather than lost in the obsession with "fixed price" and Design & Build contracting.

Forum – Main Points

Flipchart Material