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UNIVERSITY
Leeds Sustainability Institute

ARCOM: Low Carbon and Sustainability Research Workshop

Thursday 1st December 2011

The first in the series of the Low Carbon Workshop was a great success. With over fifty people attending the ARCOM event and a dozen inspiring presentations, the green knowledge within the room took a huge step forward.

As expected with any ARCOM meeting, the interaction during the breaks and friendly atmosphere proved to be a catalyst for expert discourse, matched in few other arenas, enabling academics and industry experts to form meaningful relationships.

The event was Hosted by Leeds Metropolitan University and led by Professor Chris Gorse as part of a day's events showcasing expertise and networks established through the Leeds Sustainability Institute.

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Presentation Schedule

Name	Institution/ Organisation	Presentations and Material Presented
Chris Gorse	Leeds Metropolitan University	*Introduction; questions and closing remarks* *Building Confidence: Low Carbon Futures* *The Retrofit Challenge: Low Carbon Futures*
Malcolm Bell	Leeds Metropolitan University	*Mind the gap; Low carbon housing and reality*
Akinlabi Adeyemi	University of Manchester	*Occupant use of windows in controlling personal ventilation to provide adequate indoor environmental conditions*
Markus Bleier with John Heathcote	Biodegma GmBH	*Sustainable approaches: partnering in the supply chain*
John Bradley	Leeds Metropolitan University	*Issues in Domestic Sector Decarbonisation*
Holly Castleton	University of Sheffield	*Predicted and actual energy use in low carbon buildings – are realistic predictions possible?*
Danielle Densley Tingley	University of Sheffield	*Making the case for design deconstruction*
Ginny Ginny	Leeds Metropolitan University	*Mehrauli: Integration of water systems to meet the growing water demand*
Simon Hatherley	Cardiff Metropolitan University	*An introduction and review of the challenges facing a Registered Social Landlord and their stakeholders in relation to the design and construction of an exemplar low carbon, ecological development in a rural area of Wales*
Greg Keeffe Professor	Leeds Metropolitan University	*Sustainability: the big picture matters*
Dominic Miles Shenton	Leeds Metropolitan University	*Monitoring existing buildings – building fabric performance*
Jennifer Muston	Isover	*Exploring the potential of BIM; perceptions and possibilities*
Anne Schiffer	Leeds Metropolitan University	*Creating sustainable energy systems in rural Gambia through transformation design*

Melanie Smith	Leeds Metropolitan University	*Thermal testing of existing properties*
Anne Stafford	Leeds Metropolitan University	*Heat Pumps – A Low Carbon Technology?*
Ruth Sutton	Leeds Metropolitan University	*In use monitoring – smart information and relationship with building fabric and service performance*

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Workshop Attendees

Name	Institution/ Organisation
Akinlabi Adeyemi	University of Manchester
Andy Aldridge Managing Director	3A
Mark Allen Technical Development Manager	Saint-Gobain Isover
Greg Barnes	Leeds Metropolitan University
Malcolm Bell	Leeds Metropolitan University
Carole Birtwhistle	Leeds Metropolitan University
Markus Bleier with John Heathcote	Biodegma GmBH
Ismail Boussashia	Leeds Metropolitan University
John Bradley	Leeds Metropolitan University
Paul Breaks	University of Central Lancashire/ BAE Systems
Adorkor Bruce-Konuah	University of Sheffield
Holly Castleton	University of Sheffield
Leigh Champagnie	
Danielle Densley Tingley	University of Sheffield
Ian Dickinson	Leeds Metropolitan University
Geoff Edgell Director	Ceram
David Farmer	Leeds Metropolitan University
Ginny Ginny	Leeds Metropolitan University
Chris Gorse	Leeds Metropolitan University
John Grant	Sheffield Hallam University
Simon Hatherley	Cardiff Metropolitan University

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John Heathcote with Markus Bleier	Leeds Metropolitan University
Richard Jack	Loughborough University
Hannah James	University of Leeds
Phil Jones	Leeds Metropolitan University
Greg Keeffe Professor	Leeds Metropolitan University
Professor Dennis Loveday	Loughborough University
Ericcson Mapfumo	Leeds Metropolitan University
Robert Mark	ICC
Dominic Miles Shenton	Leeds Metropolitan University
Jennifer Muston	Saint-Gobain Isover
Alan Newall	Leeds Metropolitan University
Masoudeh Nooraei	Oxford Brookes University
Parichay Parivesh	K G Creation
Anne Schiffer	Leeds Metropolitan University
Jianchao Schen	Leeds Metropolitan University
Melanie Smith	Leeds Metropolitan University
Anne Stafford	Leeds Metropolitan University
John Sturges	Leeds Metropolitan University
Ruth Sutton	Leeds Metropolitan University
David Woolley	Leeds Metropolitan University

CeBE Centre for the Built Environment

leeds metropolitan university

Professor Chris Gorse

The ARCOM Low Carbon and Sustainability Research Workshop and Road Show

ARCOM
Association of Researchers in Construction Management

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- No Fire drill – so if Alarm exits safely
- Toilets
- Relaxed informal session – spirit of ARCOM
- Experienced and new researchers
- All here to learn

- Timekeeping
- Questions
- Open up an offer to presenters to submit papers, which will be taken forward into an ARCOM LSI publication

Low Carbon and Sustainability Roadshow

- Leeds Metropolitan University
- University of Reading
- University of West of England
- University of Plymouth
- Sheffield Hallam University
- The Chartered Institute of Building

- Dec 2011
- March 2012
- June 2012
- June 2012
- July 2012
- September 2012

Centre for the Built Environment

leeds metropolitan university

Professor Chris Gorse

Leeds Sustainability Institute

The Green Agenda

New Build and Retrofit

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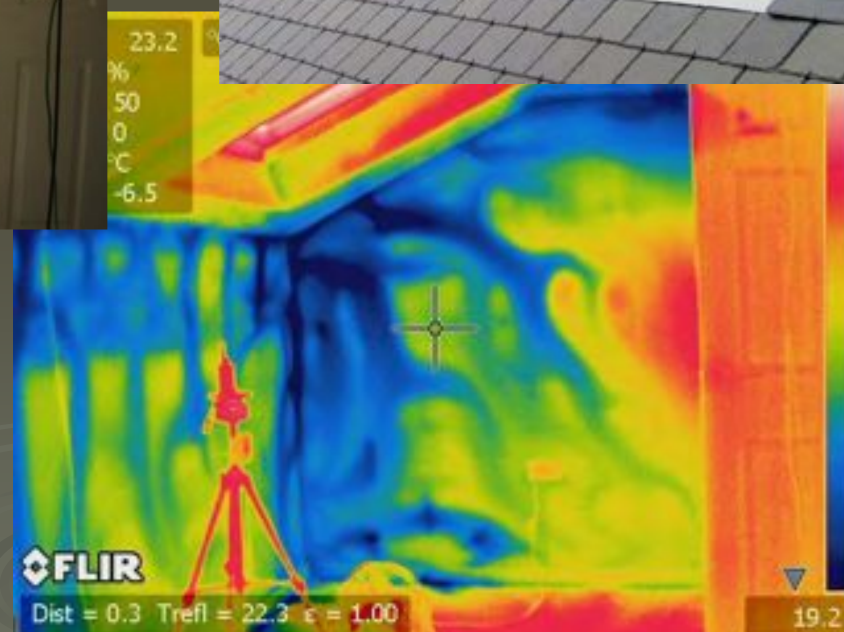
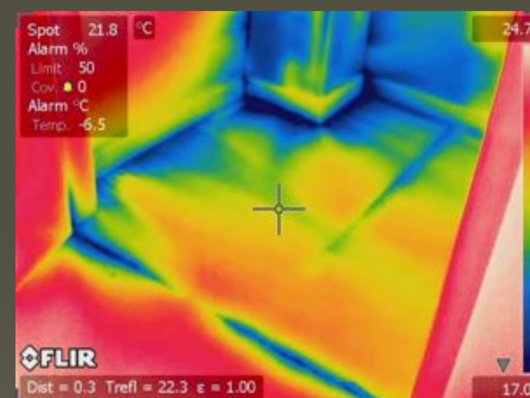
Why it is important that academic and business pull together to advance research, develop knowledge, for commercial opportunity, advantage and to reduce risk?

Why are these images so important?



How does the fabric behave?



How much is it going to cost over the life of the building?
What are the risks?

Energy Act 2011

Green Deal

Financial Framework for fixed improvements to the energy efficiency of households and non domestic buildings.

Private rented sector – landlords will be unable to refuse a tenants reasonable request for energy efficient improvements where a financial package or Energy Company Obligation is available

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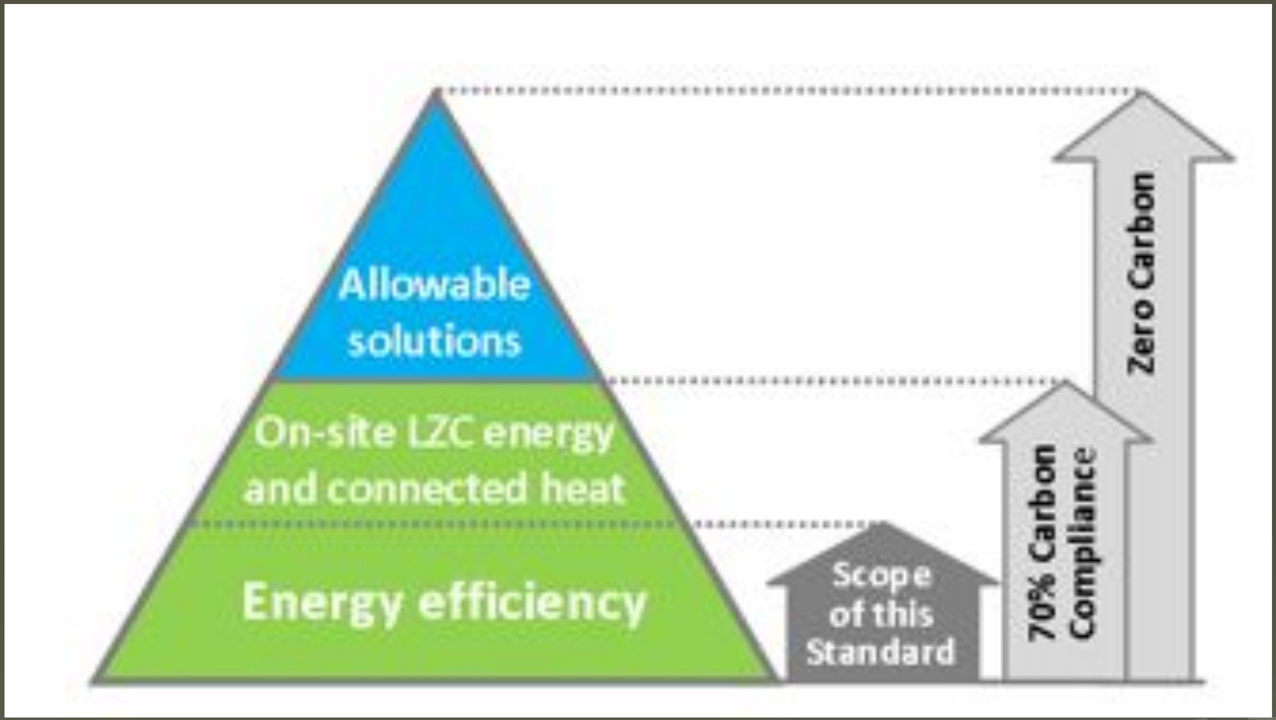
2016 ZERO CARBON



70% reductions to the building fabric

Figure 1 Zero carbon hierarchy (Zero Carbon Hub , 2009)

Gorse’s Deal -

- Improved payback deal for clients that work with contractors and suppliers who don’t understand their product, process and performance.

- The Greed Deal – Claims conscious.
- Fair Deal – What the client paid for.

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Where energy improvements don't perform the risks are high:

- Energy prices
- New Build – slow stock turnover – 50 years
- Refurb – built to last – life times of 25 years

- Risk: Payback when its wrong:
  - No ability to change – compensation for work and additional energy costs incurred
  - Change – compensation for alteration, time and expenses and energy cost incurred

- We have an excellent construction law department at Leeds Metropolitan University

Managing the risk and collecting benefits

- Invest, better understanding:
  - products
  - processes
  - competition

Who should invest, the best performing companies or the worst?

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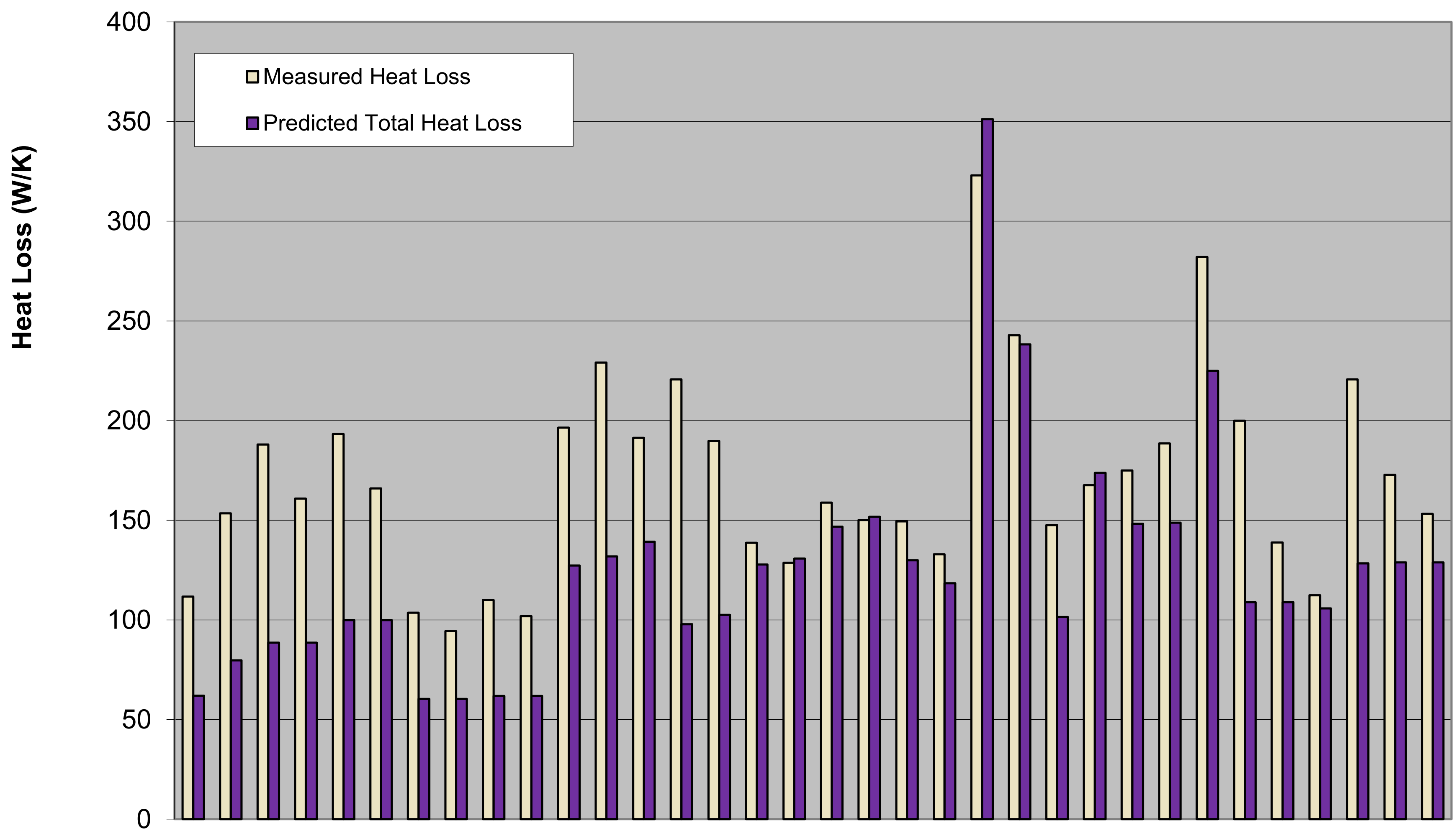
Whole House Heat Loss - Measured Coheating versus Predicted



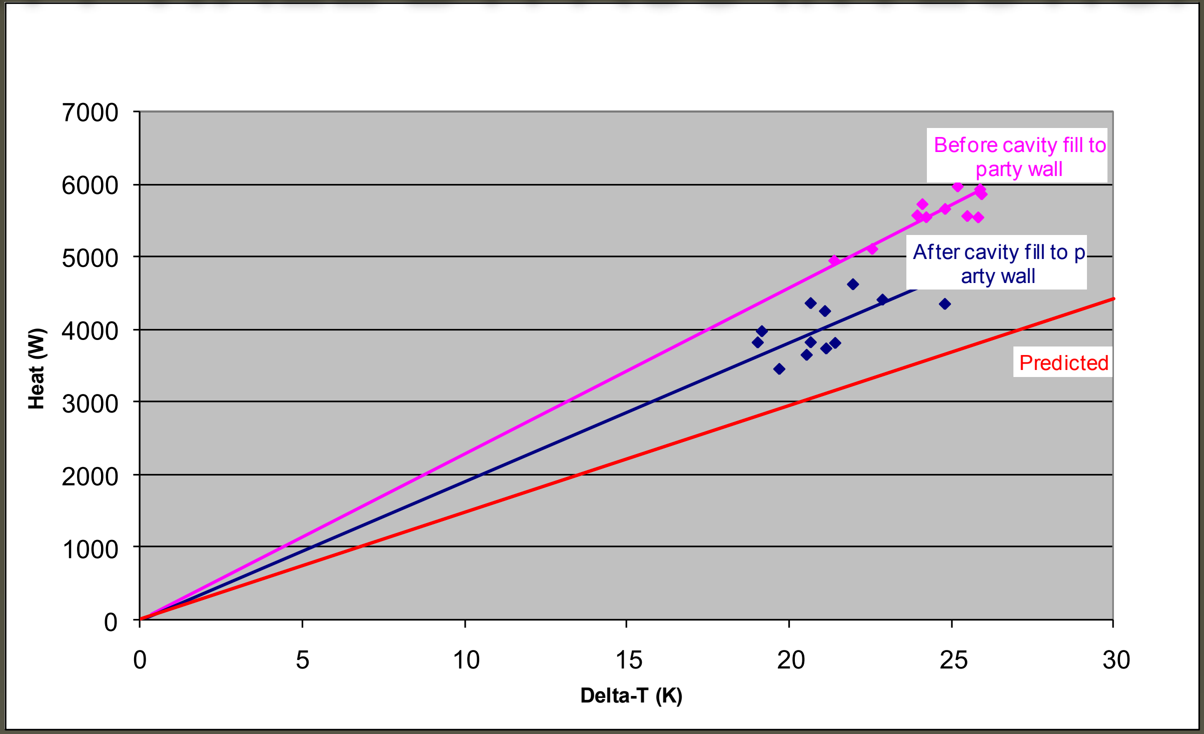
Party Wall Bypass – Professor Malcolm Bell

A better understanding of a building leads to impact and improvement

CeBE Centre for the Built Environment

leeds metropolitan university

PARTY WALL BYPASS INVESTIGATIONS



Heat Loss Before Fill (W/K)	Heat Loss After Fill (W/K)	Heat Loss Improvement (W/K)
y = 229	y =19	38 (-16%)

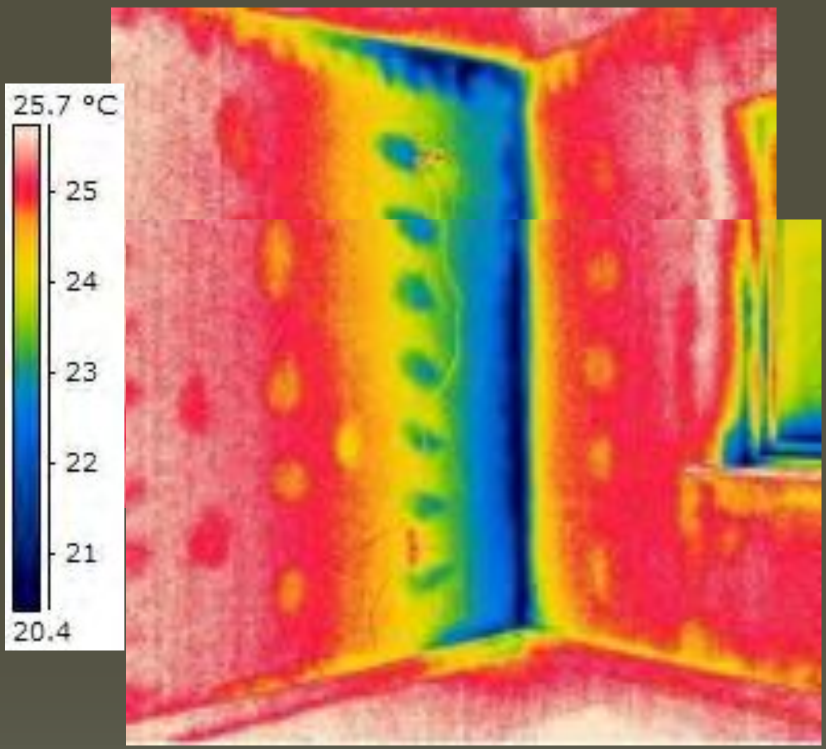
Most significant improvement of this century

Estimated UK CO_2 savings if party wall bypass eliminated

From New Housing built in One Year (~190,000 units)	18,000 tCO_2/a
From Existing Stock (built since 1965)	~750,000 tCO_2/a

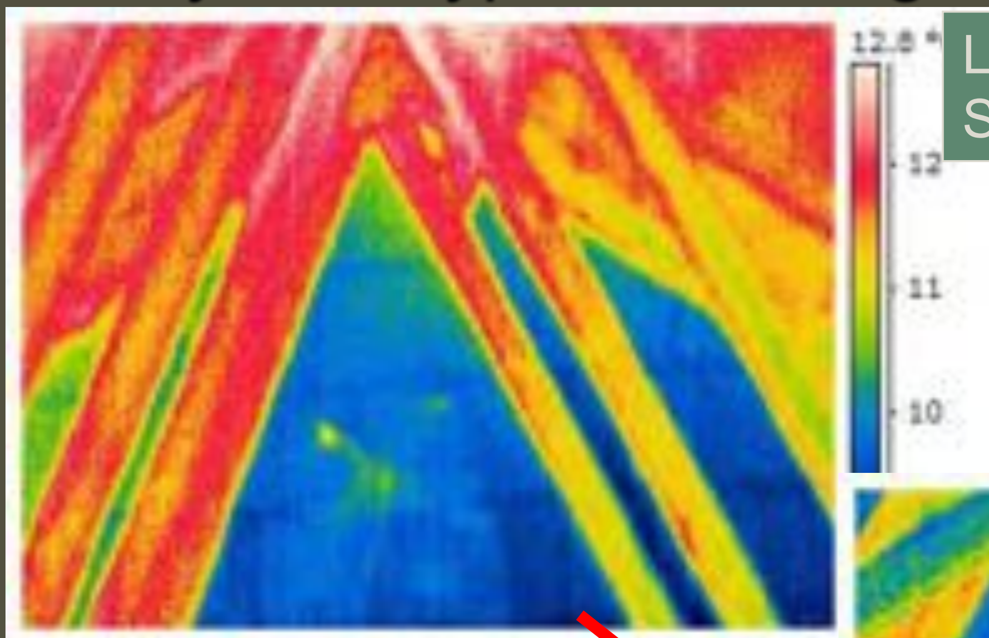
Assumes Party Wall *U*=Value = 0.5 W/m^2K
Assumes 10% semi-detached, 20% terrace in stock and new build
Calculations for semis and terraces only – no estimate for apartments

Party wall bypass investigations



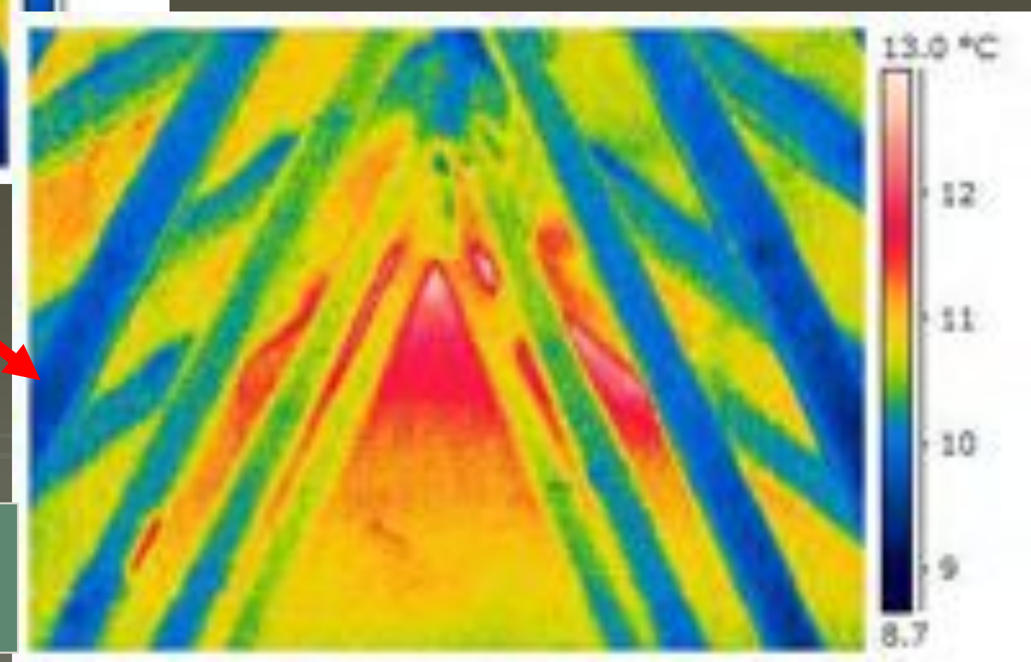
Second Floor – Party Wall to External Wall Junction – Sock Out

Party wall bypass investigations – Stamford Brook



Loft Party Wall
Sock in

Remove Sock



Loft Party Wall
Sock out

Hygrothermal analysis and forensic investigation

Surface Thermocouple

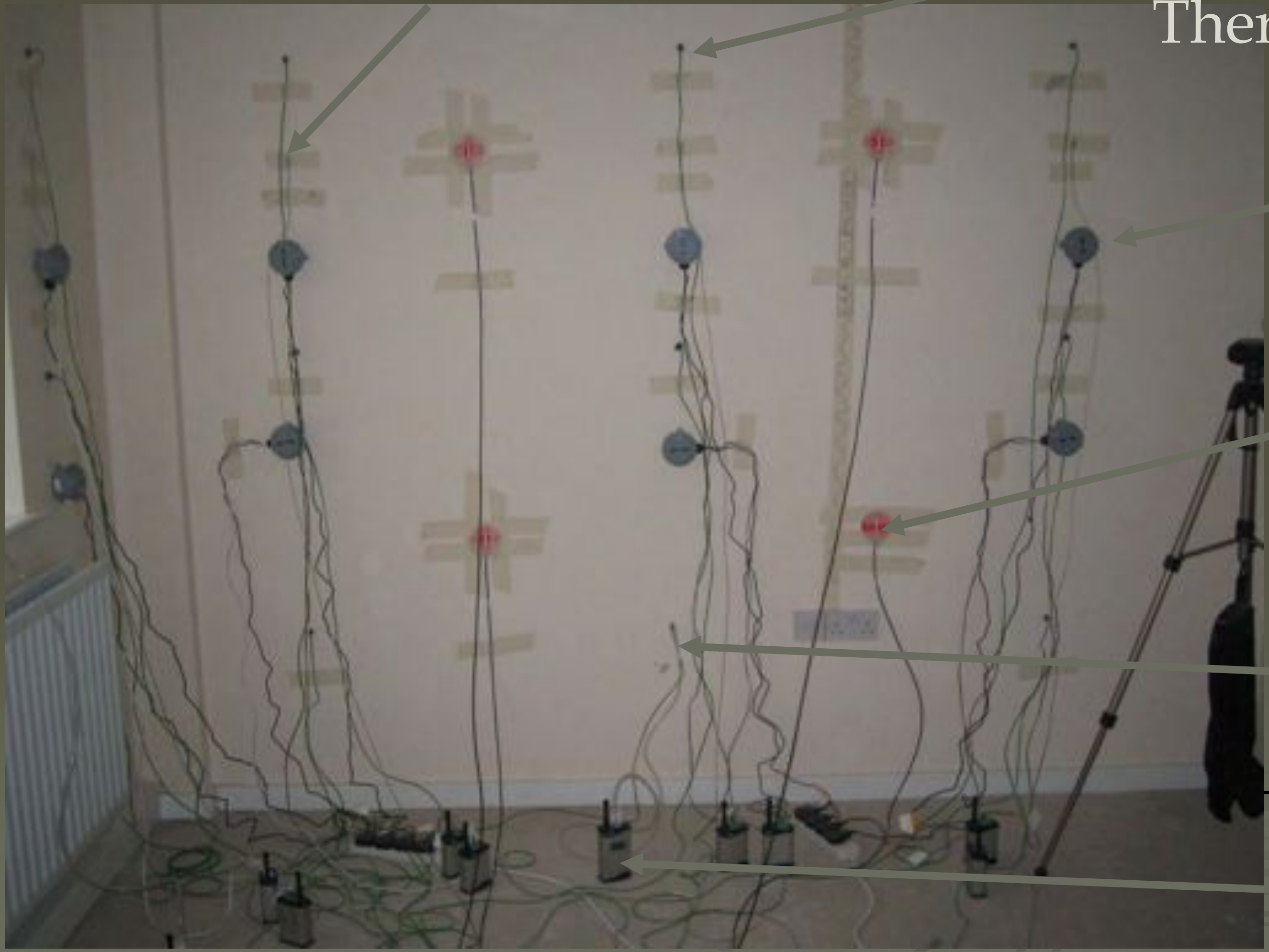
Cavity Thermocouple

Air Flow Transducer

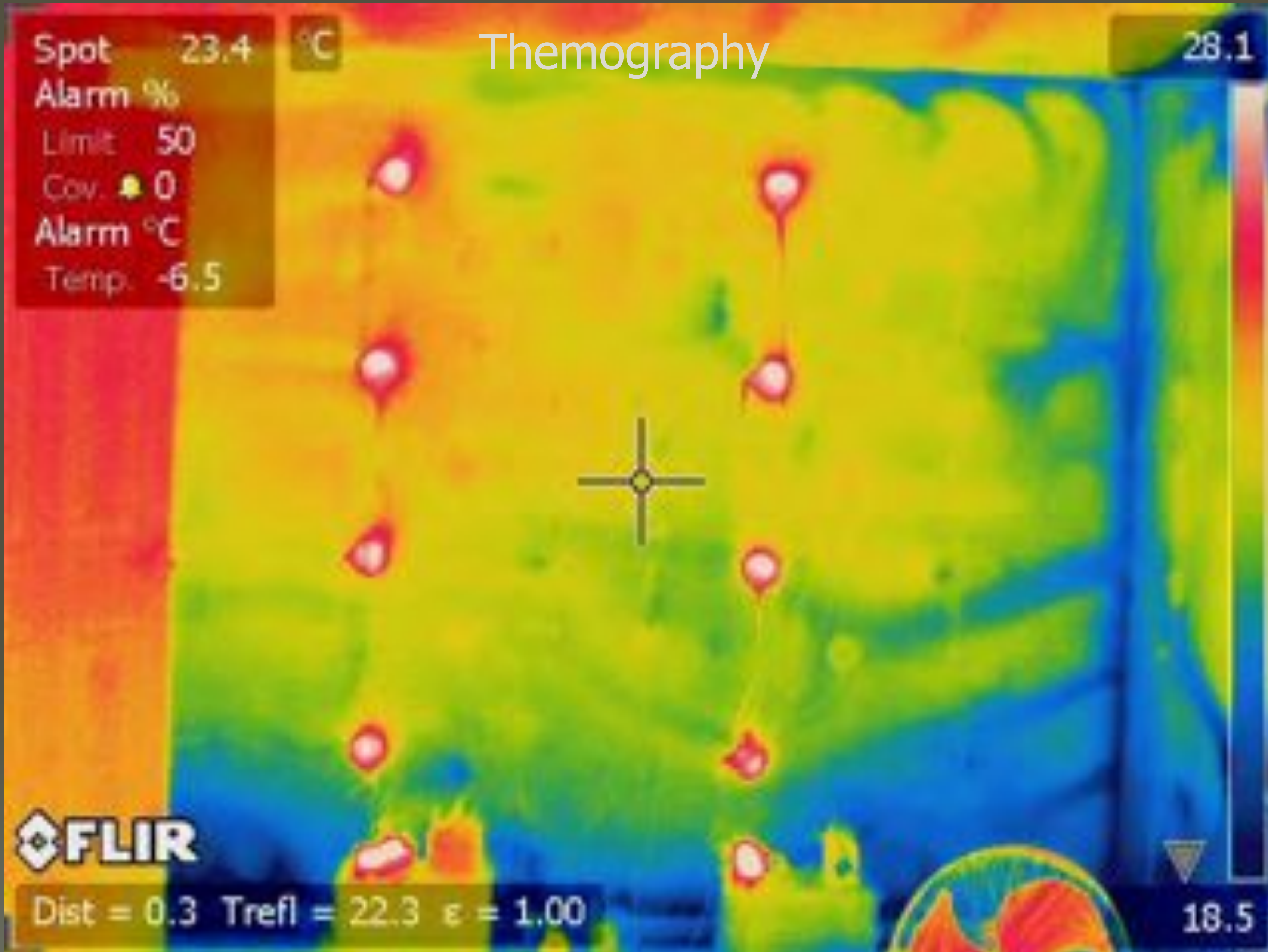
Heat Flux Plate

Differential Pressure

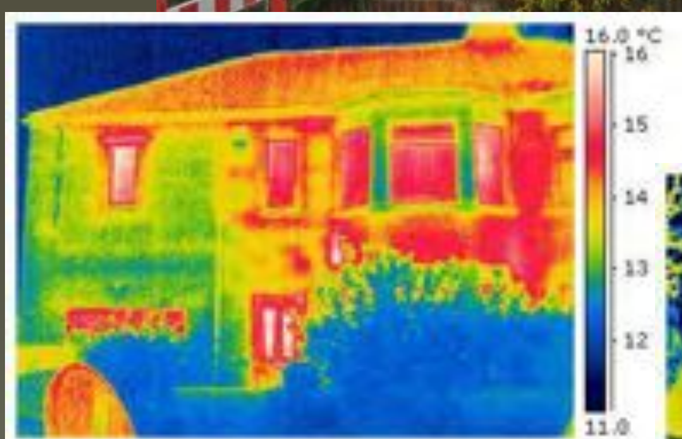
Transmitter



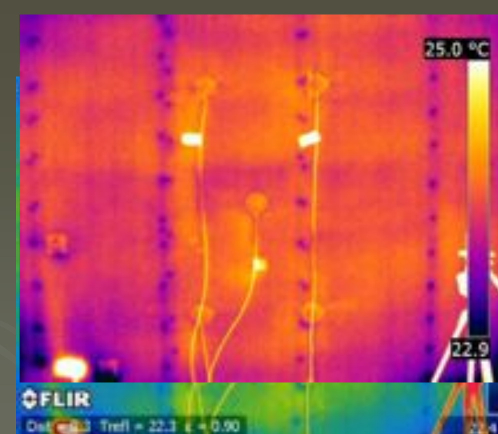
Themography



Existing dwellings



Understanding new materials



Professor Chris Gorse

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2050

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Building Confidence – A working paper

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The term 'performance gap' is often used to refer to the difference between the design thermal performance, and the measured thermal performance of buildings, treated as a whole system.

Reducing the performance gap is important to ensure we achieve real and significant energy savings from the built environment: critical if we are to reach the UK's 2050 target of an 80% reduction in carbon emissions.

The purpose of this paper is to offer an analysis of the accumulated Leeds Metropolitan University data around as-built thermal performance for new build and retrofitted homes. What are the key factors that determine the performance gap? The analysis enables stakeholders to consider targeted processes or standards which can improve performance, helping the industry to move towards minimising, and eventually eliminating, the performance gap.

CONTENTS

Report no: 008

Publication date: March 2012

INTRODUCTION FROM THE CENTRE FOR LOW CARBON FUTURES

In the recent Centre for Low Carbon Futures report 'The Retrofit Challenge', produced by Leeds Metropolitan University,we presented the research evidence for the gap between as-designed and as-built energy performance of retrofitted homes.

In this analysis, 'Building Confidence', we begin identifying the determinants of the performance gap for different house types, both newbuild and retrofitted. The aim is to begin a dialogue with the construction industry about taking action – about the processes or standards which can improve as-built energy performance in the most cost-effective ways.

Why does the performance gap matter? The drive towards zero carbon homes from 2016 in England means rapidly tightening building regulations and a growing interest from customers in low energy/low carbon homes. Customers who make the investment in a low carbon home need to know that it will achieve the warmth, comfort and low bills promised. Similarly, the Government have signalled their intention to require the industry to demonstrate the achievement of zero carbon standards in practice as well as in theory. These pressures will bring significant commercial risks for house builders, risks that will need to be mitigated through effective systems that assure real performance.

The Centre for Low Carbon Futures is committed to helping the house building industry provide certainty to clients around the real delivered energy standards of their homes. We want to work with the home building and retrofitting industry in two areas:

Firstly to establish the evidence base of real, measured energy performance of homes. This new research report is based on an analysis of 34 thermal performance tests of homes. We believe it's the best available dataset in the country, but there's clearly a lot more data that needs to be gathered. That's why the Centre for Low Carbon Futures is developing an Energy Systems Performance National Data Centre. This centre will provide a highly flexible repository to store and analyse the widest possible dataset of building energy performance data. We will be working with the construction industry to gather that data.

Secondly, in a continuing collaboration with Leeds Metropolitan University and with a small number of construction industry partners, we will identify and work on the process improvements that can start to close the performance gap, building on the analysis in this report.

Our successful transition to a low carbon economy by 2050 rests on a rapid decarbonisation of our built environment. We have to get it right, first time.

1.INTRODUCTION

The term 'performance gap' is often used to refer to the difference between the design thermal performance and the measured thermal performance of a dwelling treated as a whole system.

Many years of experience in co-heating testing and associated forensic analysis at Leeds Metropolitan University indicates the possibility that the incidence of such performance gaps may be widespread, and in many cases worryingly substantial. Although the number of full investigations undertaken to date is limited (due to the comprehensive nature of the testing involved), the majority of tests demonstrate a performance shortfall.

This is not unexpected, since many other studies have identified significant underperformance of building elements in situ. A review of evidence relating to the performance gap is given in Bell et. al., 2010, and a summary of that review is provided in Appendix A. The underperformance of building elements must be considered together with the fact that build processes are also necessarily imperfect. As a result, performance gaps are almost inevitable, especially in the absence of a design process which uses tolerances to take account of shortfalls [Bell et. al., 2010].

The purpose of this paper is to offer an analysis of the accumulated Leeds Metropolitan data, (which deals specifically with whole-house heat loss), in a form which may enable stakeholders to consider processes or standards which could be used in improving developer confidence and performance, helping the industry to move towards minimising, and eventually eliminating, the performance gap.

This fits in well with many of the aims identified in the Zero Carbon Hub (2010) report and forms an initial attempt to address their assertion that "it will be of particular importance that the commercial risks of underperformance are sufficiently salient as to reward those designers and developers who invest in improvements and penalise those who do not." Furthermore the recent DCLG consultation proposals for amendments to Part L of the Building Regulations [DCLG, 2012a] suggest a requirement for some form of Quality Assurance process relating specifically to thermal performance, which will perform exactly this function.

The Zero Carbon Hub (2010) report stresses that a distribution of carbon performance is naturally to be expected, leading to a necessity for an enhanced regulatory system that is sensitive to performance variability and is able to accommodate different approaches to achieving the required as-built standards. In an ideal world all housing producers would rapidly improve their development and control processes to the point where their performance distribution was known to them, was as tight as possible and satisfied the appropriate regulatory requirements. It is recognised that not all developers will be able to undertake the necessary investment to achieve this, at least in the short term, so provision should be made for an alternative approach which incorporates a degree of 'overdesign' to compensate for a somewhat wider and less controlled distribution in as-built performance. However, provision for rewarding and encouraging investment in the more controlled and evidence-based approach is also appropriate, especially if the resultant learning can eventually be co-ordinated and disseminated to the benefit of the industry as a whole.

1.1 BACKGROUND ON CO-HEATING TESTING

The whole house heat loss is determined by means of a co-heating test, where essentially the energy required to maintain internal conditions at a constant elevated temperature is compared with the internal/external temperature difference. However, the technique of co-heating testing, (as performed by Leeds Metropolitan University Buildings and Sustainability group), encompasses much more than simply obtaining an experimental figure for the heat loss coefficient.

In fact the main value and purpose of the co-heating test lies in 'closing the loop', which involves identifying and measuring or estimating the contribution of different factors to the performance gap, and thus explaining the reasons for the performance gap's existence and magnitude in any given case. In order to achieve this, a range of additional techniques must be used, from construction observations and thermography to heat flux measurement of building elements. Construction observations may identify, for example, cases where product substitutions have been made, or specified procedures not followed. Heat flux measurements establish the in-situ performance of elements such as external walls, party walls, floors and windows.

The performance gap to be explained is simply the difference between the measured heat loss coefficient and the predicted value. In this context the predicted value is that which would be calculated according to standard heat loss calculations for dwelling fabric (U-values and thermal bridging ψ-values) as used in SAP assessment procedures. Ventilation losses are also taken into account, but this aspect of the predicted value is calculated from experimental results, either via air permeability measurements or via background ventilation rate from tracer gas measurements, so that any performance gap identified by this method would be due to fabric and thermal bridging losses only, and not to higher than expected direct ventilation losses[1].

1. Air permeability is measured using a fan and blower door according to the ATTMA technical standard (ATTMA, 2006), with the background ventilation rate calculated using the n/20 rule of thumb. Alternatively background ventilation rate may be measured directly using a tracer gas (normally CO2) which is delivered as a pulse in order to track its concentration decay. The measured value of the background ventilation rate is then used as part of the total heat loss prediction.

In order for the whole exercise to have maximum validity, researchers need to have confidence in both the prediction methodology and the testing and assessment methodology. Clearly neither methodology is perfect and both should be subject to a continuous process of refinement. For example increased understanding of the party wall bypass mechanism has recently led to changes in the regulations regarding the way this element is assessed. However, work is currently on-going to improve some aspects of our understanding of the effects of solar radiation on co-heating test results.

A summary of the methodology of co-heating testing is given by Wingfield et. al. (2010a). Using this, or an equivalent methodology, results may be regarded with reasonable confidence where a good spread of external temperatures leads to data-points (heat input vs temperature difference) being distributed along a well-defined straight line, once solar and wind conditions have been taken into account.

In total, 34 co-heating tests have been undertaken by Leeds Metropolitan University on a variety of dwelling types over the last six years. Some were multiple tests on one dwelling (e.g. before and after interventions). The majority (though not all) were on new-build developments where the research team were able to observe construction from an early stage and consult with site operatives as necessary. Although statistically 34 is only a very small number, it represents by far the most extensive dataset of its kind in existence in the UK. Furthermore, it is not only the range of tests but also the depth of engagement with each individual test that adds significantly to the richness of the Leeds Metropolitan dataset.

Although some of the results reported in this paper have been published, this does not apply to all. In order to avoid ethical and contractual issues all results are presented in anonymous form.

2. THE PERFORMANCE GAP: ANALYSIS OF LEEDS METROPOLITAN DATA

Of the 34 tests referred to in the last section, 30 showed a performance shortfall to some degree. Fig. 2.1 shows a simple distribution of the percentage performance gap for all the tests performed (i.e. the percentage difference between the predicted and measured whole house heat loss, including both fabric and ventilation losses). While this is a useful starting point, clearly it represents highly aggregated data which skims over a number of important issues and distinctions (discussed in detail in the following sections), and therefore caution should be exercised in drawing conclusions from this data alone.

The following paragraphs in this section give a brief overview of some of the issues which are considered in the further analysis of this data.

Fig. 2.1 shows the performance gap as a percentage difference between the measured and predicted heat loss coefficient (the total rate of heat loss per degree of temperature difference, in units of W/K). This heat loss coefficient (both measured and predicted) will be affected by parameters such as dwelling size and type, but the magnitude of the performance gap may also be affected to some extent by these parameters. For example, if the primary causes of performance gaps in a particular development are due to the external wall performance, then detached houses may show a greater gap than mid-terraces. Conversely if the primary problems are associated with party walls, then the opposite may be true. Of course, this simple picture is also complicated by the fact that the primary problem is not necessarily the same either between developments or even within a single development, and also that there is likely to be a complex mixture of significant factors (see section 3). The influence of dwelling type is discussed further in Section 2.1, and factors relating to dwelling size are considered in Section 2.2.

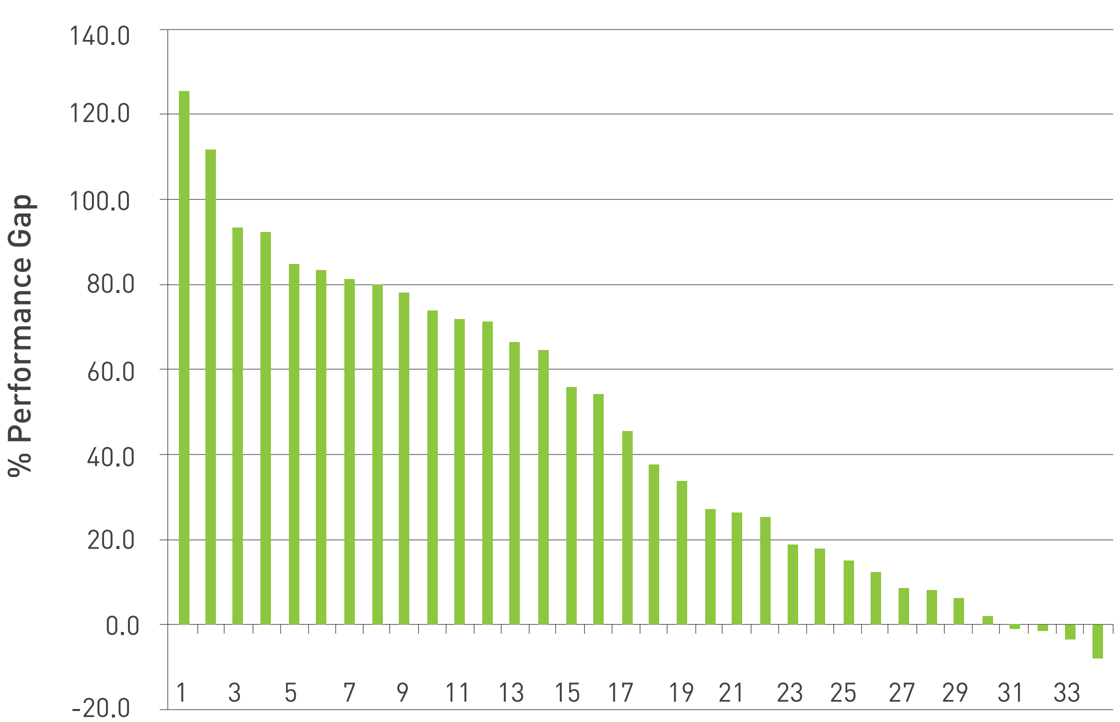

Fig 2.1: Raw Co-heating test data (tests in order of performance gap)

Of the four tests which show a negative discrepancy (measured performance apparently exceeds predicted performance), the two with the higher negative values are both tests which took place on existing dwellings. For this reason, less confidence could be placed in the predicted values used, as the precise details of products, construction methods and thermal bridging calculations were not known and had to be estimated according to rdSAP[2] procedures for older dwellings. Issues relating to retrofit are discussed in more detail in Section 2.3.

The other two negative discrepancy tests arise as a result of a physical intervention (full insulation of party walls), but the negative values are small, and given the uncertainties in the testing procedures may be regarded as zero, thus indicating that in these two cases, after the physical intervention, the dwellings were in fact effectively meeting the as-designed performance expectation.

It has been suggested that expressing the results as a percentage obscures the fact that for very low energy dwellings a substantial percentage gap may represent only a very small absolute additional energy consumption (over the design target), while for dwellings with a less stringent target, even a modest percentage gap may represent a large energy loss. This is discussed in more detail in Section 2.5. We note here, however, that an alternative method of presenting the data is in terms of the absolute measured and predicted heat loss for each test. Fig. 2.2 below shows the data presented in this form, in exactly the same order as in Fig. 2.1.

In Section 2.6 data is presented on the effects of remedial interventions, particularly those relating to amelioration of the party wall thermal bypass.

Finally, in Section 3, we demonstrate how in-depth knowledge of the different contributory causes of underperformance can be used to understand and characterise the performance gap in individual cases.

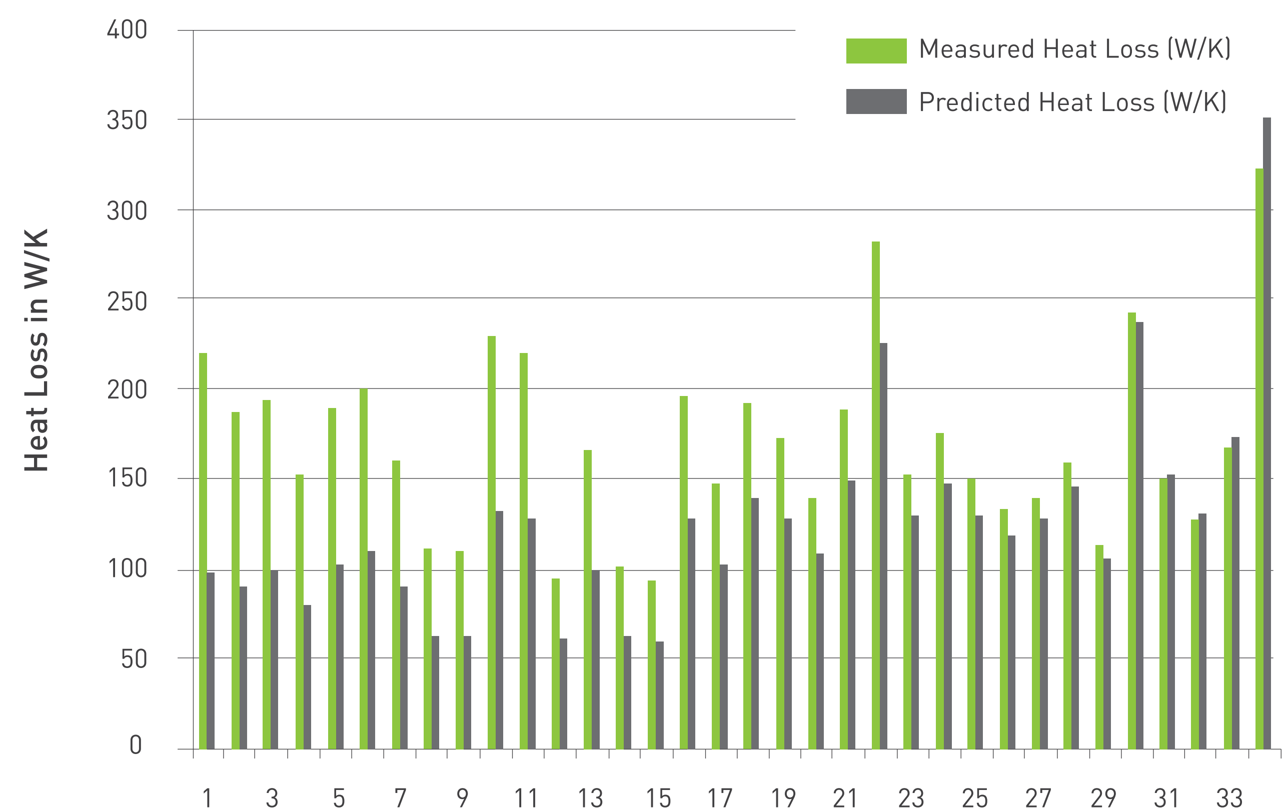

Fig 2.2: Data from Fig.2.1 shown as absolute values of measured and predicted heat loss

2. rdSAP is the version of the National Calculation Method used to calculate the energy performance of existing dwellings, where full data is not available and therefore standard estimates based on factors such as dwelling age are used.

2.1 INFLUENCE OF HOUSE TYPE

House types may be divided simply into detached, semi-detached or end-terrace (one party wall) and mid-terrace (two party walls).

In order to draw out any potential differences, Fig.2.1 has been repeated in Figs 2.3a, 2.3b and 2.3c, with those tests performed on the house type of interest shown in blue and/or grey

The majority of dwellings tested have fallen into the end-terrace/semi-detached category, with only five tests taking place on dwellings in each of the other categories. However, it is clearly noticeable that the mid-terraces are clustered at the higher end of the distribution, with the detached dwellings occupying lower or mid-range positions. This is almost certainly attributable largely to the party wall bypass effect, which was not recognised by regulations at the time the dwellings were constructed. Since mid-terrace houses have two party walls, the additional heat loss due to the bypass is greater in this type of dwelling.

However, now that the effect has been recognised, and Part L changed accordingly, the predicted heat loss in the future should match the experimental heat loss more closely, i.e. the measured performance gap should be somewhat less for these types of dwellings in any tests performed after adoption of the new Part L (whether due to reduced design expectations or to increased performance due to build modifications such as filling the party wall). It is worth noting that a recent test (not shown in the figures) on a mid-terrace dwelling has demonstrated a performance gap of the order of 20%, using a predicted U-value for the party wall of 0.2 W/m².K (i.e. the new Part L value for an edge-sealed party wall).

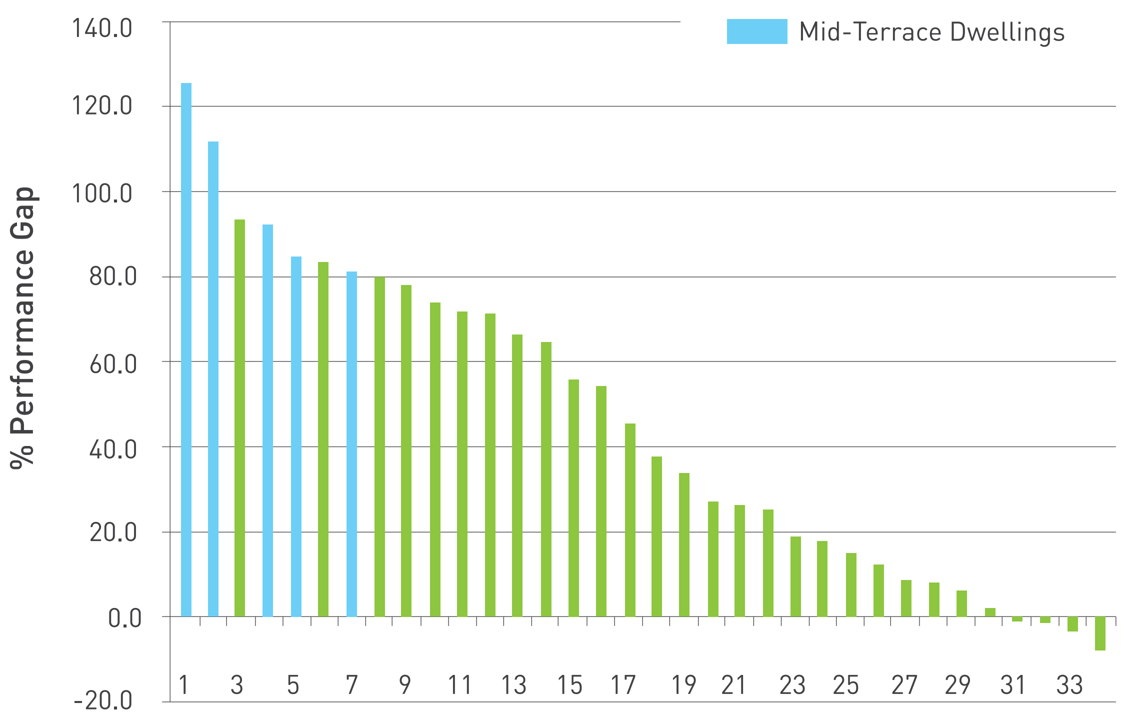

Fig 2.3a: Part of distribution occupied by Mid-Terrace dwellings

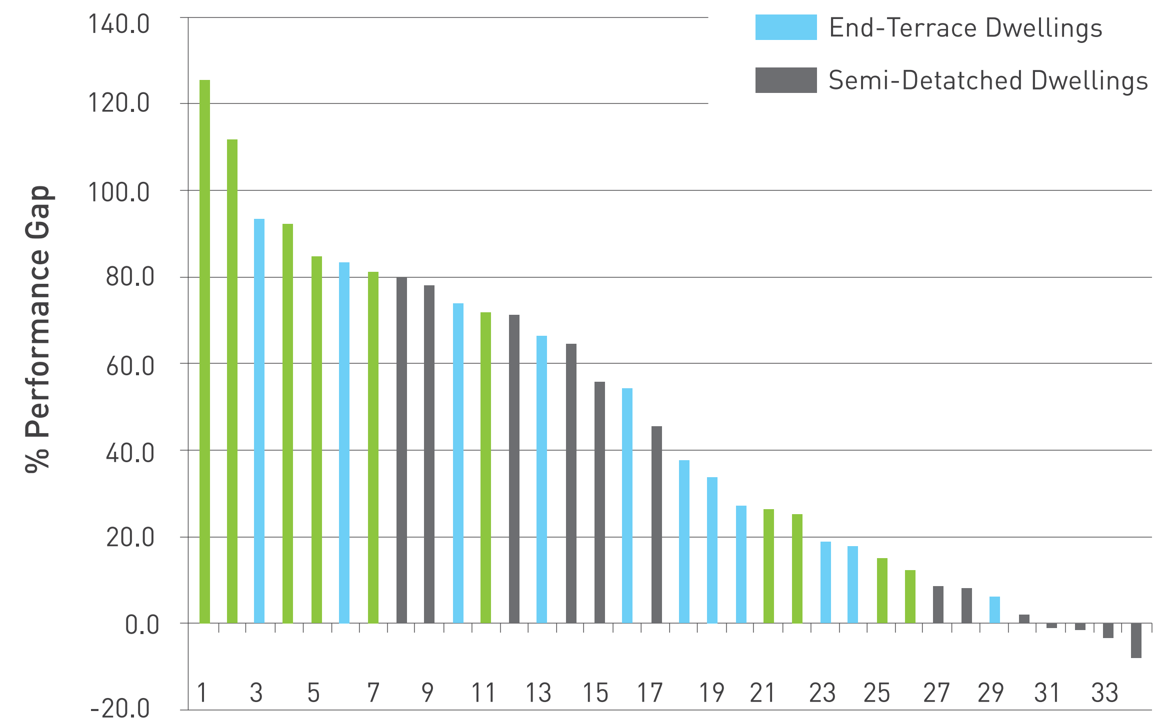

Fig 2.3b: Part of distribution occupied by end-terraces and semi-detatched dwellings

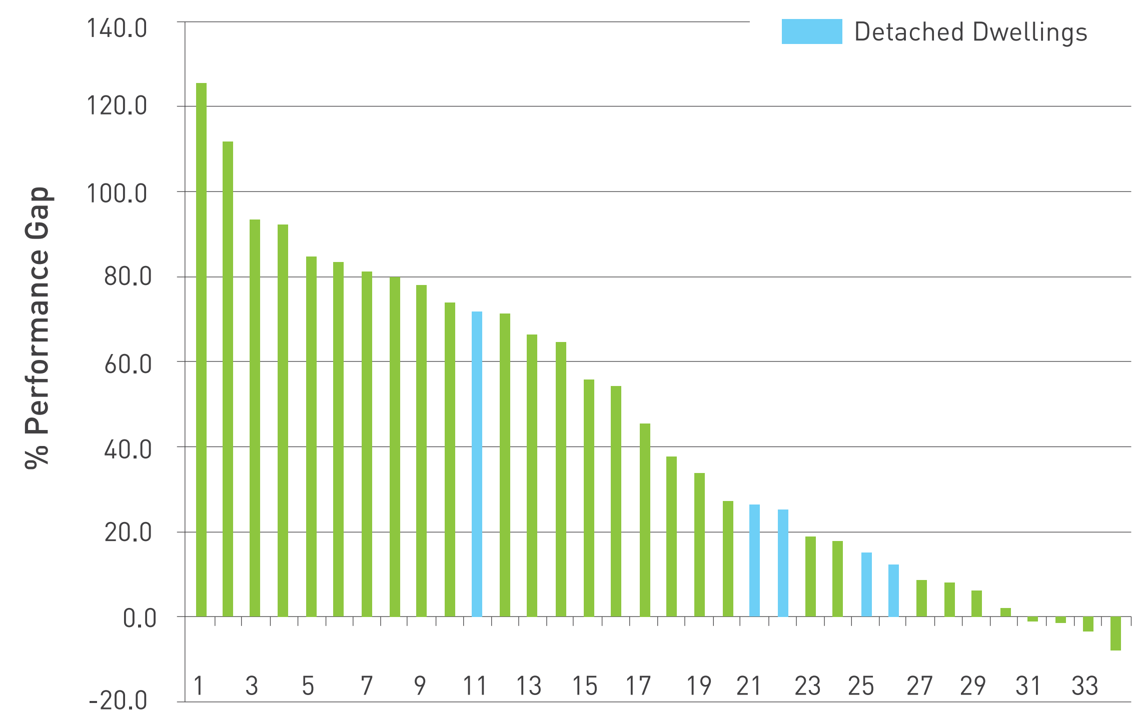

Fig 2.3c: Part of distribution occupied by detached dwellings

In fact the five mid-terrace tests shown in Figure 2.3a represent only three dwellings – one of which was tested only once and the remaining two tested both before and after a physical intervention. Both interventions were related to the party wall (either fully filling or edge sealing), and resulted in each case in a reduction in the performance gap. This represents a real and genuine improvement in performance, but the predicted heat loss used in the calculations was still zero (according to the 2006 regulations), so that the percentage performance gap figures are still somewhat misleading in each case. A better assessment of these dwellings for our purposes would be to recalculate the performance gap for all five tests based on a U-value of 0.5 for an unfilled party wall, 0.2 for edge-sealing only, or 0 for a fully-filled party wall, in accordance with 2010 regulations, as if these regulations were applied retrospectively. If we perform this exercise we find that the picture looks rather different (see Fig 2.4), with the mid-terrace dwellings now at the middle and lower end of the performance gap distribution.

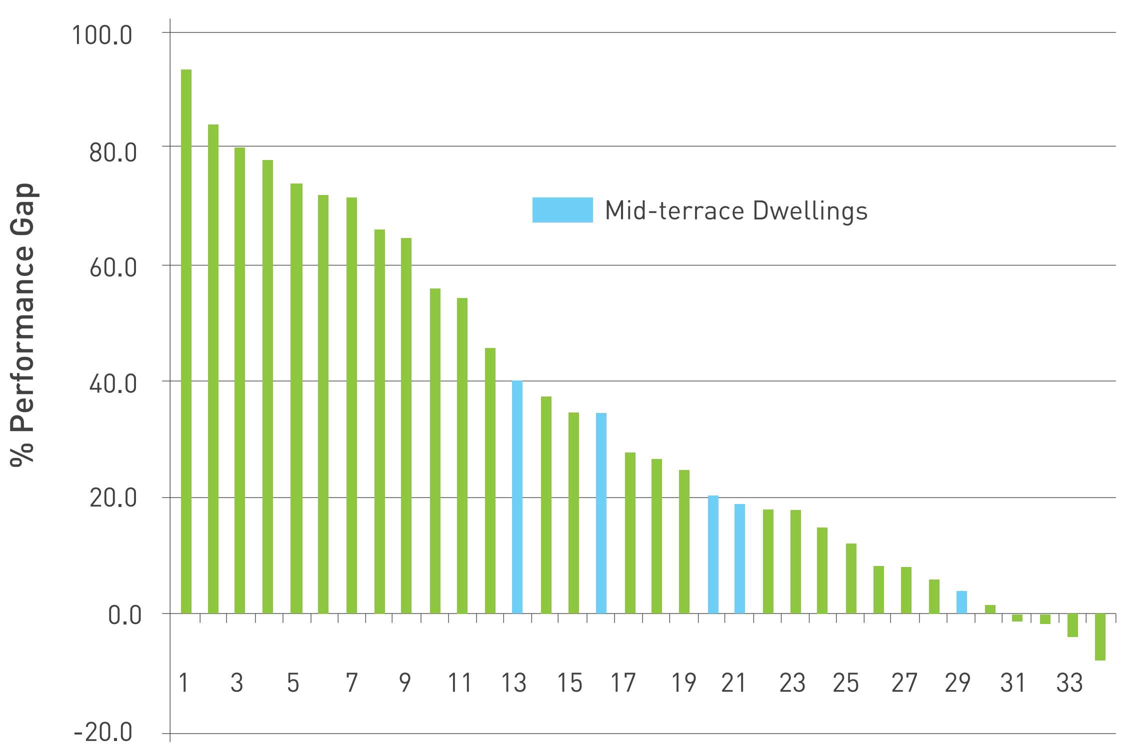

Fig 2.4: Effect of retrospective use of 2010 regulations on calculations for mid-terrace dwellings.

This clearly demonstrates the vital importance of the party-wall bypass mechanism and the new regulations in making more realistic predictions of actual heat loss.

Indeed, we may go further, and point out also that many of the remaining end-terrace and semi-detached dwellings will also have predicted heat loss values which are underestimated compared with the estimations that would have been made according to the 2010 regulations (if they have unfilled or only edge-sealed party-wall cavities). In figure 2.5 below, we re-draw Fig. 1 as far as possible using retrospectively applied regulations for the party walls in all cases.

Even allowing for the increased predicted energy loss through the party wall, we still see a large number of performance gaps at around 30% or more, indicating that there are other heat loss mechanisms and/or process issues not accounted for (i.e. the performance gap is by no means associated with the party wall issues alone). Some of these additional issues are discussed further in section 3, where "closing the loop" is discussed with particular reference to the Elm Tree Mews report (Wingfield et. al., 2011)

Note that in Fig. 2.5 the performance gap figures for dwellings which were not new build (existing dwellings) have not been altered. This was in some cases because the party wall was of solid construction, and the prediction would therefore not be altered under the 2010 regulations, or in other cases because the precise details of the party wall were unknown.

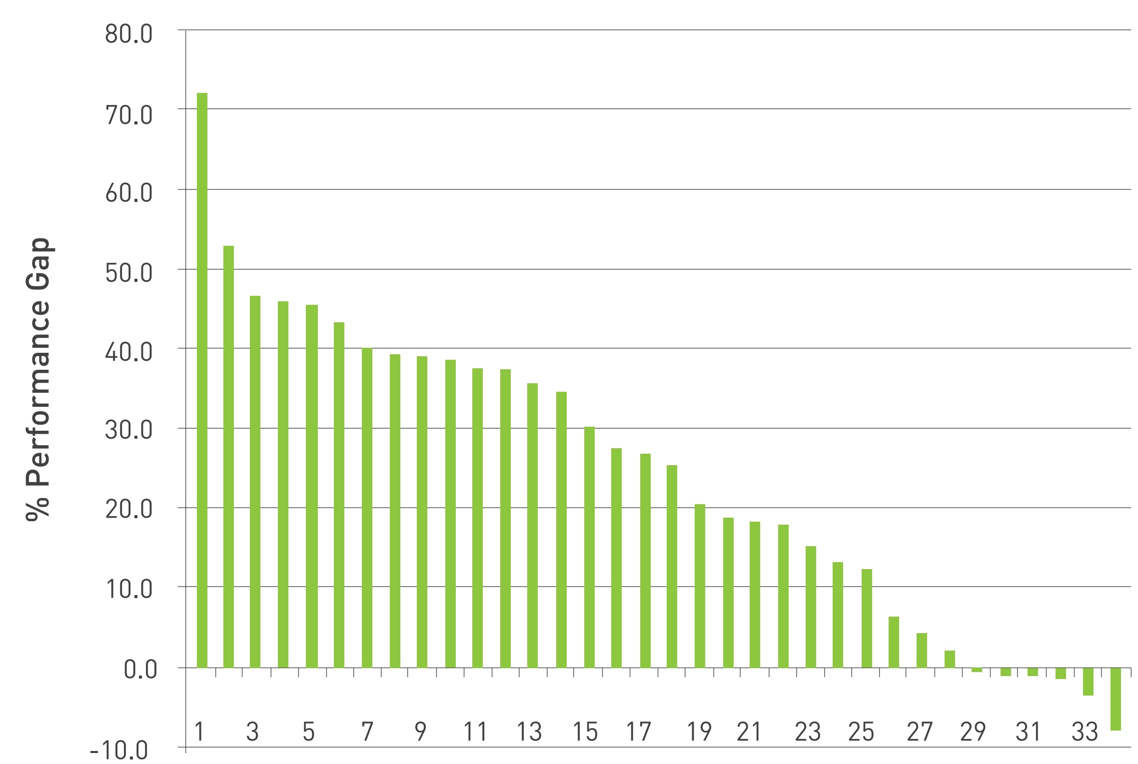

Fig 2.5: Recalculated performance gaps in all tests using 2010 regulations retrospectively.

2.2 INFLUENCE OF DWELLING SIZE

The procedure for examining the influence of dwelling size will involve dividing house sizes into groups by gross floor area, and looking at the distribution of performance gaps in terms of the different groups.

The English Housing Survey (EHS) Headline Report (DCLG, 2012b) divides dwellings into five groups according to floor area. These five groups are:

- under 50m²
- 50-69m²
- 70-89m²
- 90-109m²
- above 110m².

However, only one of the dwellings tested had a gross floor area of under 70m², so we have here combined the first three EHS groups into one category labelled 'smaller'. The 'medium' and 'larger' categories shown below correspond to the fourth and fifth EHS groups.

Using these categories, it is difficult to discern any clear trends with regard to physical dwelling size, as all three categories are distributed fairly evenly throughout the figure.

In terms of air-tightness, however, both theoretical and anecdotal evidence suggests that stringent values of air permeability ($m^3/h.m^2$) are more easily attained in larger dwellings. Air permeability is a function of envelope area, so both size and shape are contributory factors. Since experimentally determined values of ventilation rates are used in the performance predictions, effects related to differences in air permeability would not show up in Fig 2.6.

Fig 2.7 shows the value of the absolute performance gap divided by the gross floor area (in $W/K.m^2$) divided into the three size groups.

Again, it is difficult to draw any firm conclusion. This may be due to some extent to the small number of dwellings in the sample, or the width of the categories. However, the twelve dwellings in the 'larger' category represent gross floor areas between approximately 112m² and 167m², and there is no discernible correlation between actual size and position on the diagram within this category.

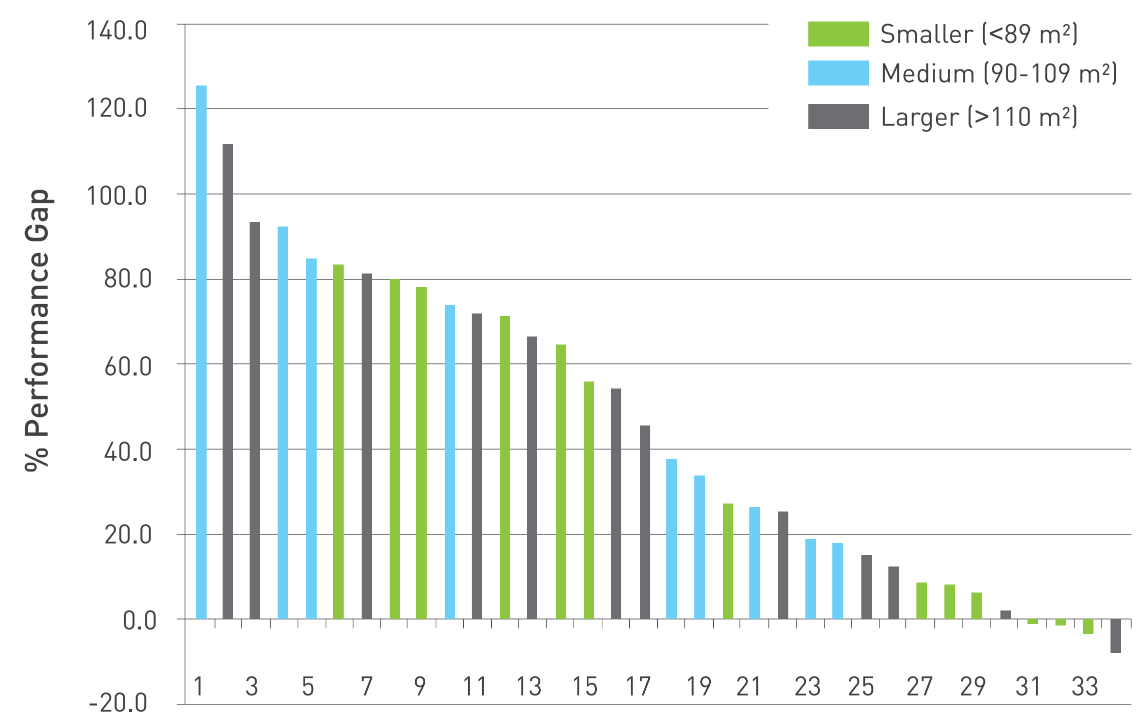

Fig 2.6: Percentage performance gap for different dwelling sizes

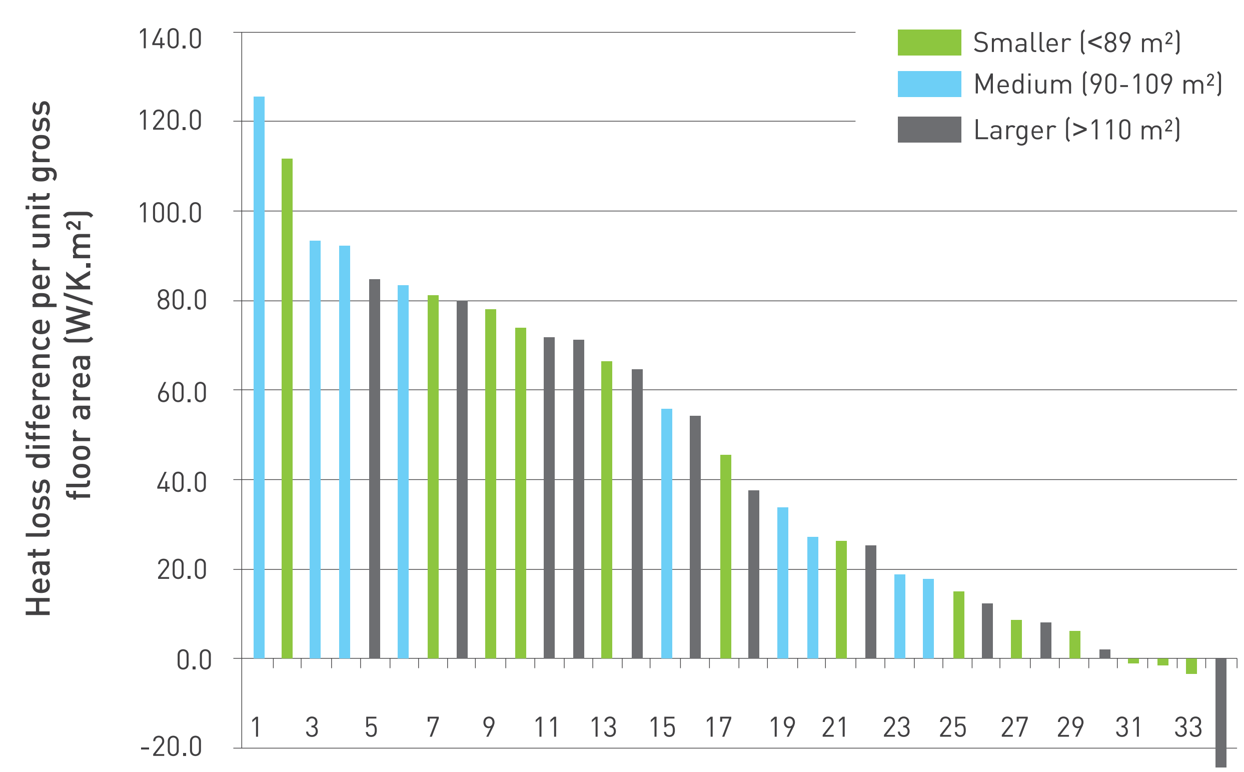

Fig 2.7: Absolute heat loss difference (between predicted and meaured) per unit gross floor area

2.3 INFLUENCE OF CONSTRUCTION TYPE

The vast majority of dwellings tested have been of standard cavity wall brick/block masonry construction (26 of 34). The remaining few are mostly timber frame but also include one or two less traditional construction types. None of the timber frame dwellings tested demonstrated a performance gap of more than 55%, though it is difficult to draw any firm conclusions from this fact since the five tests in question were performed on only three different dwellings (in two cases tests were performed both before and after an intervention – see Section 2.5).

2.4 NEW BUILD OR RETROFIT

The majority of the dwellings considered here were new-build dwellings where it was possible to have reasonable confidence in the predicted heat loss coefficient, at least insofar as Part L1 of the Building Regulations can be expected to deliver realistic values for thermal transmittance of elements, thermal bridging etc. The risk of inaccurate predictions based on design values for elements or procedures, which were subsequently changed on-site, was mitigated by the fact that the construction process was carefully observed. Such in-construction changes to the design are far from uncommon. Examples observed by the Leeds Metropolitan group include substitution of specified elements such as doors or windows, changes from wet-plastering to plasterboard and vice-versa, and changes in insulation products.

In fact only four of the tests under consideration were on existing properties. One was a social housing bungalow that was temporarily vacant. It was possible to perform pressurisation testing, basic co-heating testing, thermography and smoke detection for air-leakage pathways, but it was not practicable to investigate the U-values of elements via heat flux measurements. Furthermore, it was not practicable to heat the neighbouring dwelling to the same temperature during the co-heating test, as is the standard practice, since this neighbouring dwelling was occupied. Therefore the heat loss through the party wall during the test had to be estimated, and the estimate subtracted from the measured heat loss. The predicted heat loss coefficient was based upon the estimated U-values and thermal bridging values given in rdSAP for buildings of the appropriate age and type. In fact, despite all these difficulties, the experimental heat loss coefficient was very close to the predicted value (performance gap -3.6%). However, it is difficult to determine whether this is due to particularly good fabric performance in this dwelling, or to the possibility that SAP may generally overestimate U-values and thermal bridging estimates for older dwellings, perhaps implicitly allowing an extra tolerance as a safety margin.

The other three tests performed on an existing dwelling were all performed on the same building, firstly as-found and subsequently after two separate rounds of interventions. Again, in the as-found test, the performance gap was negative (-8.0%). After some basic interventions the performance gap remained negligible at 1.9%, but after the final round of interventions it increased to 45.5%. It must be emphasised that the absolute building performance improved markedly after each intervention round, and it is merely the difference between 'expected' and 'measured' heat loss coefficients that became wider. Possibly this may lend weight to the idea that as more became accurately known about the fabric (after various interventions had taken place), the predictions became more realistic.

More examples of co-heating tests on existing buildings are necessary in order to build up a better picture of the actual energy performance of the existing stock. Of course this observation also applies to new-build.

2.5 EFFECT OF DESIGN TARGET

As mentioned in the introduction to Section 2, developments that are attempting very high thermal performance standards may fall short by a relatively large percentage, but the shortfall may still represent lower actual energy loss than a small percentage gap in a development with less stringent aspirations.

Therefore it may be considered appropriate to allow wider proportional tolerances for such ambitious projects. However, it should be noted that this argument applies also to dwellings which have a low total expected heat loss (W/K) for other reasons – e,g, small size and/or simple design, even where the U-value specification of elements is not especially high.

Many of the co-heating tests in this analysis were performed on new-build dwellings with thermal performance design targets based only on the current building regulations at the time (2006 Regulations). A few however, were intended to be low-energy designs, with the targets being either specified by consultation with Leeds Metropolitan for that particular development, or specified by some other method such as Ecohomes rating.

Fig 2.8 shows the absolute difference between predicted and measured heat loss divided into 'standard' and 'low-energy intent' groups (where 'low energy intent' signifies that the developer has attempted a low-energy standard over and above the current (2006) Building Regulations).

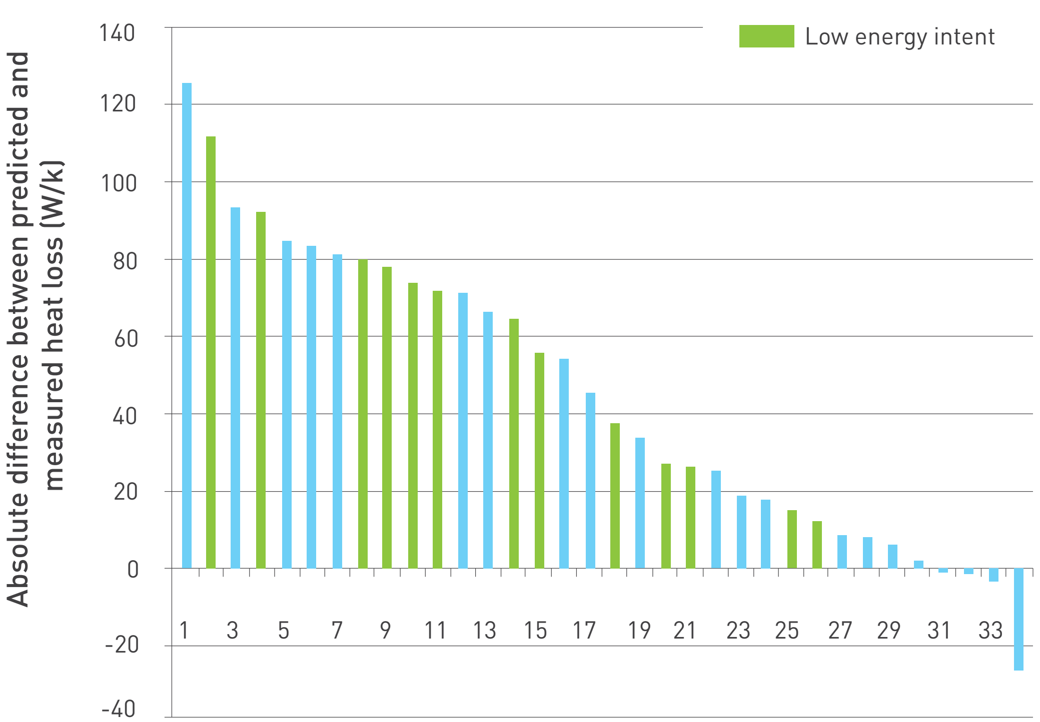

Fig 2.8: Dwellings where there was a specific intent on the part of the developer to adhere to enhanced energy standards

The differences between predicted and measured heat loss for the 'low energy intent' dwellings range from under 20 W/K up to around 100 W/K. One of the 'standard' dwellings shows a higher heat loss difference at just over 120 W/K but many show differences which are similar to, or less than those for the low energy group.

Of course the absolute value of the additional energy loss over the predicted value, as shown here, is related to other factors, such as dwelling size, as well as fabric underperformance. In addition, taking account of the 2010 regulations in respect of the party wall bypass will increase many of the predicted values, thus decreasing the absolute difference values accordingly.

Fig 2.9 attempts to account for these factors by re-plotting Fig 2.8 in terms of absolute difference between predicted and measured heat loss per unit gross floor area (W/Km²) using predicted values which have been amended as for Fig 2.5 (retrospectively applied 2010 regulations). This results in a slightly more optimistic picture though there are still many dwellings in the 'low energy intent' group which occupy the middle section of the diagram.

Note also that because the actual measured air permeability is used in the predicted heat loss values, poor performance in this aspect may result in relatively high predicted heat loss even where the design is intended to be low-energy.

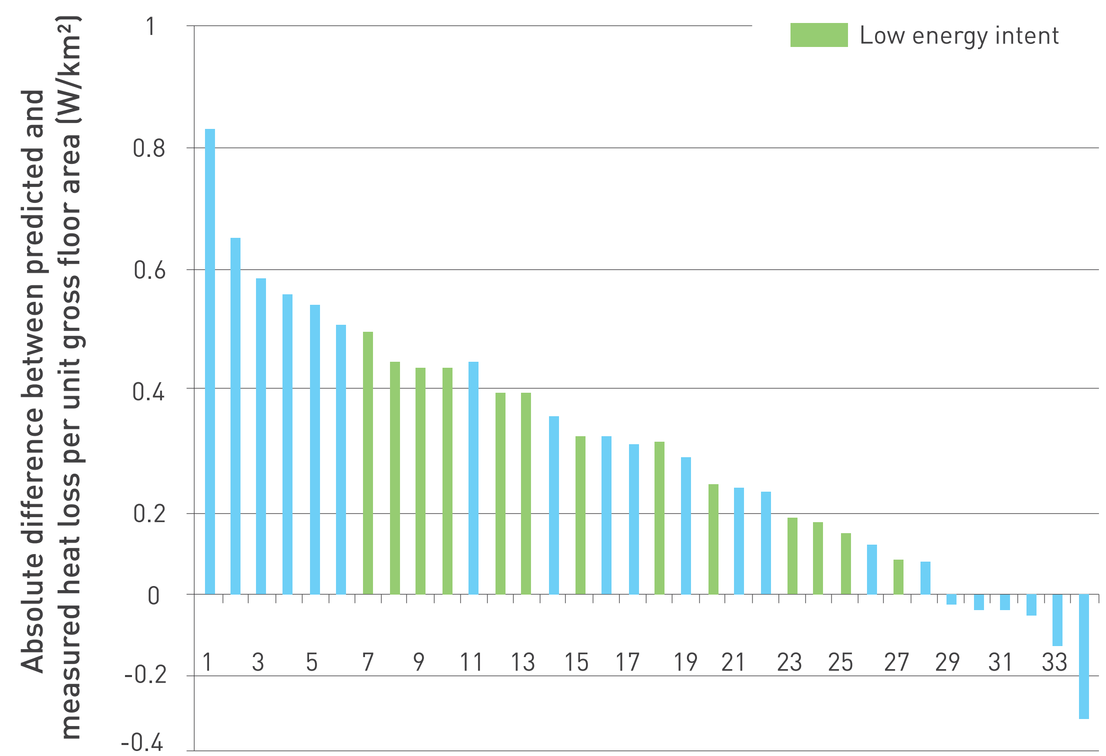

Fig 2.9: As for fig. 2.8 but expressed as a heat loss difference per unit gross floor area, and using 2010 regulations retrospectively in respect of party walls.

2.6 EFFECTS OF INTERVENTIONS

The 34 co-heating tests analysed in this paper represent tests performed on a total of 21 different dwellings.

This is because some tests were done both before and after physical interventions. In many cases the interventions were associated with investigation of the party wall bypass effect, though in one case an intervention involved additional insulation to external walls. In another case, the interventions were various upgrades to an existing dwelling.

PARTY WALL INTERVENTIONS

Four pairs of tests were done on dwellings before and after the insertion of a party-wall sock to mitigate air movement in the party wall. The reductions in the absolute performance gaps following this procedure were as shown in Table 1 (in each case the predicted heat loss assumed a U-value of 0 for the party wall).

Thus in these four dwellings (all from the same development, but not all by the same builder), an improvement in the measured heat loss of between around 8 W/K and around 27 W/K could be achieved by the addition of a party wall sock. Note that Case 1 represents a mid-terrace dwelling where only one of the party walls was modified, and therefore a larger change in the measured heat loss might be expected if both had been modified. Cases 3 and 4 represent smaller dwellings than 1 and 2.

Similarly six pairs of tests were done before and after fully filling the party wall cavity. Once again, a reduction in measured heat loss is seen (in all cases the predicted heat loss assumes no heat loss through the party wall, and is therefore unchanged after the intervention).

Again, in all cases, the measured heat loss is reduced by fully filling the party wall. In the case of 3 and 4, the performance gap is effectively removed altogether by this intervention, but in the other cases, there are clearly other issues which are also affecting the underperformance. In Table 2, Case 2 represents a mid-terrace dwelling where only one party wall was filled. Again, had both been filled, a greater reduction in measured heat loss might have been expected.

	ABSOLUTE DIFFERENCE IN HEAT LOSS (predicted-measured) before (W/K)	**ABSOLUTE DIFFERENCE IN HEAT LOSS** (predicted-measured) after (W/K)	**CHANGE IN MEASURED HEAT LOSS** (W/K)	**% CHANGE IN MEASURED HEAT LOSS**
1	99.4	72.2	-27.2	-27.4
2	93.3	66.1	-27.2	-29.2
3	43.2	33.9	-9.3	-21.5
4	48.1	40.0	-8.1	-16.8

Table 1: Heat loss data before and after modification of party walls (edge-sealing)

	ABSOLUTE DIFFERENCE IN HEAT LOSS (predicted-measured) before (W/K)	**ABSOLUTE DIFFERENCE IN HEAT LOSS** (predicted-measured) after (W/K)	**CHANGE IN MEASURED HEAT LOSS** (W/K)	**% CHANGE IN MEASURED HEAT LOSS**
1	97.3	52.2	-45.1	-46.4
2	122.8	87.2	-35.6	-29.0
3	10.9	-2.2	-13.1	-120.2
4	12.0	-1.6	-13.6	-113.3
5	91.1	29.9	-61.2	-67.2
6	43.9	24.3	-19.6	-44.6

Table 2: Heat loss data before and after modification of party walls (fully insulating)

3. CLOSING THE LOOP

The object is not merely to identify a performance gap, but rather to explain its existence quantitatively in terms of the underperformance of different elements and processes, thus opening potential pathways to improved future performance.

Fig 3.1 gives an example of this 'closing the loop' exercise, where the as-built (measured) U-values of several different elements (together with a more realistic estimate of the total thermal bridging) were substituted cumulatively for the design values, resulting in a full explanation of the observed performance gap. The example is taken from the Elm Tree Mews Field Trial (Wingfield et. al., 2011).

In this particular case, there were a number of almost equally important factors contributing to the observed gap, including party wall, external walls, windows and thermal bridging. A small contribution was also made by the roof performance.

The fact that so few closed loop studies of this type exist means that it is not possible as yet to analyse the most common areas of shortfall in any meaningful statistical sense. However, as more studies are completed, this may perhaps become possible. Such a meta-analysis might help developers to address the most fruitful areas for improvement first, thus optimising shorter-term gains in performance and performance reliability.

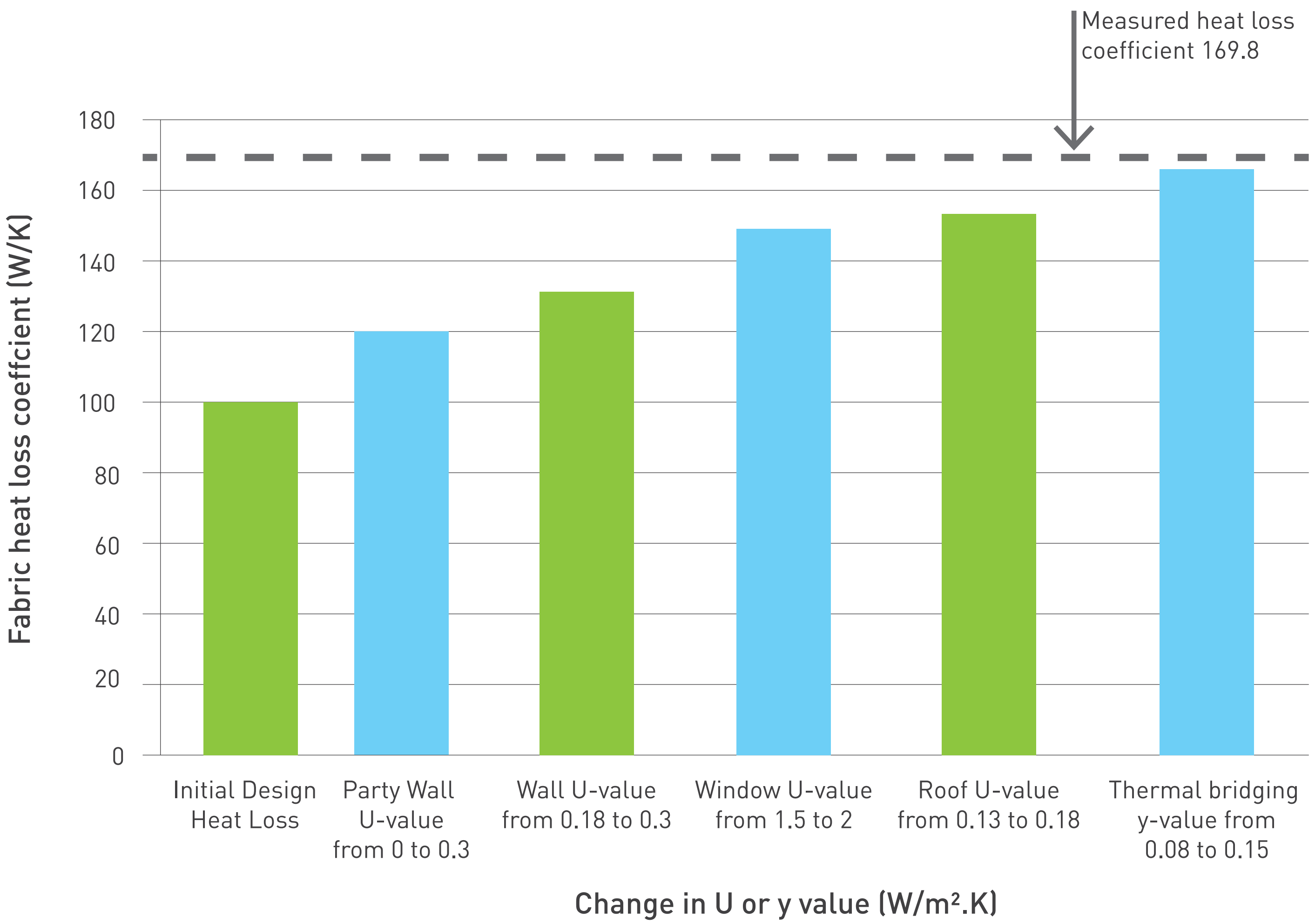

Fig. 3.1: After a figure from Elm Tree Mews Field Trial: Final Technical Report, (Wingfield et. al, 2011)

CONCLUSIONS

In the majority of the cases studied, substantial performance gaps have been demonstrated. The shortfalls can result from a whole range of different sources including party wall losses, underperformance of other building elements in-situ, process issues, lack of understanding of the principles of thermal performance, on-site alterations and substitutions and higher than expected thermal bridging. To this list, we should also add that there may still exist other heat loss mechanisms (apart from the party wall bypass) which are not yet fully understood and therefore not accounted for in the predicted heat loss calculations. The implication for the house-building industry is that a complex and ongoing process of research, feedback, education and training will be necessary if the gaps are to be fully understood and closed.

It is clear from the evidence presented here that a significant contributor to the performance gap in the past has been the issue of underestimated predictions due to a lack of understanding of the party wall bypass. To some extent this has now been addressed via the new (2010) regulations, and in the future predictions may be expected to be more realistic. The solutions of insulating and sealing cavity party walls have been accepted in the current regulatory framework, though field-testing of these solutions has been limited, to date, to the few cases included in this review. As always, we should not rest content with the new estimates of U-values for party walls, but should continually review further evidence to assess whether these new estimates are optimal, or require adjustment.

The rapid learning, which will be necessary in the case of new-build, should be applied also to retrofit projects designed to improve the thermal performance of existing buildings. The evidence base in the case of retrofit projects is unfortunately even more scant than for new-build, and there is a serious need for this to be urgently addressed. Some of the potential additional difficulties associated with studying existing buildings are discussed in Section 2.4.

Fig 2.9 suggests that the intention to attempt enhanced low-energy standards on the part of the developer can result in achieving performances relatively close to the design target when dwelling size is taken into account. However, this is by no means universally the case and additional energy losses (above the design expectations) of over 0.4 W/K per m2 of gross floor area have been observed in several cases. For dwellings where the intent was limited to compliance with current building regulations, additional energy losses above the design expectations range from very small up to over 0.8 W/K per m2 of gross floor area.

APPENDIX

APPENDIX A: SUMMARY OF KEY EVIDENCE ON THE PERFORMANCE GAP [AFTER BELL ET. AL, 2010].

GENERAL LEVELS OF TECHNICAL PERFORMANCE –

Energy and carbon performance, particularly when seeking to achieve low and zero carbon standards, is dependent on a very low incidence of defects in insulation layers, air barriers and the installation and commissioning of services. This led the group to review material on technical performance in general. It highlighted concerns about customer satisfaction, number of defects and compliance with the building regulations raised in the reviews by Barker (2004) and Callcutt (2007) as well as more specific work on defects, including insulation defects, undertaken by the BRE in the 1980s and 1990s (Bonshor and Harrison 1982 and Harrison 1993) and more recent work undertaken for CLG in support of regulation (Oreszczyn et al., 2011 and Bell et al. 2005). All studies demonstrated that defects were relatively common and that tackling the issues involved remained a challenge for the industry. The group concluded: "Given that most of these concerns were in relation to quality factors that could be observed directly, it would be surprising if energy and carbon performance, which is not so amenable to direct observation, was immune to problems of underperformance."

FABRIC HEAT LOSS –

Measurements of whole house heat loss undertaken on some 16 dwellings drawn from a variety of schemes including low energy and mainstream developments demonstrate the potential for a very wide performance range (see: Bell et al., 2010, Wingfield et al., 2010b, Wingfield et al., 2008, Wingfield et al., 2009 and Stevenson and Rijal, 2008). Of the 16 dwellings tested, 11 had heat losses between 120% and 40% higher than predicted, the remaining five less than 20% higher. In most cases whole house measurements have been supported by forensic analysis including design and construction observations and measurements of heat flux through the thermal envelope. Other work on heat loss from construction elements corroborate much of the work from whole house measurements. Work by Siviour (1994) and Doran (2005) show a wide variation in the discrepancy between calculated and as-built U values. Theoretical and laboratory work in Belgium (Hens et al., 2007) demonstrate the impact of air movement through and around insulation materials, with test results for as-built U values ranging from 0% to 350% higher than calculated depending on the closeness of fit. The emergence of an understanding of thermal bypassing (Wingfield et al., 2008 and Lowe et al., 2007) has identified a heat loss mechanism that further explains some of the gap in fabric performance, particularly in attached dwellings with cavity party walls. Although the available evidence (Wingfield et al. 2009) indicates that the party wall bypass could be reduced to zero by a combination of full filling and edge sealing, this is only part of the solution to closing the fabric heat loss performance gap.

AIRTIGHTNESS –

The group noted an encouraging improvement in airtightness of dwellings since the introduction of regulatory airtightness testing of dwellings in 2006. The data indicated that the average permeability had fallen from just over 9 m3/h.m2 (Grigg 2004) to just over 6 m3/h.m2 (NHBC 2008). However, it was acknowledged that much lower levels are likely to be required in order to achieve low and zero carbon standards. The impact of testing on airtightness was noted and provide a good indication that low levels of permeability could be achieved given the right processes and control mechanisms, backed up by testing and feedback.

HEATING AND HOT WATER SERVICES –

The group reviewed work by the Carbon Trust (Carbon Trust, 2007) and the Energy Saving Trust (Orr et al. 2009) on the performance of gas condensing boilers. Both studies suggesting that, on average, as-installed, in-use efficiencies are likely to be around five percentage points below their SEDBUK2005 ratings. In addition, carbon performance (mainly as a result of electricity loads for pumps and fans) can vary considerably with the Carbon Trust study suggesting that it could vary by a factor of two. Total systems effects from case studies of gas condensing boilers and a communal heat pump (Wingfield, et al. 2008 and Bell et al. 2010) were noted, indicating that such effects could be large and leading to the suggestion that there was a need for robust design and calculation methods that took systems effects into account.

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ABOUT US

The Centre for Low Carbon Futures is a collaborative membership organisation that focuses on sustainability for competitive advantage. Founded by the Universities of Hull, Leeds, Sheffield and York, the Centre brings together multidisciplinary and evidence-based research to both inform policy making and to demonstrate low carbon innovations. Our research themes are Smart Infrastructure, Energy Systems and the Circular Economy. Our activities are focused on the needs of business in both the demonstration of innovation and the associated skills development. Registered in the UK at Companies House 29th September 2009 Company No: 7033134.

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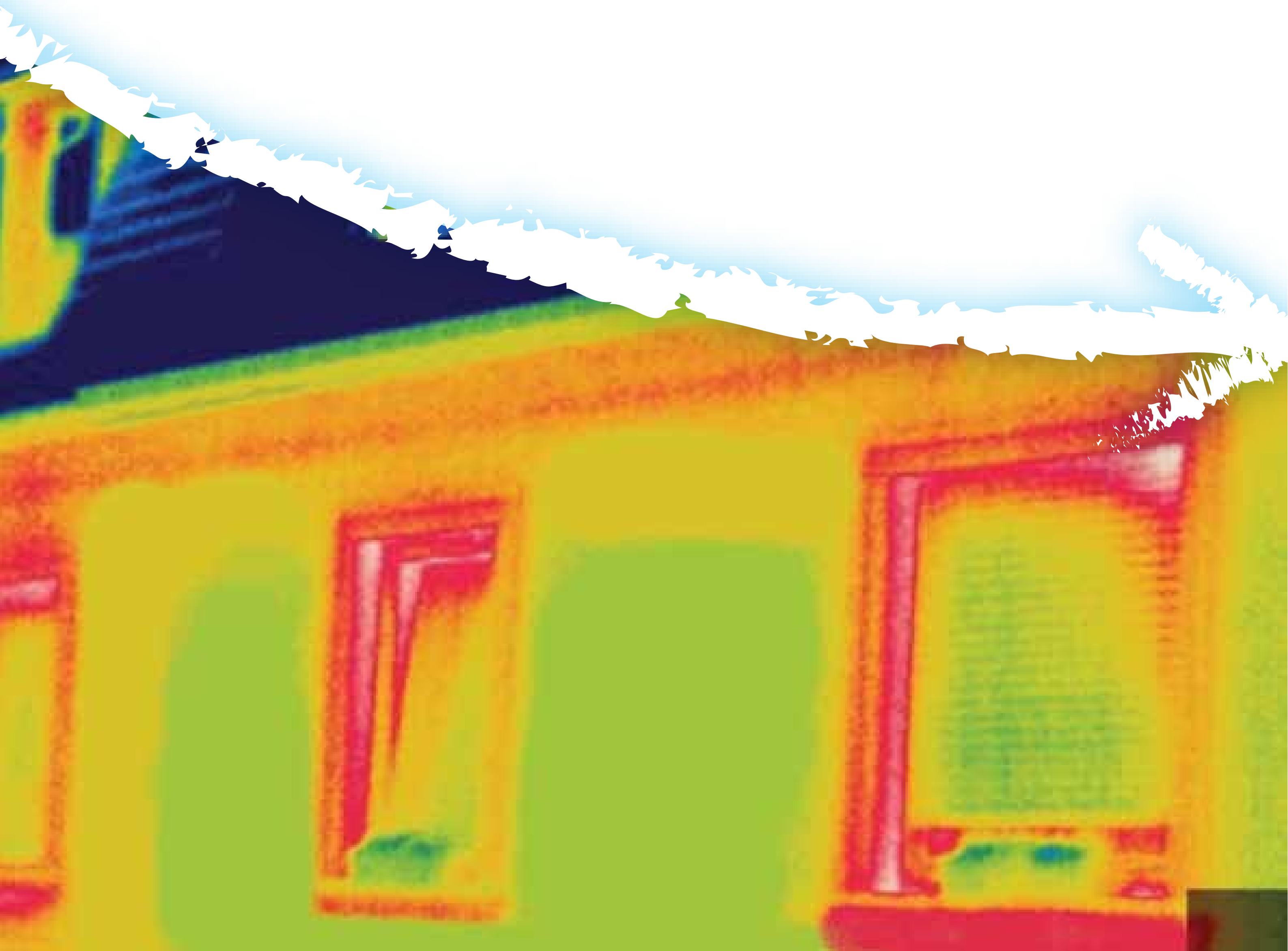
The Retrofit Challenge: Delivering Low Carbon Buildings



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the Centre for Low Carbon Futures.

This report looks at the current status and future potential of building retrofit for energy performance and carbon saving in the UK.

A brief review of current policy and building stock is followed by a discussion of ways forward. This is divided broadly into six key themes, though there is considerable overlap and connectivity between themes: a fact which illustrates well the nature of the retrofit problem. The discussion is informed by insights drawn from recent and current research in the field.

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CONTENTS

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INTRODUCTION

The spotlight is firmly on the UK this year and not just because of the Olympics. The UK Coalition Government is tackling the huge issue of the 45% of UK Carbon Emissions created by our built environment. This year they will roll out a portfolio of 'game changing' policies including Green Deal, ECO, Renewable Heat Incentive and the Localisim Act to further enable householders, industry and Cities to reduce energy consumption and carbon emissions.

The outcomes are potentially very promising with these policies collectively having the potential to draw in £bn's of pounds of investment and deliver wider local economic benefits in terms of GDP and jobs. However there is a great risk that the planned energy and carbon savings are not achieved unless there are significant changes in both our implementation and behavioural use of energy efficency in the built environment.

The Centre for Low Carbon Futures commissioned this report as part of a programme of translational research insights on energy efficiency. Our broader research agenda on Low Carbon Cities includes a "Mini Stern" review of a number of cities, and the development of a new Centre to provide independent ongoing measurement, reporting and verification of energy efficiency in the built environment. Our recent study on the Economics of Low Carbon Cities[1] was launched at the UNFCCC in Durban, and to date we have received enquires from Beijing, Tokyo and Mexico City, demonstrating the current global need for more useful research insights and tools to enable more effective energy efficiency deployment.

We are grateful to Dr A. Stafford, Professor C. Gorse and Professor M. Bell at Leeds Metropolitan University and Professor L. Shao at De Montfort University and contributions from EST and others for their work on this report

Jon Price

Director, The Centre for Low Carbon Futures

[1] Gouldson, A., Kerr, N., Topi, C., Dawkins, E., Kuylenstierna, J., Pearce, R. (2012) The Economics of Low Carbon Cities: A Mini-Stern Review for the Leeds City Region.

FOREWORD

If we are to hit our national carbon reduction target of 80% by 2050, almost every building in the country will need a low energy makeover. That means we have to improve nearly one building every minute, and we have to get the interventions right, first time. That is a challenge.

Each house is different, so there is no 'one size fits all' solution; householders and building users have different attitudes to, and understanding of, energy efficiency. Installers and tradesmen do not all have the necessary skills to fit more advanced energy efficiency and renewable energy measures. The solution is to test the real, in home performance of energy efficiency and renewable energy measures, and to make sure that everyone involved in specifying, fitting and using those measures are sufficiently informed to make sure that they work properly.
We need to make sure that standards are set and followed, taking into account national, regional and local variations. In this way we will deliver low carbon, low energy homes and commercial buildings, which cost less for occupiers to heat.

There are expert, experienced and dedicated individuals and organisations who are offering practical solutions to this challenge. The recommendations of this report provide a roadmap for achieving a much better understanding of the issues. Energy Saving Trust field trials already provide insight into the performance of technologies, and our consumer awareness-raising helps to drive demand for retrofit measures. The Centre for Low Carbon Futures is building on some of the best academic research into building energy performance in the country to take the next steps towards a comprehensive low carbon building stock for 2050.
I am very pleased that the Energy Saving Trust is working with the Centre for Low Carbon Futures on this essential work.

Philip Sellwood

CEO, Energy Saving Trust

PREFACE

The potential for reductions in carbon emissions in the built environment is considerable. However, unlocking the potential presents a multifaceted and intrinsically difficult problem. Not only is the building stock extremely diverse and numerous but ownership is equally diverse and complex. Addressing the technical, legal, economic and social issues will require considerable effort from all sectors of society. In this report the authors deal mainly with the technical and user issues but, as they are acutely aware, addressing these issues will form only part of the solution.

Perhaps the most critical of the questions raised by this report is the relationship between theoretical and as-built performance. Traditionally this discrepancy has been attributed to user variation but field test evidence suggests that a considerable element can be attributed to the underperformance of fabric and services, as-constructed. Moreover, a number of case studies have identified a clear link between the processes used in design and construction and the under-performance observed.

In addition to improving industry processes that deliver sound as-built performance, it will be crucial to adopt a range of measures that are well designed and tailored to individual buildings and building groups. This will require a considerable degree of coordination so that measures are not applied piecemeal but in a coherent and effective way.

Almost all the issues identified in this report expose a lack of fundamental understanding about the relationships involved and identify the need for a considerable research effort. However, time is very short and a great deal of learning will have to take place as action is taken. This points to the need for research to be embedded in the very actions and relationships that are being investigated. In short there must be a system of continual feedback, which will need to be amplified by the coordinated use of information technology.

If we are to ensure that the building stock in 2050 and beyond is truly sustainable it is essential that the issues identified in this report are tackled immediately but in such a way that enables us to learn as we go. There is no time to do it any other way.

Malcolm Bell

Emeritus Professor of Surveying and Sustainable Housing, Leeds Metropolitan University

EXECUTIVE SUMMARY

In order to achieve mandatory carbon reduction targets, a rapid, policy-driven transition to a low carbon economy is urgently required.

Around 45% of emissions in the UK derive from buildings. Although the Government is attempting to address the low carbon agenda with respect to new build, via progressive regulation towards a low carbon standard, the fact remains that around 70% of buildings existing today will still be in use by 2050. For this reason, low carbon retrofitting of existing buildings is a vitally important factor in the transition.

Extensive retrofit programmes, though necessary, are likely to be costly and therefore need to be properly researched and understood in order to 'get it right first time'. This is not a simple matter given the diversity of UK building stock and the fact that the real performance of buildings and retrofit interventions is as yet poorly understood.

It is now widely recognised, thanks in part to extensive research undertaken at Leeds Metropolitan University, that a 'performance gap' exists between predicted and real energy performance, both in new build and in retrofit. This points to a clear need for improved understanding of fabric, systems and build processes.

The primary gains will be achieved via improved fabric performance and this should be the initial focus of retrofit strategies. Once fabric performance is optimised further gains are available through the judicious use of micro-generation and low carbon technologies. However, there is a danger in approaching retrofit in a piecemeal fashion, as a series of disconnected project stages. Such an approach is unlikely to optimise the potential of either fabric or low carbon technologies. It also fails to take advantage of potential cost savings. The solution is to develop an integrated strategy from the beginning, even if the works themselves are staged.

Finally, a further set of gains will result from an improved understanding of behaviour and how people interact with buildings and technologies. Interdisciplinary research in this field is beginning to identify important factors, not least the complexity of influencing behaviour in ways that are both acceptable and durable.

Underpinning all the issues discussed is the potential of ICT to facilitate both research and delivery phases.

WHERE ARE WE NOW? A REVIEW OF CURRENT POLICY AND EXISTING STOCK

POLICY LANDSCAPE

Drivers

It is often stated that around 45% of the UK's total carbon emissions derive from buildings. Government aspires to achieve zero-carbon standards for new buildings from 2016 (domestic) and 2019 (non-domestic). However, since it is estimated that by 2050 around 70% of the 2010 building stock will still be in use, it is very clear that low carbon retrofit will have a huge role to play in achieving carbon emission targets.

In February 2011, ARUP published a UK Legislation Timeline poster in an attempt to summarise the overall policy landscape on carbon reduction, from 2005 Kyoto Protocol to 2020, and beyond to 2050 (ARUP, 2011). Taking into account the global, European and UK targets, it divides policy drivers into three main sections: Emissions, Energy and Efficiency. While the Emissions section applies mainly to large-scale industry processes, all of the policy drivers listed in the other two sections (Energy and Efficiency) are highly relevant to the question of building retrofit. These policy drivers are summarised briefly in Box 1.

ENERGY: RENEWABLES OBLIGATION, FEED-IN TARIFFS (FiTS), RENEWABLE HEAT INCENTIVE (RHI)
EFFICIENCY: CLIMATE CHANGE LEVY (CCL), CARBON REDUCTION COMMITMENT (CRC), CARBON EMISSIONS REDUCTION TARGET (CERT) , COMMUNITY ENERGY SAVINGS PROGRAMME (CESP), BUILDING REGULATIONS, CODE FOR SUSTAINABLE HOMES (CSH)

Box 1: Current policy drivers relevant to building retrofit

These policy drivers may vary to some extent between the constituent countries of the UK. For example, eligibility for FiTs and RHI is at present limited to England, Scotland and Wales, while the Renewables Obligation applies to England, Scotland, Wales and Northern Ireland. Similarly, Building Standards in Scotland and regulations in Northern Ireland differ from those in force in England and Wales.

Beyond these principal measures in the ARUP list, a range of further policy measures also impact on retrofit and energy use in buildings.

To raise awareness among building owners of their options for retrofit, the Government has supported impartial advice services from the Energy Saving Trust and Carbon Trust. Energy Performance Certificates – introduced as a requirement of the European level Energy Performance of Buildings Directive – are required by law to be provided by owners when they sell or rent out a home. The certificates inform the new buyer or user about energy use and retrofit options.

Government supported product labelling initiatives also play a part in raising awareness of the most energy efficient products on the market.

The Government has made use of fiscal incentives to drive energy and carbon saving. An Enhanced Capital Allowance incentivises the installation of energy saving measures in business premises and the Landlord's Energy Saving Allowance provides tax rebates for installation of insulation for private residential landlords. A reduced rate of VAT is available on many energy saving retrofit installations in homes.

Finally, driving installation of energy saving measures in homes are policies focused principally on fuel poverty. The Warm Front programme in England, or the Energy Assistance Package in Scotland, work alongside the CERT programme to help poor and vulnerable customers who cannot afford to heat their homes adequately because of poor energy efficiency. Some of the energy and carbon savings resulting from installing insulation or more efficient heating systems in fuel-poor homes are lost in 'comfort taking'. While the primary aim of these programmes is to enable people to heat their homes (see Theme 5), the overall net effect of fuel poverty programmes is also to reduce carbon emissions.

Beyond these existing programmes new policy measures are on the horizon. The Green Deal provides for upfront financing of energy saving measures on buildings, which are paid back through a long-term charge linked to the property's energy bills.

WHY ARE INTERVENTIONS NEEDED?

Investment in low carbon technologies and systems naturally becomes increasingly attractive as fossil fuel prices rise, and also as other issues such as security of supply and future-proofing become more important. Nevertheless, if the market was left to itself, the transition to a low carbon economy would happen too slowly to enable mandatory carbon reduction targets to be met in the short and medium term. Therefore government must kick-start the process by introducing policies which encourage early investment by various strategies, such as regulation and mandation, reducing risk, increasing the cost of inaction and supporting the spreading of initial capital investment over a period of time.

WHAT ARE THE COSTS OF INTERVENTIONS?

Policy interventions, such as those listed above, carry an intrinsic cost. However, many are aimed at not only decarbonising building energy use, but also at reducing overall consumption, which has the effect of mitigating or in some cases even completely compensating for any extra costs which are passed on to the end-user or building occupier.

The DECC report 'Estimated Impacts of Energy and Climate Change Policies on Energy Prices and Bills' (DECC, 2010a) looks at the effect of policies on both domestic and commercial energy costs. It takes into account the costs of the policies listed in Box 1, together with the additional costs of Smart Metering, security measures, Carbon Capture and Storage (CCS) demonstration and other initiatives. Figure 1 summarises the projected effects by 2020.

Clearly, individual decisions about uptake of energy efficiency measures will have a significant effect on actual fuel bills by 2020. In the domestic case, average projected uptake almost negates the effect of policy costs. It should also be noted that the costs of energy and climate change policies will be less if fossil fuel prices are higher than expected, since under these circumstances low carbon investment is incentivised more rapidly, irrespective of policy measures. The projected figures given in Figure 1 are based on oil prices of 80 $/bbl in 2020. Current prices (May 2010) are around 100 $/bbl, and significant long-term reductions seem unlikely (Oil-Price.net, 2011). For higher oil price scenarios, the overall domestic bill in 2020 with energy efficiency take-up is expected to be actually reduced by policy measures.

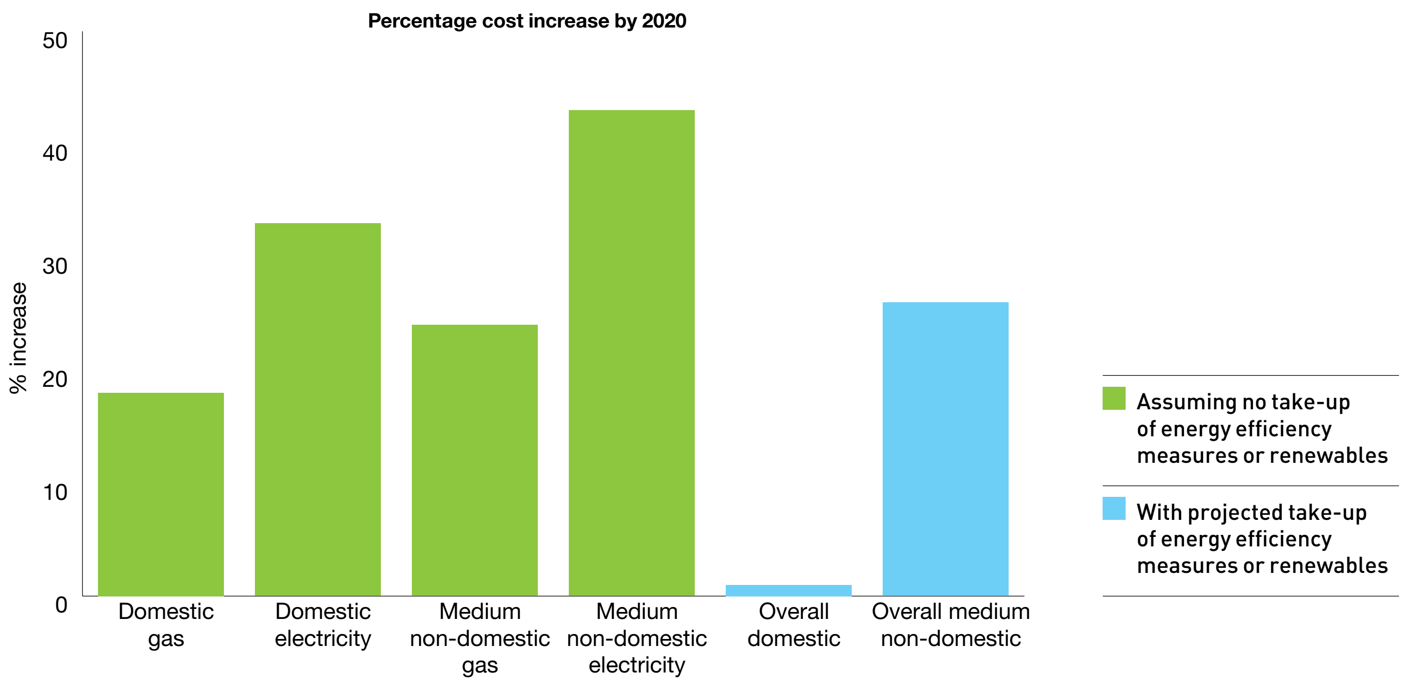

Fig 1: Projected effects of policies on fuel costs [after DECC 2010]

CURRENT BUILDING STOCK

Of the 70% of the total 2010 building stock still in use in 2050, 40% will be pre-1985, i.e. will pre-date the introduction of Part L of the Building Regulations for England and Wales (Better Buildings Partnership, 2010). The ENPER-TEBUC project final report (Hartless, 2004) offers an estimate of new build, replacement and renovation rates in a number of European member states. While annual replacement rates in the UK are thought to be low at around 0.1% of existing stock, since demolition rates are low renovation and refurbishment rates are likely to be much higher at around 2.9%–5% of existing stock for domestic buildings, and between 2% and 8% for commercial stock, depending upon the sector.

Domestic

The Domestic Energy Fact File (Utley and Shorrock, 2008a) classifies UK dwellings by age, type and tenure. The diagram below shows the age-distribution of domestic stock in 2006.

Figure 2 refers to the UK in general, but there are significant differences between the constituent countries, as described in detail in the Domestic Energy Fact File 2007: England, Scotland, Wales and Northern Ireland (Utley and Shorrock, 2008b). For example, Northern Ireland has the newest stock, with 61% of dwellings built since 1959, whereas Wales has the oldest, with 61% built prior to 1960. However, some 84% of households are located in England, with Scotland representing 9%, Wales 5% and Northern Ireland only 2%.

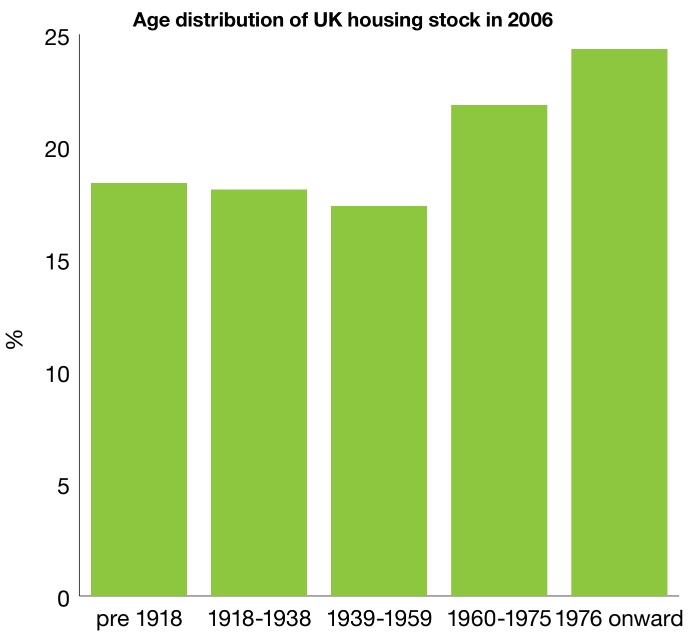

Fig 2: Age distribution of UK Housing Stock in 2006 (after Domestic Energy Fact File, 2008)

Basic insulation interventions are not sufficient in themselves to achieve required thermal performances. Nevertheless, such measures form a necessary starting point and also illustrate the complexity of the issues. For example, it is estimated from the age distribution and other data that about 30% of current stock is unlikely to have cavity walls and would therefore require internal or external wall insulation to improve thermal performance. This is not necessarily a major disadvantage, since external insulation can perform as well as, or better than, cavity wall insulation. However, by 2004 in England, Scotland and Wales less than 50% of existing cavity walls were thought to be insulated, though the figure for Northern Ireland was much higher at 78%. In 2009, some 30% of English homes failed the Decent Homes standard (down from 33% in 2008), with around 7% being specifically for reasons of poor thermal performance (DCLG, 2010). In Scotland, over 60% of homes failed the Scottish Housing Quality Standard (2009 figures), the majority of these for reasons of poor energy efficiency (Scottish Government, 2010).

Non-domestic

54% of the existing commercial building stock (representing 29% of floor-space area) was completed prior to 1939 (DCLG, 2000). It has been estimated that 80% of all current commercial stock would be rated below C on the Energy Performance Certificate (EPC) scale (Caleb Management Services, 2009).

Low carbon retrofit of commercial property has not been widely adopted so far. This has partly been due to 'split-incentive' issues, where upfront costs may fall disproportionately on short-term tenants while most of the benefits accrue to longer-term tenants and building owners. Only around a third of the commercial property market is owner-occupied. For these properties or for single-tenant/long-lease situations, some retrofit measures may have been adopted, provided they could be justified by simple economic payback perhaps combined with corporate social responsibility drivers.

Policy incentives such as CRC, FiTs and RHI may prove successful in supporting more rapid growth in this area.

THE WAY FORWARD: SIX KEY THEMES IN BUILDING RETROFIT

The following six key themes will be discussed in the following sections.

1. Retrofit isn't simple
2. Building energy performance is not well understood
3. Building fabric
4. Micro-generation and low carbon technologies
5. People use energy
6. The importance of IT and monitoring

Note that there will be considerable overlap between themes in the following sections, with some issues feeding into two or more themes. This is an illustration of the reality of the interconnectedness of various aspects of the retrofit problem, and hence the complexity of finding workable and robust solutions.

THEME 1: RETROFIT ISN'T SIMPLE

ONE SIZE DOESN'T FIT ALL

A conclusion of the Gentoo Retrofit Reality project (Gentoo Group, 2010) encapsulates the complexity of performance-effective and cost-effective retrofit interventions in the following statement: "Retrofitting is not simple, each house is different and every person behaves differently within their home."

In an ideal world, it might be possible to identify a 'one size fits all' solution to effective building retrofit. However, the diversity of UK building stock in terms of age, use, materials, build type and quality, thermal mass, location, orientation and occupancy, means that solutions need to be specifically tailored to the building or group of buildings in question.

MEASURES MAY NOT PERFORM AS EXPECTED

Even if appropriate interventions can be identified, it is a mistake simply to assume that measures will perform according to expectations. This may be due to either intrinsic performance issues or installation and process issues. For example, researchers have frequently observed nominally enhanced loft insulation, which has been assumed to be performing up to Building Regulations 2006 standards but where in fact poor installation has resulted in missing areas and underperformance (Stafford & Bell, 2009; Miles-Shenton, 2011). Similarly, cavity wall insulation has been observed which has been installed correctly according to procedure, but nevertheless has resulted in an uneven cavity fill, producing density variations and leaving some areas unfilled. These examples demonstrate the necessity for increased understanding of the real performance of even very widely used measures under different conditions and circumstances. Such understanding can only be achieved by a combination of improved training and routine monitoring of at least a significant sample of cases. Performance predictions in general tend to be based upon an assumption of ideal behaviour of materials and products under standard conditions, combined with perfect installation. It is therefore perhaps not surprising that in reality performance rarely matches expectations.

BALANCING BENEFITS AND COSTS

Retrofitting for energy performance is always a balance between benefits and costs. The TARBASE project (Banfill, 2009) suggested that it is feasible to reduce CO_2 emissions from existing buildings by at least 50% and in some cases up to 80%, though this conclusion was based on projections, not on measured performance. It is undoubtedly technically possible to refurbish existing buildings to a level of thermal performance close to that of low-carbon new-build, (Miles-Shenton, 2010), but in some cases this can be prohibitively expensive and may even approach the cost of demolition and rebuilding. The question then becomes "How much benefit can be gained for a reasonable cost?" where the definition of 'reasonable cost' depends in part on mandatory targets, energy costs, policy drivers, and economies of scale. Technical advances and the maturation of low carbon industries will also tend to drive down costs over time.

It will be clear from many of the following sections that interdisciplinary learning is important for progress in a successful UK retrofit programme. Technical and social disciplines both have a clear role to play, but economic and financial disciplines must also be included. This type of expertise is necessary for researching innovative and effective ways of financing the necessary initiatives.

THINKING ABOUT FUTURE NEEDS

Finally, it should be remembered that some degree of progressive change in the UK climate is inevitable over the next few decades and there is value in ensuring that current retrofit projects are not incompatible with energy efficiency under future conditions. Particularly in commercial buildings, retrofit strategies may need to ensure that some adaptation flexibility is retained so that present carbon savings as a result of reduced heating or lighting are not wiped out by increased future needs for air conditioning or other carbon intensive technologies (TSB, 2010). It must be stressed that this consideration does not adversely affect the value of insulation measures, but may nevertheless affect other design considerations. For example, planning for increased solar gain may need to be balanced with optional shading strategies, or especially careful consideration given to the control of ventilation.

RECOMMENDATION: THAT A KEY POLICY PRIORITY FOR FUTURE RESEARCH SHOULD BE TO ADDRESS THE URGENT NEED FOR IMPROVED UNDERSTANDING OF THE REAL, IN-SITU PERFORMANCE AND PERFORMANCE DISTRIBUTION OF RETROFIT MEASURES, TOGETHER WITH IMPROVED UNDERSTANDING OF INSTALLATION PROCESSES AND THEIR IMPACT ON PERFORMANCE.

THEME 2: BUILDING ENERGY PERFORMANCE IS NOT WELL UNDERSTOOD

A TWO-FOLD PROBLEM: PREDICTION AND DELIVERY

In applying regulatory or other performance standards (such as the Code for Sustainable Homes or Passivhaus), the usual procedure at present is to evaluate design performance based on a theoretical model.

However, the problem with this approach is two-fold: firstly the difficulty of ensuring that the performance prediction in a particular case is accurate, and secondly the difficulty of ensuring that what is specified is actually built.

Predictions are often based largely on performance values for different elements – windows, doors, insulation etc. – which have been achieved in laboratory testing, under standard conditions. However, little may be known about their actual performance in-situ under widely varying conditions. Predictions also assume that the design will be built without error and exactly to specifications.

In some cases techniques for predicting performance may be inaccurate or may fail to include significant factors. A good example is the issue of the party wall bypass. A considerable body of work undertaken at Leeds Metropolitan University has demonstrated that a bypass mechanism operating in cavity party walls does in fact result in heat loss. This is contrary to the previously accepted view that the effective U-value (thermal transmittance) could be assumed to be zero, since equal temperatures on both sides of the party wall meant that there would be no simple conductive heat transmission (Wingfield 2010; Wingfield, Miles-Shenton and Bell 2009; Wingfield et. al. 2008).
As a consequence of this work an amendment was made to Building Regulations Part L 2010 to take account of the newly-understood loss mechanism. The new regulations now allow a U-value of zero to be assumed only if the party wall cavity is fully filled and edge-sealed, specifying nominal U-values of 0.2 W/m²K for those which are edge-sealed only, and 0.5 W/m²K for untreated cavities.

Other amendments to Part L 2010 are also aimed at addressing the performance gap, e.g. the application of 'confidence factors' to thermal bridging or pressurisation test values, in circumstances where detailed calculation or measurement is not undertaken, or the requirement for energy performance calculations to be submitted at the design stage as well as at completion. This trend is expected to continue in the next iteration of the review in 2013.

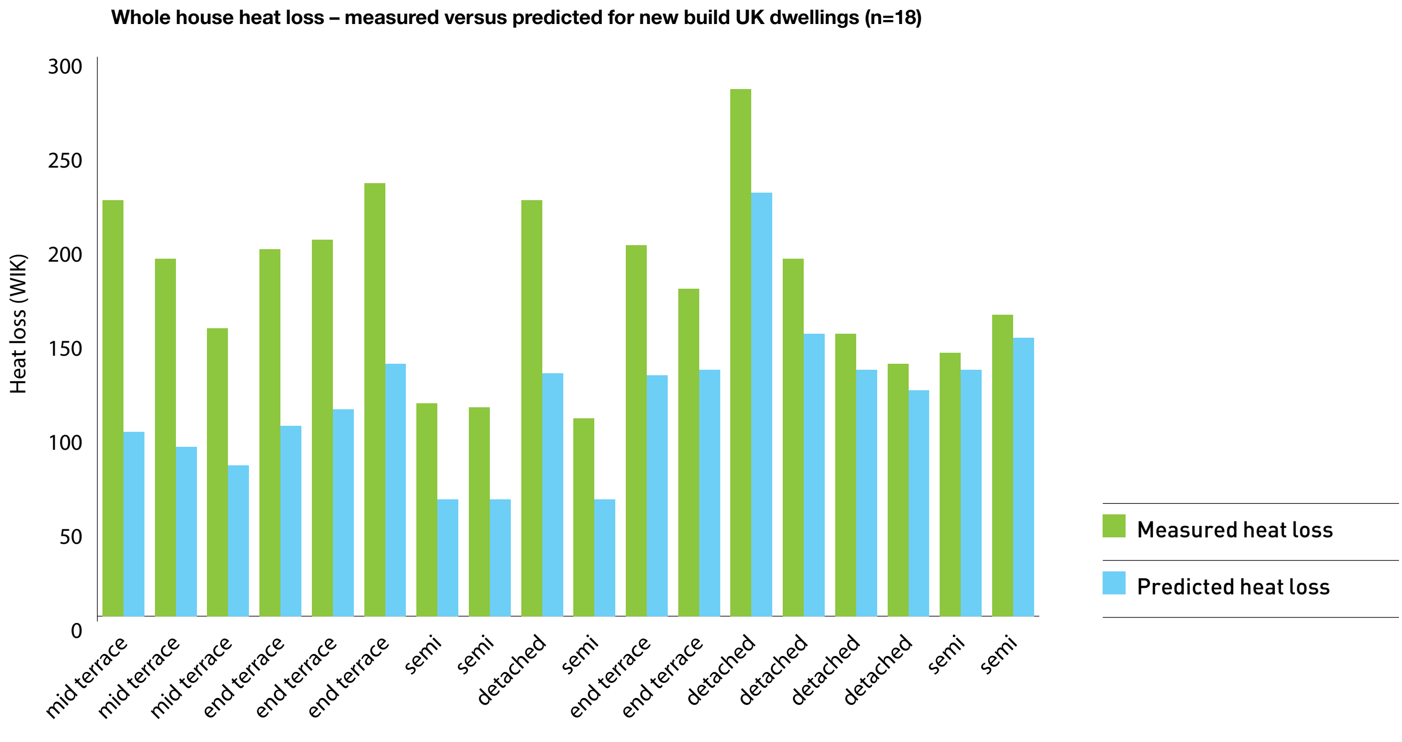

Fig.3a: Differences between predicted and measured whole house heat loss [Wingfield et. al., 2008], [Wingfield et. al., 2011], [Miles-Shenton et. al., in press, a], [Wingfield, Miles-Shenton and Bell, 2009], [Wingfield, Bell and Miles-Shenton, 2010]

However, even assuming that predictions are reasonably accurate, the problem of delivery remains. For new build in practice on-site, supply chain issues and time pressure often mean that materials and products are substituted for those specified at the last minute (Wingfield et. al. 2011). This may have knock-on effects, for example on detailing, which then may also be changed on-site. Finally there is the element of human error, and even that of experienced operatives ignoring design drawings and substituting a preferred construction that they have used in the past. All of these issues are likely to apply also to substantial retrofit projects.

At present, even contractors who are seriously engaged with learning and developing good practice find it difficult to transfer knowledge and experience between projects, because of the nature of workforce deployment in the industry.

All of the above factors mean that performance in practice tends to lag behind as-designed performance and furthermore varies from compliance in an unpredictable way.

THE PERFORMANCE GAP

Wingfield, Miles-Shenton and others have performed many detailed co-heating tests (Wingfield et. al. 2010) to measure whole-building heat loss coefficients on a variety of new build dwellings. Measured heat loss coefficients are almost always higher than predicted, sometimes by as much as 100% or more. This is likely to be attributable to a combination of incompletely understood prediction techniques, together with a failure to achieve the specified performance in practice. Figure 3a compares predicted whole-dwelling heat loss with the measured value in a total of 18 cases. Figure 3b ranks the same cases in order of discrepancy between predicted and measured mean U-values.

The cases in Figure 3 refer to new build dwellings, but similar performance gaps are observed for retrofit projects.

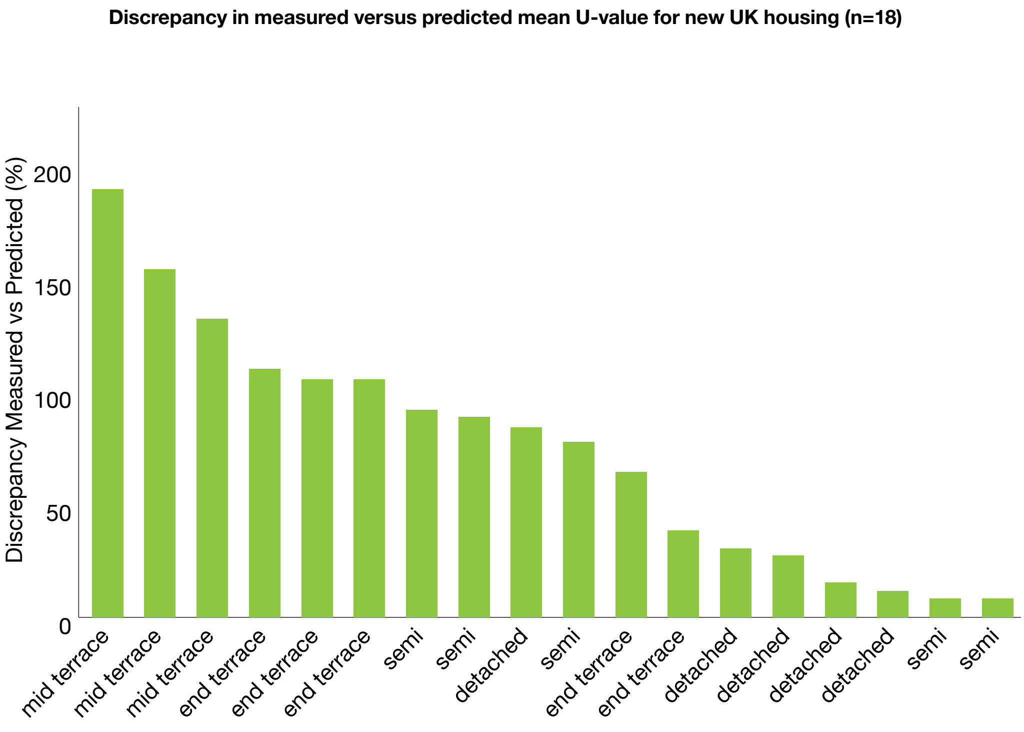

Fig 3b: Discrepancy in measured vs predicted mean U-values (references as for Fig 3a)

Figure 4 shows reductions in heat loss coefficients for the case of a staged refurbishment project, where co-heating tests were performed after each stage. It is clear that real and significant improvements in performance were observed at each stage, but nevertheless these were not as great as the predicted improvements.

Underlying the performance gap problem is a set of fundamental questions about design and construction processes. Design processes rarely make allowances for in-situ performance tolerances, modelling often contains input errors (Trinick et. al., 2009) and, as observed above, construction often contains deviations from design that are not well controlled. Although there is case evidence of the existence of a performance gap, very little is known about the links between process and performance. Some have argued that underperformance can be reduced by including a significant element of off-site production, but there is as yet very little data to support this view. Indeed data from the Elm Tree Mews project, one of the few off-site production dwellings that have been tested (Bell et. al., 2010) suggest that off-site production can exhibit a performance gap of the same order as traditional on-site approaches. It is likely that different construction forms and techniques will have different process control requirements and that as more is learned about in-situ performance, processes will need to be continually improved to ensure that not only is the gap closed but it is kept closed.

The first step will be to establish the links between process and performance. The introduction of government accredited installation standards for key energy efficiency measures as part of the Green Deal will be an important step forward in up-skilling. However, much retrofit work – particularly in the domestic sector – will continue to be delivered through sub-contractors and small builders outside government programmes. Against this background, internal dissemination and progressive learning and improvement within organisations in the construction industry will require considerable improvement from its present relatively poor level.

RECOMMENDATIONS: THAT SYSTEMATIC WORK SHOULD BE UNDERTAKEN TO CLOSE THE PERFORMANCE GAP BY IMPROVING UNDERSTANDING OF THE LINKS BETWEEN PROCESS AND BUILDING PERFORMANCE.

THAT METHODS OF ON-SITE TRAINING AND OF SHARING GOOD PRACTICE WITHIN THE INDUSTRY SHOULD BE REVIEWED, AND FURTHER RESEARCH UNDERTAKEN INTO EFFECTIVE ROUTES TOWARDS PROCESS IMPROVEMENT.

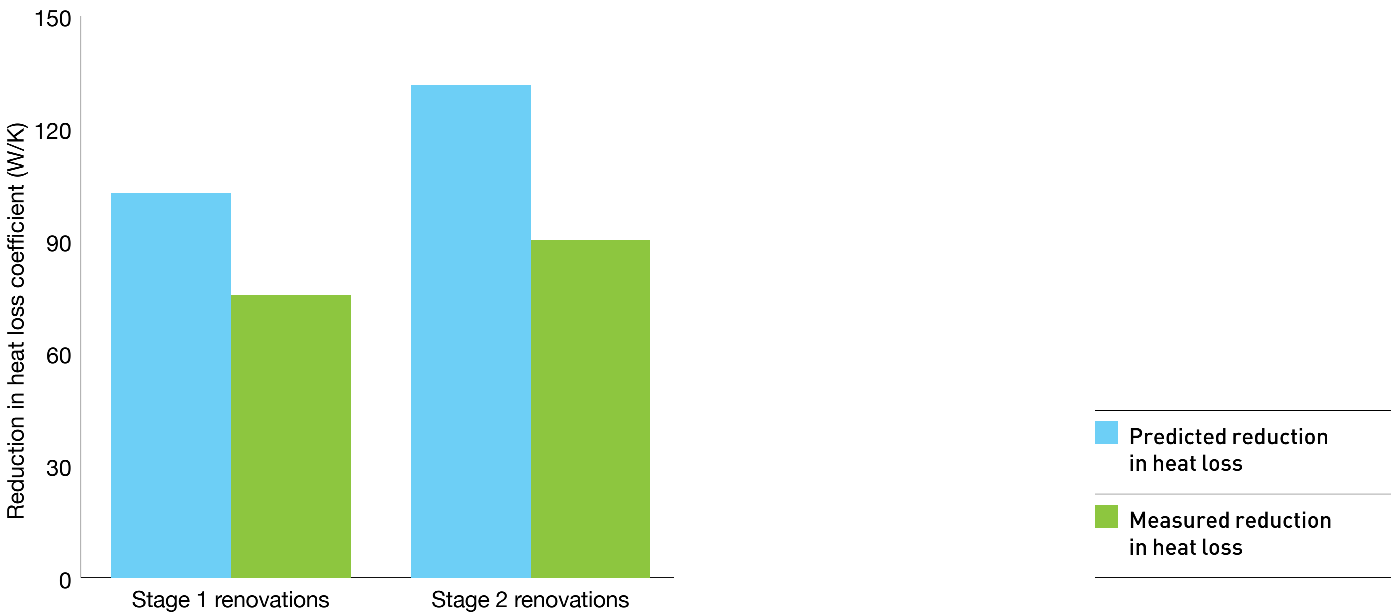

Fig 4: Predicted and measured reduction in heat loss coefficient for a two-stage refurbishment project [Miles-Shenton et. al., in press, b]

THEME 3: BUILDING FABRIC

Fabric performance is fundamental to achieving significantly reduced energy consumption while maintaining acceptable levels of thermal comfort. Only when fabric performance is clearly understood and optimised will further gains from behaviour change, on-site generation and other technologies become efficiently attainable. In the non-domestic sector there is currently a reluctance to invest in fabric performance and insulation. Organisations prefer to concentrate on non-fabric measures such as energy efficient lighting. However, policy interventions, such as the Carbon Reduction Commitment (CRC), may help to enhance the attractiveness of insulation measures in this sector in the future.

Many basic insulation measures, such as loft insulation and cavity wall insulation (CWI) are relatively inexpensive and offer payback periods which make them economically viable. Frequently these simple measures do not go far enough and policy interventions such as Green Deal (DECC, 2010b) will be required to achieve the enhanced standards which will support targets. It is estimated that around 40% of dwellings with cavity walls have cavity insulation (2006 figures). Also in 2006 almost 95% of accessible lofts reported having some insulation, though in the majority of cases this was considerably less than the currently recommended minimum thickness of 270mm (Utley & Shorrock, 2008).

Fabric performance generally is a complex web of interactions, including thermal transmission of elements (walls, floors, roofs, windows etc), air-tightness, thermal bridging and bypass mechanisms. It is therefore vital to regard refurbishment projects holistically, rather than as a series of disconnected measures, and to understand that the performance of measures in-situ can be affected by many factors, including process issues.

FABRIC PERFORMANCE TESTING

The measurement of whole-building heat loss via co-heating testing (Wingfield et. al. 2010) offers a method of assessing overall fabric performance. Performing a co-heating test before and after a refurbishment programme gives an excellent indication of performance gains. Unfortunately the technique is rather costly in terms of time, resources and expertise and, in its present form, is not likely to be practical as a standard or routine assessment tool for every retrofit project. However, as a research technique it is invaluable and could form part of a series of large-scale investigations, for example into the statistical distribution of gains achieved for different measures in different building types.

For measures intended to reduce heat loss due to air leakage, air-tightness testing (pressurisation testing) is a simpler, quicker and less intrusive method of assessment (ATTMA, 2006). However, it cannot provide an assessment of overall heat loss.

There is still much important methodological work to be done in developing robust whole-house testing methods, which can be routinely applied as part of the production process to verify quality and reproducibility.

CAVITY WALLS

As previously mentioned in Section 1, around 30% of current dwellings do not have cavity walls. For commercial stock, the figure is probably even higher. A significant proportion of the remainder have walls with un-insulated cavities. The ECI 40% House Scenario (ECI, 2005) assumes that 100% of cavity walls and 15% of solid walls would be insulated by 2050.

Following large-scale energy supplier funded programmes over several years, the percentage of cavity wall homes that presently remain unfilled is subject to debate, but in England is estimated to be around 43%, or almost eight million (DECC, 2011a). It is increasingly recognised that a significant proportion of cavity walls are unsuitable for cavity wall insulation for a variety of reasons. These homes will generally require solid wall insulation as for non-cavity wall homes.

Conventional retrofit filling of external cavity walls with mineral wool, glass wool or polyurethane foam is generally considered to be an effective and relatively low cost intervention, recommended for most buildings where cavities exist (EST, 2009).

Nevertheless, the gap between expected and real performance can exist even where accredited installers are following standard procedure. Investigations performed by the Centre for the Built Environment Research Group at Leeds Metropolitan University using thermal imaging and/or borescopy have shown a number of potential problems including areas of missing insulation, insulation material slippage, variations in density or incomplete filling of cavities (Miles-Shenton et. al., in press, b). The performance of many insulation materials is also affected by moisture.

Air movement in the cavities of internal party walls can also have a detrimental effect by allowing heat loss via a thermal bypass mechanism as described in theme 2.

It is clear from all of the above that the real gains made by current large scale programmes for insulating cavity walls are not yet fully and quantitatively understood.

SOLID WALLS

For solid walls, the choice is between insulating externally or internally. External insulation cladding is regarded as the better option, especially if windows and doors can be replaced and/or relocated at the same time so that the external insulation layer can be of uniform thickness. Room sizes are not reduced and the works need not be particularly disruptive to occupants. In larger buildings, external insulation can also have the added benefit of eliminating thermal bridges especially those at intermediate floor level. However, in some areas it is not currently acceptable to alter the external appearance of buildings.

A major drawback of internal insulation is the reduction in the size of the internal space. A more subtle consideration is the fact that internal wall insulation effectively reduces the apparent thermal mass of the building in question. This may or may not be desirable. For example, research evidence shows that low thermal mass can improve the controllability of heat pump systems, allowing greater reactivity and some planned variations in temperature to be achieved without incurring energy penalties associated with reduced heat pump efficiency (Boait, Fan and Stafford, 2011). Whilst this consideration is only one factor amongst many, it is a further example of the need to plan retrofit programmes in an integrated way from the outset.

LOFT INSULATION

Loft insulation to at least current Building Regulations standards is a clear necessity as a simple and effective measure. However, in view of frequent observations by researchers, it is vital that both installers and occupants understand the need for full coverage of the whole roof area – especially near eaves and in hard to access areas – in order to eliminate cold areas which could give rise to condensation and mould, as well as compromising thermal performance. Installers should also understand the need for the insulation to be in contact with the primary air barrier to prevent thermal bypassing.

AIR TIGHTNESS

Air tightness in new build has a maximum allowable value controlled by Building Regulations (currently 10 $m^3/h.m^2$ at 50Pa), but this aspect of performance is particularly vulnerable to subsequent modifications to the building structure, including significant retrofitting interventions as well as a host of more trivial activities that may breach the primary air barrier.

Air tightness can be measured via pressurisation testing and forensic investigations can be made via thermal imaging and smoke-testing. Such investigations at Leeds Metropolitan University have identified many common sites of unintended air infiltration, such as service penetrations, around trickle vents around and through loft hatches, around poorly-fitting windows and doors and into intermediate floor voids (Johnston and Miles-Shenton 2011). However, in addition to these direct leakage paths there can be many indirect paths which impact significantly on performance, and which are often less well understood (Wingfield et. al., 2008).

In retrofit projects, good air tightness is likely to be related to increased awareness and improved training procedures. Air tightness targets and the processes necessary to achieve them should be fully understood by all concerned from project design through every stage of implementation. The relationship between improved air tightness and ventilation requirements is an example of the necessity for a complete design strategy from the outset.

THERMAL BRIDGING AND BYPASSES

Again, process issues and more widespread understanding of the principles involved are key to improved performance. There is therefore a need for better training at all levels within the industry.

Thermal bypassing is complex and is often confused with air tightness. A thermal bypass occurs where air is allowed to move through, around and between the insulation – in effect bypassing the benefit of the insulation. Therefore, it is possible to have a very air tight house but still have thermal bypassing resulting in lower thermal performance. The air barrier and the thermal insulation should always be in the same plane and be in contact with one another in order to prevent bypassing, but this fact is not always appreciated by designers or on-site operatives.

RECOMMENDATIONS: THAT METHODOLOGICAL RESEARCH SHOULD BE UNDERTAKEN TO DEVELOP IN-SITU TESTING METHODS FOR ROUTINE USE IN PRODUCTION.

THAT THE REAL IN-SITU PERFORMANCE OF SIMPLE FABRIC MEASURES SHOULD BE BETTER UNDERSTOOD.

THAT TRAINING SHOULD BE IMPROVED ACROSS THE INDUSTRY TO ENSURE IMPROVED UNDERSTANDING OF THE PRINCIPLES OF HEAT LOSS MECHANISMS.

THEME 4: MICRO-GENERATION AND LOW-CARBON TECHNOLOGIES

In this category we include all those technologies with eligibility for Feed-in Tariffs (FiTs) or the planned Renewable Heat Incentive (RHI) payments. Those eligible at present are listed below:

ELIGIBILITY FOR FEED-IN TARIFFS

Feed-in Tariff eligibility (below 5 MW)

- Solar electric photovoltaics (PV)
- Wind power
- Hydro-electric power
- Anaerobic digestion (biogas for electricity generation)
- Micro gas powered combined heat and power (up to 2 kW)

Possible future eligibility

- Fuel cells

ELIGIBILITY FOR RENEWABLE HEAT INCENTIVE PAYMENTS

Renewable Heat Incentive eligibility (installations after 15/7/2009)

- Biomass boilers
- Biogas combustion (up to 200 kW)
- Deep geothermal
- Ground source heat pumps
- Solar thermal (up to 200 kW)
- Water source heat pumps

Possible future eligibility

- Air source heat pumps
- Hot air heating (e.g. kilns)
- Bio-liquids
- Landfill gas

The RHI scheme for domestic renewable heat installations will not come into full operation until October 2012. However, a fund of around £15m has been provided to enable interim, one-off payments to support installation of some technologies (air source and ground source heat pumps, biomass boilers and solar thermal) between 1 August 2011 and 31 March 2012. This is the Renewable Heat Premium Payment (RHPP) and single payments will be made on a first-come first-served basis. The value of the payment depends upon the technology chosen and ranges from £300 for solar thermal to £1,250 for ground source heat pumps. Only off gas-grid households are eligible for payments, except in the case of solar thermal (all households eligible). Other conditions of participation include micro generation certification (MCS) of both products and installers and the willingness to participate in monitoring if selected at random to do so. The element of monitoring will be an important factor in building up evidence about the real in-situ performance of the technologies in different circumstances, and may be used to inform tariff levels at the official start of the RHI scheme.

FABRIC FIRST – BUT ESTABLISH AN INTEGRATED STRATEGY FROM THE OUTSET

It is clear that RHI technologies should only be installed after appropriate energy efficiency interventions have already been undertaken, and indeed this is a requirement of eligibility for payments under the scheme.

What can sometimes be less well understood are the advantages to be gained from approaching refurbishment strategically as a whole rather than in a piecemeal fashion. This can save costs and ensure that conditions for the performance of the technologies are optimised. One obvious example is where roof replacement can be combined with PV installation, to save costs on building materials by specifying BIPV (building integrated PV), or on access arrangements by undertaking the work as one package. Another example is where floor works could be combined with installation of under floor heating pipes in order to improve the performance of a proposed heat pump system. The relationships between fabric and technologies can often be quite complex, as in the issue of heat pump controllability discussed in Key Theme 3.

ECONOMIES OF SCALE

Social housing providers (e.g. local authorities) can be influential in installing large numbers of renewable and low carbon technologies, taking advantage of the ability to reduce costs via economies of scale. However, this can result in a tendency for a single technology type to be championed and hence installed in both optimal and sub-optimal circumstances. Examples of this would be installation of PV on roofs with non-ideal orientations or tilt angles, or installation of heat pumps as replacement heating systems in properties which are on the gas grid (Stafford and Bell, 2009).

MORE CLARITY REQUIRED

Owners and adopters of renewable technologies are currently not always well served by their energy suppliers in terms of easy access to advice and appropriate tariffs. The need for more clarity with regard to information dissemination and also the need to improve and simplify the MCS and to review training, have all been acknowledged by government in the recent Microgeneration Strategy report (DECC, 2011b).

A number of issues around RHI payments and the assessment of outputs are still to be resolved. It is not yet clear whether domestic or small-scale RHI payments should be made on the basis of routinely metered output or 'deemed' output, whereby a level of generation is assumed based on the size of the system installed. Metering might potentially give rise to conflicts of interest in landlord/tenant relationships, giving the owner (as recipient of RHI payments) less incentive to adopt energy saving measures. Similarly, metering raises issues of protocols, equity and system boundaries. It is not always a simple matter to determine heat output accurately. For example, in the case of heat pumps, the location of meters can significantly affect the measured output in ways that are not easily standardised between different installations (Stafford, 2011). While these are both good arguments for using 'deemed' output, this approach is potentially problematic in terms of accuracy and assessing the output of individual systems.

RECOMMENDATION: CONSIDERATION SHOULD BE GIVEN TO ESTABLISHING SETS OF INTEGRATED DESIGN SOLUTIONS FOR WHOLE HOUSE IMPROVEMENTS COVERING ENERGY EFFICIENCY AND RENEWABLE ENERGY. SUCH INTEGRATED SOLUTIONS SHOULD BE FIRMLY UNDERPINNED BY MONITORED IN-SITU PERFORMANCE DATA, WHICH SHOULD BE READILY AVAILABLE, FOR EXAMPLE BY FORMING PART OF A UK DATABASE OF SYSTEM PERFORMANCES.

THEME 5: PEOPLE USE ENERGY

No matter how well performing the building fabric, or how suitable and effective the micro-generation technology, it is an inescapable fact that overall energy use depends to some extent upon occupant behaviour. In fact, the ECI 40% House report (ECI, 2005) states that: "if UK society continues to develop along current trends, no carbon reductions are expected by 2050. Only societies where environmental concern and awareness are much stronger than today will produce significantly reduced carbon emissions." This is a complex area of study, encompassing issues of occupancy and employment patterns, day-to-day behaviour and attitudes, and user experiences of interaction with services and technologies. Many of these issues are explored in some detail in the Joseph Rowntree Foundation low carbon housing study 'Lessons from Elm Tree Mews' (Bell et. al., 2010).

FEEDBACK

It has been suggested that appropriate feedback can be helpful in encouraging people to reduce energy use and much has been made of the future role of smart meters in providing this feedback. However, the long-term role of feedback is complex and uncertain. The recent Energy Demand Research Project (AECOM, 2011) found that interventions without the use of smart meters generally did not result in energy savings, whereas the use of smart meters combined with Real Time Displays could achieve savings of around 3%. However, the evidence was somewhat difficult to interpret since the trials were not standardised between the different suppliers and a range of additional interventions were used simultaneously, leading to variable results. The simplest and most user-focussed form of feedback at present is probably that provided by simple pre-payment meters – the Gentoo group (2010) found that customers who use pre-payment meters were generally more conscious of their energy usage than those who paid monthly or quarterly bills though this is almost certainly related to income levels.

Between 2014 and 2020, every British home will be fitted with a smart meter, including an in-home display of energy use. To be of significant benefit to consumers, an EST study concluded that smart meters should be located appropriately within the dwelling, be easy to read and interpret, and include real-time information in the form of costs (£/day) as well as power consumption (watts) (EST, 2009). This EST study found that there were also strong preferences for graphical displays in addition to digital information, and for historical data and data on cumulative daily spend to be accessible. Comparisons of usage against a local average or norm may also help to encourage and sustain desirable behaviours. Work still remains to be done on maximising and quantifying the effectiveness of such comparisons, and on understanding how engagement can best be encouraged to persist rather than decline over time with exposure.

TAKE-BACK EFFECTS

In dwellings where fuel poverty is a factor in restricting energy use, the effect of retrofit interventions may not be to reduce consumption, but instead to allow occupants to increase their levels of comfort. This is the so-called 'take-back' effect. For example, in their social housing study the Gentoo group (2010) found that homes with the lowest energy use before retrofitting interventions achieved the lowest savings afterwards, and they attribute this to the fact that these customers preferred additional comfort and warmth over money savings. Clearly then, in the worst cases it is possible that retrofitting interventions may neither reduce energy usage nor be sufficient to lift occupants out of fuel poverty, even though the interventions are effective.

UNDERSTANDING REAL BEHAVIOUR

It is also vital to ensure that there is a robust understanding of real practices, preferences and behaviours within the population. For example, the fact that improvements in energy efficiency have failed to result in expected energy savings has sometimes been attributed to assumed increases in internal demand temperatures over recent years. However, a repeated cross-sectional social survey of owners of centrally heated English houses found no evidence of change in reported thermostat settings between 1984 and 2007 (Shipworth, 2011). The lack of expected savings has instead been attributed to factors such as energy efficiency interventions failing to deliver expected performance, increased penetration of central heating (so that mean daily temperatures are increased but not maximum temperatures), increases in the dwelling area heated or the duration of heating, or changes in behaviours such as window opening.

POST OCCUPANCY EVALUATION

It is becoming increasingly common to assess the performance of larger commercial buildings and some others via Post Occupancy Evaluation (POE), which consists of a detailed study based on questionnaires, walk-through surveys, interviews and other techniques. This type of research focuses on the experience of the actual building user and can be an invaluable source of learning, provided the prevailing culture is tolerant of freely available information relating to failures as well as successes (Leaman, Stevenson and Bordass, 2010). POE may have an increasing role to play in the domestic sector also, either in new build or after significant retrofit interventions. It has the capability of generating rich data about the actual practices of building users, as well as the performance of technical interventions. It is vital that this growing knowledge is systematised and properly analysed if it is to be useful in informing retrofit strategic design in the future.

In commercial buildings it has long been assumed that thermal comfort is best provided by a neutral and unchanging environment. However, recent research strongly suggests that people prefer an environment that includes some variation, especially if they have a degree of personal control or at least opportunities for adaptive behaviours, such as additional clothing or access to windows and thermostats.

As well as deliberate behaviours based upon occupant preferences, practices arising from poor functioning or commissioning of services can also affect energy consumption. For example, in the Stamford Brook large-scale energy monitoring project (Sutton et. al. 2011), a particular dwelling was identified where the electricity consumption was well in excess of that expected, given a detailed understanding of the fabric and occupancy patterns (although still within the normal range for UK dwellings as a whole). Upon further investigation the problem was found to be caused by a commissioning failure. Incorrect installation of the heating system had resulted in all hot water being supplied by an immersion heater instead of the gas boiler, without the occupants being aware of this fact. Without the detailed knowledge of the monitoring team this error may not have come to light. Similarly, researchers at Leeds Metropolitan University have frequently observed MVHR systems that have passed commissioning checks but have not, in fact, been operating within parameters.

RECOMMENDATION: THAT THE CURRENT TREND TOWARDS REAL-WORLD SOCIO-TECHNICAL RESEARCH, INCLUDING RESEARCH INTO THE DRIVERS AND BARRIERS ASSOCIATED WITH BEHAVIOUR CHANGE, AND THE UNDERSTANDING OF REAL PRACTICES SHOULD CONTINUE TO BE WELL-SUPPORTED, AND SHOULD INFORM POLICY WHERE APPROPRIATE.

THEME 6: THE IMPORTANCE OF ICT AND MONITORING

ICT has a vital role to play in providing the tools needed to achieve the goals identified in the previous themes. ICT can support the collecting and organising of data, dissemination of knowledge, improvement of design processes, appropriate feedback and understanding of routes to durable behaviour change. Without ICT none of this activity would be possible on a sufficiently ambitious scale to meet proposed targets.

Because of the almost universal nature of its applicability, we confine ourselves in this report to highlighting a few illustrative examples of current ICT research, demonstrating how they feed in to the previous themes.

ICT AND THE DISSEMINATION OF KNOWLEDGE IN DESIGN AND CONSTRUCTION

In Theme 2 we discussed issues of understanding the thermal consequences of designs and the difficulties of learning efficiently from past experience. A large proportion of design and construction is undertaken by small organisations that may find it particularly difficult to access practical knowledge from intensive studies undertaken by larger and better resourced organisations. Even within larger organisations, communication of lessons learned may be poor, or may be hampered by significant outsourcing. Therefore there is a clear need for readily accessible information on 'what works and what doesn't work' and assistance with designing for improved thermal performance.

Similarly, as discussed in Theme 5, the lessons learned from POE studies are also often difficult to disseminate widely and effectively and ICT tools could help to facilitate dissemination of techniques and data.

De Montford University is currently undertaking research within the LESSONS project (Wright, n.d.) with the aim of establishing an accessible database of case studies on building performance, together with designer-centred tools which will enable rapid formulation and evaluation of proposed designs, including retrofit and new build. The success of this approach will depend very much on the open contribution of experience from research and practitioner organisations to inform best practice design and evaluation.

ICT AND BUILDING PERFORMANCE VISIBILITY

Theme 3 emphasised the importance of building performance, especially in terms of the building fabric. In the non-domestic sector building energy performance is characterised by the Energy Performance Certificate (EPC) and by the Display Energy Certificate (DEC), which has to be displayed in the building itself. However, access to the latter information is limited and often only visible to visitors to the building. Using ICT appropriately, there is no reason why this information should not be freely and openly available online, and consequently fully in the public domain. Indeed, this could go further, to include detailed monitoring data relating to real energy consumption. This approach would also help to identify areas where the EPC model might be failing to match the real performance.

ICT AND BEHAVIOUR

ICT need not be seen as a 'top-down' solution, precluding user engagement. It has the capacity to focus on energy users, both as individuals and as groups, providing valuable information on practices and preferences, and hence enabling acceptable and durable behaviour changes.

The factors that influence and entrench behaviour change are not yet well understood, but it is clear that feedback in appropriate user-responsive forms is a necessary pre-condition. The current EPSRC project 'Reduction of Energy Demand in Buildings through Optional Use of Wireless Behaviour Information (Wi-be) Systems' (Li Shao, 2010), explores the use of wireless systems for monitoring personal energy use and feeding back information in a form that is preferred by the user (e.g. to mobile phones or personal computers). The system is low cost and low power, and is applicable in principle to both workplace and domestic use, but does require both in-building and on-body sensors. There may be considerable scope here for acquiring a better understanding of the practices and motivations of different groups, with different initial attitudes to energy saving.

ICT AND MICRO-GENERATION

As the penetration of renewable energy sources increases, grid management and supply management issues become more and more important. ICT will be vital in tracking, monitoring and optimising micro-generation installations, and in identifying opportunities for demand management and the use of multiple systems to maximise local renewable energy use.

Again the users should be placed at the centre of technology development. An example of user-centred design is the Wattbox, developed at De Montfort University. This device learns behaviour patterns from users and controls multiple micro-generation devices based on this insight. By doing so, the ICT technology returns the control of novel, sometimes complicated and off putting technologies to users of all levels of technical competency. As a result, not only are energy efficiency and indoor comfort maximised, the acceptability and uptake of novel energy technologies are also greatly enhanced, thanks to user involvement in control.

RECOMMENDATIONS: THAT FURTHER RESEARCH SHOULD BE UNDERTAKEN WHICH EFFECTIVELY COMBINES INNOVATIVE ICT INTERVENTIONS WITH REAL ENERGY MONITORING AND SOCIAL INVESTIGATIONS IN ORDER TO INCREASE UNDERSTANDING OF THE TYPES OF BEHAVIOURAL ISSUES THAT CAN BE ADDRESSED USING ICT.

THAT ICT SHOULD ROUTINELY BE USED AS A TOOL FOR THE DISSEMINATION OF TECHNICAL AND DESIGN INFORMATION, FOR USE BY SMES AS WELL AS LARGER ORGANISATIONS.

THAT ICT FOR BUILDING ENERGY CONTROL SHOULD ADOPT A USER-CENTRIC APPROACH; AUTOMATIC CONTROLS SHOULD BE BASED ON USER BEHAVIOUR INFORMATION AND MANUAL CONTROLS SHOULD BE INFORMED BY SMART INFORMATION TECHNOLOGIES.

CONCLUSIONS

Retrofitting of existing buildings for improved energy performance will play a vital role in achieving the UK's carbon reduction targets, but the problem is complex and the route to optimum effectiveness is not yet clear.

Investment in research is required to ensure real and progressive savings. This research must be interdisciplinary in nature, bringing together technical, social and economic expertise.

Ways must be found of enabling fundamental changes to be made in the industry, including better training at all levels as well as improved dissemination of knowledge and best practice.

ICT can support and enhance the process of identifying and delivering necessary change in all areas, including user-centred learning.

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ABOUT US

The Centre for Low Carbon Futures is a collaborative membership organisation that focuses on sustainability for competitive advantage. Founded by the Universities of Hull, Leeds, Sheffield and York, the Centre brings together multidisciplinary and evidence-based research to both inform policy making and to demonstrate low carbon innovations. Our research themes are Smart Infrastructure, Energy Systems and the Circular Economy. Our activities are focused on the needs of business in both the demonstration of innovation and the associated skills development. Registered in the UK at Companies House 29th September 2009 Company No: 7033134.

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OCCUPANT USE OF WINDOWS IN CONTROLLING PERSONAL VENTILATION TO PROVIDE ADEQUATE INDOOR ENVIRONMENT CONDITIONS

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In buildings, a large proportion of energy use is due to space heating and so improvements in energy efficiency through improved insulation and air tightness can significantly reduce energy demand. Ventilation is associated with indoor air quality (IAQ) and consequently the health and comfort of building occupants. Ventilation is generally provided by air infiltration (uncontrolled) and purpose-provided (controlled) ventilation. Reduced infiltration due to improved insulation and increased airtightness will lead to greater dependency on appropriate ventilation design to provide adequate indoor air quality. In naturally ventilated buildings, window use is necessary in addition to background, uncontrolled ventilation to provide adequate ventilation and IAQ. To support the growing interest in energy efficient buildings, there is a need to understand occupant behaviour in buildings with openable windows, particularly, the influence of indoor environmental conditions on window use behaviour. The aim of this project is to observe if manually operated windows can be used to achieve adequate IAQ. This will explore the relative importance of indoor environmental conditions on occupant control of ventilation to achieve adequate IAQ. A pilot study has been designed to observe occupants' response to indoor environment conditions through interaction with windows. The indoor environment and occupant use of windows will be recorded during the test using data loggers. In addition, subjective perception of the environment will be evaluated using questionnaires issued to participants during the test. On completion of the project and based on the results, an improvement can be made to the representation of window use in building performance simulations.

Keywords: indoor air quality, occupant control, ventilation, window use.

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BIODGEMA

OUR APPROACH TOWARDS SUSTAINABILITY

BIODEGMA GmbH
Martin- Luther- Str. 26 / 71636
Ludwigsburg / www.biodegma.de

Who we are

BIODEGMA is a supplier of waste treatment technologies.
with more than 15 years experience in engineering and construction.

BIODEGMA was the first company to use semi-permeable laminates in the aerobic treatment of biogenic waste.

The annual throughput volume of plants in operation is exceeding 928,000 tonnes per year

Project Management DIN ISO 9001 certified
Technology ABPR approved

All BIODEGMA-sites in Germany are certified and producing compost according to the RAL-quality label of the German „Bundesgütegemeinschaft“ (European Compost Network ECN Quality Assurance)

Group of companies

Privately held group of companies

Shareholders: Herbert a. Manfred Eichhorn, Reiner Glock, Bernd Jörg, Ralf Müller

BIODEGMA GmbH

Engineering and Construction of Waste Treatment Plants

BINOWASTE GmbH (100% BIODEGMA)

Engineering and Construction of Waste Treatment Plants

BEM Umweltservice GmbH

Service Provider for

Waste Management and Reycling

KGH Umweltservice GmbH
Composting Plant Obersontheim

49% BEM

B & P GmbH
Composting Plant Walldorf

51% BEM

CaRo Süd GmbH Co. KG 60% BEM

RDF Management and Recycling

BB-Umweltinvest GmbH & Co. KG

Beteiligungsgesellschaft

COMPARIS GmbH & Co. KG 25% BEM

Marketing of Compost

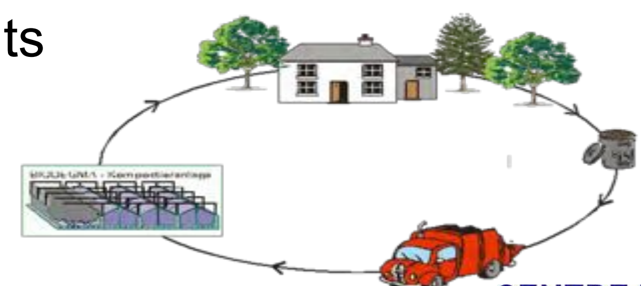
What we do

Waste Management and Recycling (BEM/CaRo/Comparis)

- Management and Logistics of biodegradable wastes (130.000 t p.a.) and RDF (75.000 t p.a.)
- Operation of Treatment Plants (BEM -Germany)
- Investment in New Plants (BEM - Germany)
- Recycling of compost fertilizers to farmers (35.000 t p.a.)
- Quality Management

Engineering and Construction (BIODEGMA)

- Design and Construction of Aerobic Waste Treatment Plants
- Planning Scope from Basic Engineering to detailed Design
- Improvement of existing plants
- Consulting



Where we are

- Finland
- Sweden
- Poland
- UK
- Spain
- Germany
- Slovenia
- Argentina
- China (Project Management)

Sites with treatment capacities from 5,000-200,000 tpa in operation

Proven track record of more than 35 reference sites

BIODEGMA GmbH
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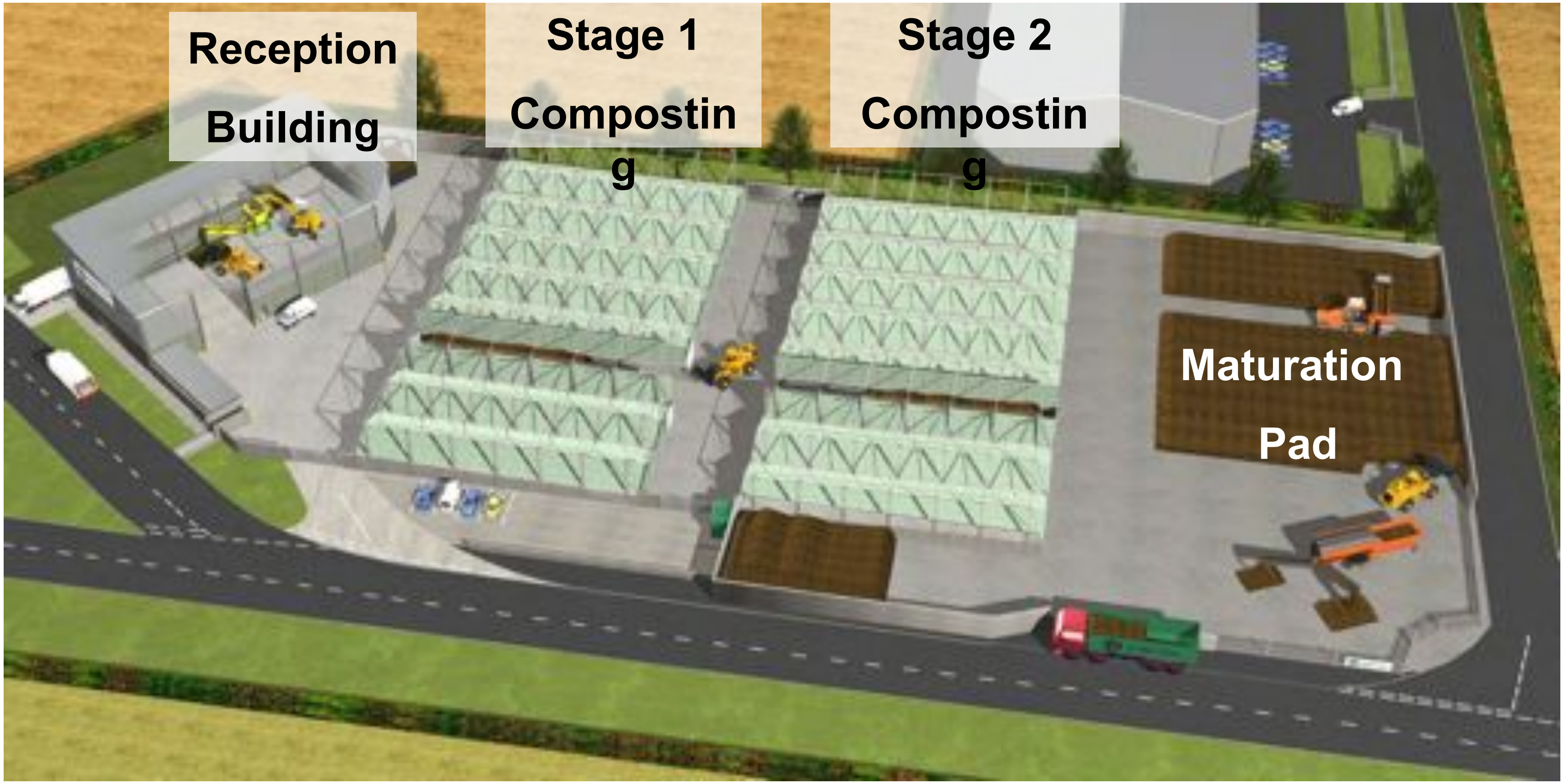
The BIODEGMA System

Tunnel Composting – In Vessel Composting (IVC)



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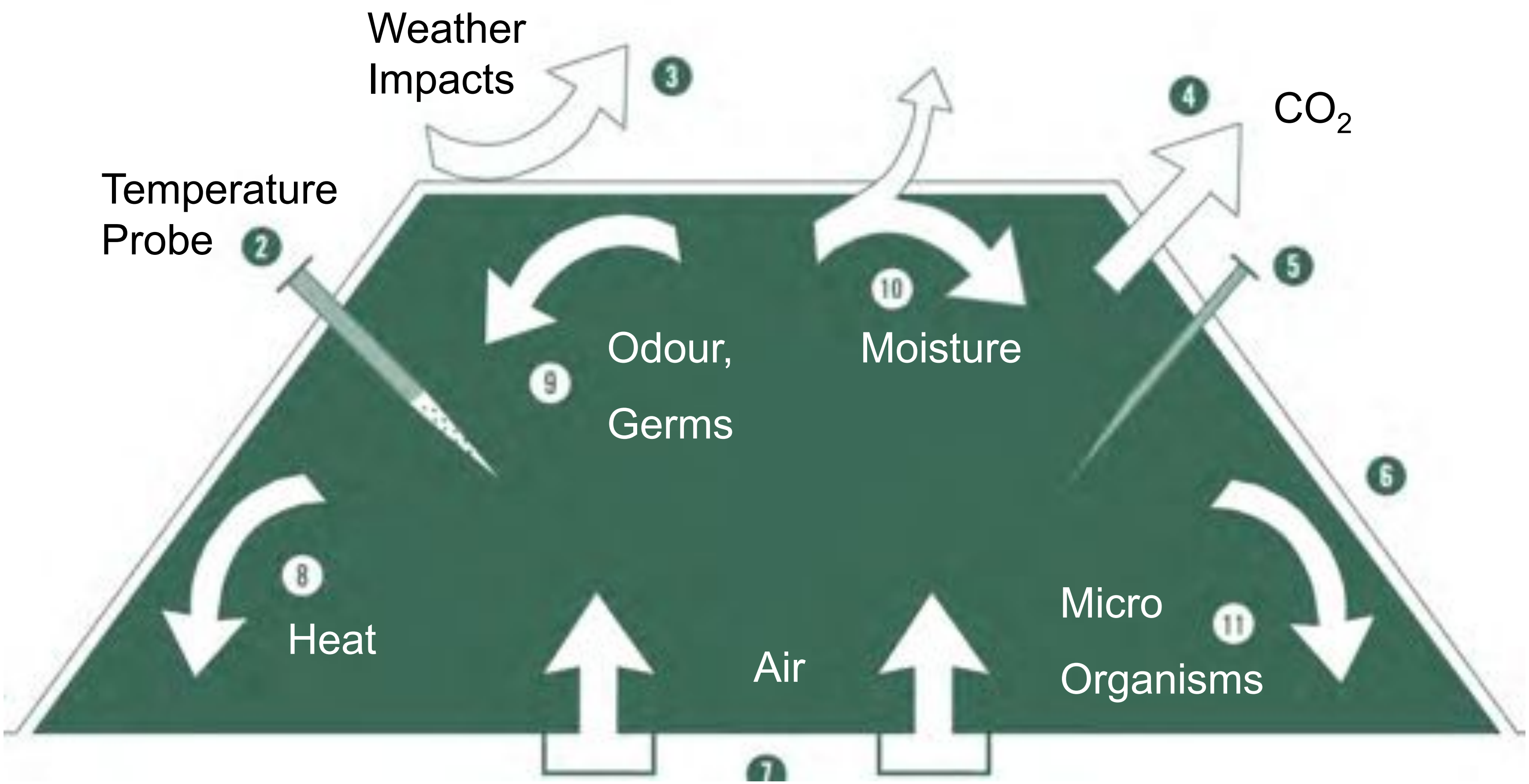
BIODEGMA Composting Tunnel

Principle GORE™ Cover



BIODEGMA System: Components

- Infloor aearation system for positive aeration
- PLC control and temperature monitoring
- Control and Documentation Software
- Semipermeable Membrane with automatic roof construction

Input Material and Products





Kitchen Waste Catering Waste	Sludges Sewage Waste	Green Waste	MSW	MSW
Composting	Composting	Composting	Stabilization	Drying
Compost Fertilizer	Compost Fertilizer	Compost Fertilizer	EU landfill directive	RDF

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References – MBT Elblag, Poland
28.000 t p.a. organic fraction of household waste

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References – MBT Plonsk, Poland

13.000 t p.a. Organic Fraction of Municipal Waste (30-80mm)

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References IVC Edmonton, UK

30.000 t p.a. Kitchen Waste

References MBT Cordoba, Spain

85.000 t p.a. Municipal Waste (MSW)

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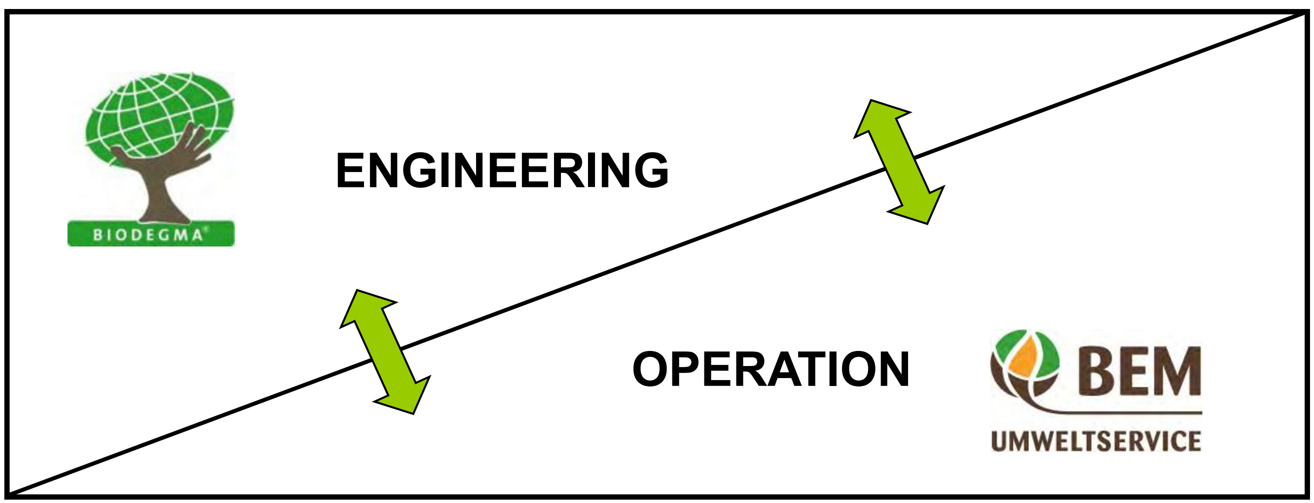
OUR APPROACH

Sustainable Development of our technology through a constant transfer of experience from site operations into the design of the BIODEGMA technology



LESSONS LEARNED

Waste Treatment requires

- A robust and reliable technology
- Easy Maintenance and Cleaning
- High Availability
- Protection of your Workforce
- Protection of your Surroundings and the Environment
- Expertise in Planning and Operation

BIODEGMA System: Characteristics

- Modular Design
- Very **Low energy consumption** in operation (5-8 kWh/ton)
- **Low maintenance and repair** (3 - 5% p.a. of investment costs)

- High Flexibility
- Modular design and use of mobile machines avoids „bottlenecks“ -> **high availability of the technique**
- Significant reduction of **odour and bioaerosols** by the use of semipermeable membranes. No expensive odour treatment with biofilters: Odour freight reduction > 90% by use of the membrane
- Flexibility / Adaptability – many different wastes treatable
- **Very low Carbon footprint** of the treatment process (12 kg CO_2- Eq. / MG Input – Average of all composting systems in Germany is 47 kg CO_2- Eq. / MG Input)
- Composting has been proven to have a **negative Carbon Footprint**
- Low **water consumption**. Separate collection of rain water and leachate water.

OUR APPROACH

Germany based SME company delivers its technology world wide

- Installation is splitted in local part (civils, infrastructure,…) and installation of technology (BIODEGMA)
- Know how is with the main supplier (BIODEGMA)

-> knowledge transfer to local (construction) companies neccessary

-> get into projects as early as possible

-> establish local partners (business case: ICC (UK Civils))

Advantages (expected)

- Market Access via local partners
- No „Language Issues“ and local presence

OUR APPROACH to the ‚*new*„ partnership
The Problems, in theory..

- Here we have a highly effective new technology,
- & A market,
- We ought to be selling a lot….
- As with all sustainable technologies the purchase decision is complex, solutions must be designed..
- Co-ordination requires project ***management*** on site supervision, design planning and preparation....

- To assist this situation the SCM theory suggests we by moving towards repeatable ‚products„

OUR APPROACH to the ‚*new*„ partnership
The Solution, in theory..

- To assist this situation the SCM theory suggests we can achieve this through more towards repeatable ‚products„

- Remove overheads
- Improve the delivery reliability
- Speed solution delivery
  - In design
  - In construction

Latham 30%
Egan ++%

OUR APPROACH to the ‚*new*„ partnership

The Solution, in practice..

FHWS

Hochschule für angewandte Wissenschaften
Fachhochschule Würzburg-Schweinfurt

Frame the problem (With the Universities)

- Examine the case study, ***off-line from any agreement or contract****.
- A UK ‚partner„ emerges..
- Solutions emerge, and are listed as ‚***candidates***„
- The detail of the issues emerge as *proposed* ***solution candidates*** *are* ***rejected*** and an understanding of the products/service develops (***the knowledge project***)
- ***Risks are refined***.
- ******* Any agreement relies on a cooperative solution***. Win-Win***
- (Not trust, but a shared interest.) This directly supports our Anglo-German workshop findings.
- Now the framework for solution testing in feasibility is created……

OUR APPROACH to the ‚*new*„ partnership
The Solution, in practice..

Now the framework for ***solution testing*** in feasibility is created……

- And some serious on-site “**Value Engineering**” occurs…
- Again off-line, no order yet..
- …leads to pre-cast modularisation, standardised design, rationalisation of critical performance systems, fixing of the rest of the supply chain,
- ..now there‟s a „product‟ off the shelf, still customisable, and risk to customer removed.

What becomes possible..

- Improved design,
  - For performance, (**+ 20%**)
  - For installation. (**+ 100%**)
  - Reliability of the Quality of product (**+ ??%**)
- Modularisation & Standardisation of previously in-situ,

locally sourced sub-contracts.

Confirming
Latham & Egan‟s
high expectations

OUR APPROACH to the ‚*new*„ partnership

What have we really done?

- Framed the problem,
- Using an Interest Based Negotiati
- That was „facilitated“ (Needed to i
- And itself created a thinking „spac en.
- Dramatic improvements that „relea
- Certain knowledge more can be d
- Joint motivation to create sales su
- “trust” ? , Mutual gain, & No p

2. Analysis Diagnose the problem Sort symptoms into categories Suggest causes What is lacking Note barriers	3. Approaches What are the possible strategies? What are theoretical cures? Generate broad ideas about what might be done.
1. Problem What‟s wrong Current symptoms? What are the disliked facts compared with a preferred situation?	4. Action ideas What might be done? What specific steps might be taken to deal with the problems

CONCLUSIONS

Develop Cradle to Grave Solutions: Looking *„behind the boundaries“*

for both the product and the way it is delivered

Constant Improvement through information flow between Operation and Planning: Deliver a technical Solution AND know how

Develop a indivisible network through *strong* Partners

Deliver a robust and durable solution with no losses, & many quality gains.

Further reducing our Carbon Footprint and save water

How: Off line (University initiated) innovative environment, mutual gain, facilitated problem solving,

All possible without formal agreements.

THANK YOU

BIODEGMA

ICC

FHWS

Hochschule für angewandte Wissenschaften
Fachhochschule Würzburg-Schweinfurt

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Issues in domestic sector decarbonisation

an economist's perspective

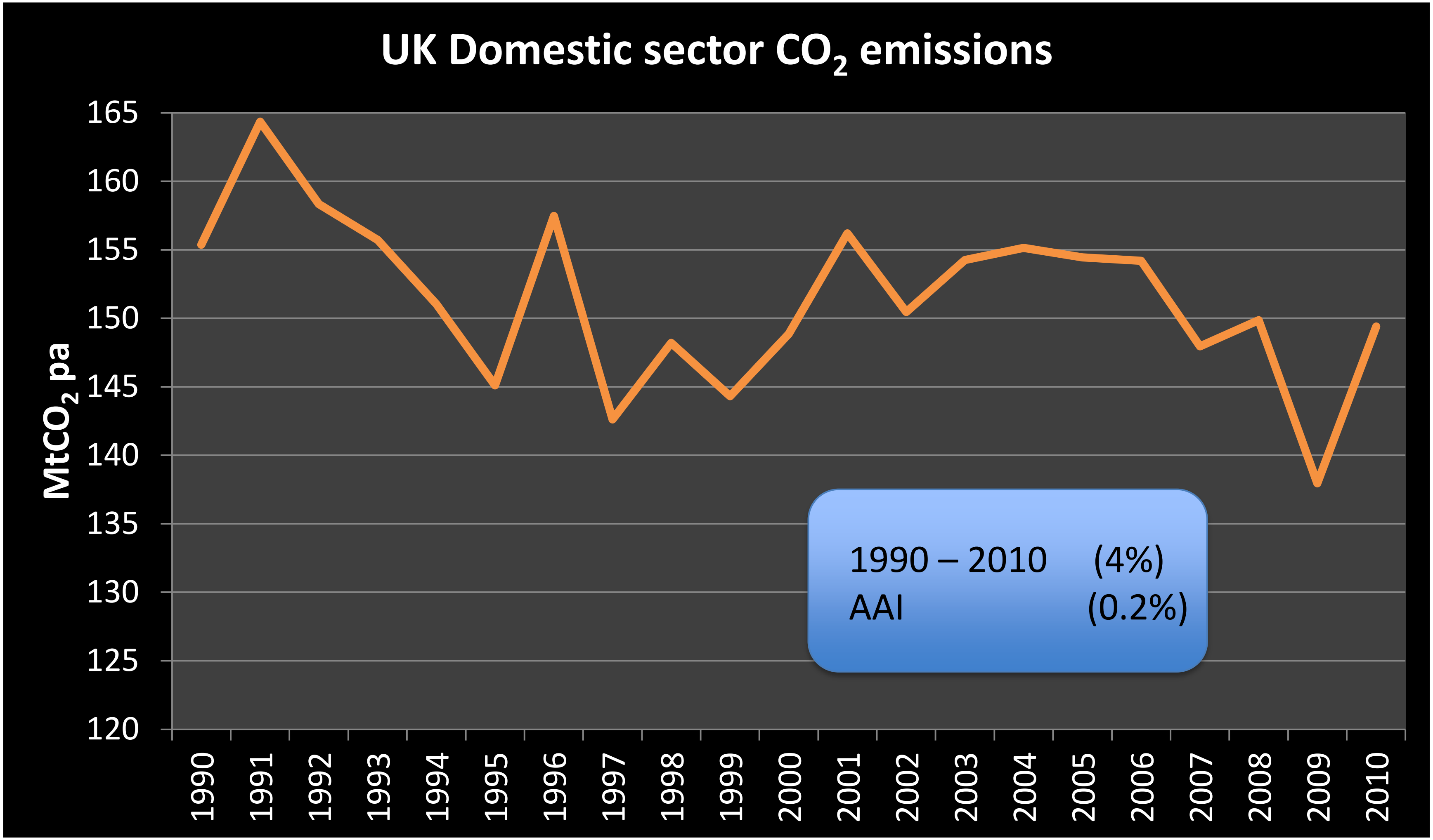
John Bradley

LEEDS METROPOLITAN UNIVERSITY

Climate Change Act (2008)

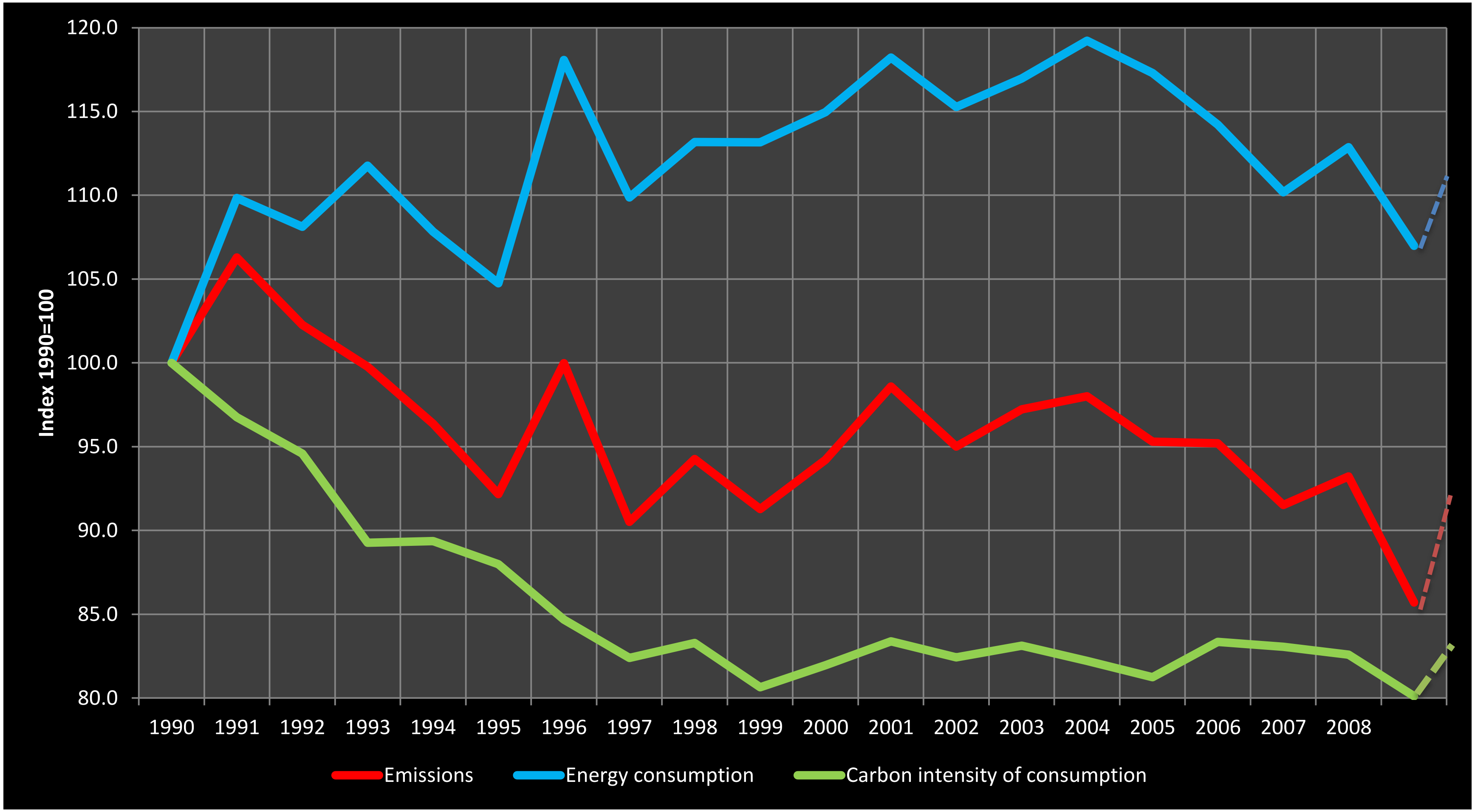
- **Born out of economics… the Stern Review (Stern, 2006)**
- **Blair ‘The economic benefits of strong early action easily outweigh the costs’ (Stern, 2007 p.ii)**

This is what has been achieved in 20 years



Net CO_2 emissions by end user: residential combustion, including allocated end use share of CO_2 emissions from electricity generation
Data Source: **DECC, 2011**. 2010 author estimate

Emissions, energy consumption, carbon intensity



Time series decomposition

- **Temperature correction**
- **Kaya identity**

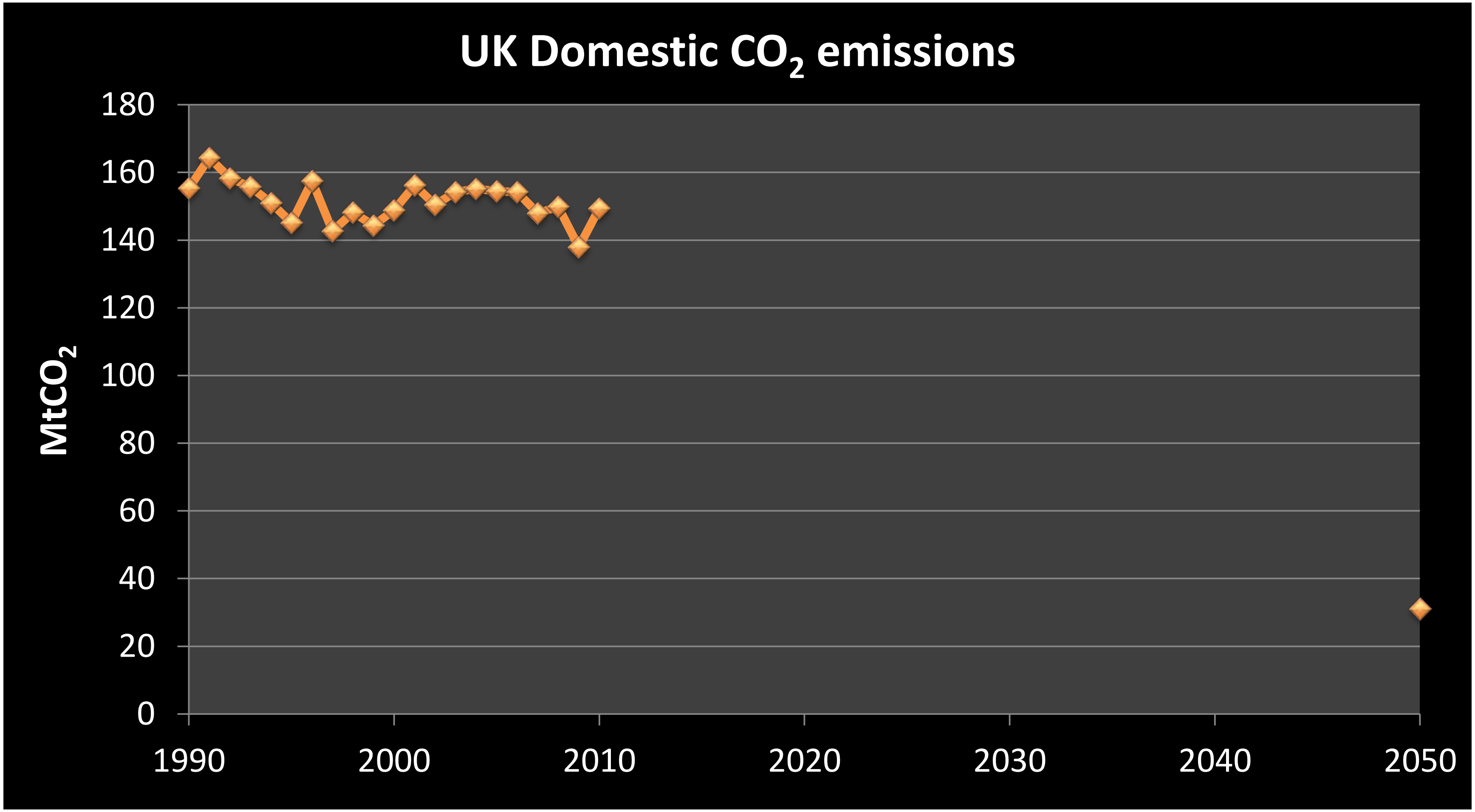
$$CE = H \frac{E}{H} \frac{C}{E} \qquad CE = f\left(H, \frac{E}{H}, \frac{C}{E}, R \right)$$

- **Logarithmic Mean Divisia Index (LMDI)**
  - Laspeyeres: asymmetrical
    C_o=10;C_t=20 ΔC=100% (C_o base) or ΔC=50% C_t base
  - LMDI: symmetrical
    ln(20/10) = 0.693
    ln (10/20) = -0.693

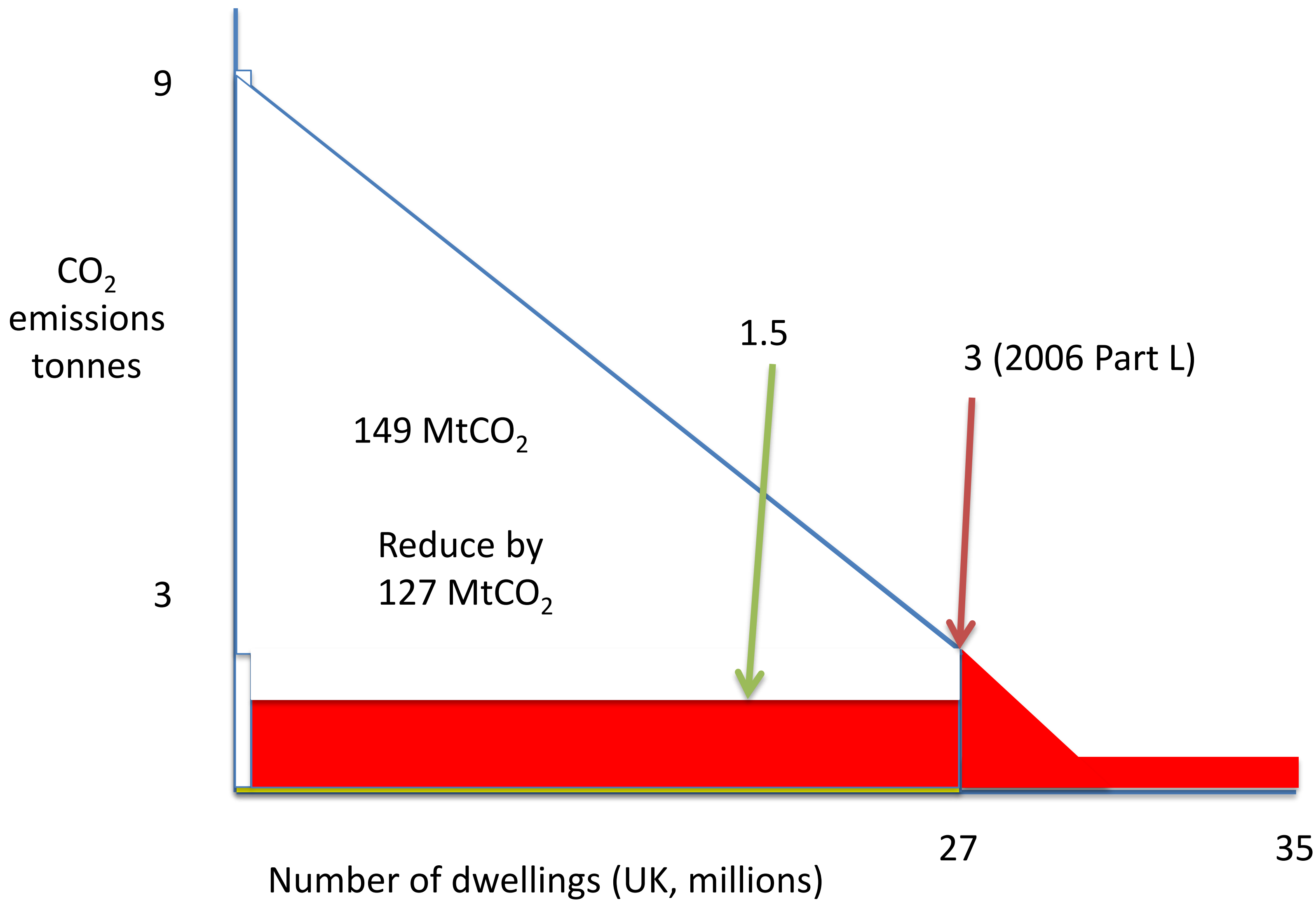
Analysis

- Energy use per household *declined* by 8%
- Number of households *increased* by 19%
- Energy consumption *increased* by 10%
- Carbon intensity of electricity generation *declined* by 18%
- Change in fuel mix in consumption
- Emissions *declined* by 4%

...forty years to go



The requirement



Implications

- New build
- Demolition
- Current stock
- Energy supply

New build

This Government are committed to ensuring that all new homes post-2016 can be zero-carbon while ensuring that the costs of new build do not prevent appropriate and sustainable development.

(Grant Shapps, Minister for Housing: Written Ministerial Statements *27 July 2010*)

New build: Fabric Energy Efficiency Standard (FEES)

- *We have already made clear our intention to introduce the Fabric Energy Efficiency Standard as based on the work of the Zero Carbon Hub.* (Grant Shapps Ministerial Statement July 2011)

- Apartment blocks and mid-terrace 39 kWh/m^2/year
- Other dwelling types 46 kWh/m^2/year

- This is about **50% higher than Passiv haus** (when modelled in SAP)

- *We are also keen to build on industry's commitment to move to an approach based on real world carbon savings, rather than modelled reductions in emissions* (*ibid.*)

New build: Implications

- Need to develop a practical means of assessing as-built performance
and
  - Need to research performance over time

Implications for refurbishment standards

- Implications for refurbishment standards
  - ❑ More pressure on reducing emissions from existing stock
  - ❑ Highlights practical difficulties of achieving tight standards for fabric

FEES Standard for new build			Realistically achievable in refurb?	Sheffield eco-terrace EST, 2010 (Cost £45k)
U values	Wall	0.18	?	0.28
	Floor	0.18	?	0.18
	Roof	0.13	maybe	0.20
	Window	1.40	yes	1.4
Air permeability $3m^3/m^2/hr$ @50Pa			?	6.7
Thermal bridging y-value		0.05	?	0.04 (??)

You can design in airtightness and design out thermal bridging on the drawing board for new build (Farmer, 2011), it is more difficult to patch up a leaky existing building and refurbish out thermal bridges

Whole house refurbishment

The cost of a whole house energy efficient refurbishment is currently prohibitive (Purple Market Research, 2010)

Demonstration projects

Oxford 3-bed terrace	£55k	2.2 tonnes CO_2
London 3-bed semi	£82k	2.9 tonnes CO_2

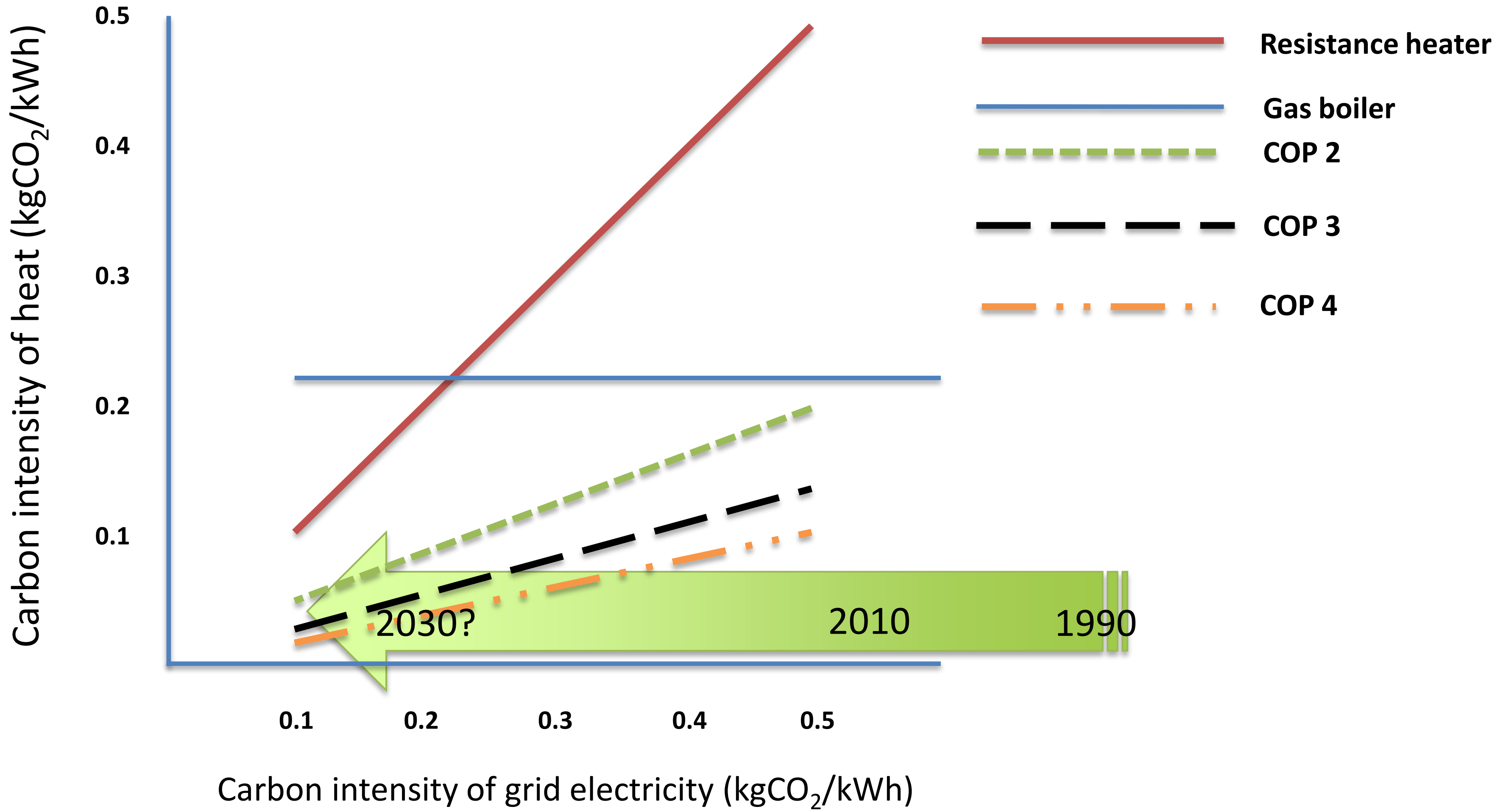
Current stock

- Problem is not solid walls.
  - Insulation of solid walls achieves a reduction in U values of a factor of 10 (Lowe, 2007)
  - Theoretical U values *over*estimate heat loss from solid walls (Baker, 2011)
- Problem is cavity walls:
  - Width of cavities retro filled
- Uncertainty of effect on thermal performance

the improvement in thermal resistance is, on average, around 38% less than that which would be expected on the basis of measured cavity width (Doran, 2008)

- Difficulty of dealing with thermal bridging

Energy supply: is the future electric?



Adapted from: Lowe, 2007

The University Of Sheffield.

Making the case for design for deconstruction

Danielle Densley Tingley

Supervisor: Buick Davison

The finite limit of materials....

Extraction of raw materials

↓

Processing

↓

Production/fabrication

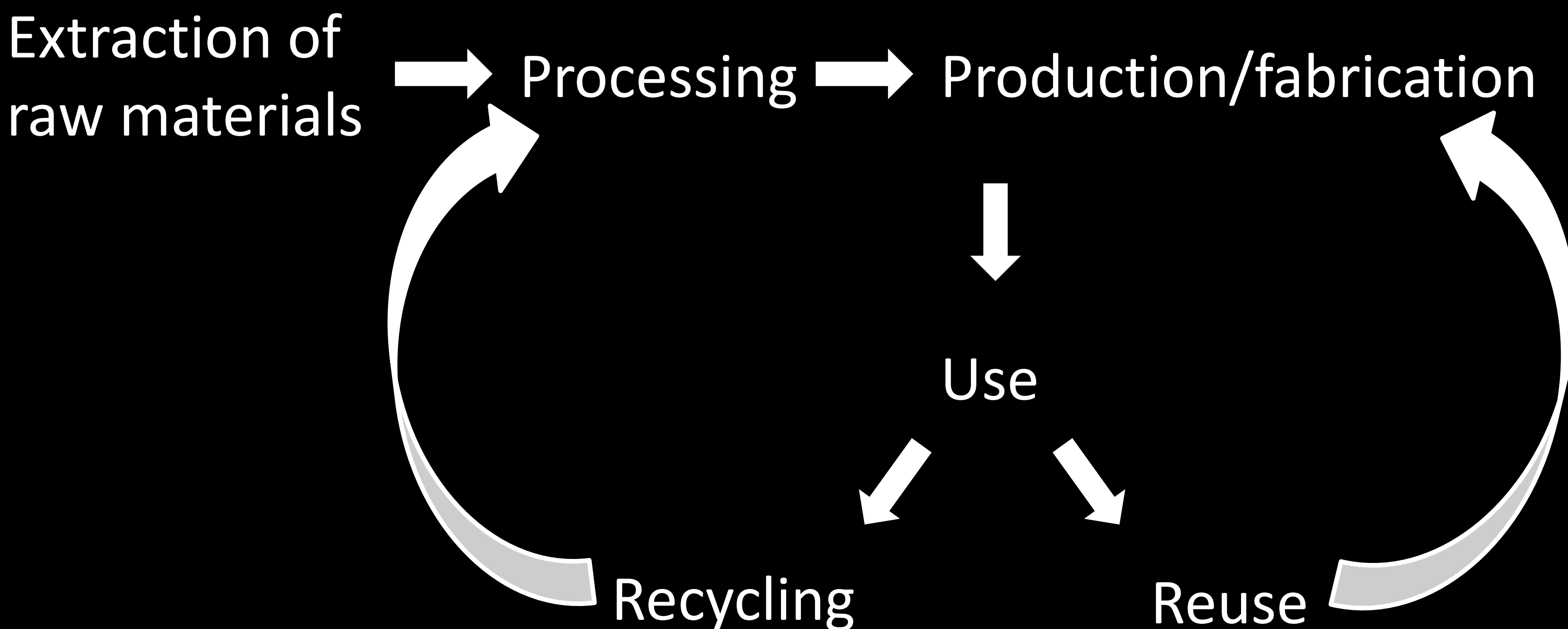
↓

Use

↓

Disposal to landfill

Moving towards a closed material loop....



Waste Hierarchy:

Prevention

Construction reuse

Element reuse

Material reuse

Useful application

Immobilisation with useful application

Immobilisation

Incineration with energy recovery

Incineration

Landfill

BedZED, England

UTSC's Student Centre

Ottawa Convention Centre

Design for Deconstruction (DfD) as a way to increase the future supply chain of reused materials

Vulcan House

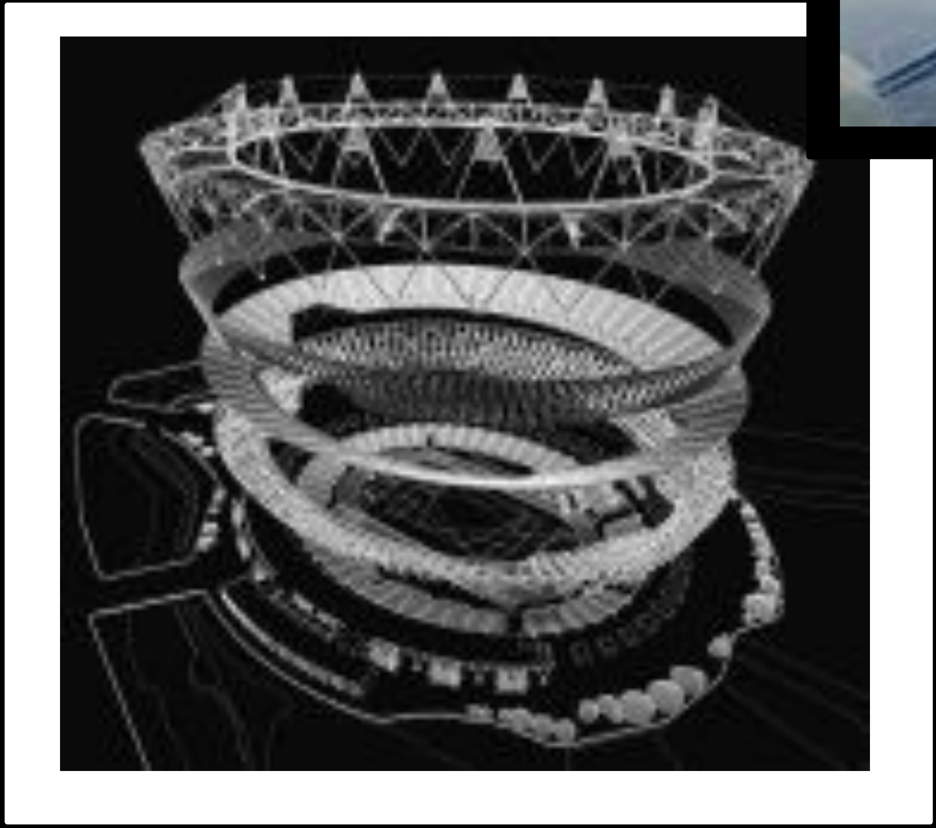
Photo credits: David Millington

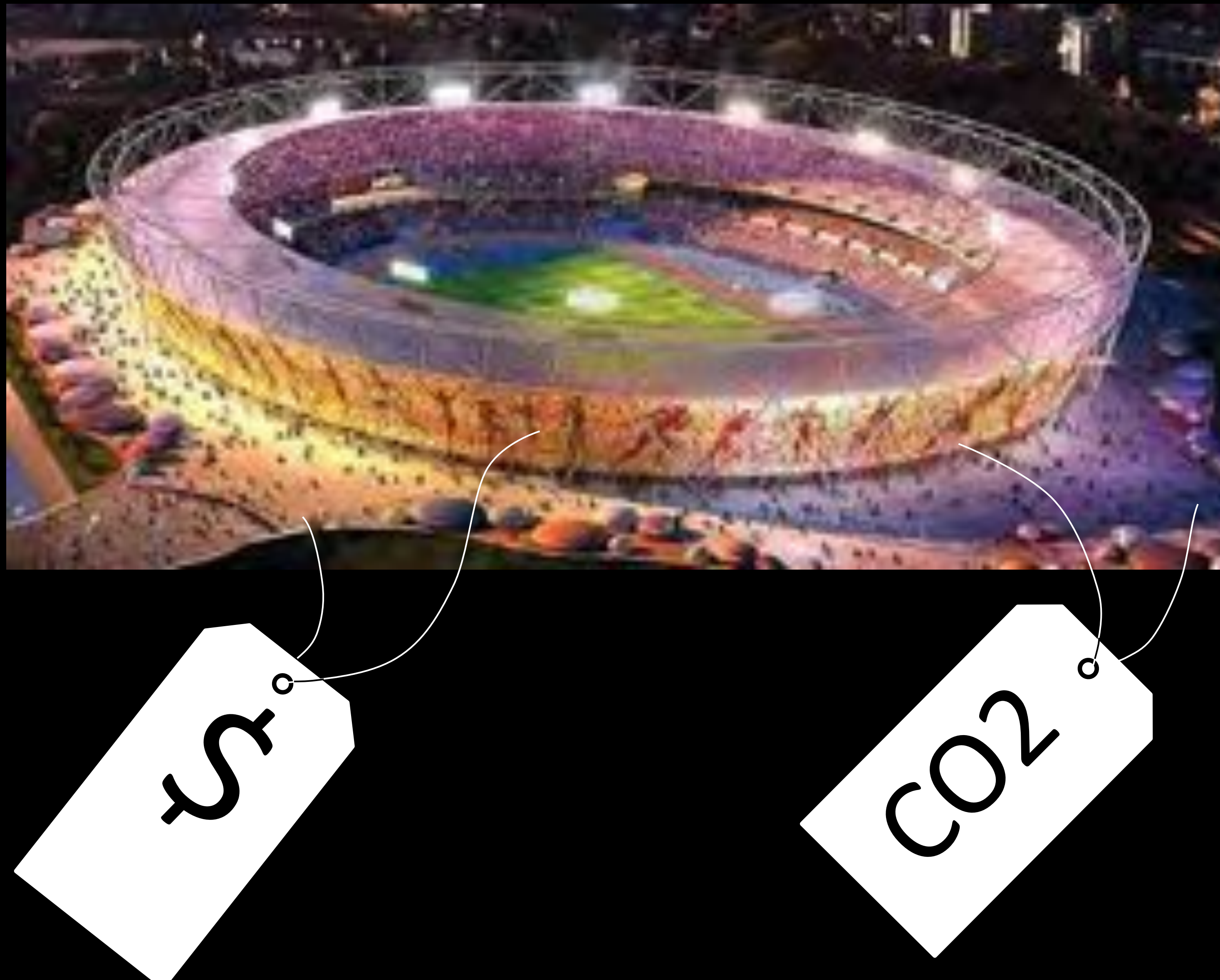
ProLogis
Park,
Heathrow

Chartwell School

Photo credits: Michael David Rose

2012 London Olympic Stadium




$
CO2

WEEE Directive – to reduce electronic and electrical waste, encouraging reuse and recycling

By designing for disassembly kodak can increase reuse and recycling rates

Conclusions

- By designing all new buildings for deconstruction the future supply chain of reused materials can be significantly increased
- Reusing materials will help to close material loops – relying less on the extraction of natural resources
- Consider DfD at an early stage
- Use tool to demonstrate the environmental benefits of DfD to specific project

Mehrauli

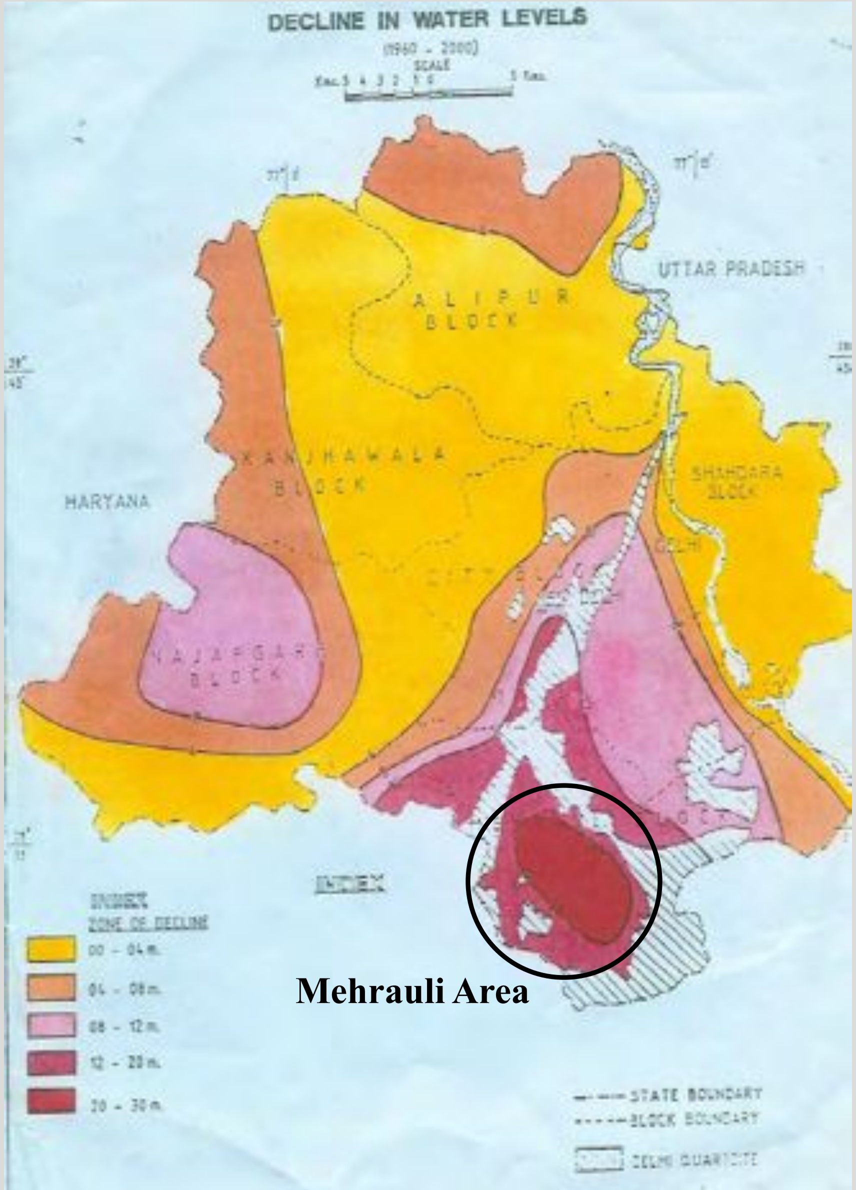
Integration of Water Systems to meet the Growing Water Demand

By: Ginny

Brief History Of The Region

- The first Islamic city of Delhi was founded by the slave dynasty at Qila Rai Pithora at Mehrauli, roughly 18km from the Yamuna river. The hilly and rugged terrain of Mehrauli did not permit the development of a canal, so the sultanate harvested rainwater to cater to their needs.
- Iltutmish (1210-36 AD) built the Hauz-e-Sultani or Hauz-e-Iltutmish, the tank however was clogged and was repaired by Alauddin Khilji and Feroz Shah Tughlaq. This tank measures 200m by 125m and is still visited by pilgrims.
- Apart from these tanks, *baolis* or step wells were made by these sultans. Baolis were secular structures from which people could draw water.
- Gandak-ki-baoli was made under Iltutmish’s reign, adjacent to which lie the ruins of Rajon-ki-baoli and a caved baoli behind Mahavir Sthal.
- Alauddin Khilji constructed the Siri reservoir at Siri to harvest water of the aravalli region and having a catchments area of 24.29 Ha. The reservoir measured 600m by 600m and was named Hauz-e-Alai, and later renamed Hauz-e-Khas.
- The increase in population at Mehrauli and Siri prompted Ghias-ud-din Tughlaq to lay another settlement around 8km east of Qutub Minar; The Tughlaqabad Fort. The fort contains ruins of seven water tanks and three extensive baolis, not to mention numerous deep wells.
- The water here was provided by damming the natural eastward drainage line.
- The surplus water from the reservoir Hauz-e-Shamsi near Mehrauli was diverted to the Naulakhi nallah and this canal was diverted to Tughlaqabad.

Decline in Water Levels

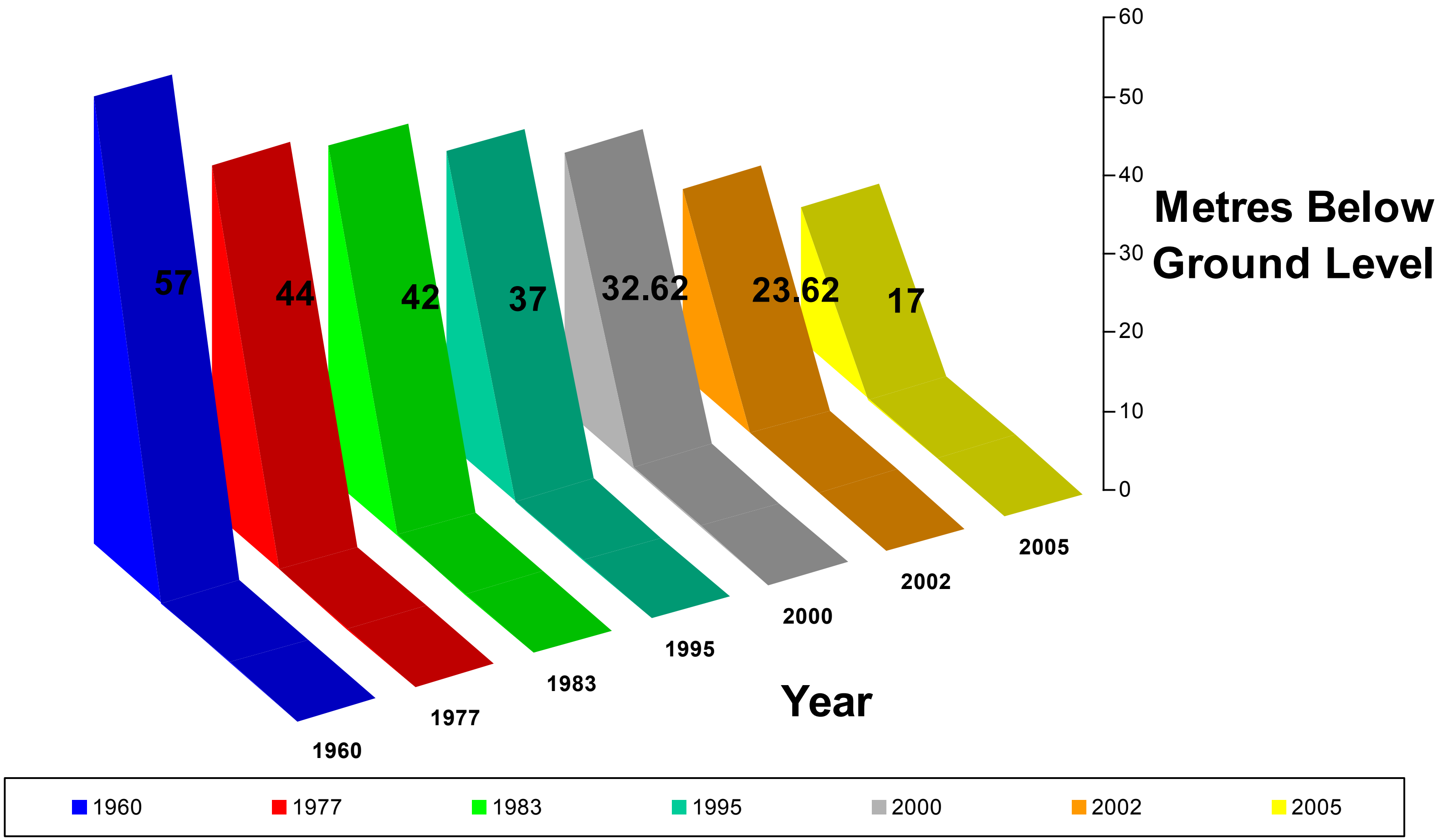


Mehrauli village blocks road

MEHRAULI VILLAGE residents on Tuesday come out on streets to protest against poor water supply. Residents alleged that they have not received water for about a month.

- **On an Average a family of 4 consumes 800-1000 liters of water per day.**
- **If waste recycling is done, 650-800 liters can be saved.**

Average Pre-monsoon Ground Water Level in Mehrauli



Water Potential and Exploration in Mehrauli Block

- Total area of Mehrauli : 149 Km^2
- Total population of Mehrauli Township : 1.2 lakh
- Water supply Required for a Developed Urban Area : 50 g./c /d *
- Water supply Required for an Urban Village : 35 g./c./d.
- Water supplied by Delhi Jal Board to Mehrauli Township : 10 lakh g./d. **
- Water supplied per dwelling unit : 40 g./d.
- No. of Tankers sent into Mehrauli Township (depending on scarcity) per day : 25-30
- Capacity of each Tanker : 3000 L
- **"Mehrauli township is divided into 84 odd pockets with each pocket getting water for 45-60 mins. Once in 60-70 hours"**, as stated by the **DJB**.
- Total Replanishible Ground Water Resource:

    1983- 23.03 Mcm

    1995- 18.75 Mcm

* g./c /d : gallons/capita/day

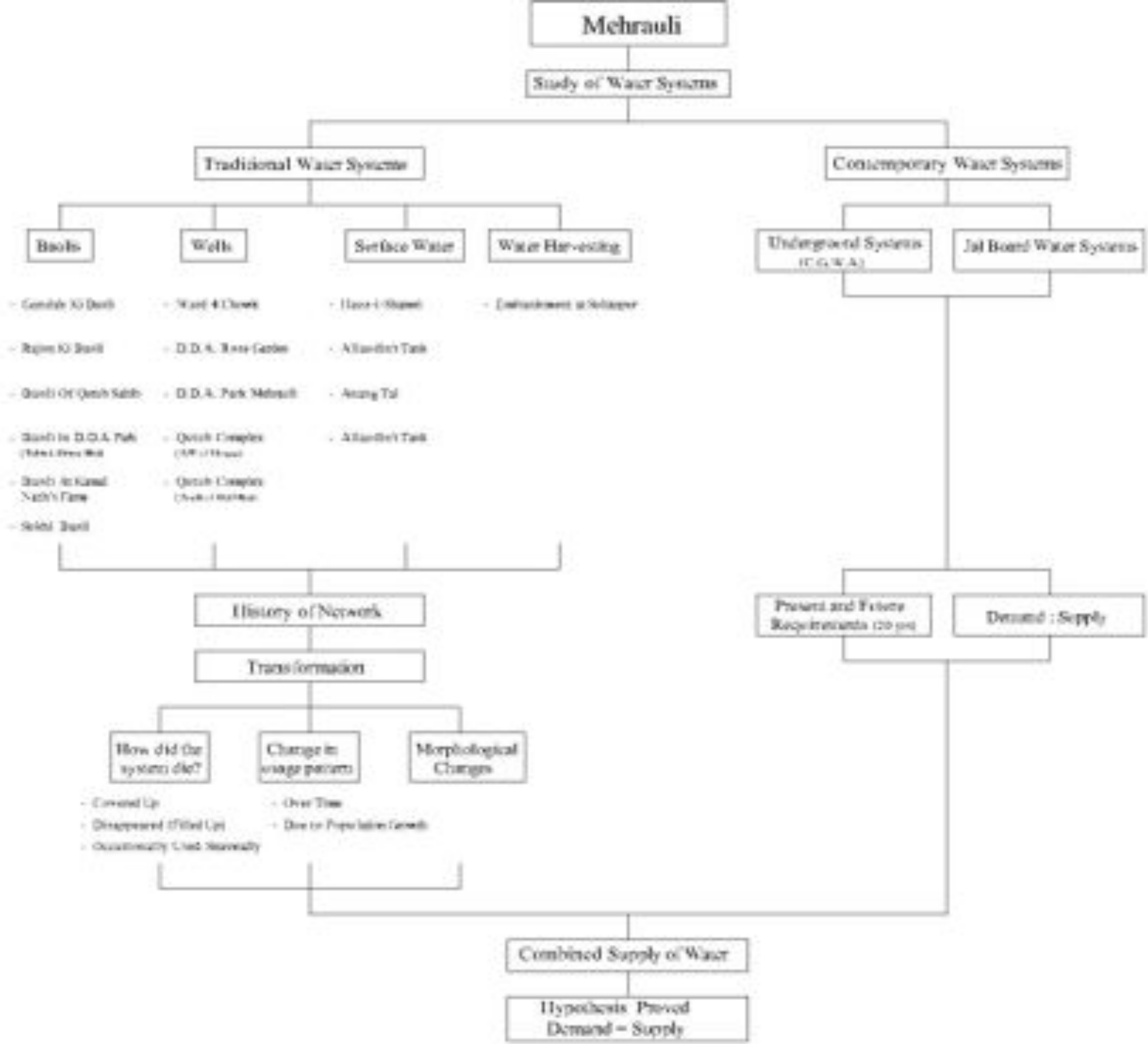
** g /d : gallons/day

Hypothesis : Revitalization and integration of the traditional water system (baolis etc.) with the conventional water system will help solve the water problem at Mehrauli.

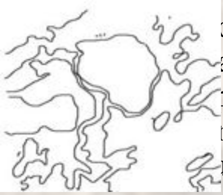
Aim : To revitalize the traditional water system and integrating it with the contemporary water system to meet the water requirement of Mehrauli.

Objectives: To trace the existing traditional network of WELLS and BAOLIS and to understand their functions. To identify the surface water bodies in MEHRAULI. To revitalize the traditional water system. To fulfill the water requirement of the region by combining the traditional and contemporary water system.

Scope of Work: To resolve the water related issues of Mehrauli by finding and comparing water demand and supply of the area.



The hypothesis will be enforced with relevant references and case studies, for example the revival programme for tanks at *Sringaverapura* etc.



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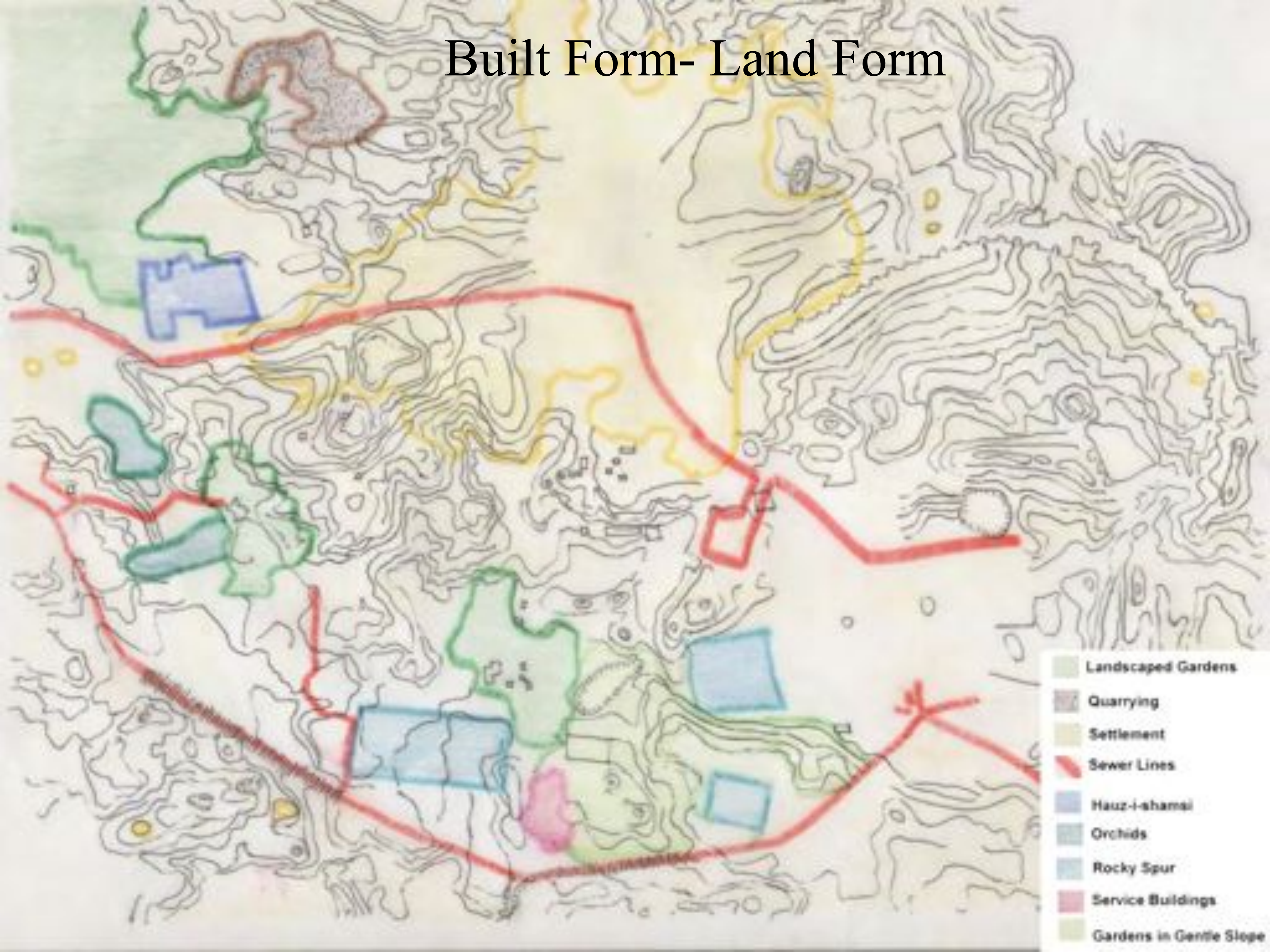
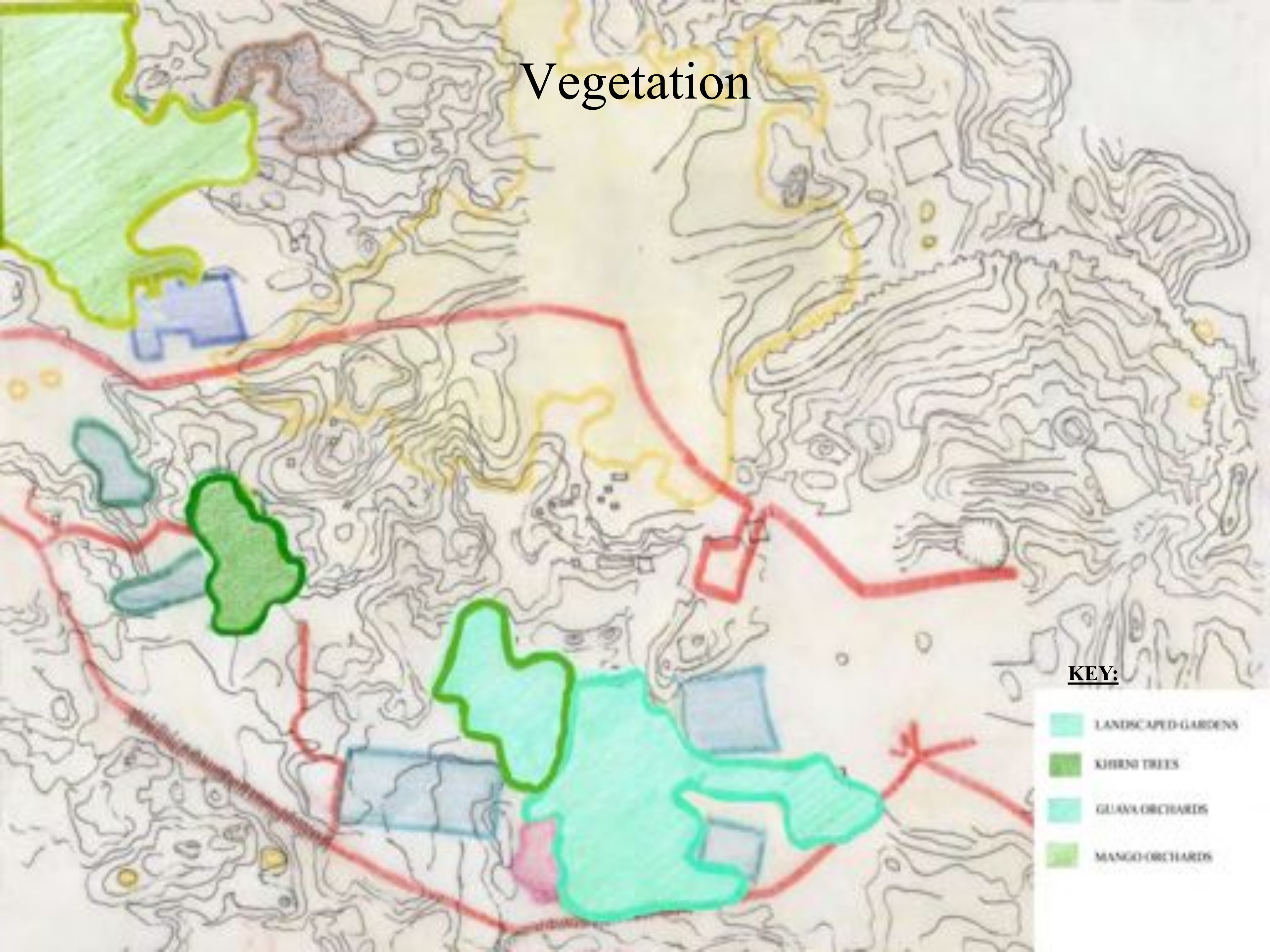
Chaumachi Khan and Adam
Khan and Quli K...
to this period.

Layer 5: Mehrauli became a

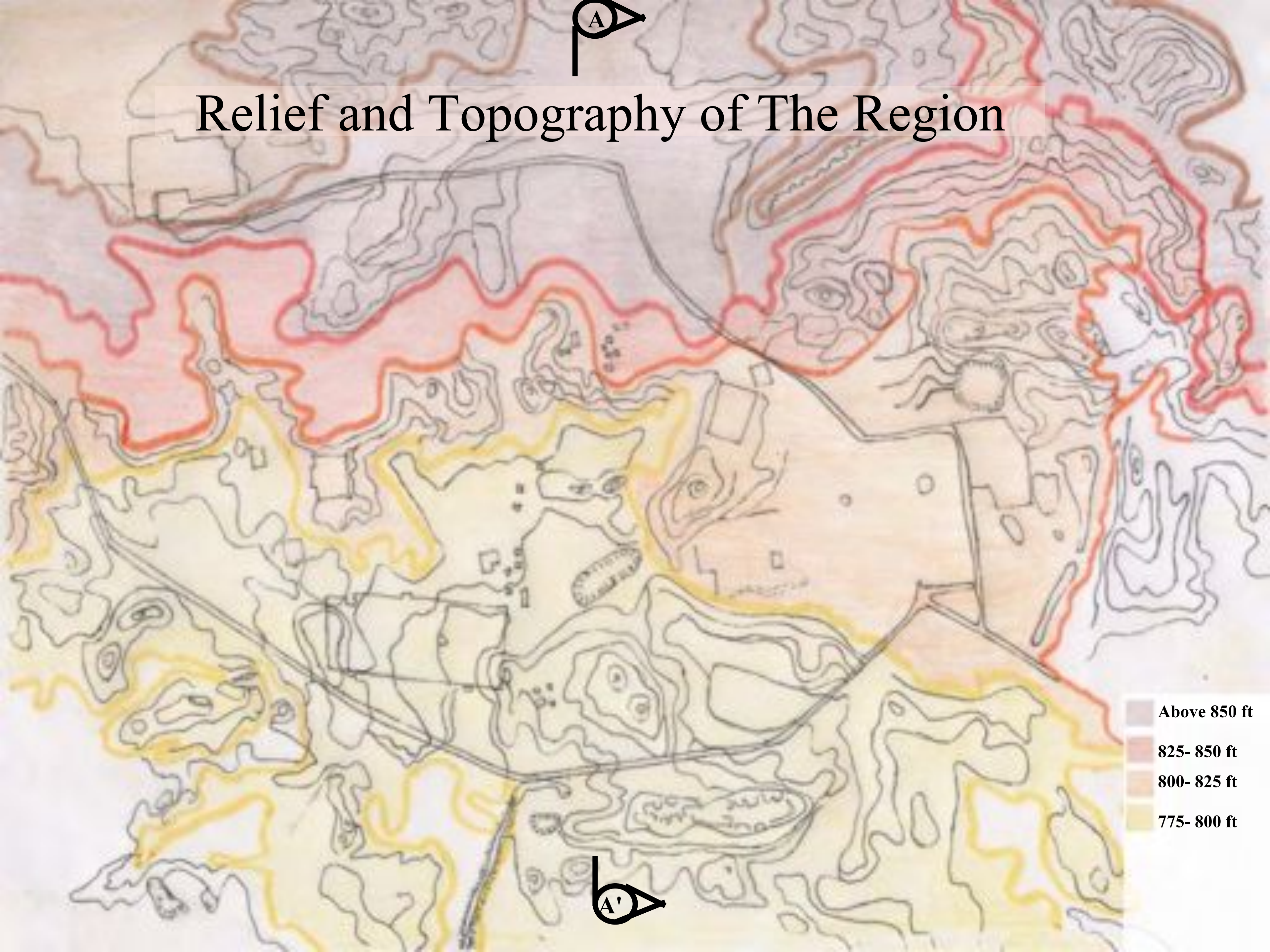
Built Form- Land Form



Vegetation

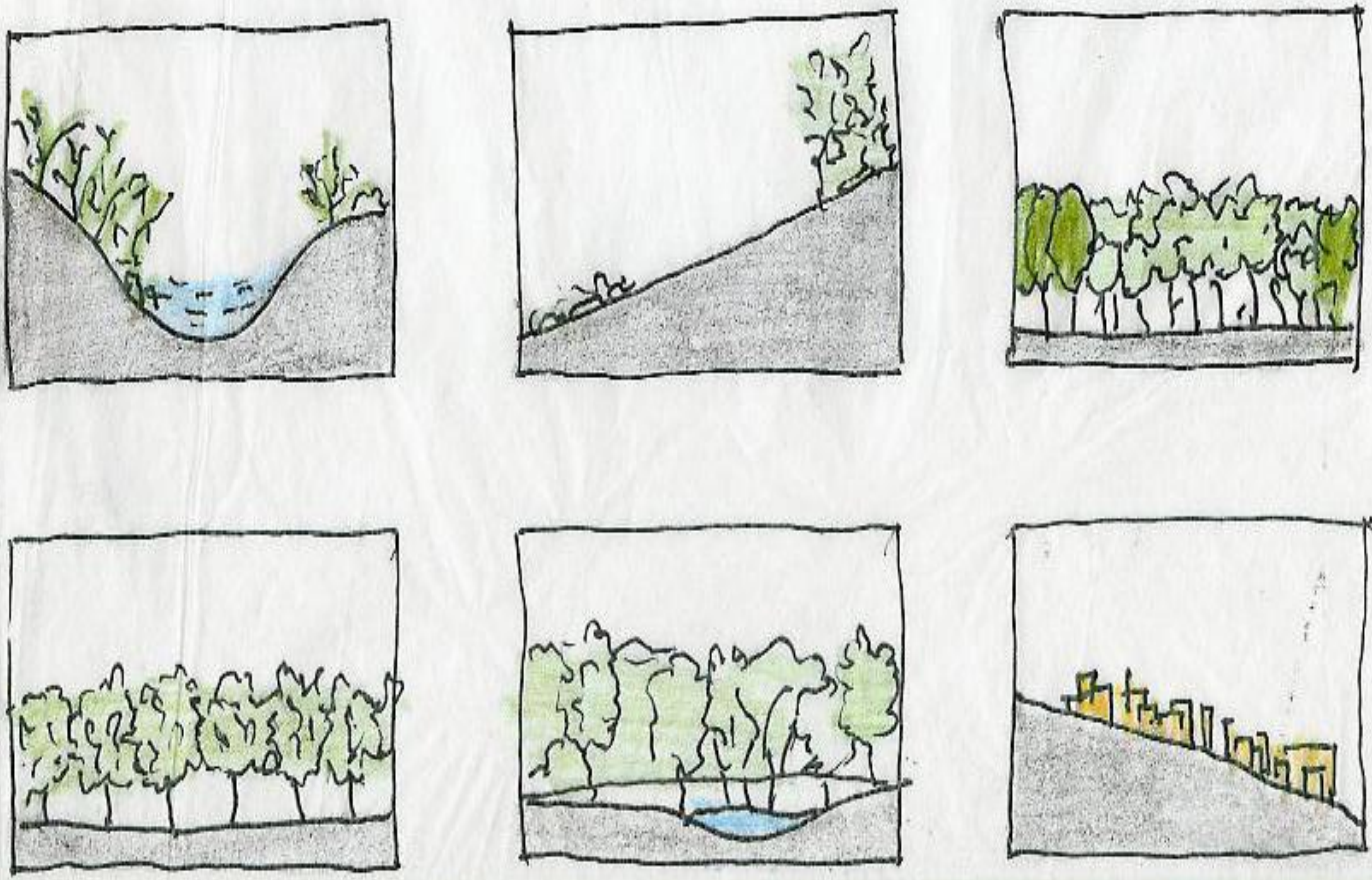

KEY:
LANDSCAPED GARDENS
KHIRNI TREES
GUAVA ORCHARDS
MANGO ORCHARDS

Relief and Topography of The Region



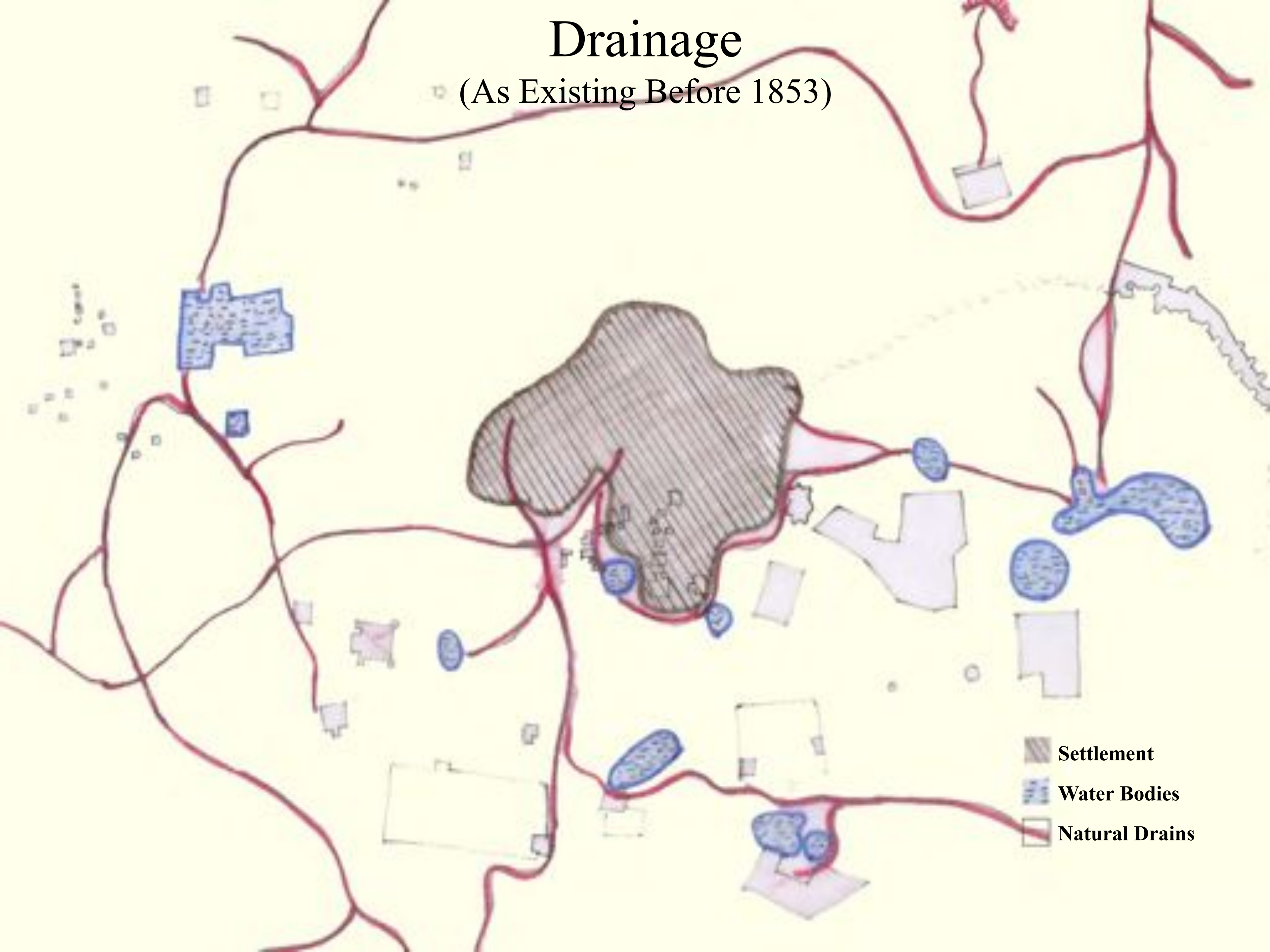
Schematic Site Section

Schematic Spot Sections



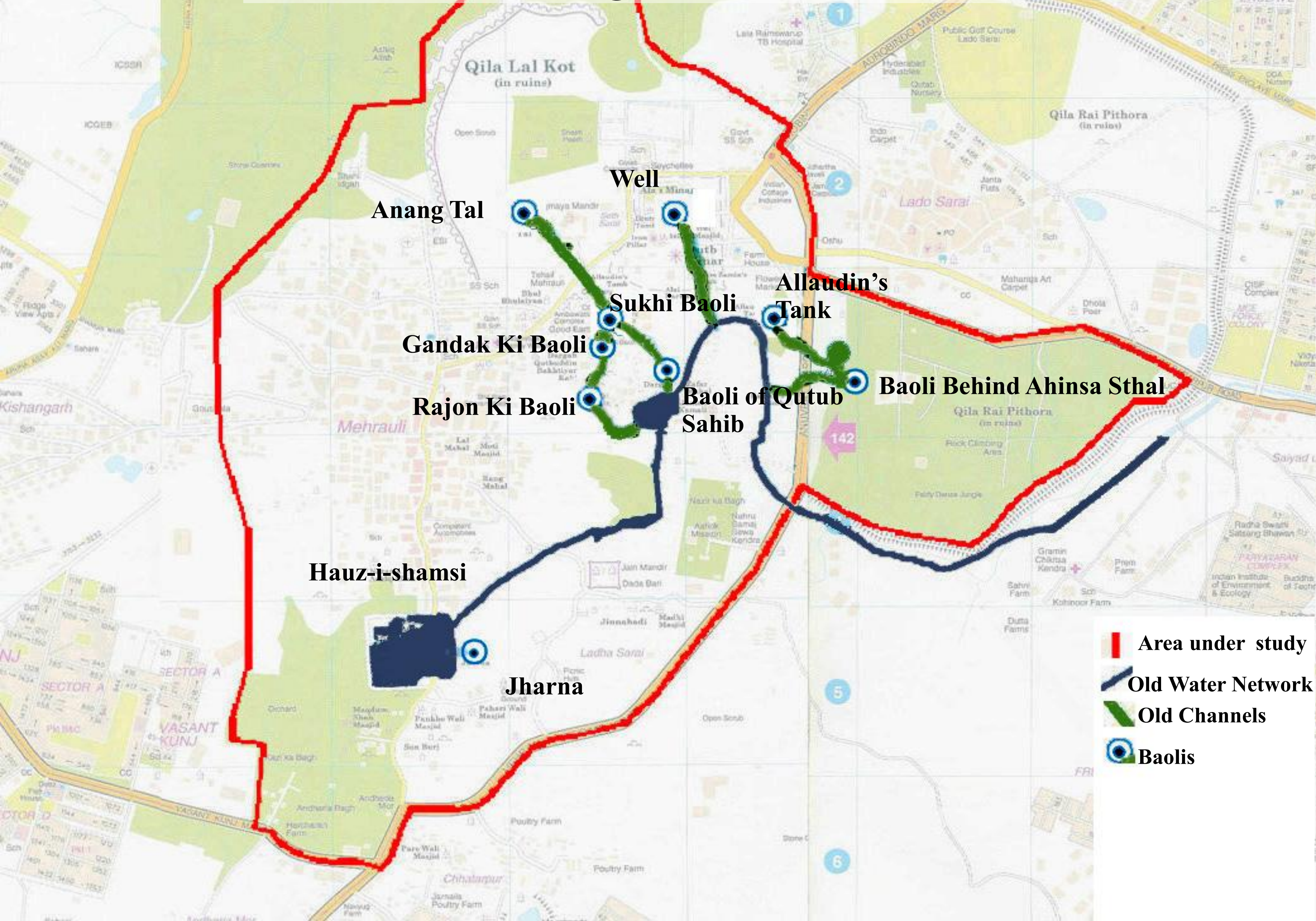
Drainage

(As Existing Before 1853)

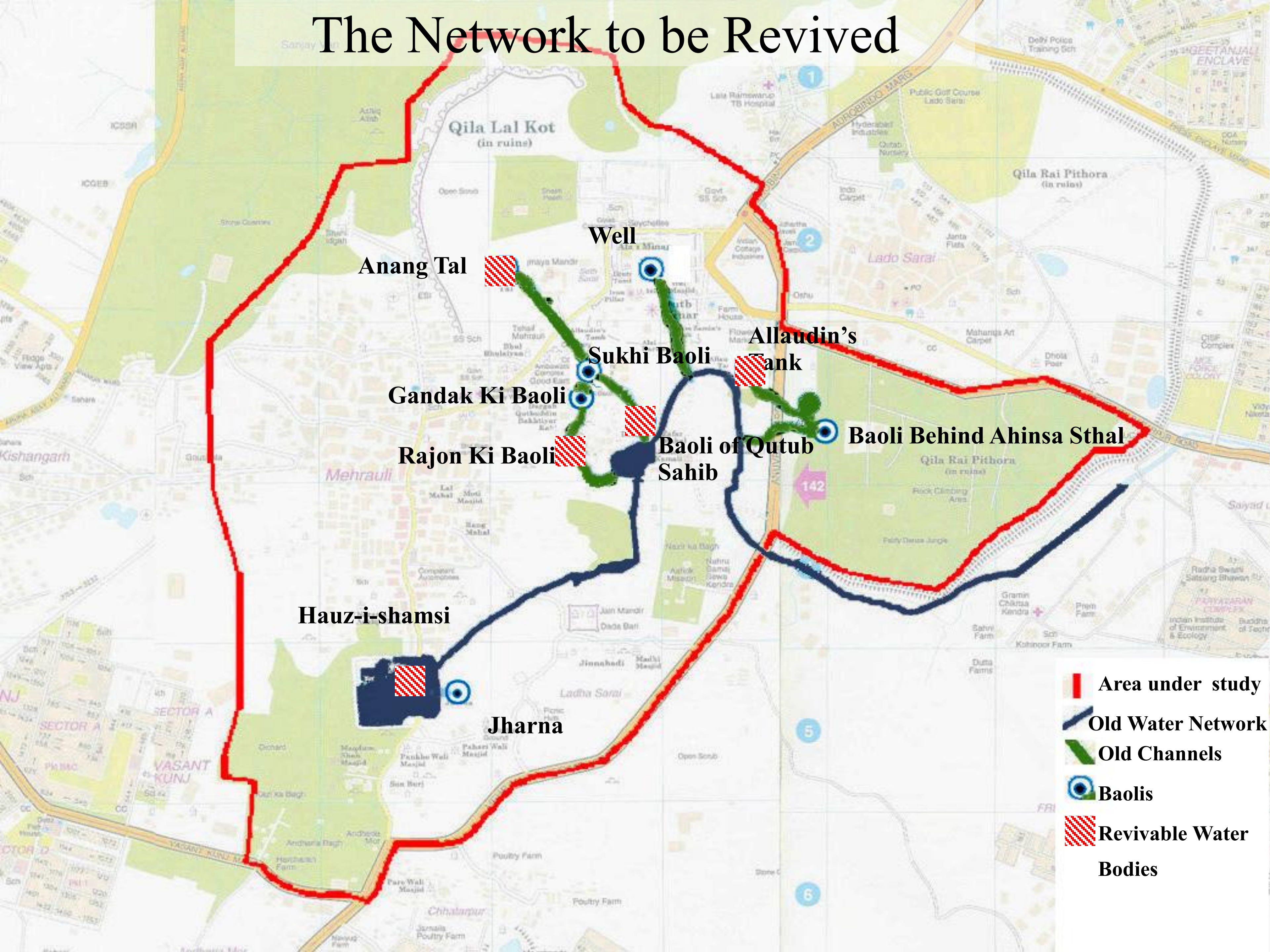


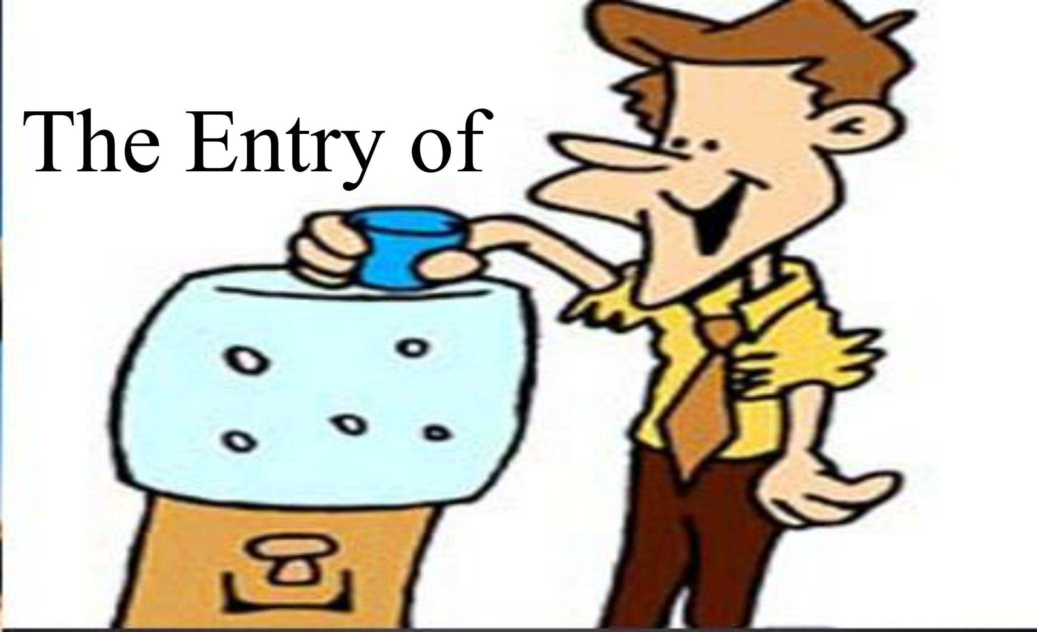
Drainage
(Present Day)

The Pre-existing Water Network



The Network to be Revived





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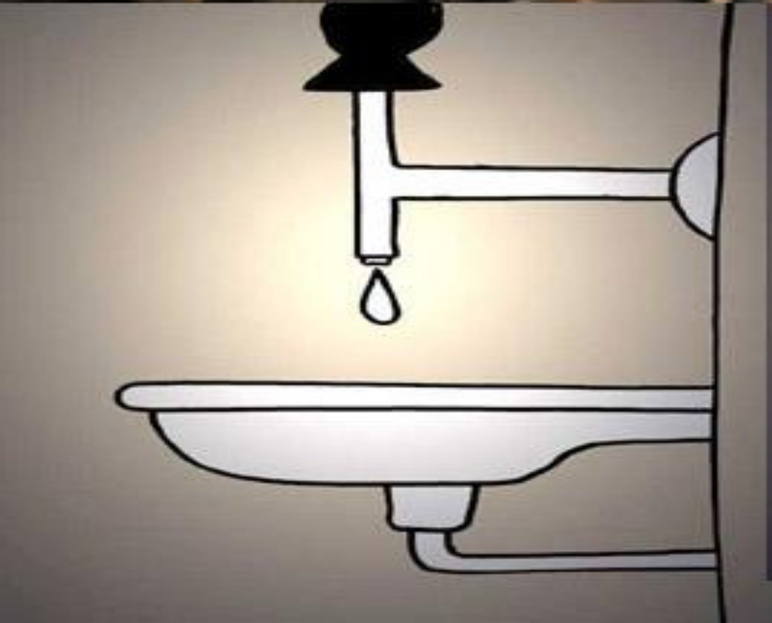

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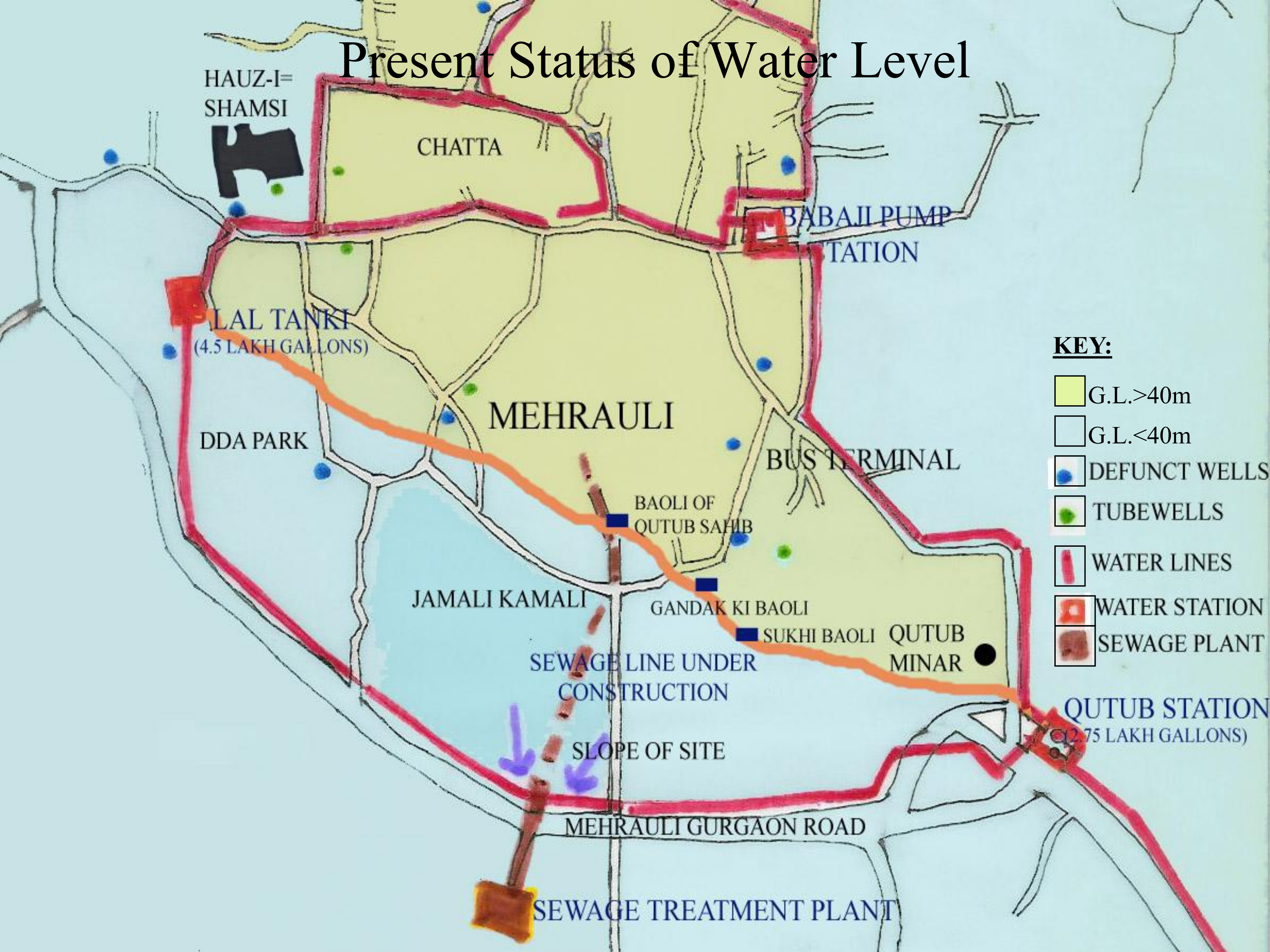
The Water Network As Of Date

Present Status of Water Level



Proposal for Future Supply

For the short term planning to solve the water problem, DJB is proposing the implementation of the Sonia Vihar Water project in the area.

But this cannot completely solve the water problem thus in the long term, the ground water levels will have to be replenished, hence :

The identified Baolis and the Hauz-i-Samshi can be completely restored by making embankments and thus helping to replenish the ground water level of the area.

This can be successfully done with the help of water harvesting techniques with the baolis acting as primary water collecting pits.

Some other Natural Depressions can be converted into Catchment Areas to help create a network along with the baolis.

Due to the proximity of the STP, the treated sullage can be reused for various other purposes such as horticulture, washing etc.

Need for Rain Water Harvesting:

Rainfall occurs during short spells of high intensity, because of such unpredictedrains, most of the rain falling on the surface tends to flow away rapidly, leaving little water for ground water recharge.

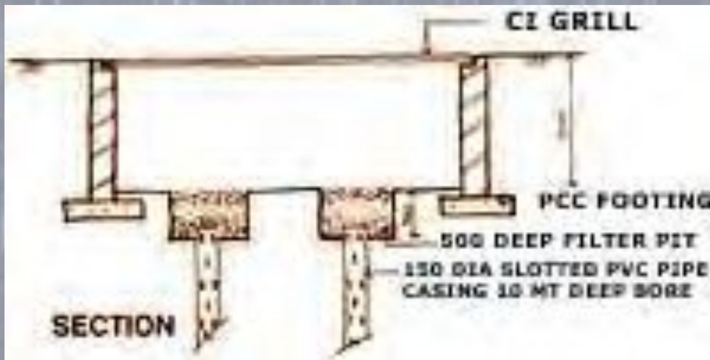
Mehrauli suffers from acute shortage of drinking water, primarily because the rain water is not conserved and allowed to drain away. This highlights the need to increment measures to ensure that the rain falling over the region is tapped as fully as possible through water harvesting, either by recharging it into the ground water aquifers with the help of *baolis* and other catchment areas or storing it for direct use after harvesting it from the roofs of houses.

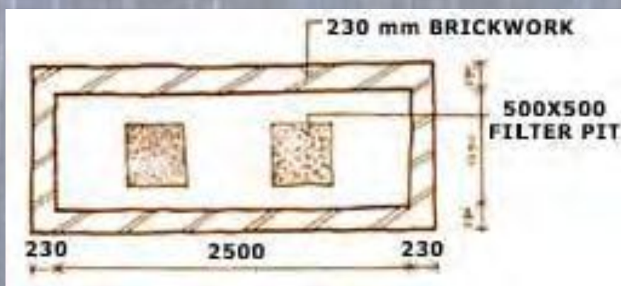
Water Harvesting Potential:

Area of the Settlement	**= 149 km2**
Total area suitable for roof top harvesting (40% of the site)	**= 59.6 km2**
Amount of Rainfall (for Delhi Region)	**= 611 mm**
Volume of Rainfall = (area of plot x height of rainfall) = (5,96,00,000 x 0.6)	**= 3.5760 x 107 KL**

Assuming that only 60% of this water can be harvested, only 2.1456 x 107 KL can be effectively harvested.

Construction of Catchment Areas & Recharge Pits





Step 1: Excavating the earth

Step 2: Making a borehole to facilitate groundwater recharging

Step 3: Providing masonry or RCC walls in the excavated portion.

Step 4: Covering the tank made with a RCC or stone slab provided with a manhole.

Conversion of a Dried-Up Tube Well into a Recharge Well:

Step 1: Replace top few metres of the cast iron casing pipe of the dried tubewell with a perforated poly Vinyl chloride (PVC) pipe.

Step 2: Wrap the perforations with a screen-made of either coir screen or closely knit nylon mesh.

The End

Thank You

Gandhak Ki Baoli

- **Location** : Ward 7, Mehrauli, about 100m south of Adam Khan's Tomb on the road leading to the Dargah.
- **Ownership:** Public, Archeological Survey of India
- **Type** : Baoli (Stepwell)
- **Status** : Protected Monument
- **Features** : As per Zafar Hasan's (ASI) report, the baoli was originally in five tiers which could be reached by galleries on the eastern and western sides. Of the five tiers, four are now visible. The well is situated to the south. Each tier is reached through galleries on the east and the west which give access to the well.
- **Material** : Walls : stone masonary
  Floor : stone
- **Date** : A.D. 1210 – 36 (during Sultan Iltutmish's reign)
- **Restoration:** Possible
- **Capacity** : 1444.8 Kilo L

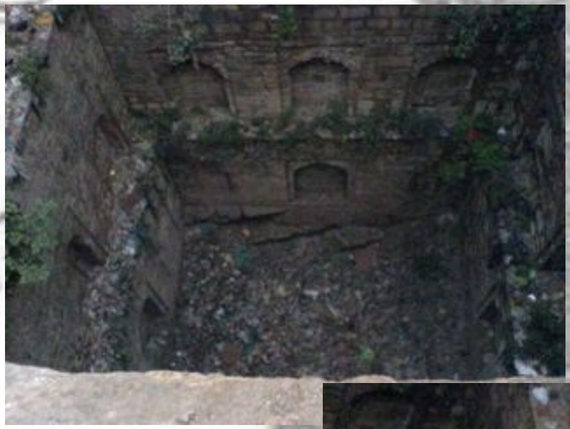
Rajon Ki Baoli

- **Location** : DDA Park, Mehrauli, about 700m North-west of Jamali Kamali
- **Ownership:** Public, Archeological Survey of India
- **Type** : Baoli (Stepwell)
- **Status** : Protected Monument
- **Features** :
  - The baoli is oblong, with steps leading downward from the North.
  - The walls of the lowest visible storey are decorated with deeply recessed arches. The top storey is surrounded by an arcade with massive piers. The top storey had *chujjas* which have now disappeared.
  - On the south side is a well.

Material : Walls : Random Rubble
Floor : Stone
Roof: Vaulted, Domed Stone Roof

- **Date** : A.D. 1506
- **Capacity** : 1836.1 Kilo L

Baoli Of Qutub Sahib

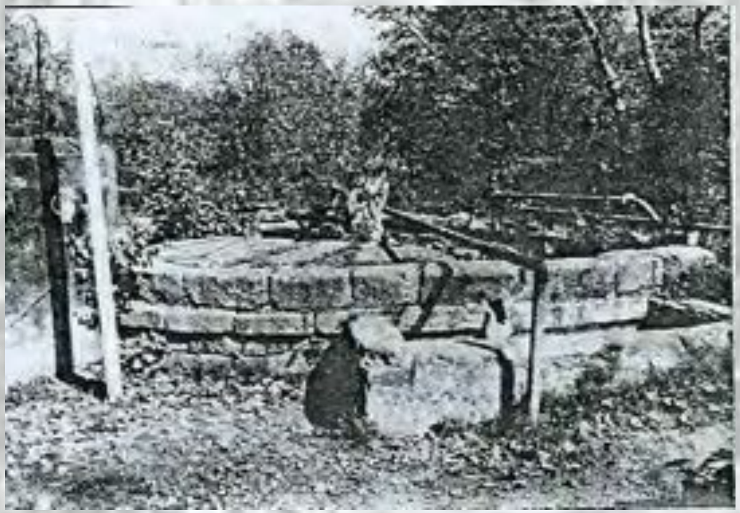


- **Location** : Dargah Of Qutub Sahib, Mehrauli, On the South-East end of the dargah complex
- **Ownership:** Public
- **Type** : Baoli (Stepwell)
- **Status** : Unprotected Monument
- **Features** :
  - The baoli measures 29.25m east to west, and 12.8m north to south, and is 22.85m deep.
  - It consists of three stages, divided by galleries without balustrades.
  - The access staircase to the baoli starts about 18m to the west of the baoli and is now kept locked.
- **Material** : Walls : Stone Masonry
- **Date** : A.D. 1846
- **Restoration:** Possible
- **Capacity** : 855.27 Kilo L.

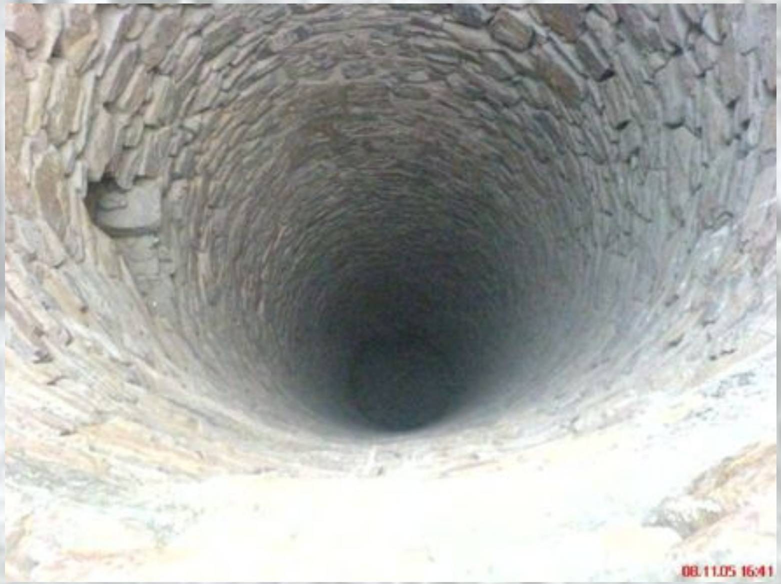
Hauz-i-Shamsi

- **Location** : Ward 8, Mehrauli, to the west of *Jahaz Mahal*
- **Ownership:** Public, MCD
- **Type** : Reservoir
- **Status** : Unprotected Monument
- **Features** :
  - The reservoir was commissioned by Iltutmish.
  - It is said to have originally covered over 100Ha. And was lined by Red Sandstone.
  - It is recorded that Iltutmish built a domed platform
  - The tank is now considerably smaller in size, it is lined by Delhi stone and is still used for washing clothes and bathing cattle.
- **Material** : Delhi Quartzite Stone and Red Sandstone
- **Date** : A.D. 1229- excavation of the reservoir

Well



source: INTACH listing of historical monuments in Delhi



- **Location** : DDA Park Mehrauli, at the north east part of the DDA rose garden
- **Ownership:** Public, DDA
- **Type** : Well
- **Status** : Un-Protected Monument
- **Features** :
  - The well has a diameter of about 4m and a dressed stone facing
  - The depth of the well is about 30m and is dressed stone inside as well
  - The well is still in use though the water is drawn up using electric pumps.
- **Material** : Dressed Delhi Stone
- **Date** : Lodhi Period

Well

source: INTACH listing of historical monuments in Delhi

- **Location** : DDA Park Mehrauli, 150m north of Jamali Kamali Mosque
- **Ownership:** Public, DDA
- **Type** : Well
- **Status** : Un-Protected Monument
- **Features** :
  - The well is constructed of random rubble masonry and has a diameter of about 3m
- **Material** : Random Rubble
- **Date** : Late Mughal Period

Jharna

- **Location** : Ward 8, Mehrauli, 50m South-East of *Jahaz Mahal*
- **Ownership:** Public, MCD
- **Type** : Mughal Garden
- **Status** : Unprotected Monument
- **Features** :
  - This Mughal Garden was built around A.D.1700 and additions were made by later kings.
  - The block of buildings has earned its name from a water-fall which once drained off surplus water from the Hauz-i-Shamsi.
  - Akbar Shah-II (A.D. 1806-1837) constructed pavilions to the North and Bahadur Shah- II (A.D. 1837-1857) added the *Baradari* in the centre.
- **Material** : Walls: Random Rubble
- **Date** : A.D. 1700

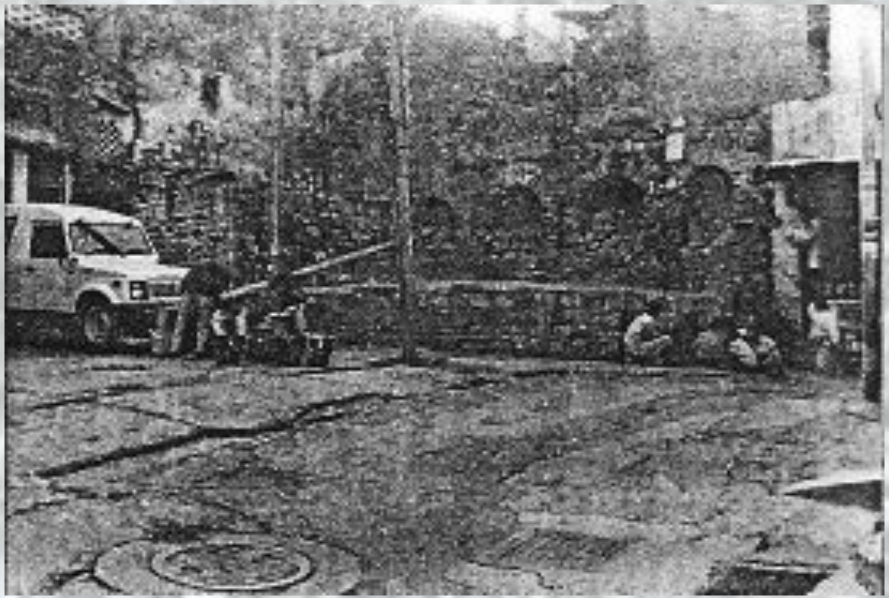
Well

- **Location : ** Qutub Complex, Mehrauli, 15m SW of the mosque
- **Ownership:** Public, Archeological Survey of India
- **Type :** Well
- **Status :** Protected Monument
- **Features :**
  - The well with a diameter of about 3m is about 15m deep and currently dry.
  - The mouth of the well is about 1.5m above ground level
  - Some stone slabs here seem to have been re-used and belong to an earlier structure.
- **Material :** Random Rubble
- **Date :** Mughal Period

Well

- **Location** : Qutub Complex, Mehrauli, 50m South of Alai Minar
- **Ownership:** Public, Archeological Survey of India
- **Type** : Well
- **Status** : Protected Monument
- **Features** :
  - The well is about 10m deep and has an internal diameter of about 2m.
  - The mouth is at a height of 1.5m
  - There is moulding in plaster near the top on the external face.
- **Material** : Random Rubble
- **Date** : Late Mughal Period

Well



source: INTACH listing of historical monuments in Delhi

- **Location** : In a chowk in Ward 4
- **Ownership:** Public, MCD
- **Type** : Well
- **Status** : Un-Protected Monument
- **Features** :
  - The well defines the boundaries of a big chowk.
  - The well has a dressed stone lining around it
  - About 2m from the top, there is a plaque in urdu.
  - A 1m high *chabutra* is built around the well
  - There are 4 arches behind it
- **Material** : Random Rubble
- **Date** : Late Mughal Period

Baoli At Kamal Nath's Farm

source: INTACH listing of historical monuments in Delhi

- **Location** : Kamal Nath's Farm, Sultanpur, Approximately a kilometre east of MG road, within Sultanpur.
- **Ownership:** Private
- **Type** : Baoli (Stepwell)
- **Status** : Unprotected Monument
- **Features** :
  - The baoli is enclosed by a 1m thick masonry wall, with stone steps leading to an octagonal *chattri* of high merit on the eastern end.
  - It is learned that the bed of the baoli has been excavated to reveal additional floors.
- **Material** : Walls : Delhi Quartzite Stone
- **Date** : Lodi period

AN INTRODUCTION AND REVIEW OF THE CHALLENGES FACING A REGISTERED SOCIAL LANDLORD AND THEIR STAKEHOLDERS IN RELATION TO THE DESIGN AND CONSTRUCTION OF AN EXEMPLAR LOW CARBON, ECOLOGICAL DEVELOPMENT IN A RURAL AREA OF WALES

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In October 2010 Pembrokeshire Housing Association (PHA) completed a development of six residential units, as part of the Welsh Government pilot project scheme to promote the development of sustainable housing in Wales. Researchers from Cardiff Metropolitan University, are working in collaboration with PHA to understand the obstacles that were encountered in developing their pilot project, and consider the effectiveness of the scheme in achieving its low carbon objectives. This paper explains the methodology and results of structured interviews that were conducted with the design and construction team considering their approach to low energy design; the development of the environmental strategy of the project; perception of obstacles to the design process; and interaction of the design with the building users. The initial results of the interviews highlight the problems associated with developing low carbon schemes to a tight budget and also suggest that there is a degree of dislocation between the design team and the end users. The broader implications of the results are discussed with regard to a three year research project to develop a best practice model to develop innovative, affordable, low carbon housing in rural areas of Wales.

Keywords: Design, Green Buildings, Housing, Post-occupancy evaluation, Sustainability.

INTRODUCTION

In March 2010 Pembrokeshire Housing Association (PHA) completed a development of six residential units on Britannia Drive, in Pembroke Dock, built to Code for Sustainable Homes level four, as part of the Welsh Government Code for Sustainable Homes (CfSH) pilot project. The Welsh Government CfSH Pilot Project started in

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2008 and used a portion of the Social Housing Grant programme to support twenty two schemes throughout Wales to understand issues arising from developing dwellings to meet levels four and five of the CfSH (Welsh Government 2011). The initiative formed part of a broader strategy by the Welsh Government to move towards zero carbon construction based on the CfSH and culminated in amendments to Planning Policy, in September 2009, requiring all new housing developments of over five units in Wales to meet code level three of CfSH to receive planning permission (Welsh Assembly Government 2010). It was hoped that the exemplar pilot projects would help the industry develop the skills and supply chains required to deliver low carbon dwellings and assess the implications of building to higher standards of the CfSH. In addition, it was also believed by the Welsh Government that these projects would inform the timetable for achieving the aspiration for all new homes to be zero carbon (Welsh Government 2011a).

Funding was not provided within the pilot project initiative to investigate the differences between developing housing in urban areas of Wales compared with rural areas, such as Pembrokeshire; consider the relationship of the designers to the end users; or review whether the standards set by the initiative were being achieved in the completed buildings. An extensive on-site monitoring was envisaged as part of this scheme but was restricted due to economic constraints (Welsh Government 2011). This means that many of the project‟s ambitions of assessing the implications of building dwellings to higher standards of the CfSH and looking at the impacts of higher standards will have on fuel costs and carbon emissions have been largely undermined. This failure to provide widespread monitoring of the pilot projects is significant in light of increasing evidence that designs produced for low and zero carbon housing are not achieving their expected designed performance on completed buildings (Zero Carbon Hub 2010).

In order to consider how the issues of design and building performance were being addressed on the PHA‟s own pilot project researchers from the Ecological Built Environment Research & Enterprise group at Cardiff Metropolitan University are working with PHA to develop a monitoring programme of their scheme. This monitoring programme forms part of a doctoral research project to develop a best practice model for affordable, ecological, low carbon dwellings in rural areas of Wales. A first step in approaching the evaluation of PHA‟s Pilot project which reached practical completion in March 2009 is to consider the following questions:

- Are the final dwellings achieving the standards set by the design?
- What are the barriers to low carbon design in rural areas?
- What are the factors that influenced the design of the project?
- What was the nature of the relationship of the design team with the tenants?
- How successful have the designs been in meeting the user‟s (tenants) comfort requirements?

This paper discusses the methodology and results of structured interviews with the design and construction in relation to the questions above and provides an insight into their approach to the low energy design of the scheme. Structured interviews were also prepared for the tenants considering a range of issues including occupant behaviour, occupant attitudes, energy use, perception of comfort and interaction with building control systems but at the time of writing this paper none of the occupants have volunteered to take part in the study.

METHODOLOGY

A combination of open and closed questions was used for the structured interview questionnaire, which were designed to last between forty minutes to an hour. The questionnaire was divided into five sections, which are as follows:

- the first section asked for contact information;
- the second investigated the participants general approach to low carbon housing design;
- the third section was specific to the pathfinder house and asked about various influences on the low carbon design;
- the fourth was again specific to the pilot project and asked about obstacles to the scheme‟s development;
- the final section asked about consideration for the building users in the design process.

Closed questions were used to establish the theme of each section and to provide easily comparable results and open questions were used to provide more detailed answers. Interviewees were provided with opportunities to qualify their responses to the closed questions at the end of each section; however, in practice, as the interviews were recorded, the interviewees generally explained their answers as they responded to each question.

This approach of using open and closed questions can be criticised for making the examination of results more difficult and there is evidence that using a combination of open and closed questions can mean that interviewee‟s shorten their responses to the open questions (Vitale et al 2008). However, in practice it provided a useful means to raise points in structured manner that the interviewee might not have otherwise considered. This approach proved particularly effective with regard to questions about the relationship of the design team with the building users.

A seven point Likert item approach was employed for the closed questions with interviewees asked to rate various factors such as, for example, 'whether they saw planning policy as an obstacle to development' from 1("None at all") to 7 ("A lot") (Johns 2010). The open ended questions were generally related to the closed questions and asked questions such as „Do you think that user behaviour will be a significant factor in the energy efficiency of the pathfinder houses since construction?‟ To overcome some of the problems of consolidating data generated by open and closed questions the software package NVivo was used to analyse the results.

The small sample of seven key members of the design team allowed one to one interviews to be employed to gather information for this stage of the research. The interviewees included the following professionals:

- Development Officer
- Quantity Surveyor
- Architect
- Mechanical Engineer
- Electrical Engineer
- Clerk of Works
- Contractor

Because of the ongoing nature of the research with PHA the interviewer had met most of the interviewees on previous occasions. The fact that the interviewee‟s were aware of the research could well have resulted in some social desirability bias in responses (Marlowe and Crowne 1961) and there is evidence that it socially desirable to be seen to promote sustainability in the work place (Payne and Raiborn 2001). However, given the context of the research project it would have been difficult to design social desirability bias out of the questionnaire and there is evidence that researchers who are familiar with their respondents can arrive at a level of understanding that will result in their answers being more honest (Miyazaki and Taylor 2007).

It was recognised in preparing the questionnaires that the specific nature of some of the questions and the broad nature of the different disciplines in the design team may mean that not all of the participants would be in a position to answer the questions to the same level of detail. This aspect of the data gathering would be difficult to design out and, for example, another approach might have been to prepare separate questionnaires for each one of the different disciplines each individually catered to their approach. However, this would have been time consuming to prepare and, more importantly, would have made comparison of results difficult.

RESULTS

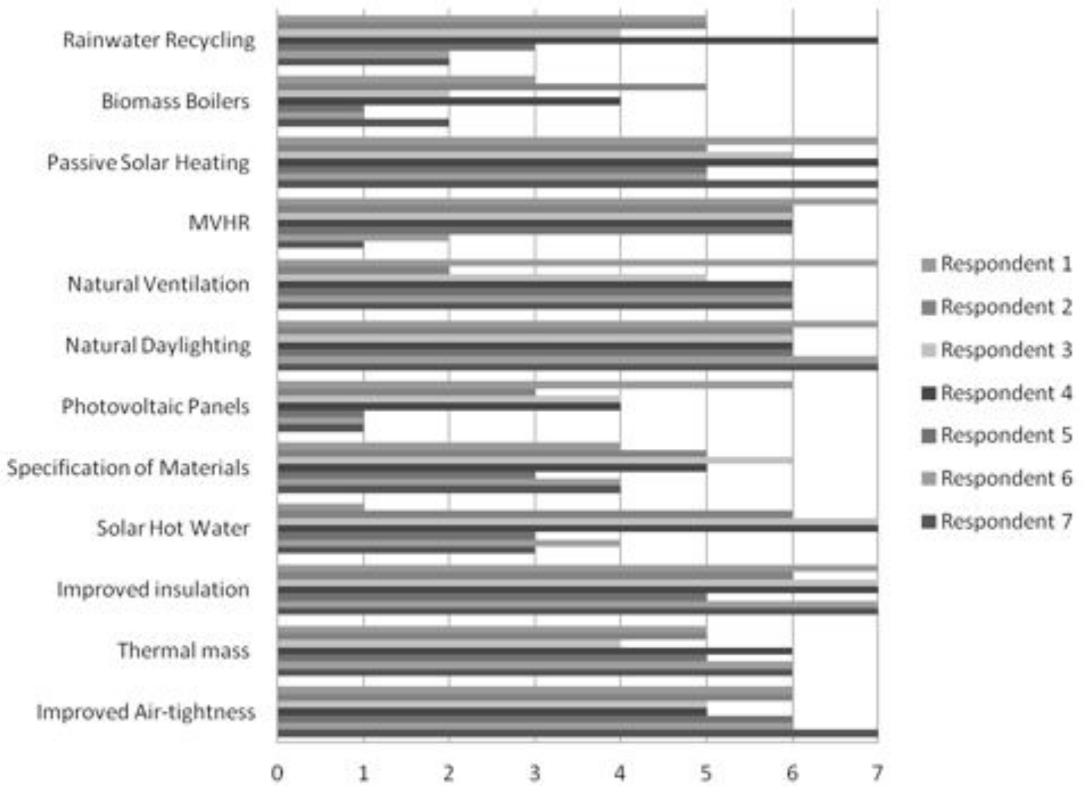
As mentioned in the previous section, the nature of the interview topic meant that there was potential for social desirability bias; however, the evidence for this is limited to some of the responses in the last section about consideration for the building users in the design. For example, a socially desirable response was evident in the answer to the question of „whether user attitudes were a consideration in design process?‟ One interviewee answered that „I would like to say yes but I am just trying to think where we actually applied that to our design process - I would say yes.‟ Un-evidenced responses, such as this, especially when they go conflict with other answers, suggest that in this case the interviewee was providing a socially desirable response.

With regard to acquiescence bias, whereby the interviewee has a tendency to agree with all the questions or indicate a positive connotation, there is some evidence of this from one of the participants. However, the acquiescence bias of this participant appears to be limited to sections three and four.

General Approach to Low Carbon Housing Design

With regard to the initial questions about the interviewees general approach to the design of low carbon housing and what they considered as cost effective approaches there was a high level of agreement, which is interesting considering the range of disciplines interviewed. Virtually all of the participants rated passive solar heating, natural ventilation, natural daylighting, improved insulation, improved levels of airtightness and thermal mass as cost effective measures with ratings of five or higher in the closed questions (see chart one below). The fact that there was so much agreement on the cost effectiveness of these passive design approaches in the development of low carbon housing raised the question with the interviewer of why these approaches had not played a greater role in the exemplar project which relied on photovoltaic panels (PV) to achieve CfSH level four.

Chart 1: Perception of the relative cost effectiveness of various design approaches to achieve low carbon housing



As previously mentioned, PV played a considerable part in the pilot project achieving CfSH level four; however, the closed question responses gave this technology the second lowest overall score of all the options presented. However, as the interviews progressed the justification for using PV on Britannia Drive became apparent in responses such as the one below:

"That's [referring to PV] better for the housing association because of feed in tariffs - if we can ever get them sorted out. So I would say that's a win win for the both housing association and end user so I would rate that quite highly."

In addition, it was apparent that various members of the design team saw PV as suitable for social housing projects, for its ease of use and the fact that it requires little or no interaction with the tenants. This was explained in one of the responses below:

"the reason why we got to PV and solar was because we considered that you could have other systems there; you open up the cupboard and it's like a NASA control centre and they'll [the tenants] just shut the door and say oh my God what's that - its like their worst nightmare."

With regard to other approaches biomass scored the lowest and there was a mixed response within the design team about the cost effectiveness of technologies such as rainwater harvesting and solar hot water. As might be expected, there was some differences in the interviewee‟s experience of the technologies and approaches offered, with some participants having had first hand experience of these technologies and approaches and others merely having read about them in industry publications which had to be considered when examining the results.

Influences on the Low Carbon Design of the Pilot Project

With regard to the various influences on the low carbon design of the project and its location in Pembroke Dock there was a high level of agreement that the locality of the scheme was not a significant influence. The response from the design team to the question of whether the rural location of the project had been important was that they did not consider the setting of the scheme as especially rural. Several of the responses pointed out that the availability of mains gas was a significant factor in defining a project as rural and one interviewee explained that the availability of mains gas at Pembroke Dock was probably influential in the site being used for the pilot project:

"I think that if it was any more rural as in outside of an area served by gas it would never have been picked as the pilot scheme to achieve code four because it's too difficult with oil or other forms of heating."

There was general agreement among the interviewees that the houses designed for Britannia Drive did not differ significantly from conventional houses developed by PHA. A number of interviewees used the question of whether they saw the houses as significantly different to a conventional scheme by PHA, as a means to describe, and in some cases justify, the approach that had been taken, as explained below:

"I would say that it doesn't differ greatly… Which is in a sense a good thing because you haven't got to push the boundaries and do silly things. You can do the low carbon solution with just standard kind of approaches. Obviously the M&E isn't standard any longer - but all the building form can be very similar."

Experience of the design team on an earlier low carbon scheme, that went significantly over budget appears to have contributed to a desire not to deviate from their typical approach and was referred to by a number of interviewees in reference to the pilot project. Nevertheless, it is interesting that a micro-renewable led design strategy was adopted to meet the project's low carbon aspirations despite there being debate within the construction industry about the merits of this approach (Energy Saving Trust 2010). Several interviewees gave detailed accounts of the micro-renewable led approach and why it was adopted on the Britannia Drive scheme:

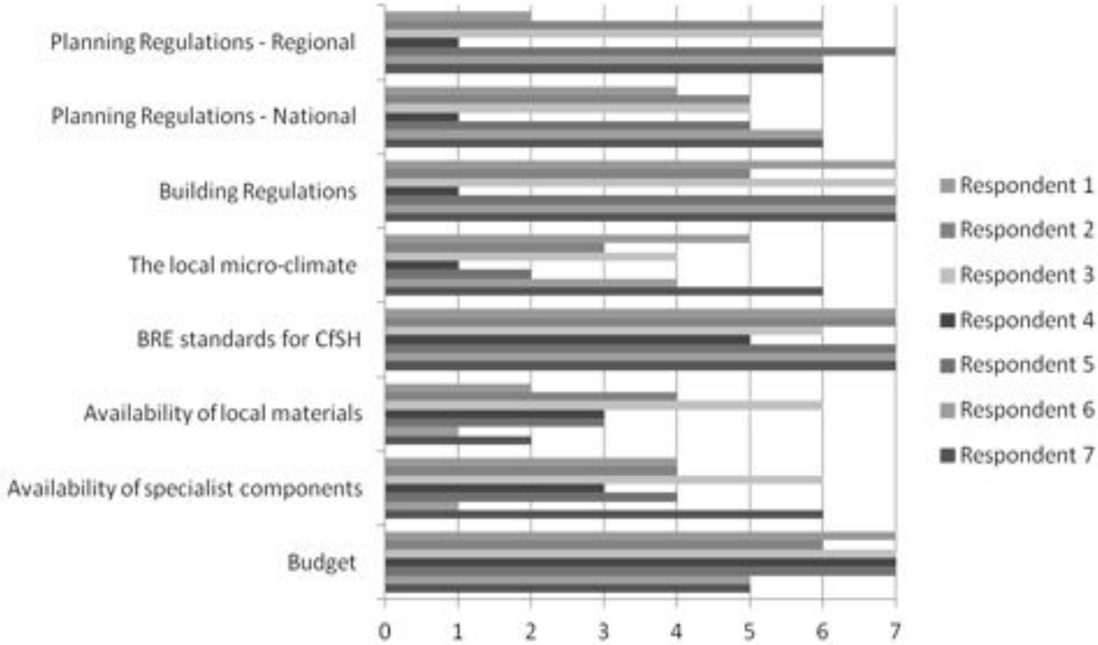
" I think the way we approached it [was] a little like stepping into the unknown - going from the BREEAM standard of Eco homes... we stuck with our traditional 140 stud so the fabric of the building and the general details didn't change too much. What we looked upon was the eco-bling… to achieve code four taking our standard unit and possible looking at… [adding] the PV system and an efficient gas boiler."

As discussed above, there has been debate within the construction industry about the viability of micro-renewables led approach and these arguments were reflected in the responses of the design team. While some interviewees defended the approach that was taken on the project, others were more critical explaining that if the PV failed for whatever reason it would undermine the environmental strategy of the scheme:

"But you think that it has achieved code four it's just with the bolt-ons, with all the PV - it's not really which the right approach - is it? Because if the PV fails the house doesn't perform with regard to code four and all the aspirations."

Chart Two below illustrates a high level of agreement that the building regulations and the CfSH were significant influences on the development of the low carbon design of the pilot project; however, the budget stood out as the most important factor. This was an interesting response for a project that was supposed to be designed as an exemplar low carbon scheme, but perhaps representative of the issues facing the development of low carbon housing by Registered Social Landlords and the difficulty of developing low carbon dwellings within the social housing budget was recognised in the Welsh Government Pilot Project Interim Report (Welsh Government 2011).

Chart 2: Perception of the influence of various factors in the development of the low carbon design of the pilot project houses.



The significance of budget on the development of the scheme was an aspect of the design that all of the interviewees felt was worthy of comment and the importance of the social housing budget in the approach of PHA to development is discussed in the quote below:

"Affordability is really at the forefront of thinking in most cases. We operate on very tight margins - I mean our main source of income is obviously the rent which is often bench marked… our grant funding comes conditioned with meeting DQR and the code and everything now I think... budget is really something which we...[it] is a big issue."

From the response to questions about the influence of various factors on the development of the low carbon design of the pilot project it was apparent that one of the chief drivers for adopting a mico-renewables led approach was that it was seen as simple, cost effective means to achieve CfSH level four. This initial finding was confirmed in the next section where obstacles to the development of the pilot project were considered.

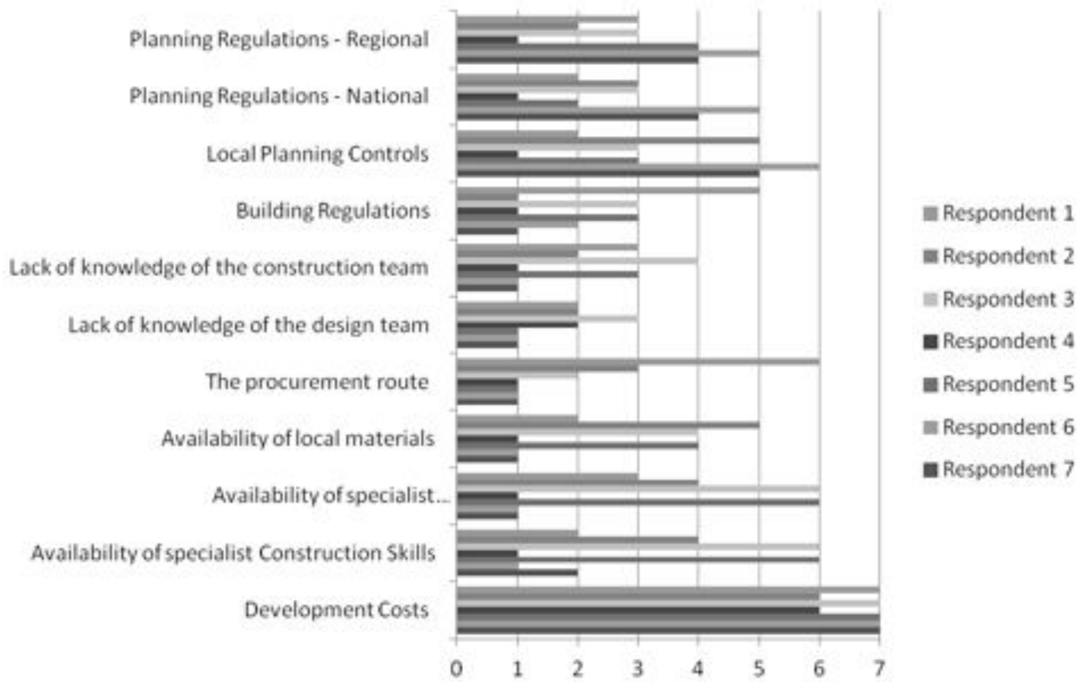
Obstacles to the Development of the Pilot Project

With regard to questions on obstacles to the development of the pathfinder houses, in contrast to the answers in previous section, there was evidence that interview responses were more contextualised. Answers appeared to be much more influenced by the role of the interviewee in the design team and their professional background. However, as with the questions about influence on the design strategy, it was apparent that there was a consensus on the role of the budget which was perceived as the chief obstacle to development (see chart three below). Additional anecdotal evidence about the importance of developments costs was provided by the fact that Development Officer and Quantity Surveyor's responses to the closed question were very similar in this section suggesting a degree of accord between the project leader and the professional charged with ensuring that the project is within budget. A detailed explanation for the reason why development costs can be a significant obstacle was provided in the response below:

"I'd say development costs are often an obstacle on all schemes that we deal with. The problem we have, if I can elaborate on that, is that a lot of the land that we source tends to come predominantly from the local authority - former garage sites scrappy bits of land which have often not been developed for the reason that from time when the local authority used to develop housing it was often deemed to be undesirable. Consequently we have a lot of abnormal costs with developing these sites."

With regard to the other responses to questions about obstacles to the development of the pilot project it is more difficult to find a clear consensus. Lack of knowledge of the design team was not perceived as an obstacle and most interviewees, with the exception of the Clerk of Works, did not perceive the procurement route (which was design and build) as a hindrance to the development of the scheme. The role of planning controls as an obstacle had a mixed response as did the role of building regulations and, as explained above, these responses often had a professional context.

Chart 3: Perception of obstacles to the development of the pathfinder houses



Only the Quantity Surveyor and Development officer, and to a lesser extent the Architect perceived a lack of skills and availability of specialist materials to be an obstacle on this project. This was in spite of problems gaining Micro-generation Certification Scheme (MCS) accreditation for the PV to take advantage of the feed-in-tariff. The experience of getting a suitably qualified contractor to install and commission the PV, which is a fundamental element of the low carbon strategy, would support the case for a lack of skills. The problem with regard to taking advantage of the feed-in-tariff, and it"s implications in gaining revenue, is described below:

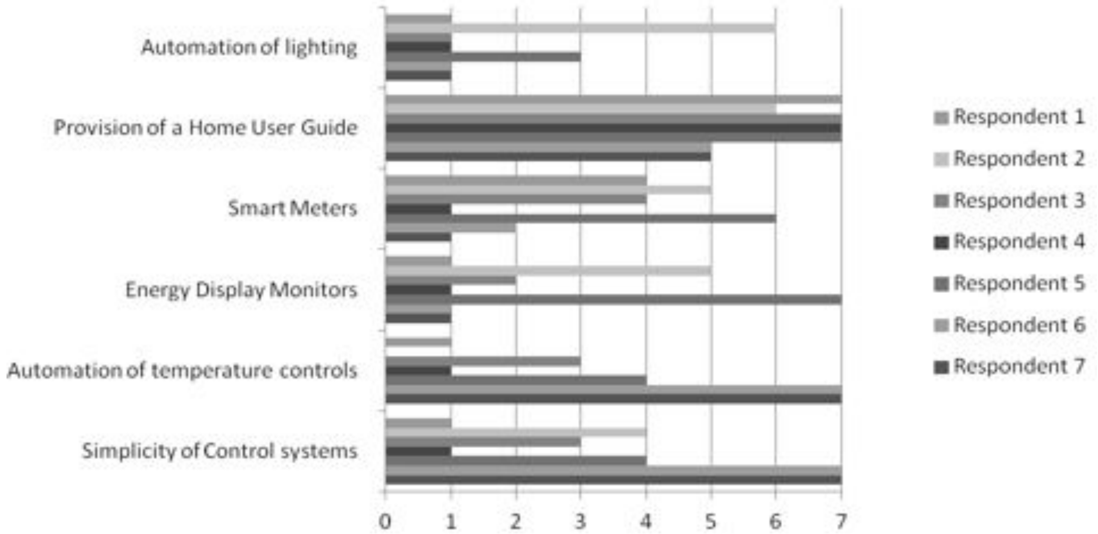
"I suppose at Britannia the problem we have... we didn't have the MCS accreditation at the time and we are now sourcing that through another contractor so I guess we have now missed out on twelve months of generation tariff so hopefully once we get the other contractor and get certified, we've had all the quotations in now, get the generation meters fitted; then yes we will see some payback on it."

The difficulty in gaining revenue from the feed-in-tariff suggests that in the short term one of the advantages of adopting a micro-renewable led approach has been partially undermined. In addition, an issue surrounding the installation of the photovoltaic panels on a scheme that is dependent on its micro-renewable technologies to meet its low carbon objectives raises questions about their performance; however, further monitoring would be necessary to confirm their effectiveness.

Consideration for the Building Users in the Design Process

It was apparent from the answers in the final set of questions that, aside from provision of a home user guide, the consideration of many aspects of user behaviour had been neglected in the design of the pilot project. Of the thirty-five answers provided by all of the participants in this section fifteen were given a one rating meaning that the interviewee believed that the particular item had not been considered at all. In addition, as mentioned previously, there was evidence that positive responses were given in a number of cases because it was socially desirable and in one instance the interviewee refused to answer a question, citing the fact that he felt that it was outside of his field of expertise.

Chart 4: Consideration of user behaviour in the development of the pilot project houses



Even where some aspects of interaction of the design with the building users had been considered, such as simplicity of the control systems, there was debate about just how effective these measures had been. The statement was made that „we try and make things as user friendly as possible, we avoid as many controls and gadgets - things that can be messed with and altered‟. However, there was still a belief by those members of the design team that interact with the tenants‟ post-practical completion that control systems were still too complicated. This opinion is expressed below:

"You've got central heating systems where we're zoning upstairs from downstairs because we get an extra point for the code if we've got them as two separate systems;

but then we've got a digital control... in the sitting room for the downstairs and then we've got another digital control in the kitchen that runs the upstairs with a separate room stat upstairs and its just far too complicated to get people to understand and the water's controlled off one for both but the heating is controlled off two separate ones and they're not the same make... well they're the same make but they're not the same model so its far too complicated."

As suggested by the quote above, several interviewees questioned whether focusing on the requirement to achieve CfSH level four to meet the pilot project objectives had led to the neglect of consideration of the users as part of the energy efficiency strategy. The opinion that focusing on achieving CfSH requirements by the most cost effective means had led to the neglect of some fundamental low carbon design considerations was reflected in other comments, such as the one below:

"The only reason why they're putting them in [energy saving technologies] now is because they can't achieve the code for sustainable homes - they can't achieve the ratings without putting them in and that's driving it rather than anything else. Rather than thinking well if we put them in it would be better for our tenants… I think we're designing it to achieve a code pass and that's what I was saying earlier about they need to rethink the whole design for it to start including some of these things into the design… light levels and laying the site out to work best with the way the sun is shining... you need to start doing that to make some of this stuff work - the more cost effective stuff"

Whatever the validity of the criticisms above they do mirror the remarks of some commentators that the CfSH"s focus on reducing emissions rather than energy saving make micro-renewable led approaches more desirable often to the detriment of passive design approaches (Climate Works 2011).

CONCLUSION

The results of the interviews highlight the problems associated with developing low carbon schemes on a social housing budget and also suggest that even on exemplar schemes, such as the one described in the paper, that affordability can be the primary concern. No doubt part of this concern was derived from earlier unsuccessful low carbon schemes; however, there is evidence that budget will be a significant factor in the development of low carbon dwellings in England and Wales (Osmani M and O'Reilly A 2009). The results of this paper indicate it is likely that many housebuilders will take a path of least economic resistance in the development of these schemes (Ibid) and thus the micro-renewable led approach taken by PHA on this project could be representative of future affordable housing as long as the focus of legislation remain on reducing emissions rather than energy saving. There is evidence that in the development of Welsh Building Regulations that this issue will be addressed and the Welsh Government Policy Document explains that the objective will be reducing demand through passive measures such as an efficient fabric before consideration is given to renewable generation (Welsh Government 2010b).

A number of interviewees expressed the opinion that some approaches to low carbon design that could have produced significant energy saving were neglected in the development of this project. From the interviews, it was apparent that budget restraints and adherence to the CfSH did go some way to answering the question of why passive design approaches, which had been considered cost effective by most members of the design team, had been ignored in the final design solution in favour of micro-renewable led approach. However, it is also true that many of the participants maintained that the approach that was taken was the most suitable given the constraints of the project. Ultimately the success of the micro-renewable led approach adopted by PHA can only be confirmed by further investigation, including interviews with the tenants and building performance monitoring which would provide the opportunity to benchmark the scheme against its own aspirations and other similar projects that have taken a fabric first approach to meet their low carbon objectives.

Although the project is located in a rural town in Pembrokeshire there was a perception among the design and construction teams that because the site had access to mains gas rather than solid fuel that this project was not fully representative of the issues facing developers in rural areas of Wales. In part, this response could be explained by the relative experience of the members of the design team and the fact that, generally, the scope of their businesses does not extend to the more metropolitan areas of south Wales, such as Swansea or Cardiff. However, this result is significant for the development of a best practice model for affordable low carbon dwellings in rural areas of Wales because it raises questions about what constitutes a rural project. One of the biggest obstacles mentioned in interview responses was the availability of gas in an area and initial evidence suggests that the availability of mains gas will be a significant factor in defining an area as rural, in the context of the research project, and a significant obstacle to low carbon development (Baker 2011).

The results indicate that beyond the requirement of the CfSH to provide a home user guide little consideration is given to user behaviour in the development of the design this is despite evidence that the building users can play a considerable part in the energy efficiency of a project (Combe et al 2011) and that design can be a tool to influence user behaviour (Lockton et al 2009). The results suggests that there is a degree of dislocation between the design team and the end users that means that even when the professionals believe that they are delivering simple user interfaces they can nevertheless be too complicated for the occupants.

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TRANSFORMATION DESIGN: A METHODOLOGY FOR DESIGNING SUSTAINABLE ENERGY SYSTEMS IN RURAL GAMBIA

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In 2006, RED, the research body at the UK Design Council presented a new discipline called Transformation Design. This emerged from research carried out by RED that applied *design thinking* to complex problems such as improving the National Health Service.
A literature review follows the evolution of design in relation to sustainable development and social change. It demonstrates a shift of designing f*or* to designing *with* users. In the context of energy systems in rural Gambia the literature highlights additional knowledge and skills to aid the transformation design process.

Keywords: design thinking, developing countries, gambia, transformation design, sustainability.

INTRODUCTION

The discipline of Transformation Design was described by the UK Design Council‟s research body RED (Burns et al 2006) as an approach whereby design processes and skills are employed in a non-traditional context such as national health services (Chick & Micklethwaite 2011: 37; Burns et al 2006; Cottam & Leadbeater 2004a). Transformation design has emerged at a time where designers are increasingly exploring their role in regard to social well-being and sustainable development. This literature review assesses the evolution of design in relation to sustainable development and draws conclusions for its application as a design methodology for energy systems in rural Gambia.

A new discipline

The Design Council research body RED (Burns et al 2006) has defined transformation design as a new discipline because it has six distinct characteristics that are not yet commonly applied as part of one design methodology: according to RED transformation design is interdisciplinary, participatory, ambitious, emphasises problem definition, aims to build capacity and is open to non-traditional design outputs such as systems and experiences.

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Transformation design is a form of *design thinking* which has raised its profile in recent years particularly in the United States of America and in the context of business innovation (Brown 2009). Fuad-Luke (n.d., quoted in Chapman & Gant 2007: 37-39) states transformation design is co-design which “sees everyone as designers, yet simultaneously recognises the catalytic power“ of design professionals. Similarly Brown (2009: 59) notes the blurring of “boundaries between creators and consumers” but warns of the limitations of purely “user-generated content and open source innovation” at this point in the “evolution of design”.

The term design has four common meanings: the finished product, a plan such as an architectural drawing, the discipline of design and the process of designing (Chick & Micklethwaite 2011: 15; The Concise Oxford Dictionary 1995: 366). The research is concerned with the latter, the process which is creative, human-centred and holistic.

Traditionally the design process tends to start with a project brief set by a client. Although design seldom follows a linear path it is likely to include phases of research, concept generation, design development, prototyping and in some cases designers work with clients through the implementation phase.

RED (Burns et al 2006: 18-19) state that a human-centred design approach relies on three fundamental skills: „Looking", „Making things visible" and „prototyping".

Looking asks to understand a context from the perspective of the user with the help of different qualitative methods such as immersion or observation. According to RED (Burns et al 2006: 18) the purpose of understanding a situation from a user's perspective is not to generate an objective truth but to "provide inspiration and actionable insights." Brown (2009: 49) refers to this stage as gaining “empathy”.

Making things visible is based on a designer"s ability to "make visual sense of complex information" (Burns et al 2006: 18). The aim here is not to package information beautifully but to turn what is imagined or intangible into something that can be shared and discussed.

Finally, *prototyping* allows for concepts to be tested and reflected upon. As well as producing a working model of a product, prototyping may refer to role play, mock-ups and the creation of storyboards (Burns et al 2006: 19; Brown 2009).

THE RISE OF SUSTAINABLE THINKING

In Britain, environmental degradation was linked to manufacturing industries as early as the period of the Arts & Crafts movement during the late 19th and early 20th century (Fuad-Luke 2004: 8).
During war time resource scarcity led to a brief period of producing only what was considered necessary. From 1943-1948 the British government controlled the furniture industry: “Initially furniture were only available to newly-weds setting up home for the first time, or to those replacing essential furniture damaged by bombing” (Denney 1999, quoted in Lees-Maffei & Houze 2010: 135).

Across the Atlantic, Vance Packard, an American “social observer” started to point the finger at advertising campaigns that promoted US waste culture in the late 1950s. He criticised planned obsolescence of big business such as car manufacturing in Detroit in his book the *Waste Makers* (Packard 1960, quoted in Lees-Maffei & Houze 2010: 226-235). Back in the UK graphic designer Ken Garland published the *First Things First Manifesto* in 1964. The document was signed by 22 design professionals concerned over graphic designers‟ preoccupation with advertising (Berman 2009: 136 &159).

It was Rachel Carson's book *Silent Spring* in 1962 that is widely attributed with inspiring the modern environmentalist movement (Walker 2006: 20; Ehrenfeld 2008: 31-32; Hynes 1989; Smillie 2000: 190). Following the publication of *Silent Spring* the US based environmental group Sierra Club saw its membership triple within three years (Smillie 2000: 190). After splitting from the Club its former executive director, David Bower, founded Friends of the Earth in 1969 which has since grown into an international network of grassroots organisations with national groups in 76 countries (Friends of the Earth n.d.). Similarly Greenpeace established itself in 1971 when a group of activists set sail for Amchitka island off the coast of Alaska to stop United States nuclear weapons tests (Hunter 2005, quoted in Greenpeace 2007).

The period was also marked by advances in astronomy and the race between the US and Soviet Union for dominance in space exploration. In 1969 the American architect and futurist, R. Buckminster Fuller wrote in his *Operating Manual for Spaceship Earth*: "I've often heard people say, "I wonder what it would be like to be on board a spaceship," and the answer is very simple. What *does* it *feel* like? That's all we have ever experienced. We are all astronauts" (Snyder 2008: 55-56). A year earlier, the Apollo 8 mission became the first manned space flight to leave the Earth's orbit and the first time for mankind to look back and *see* the limits of planet Earth.

Design for the Real Word

In *Design for the Real World* (1985) which was first published in 1971, Victor Papanek called for a design *tithe*, a system whereby all designers should spend 10% of their professional time solving social problems. Papanek (1985: 54-85) insisted on “social and moral responsibilities of design”. He inspired designers such as Finnish jewellery artist Björn Weckström to spend one year in East Africa designing survival shelters during the 1970s (Papanek 1985: 69).

Elsewhere Fred Cuny started to focus his attention on the design of refugee camps after returning from Bangladesh where he had worked as an engineering consultant for Oxfam. Kate Stohr of Architecture for Humanity describes how Cuny was able to test ideas that drew attention to human dimension in Nicaragua in 1972: “Cuny‟s design housed victims in single-family tents clustered around common spaces. Each cluster had its own latrines, cooking areas, and other basic services. ... While nearby camps built by the US military experienced a continual surge of refugees, ... in the camp Cuny designed for Oxfam the population quickly stabilized. Whereas other camps initiated mass inoculations to curb the outbreak of disease, at Oxfam"s camp there was no major outbreak of disease and therefore no need for mass inoculations. Likewise, while security issues plagued other camps, at Oxfam"s camp cottage industries and self-help organizations sprouted instead" (AfH 2006: 47).

Around the time of Cuny"s ventures to the developing world, The Club of Rome, a global think tank, commissioned *The Limits to Growth Repor*t which explored exponential growth in a world of finite resources (Meadows, Randers & Meadows 2005). Sustainability entered the political arena with the first major gathering on international environmental issues - The United Nations Conference on the Human Environment. In the following decades Green Parties started to form in western countries, particularly across central Europe.

Examining the early 1980s Fuad-Luke (2004: 11) concludes that "green design got buried in an avalanche of market-driven, environmentally unfriendly products from the emerging capitalist-driven „global economy" but "gathered momentum" with the publication of the *Our Common Future* in 1987. Commonly known as the Brundtland Report, *Our Common Future* defined sustainable development as: "development which meets the needs of the present without compromising the ability of future generations to meet their own needs" (UN, 2007). Although debates on the definitions have yet to settle, it is commonly accepted that sustainable development has environmental, social and economic dimensions. Economists may favour the three pillar model where environment, society an economy are of equal significance. Contradictory, the concentric circles model argues that society and economy have to work within the limitations of nature"s capacity (Chick & Micklethwaite 2011: 82-83).

Since the Brundtland Report and the subsequent 1992 Earth Summit in Rio, United Nations conferences and reports, international agreements and targets continue to be held and discussed. However with arguably few exceptions it took until the millennium for a broad spectrum of design practitioners and researchers to re-start the debate on the purpose of design as an agent for social change and sustainable development.

Design thinking in the new millennium

Since the beginning of the 21st century books that illustrate *green* design have been published en masse. To a large extent these are collections of designs that are used to depict sustainable strategies or approaches in particular fields such as product design, graphics, fashion and furniture. One of the first of these books was Fuad-Luke"s *The Eco-Design Handbook* which was originally published in 2001. Titles that have since followed include: *Experimental Eco Design* (Brower, Mallory & Ohlman 2005), *Green Design* (Poole 2006), *Design Ecology!* (Nachtwey & Mair 2008), *DVA Öko Design Guide* (Proctor 2009) and *Ecodesign* (Barbero & Cozzo 2009).

An array of different approaches to sustainability have started to come out of design literature and practice. *Cradle to Cradle* (Braungart & McDonough 2002) proposes two material cycles for "biological" and "technical nutrients" where materials are infinitely recycled or "upcycled" and waste is eliminated. "Cradle to cradle" is closely linked to biomimicry, an area that has been popularised by Janine Benyus and describes technologies that are inspired by the processes of nature (Mau & Institute without Boundaries: 156-157; TED Talks). Chapman (2005) has followed a different approach and explores *Emotionally durable design*, Walker (2006) experiments with the aesthetics of electronic household appliances and Thorpe (Chick & Micklethwaite 2011: 72-73; Thorpe 2010) has become increasingly interested in the area of *design activism.*

Design organisations that underline the notion of social well being have started to emerge. Architects for Humanity (AfH) was formed in 1999 by Kate Stohr and Alistair Sinclair after Sinclair decided to respond to housing crises in the aftermath of the Kosovo conflict (AfH 2006: 12). Designers Without Borders (DWB) was founded in 2001, in Uganda, with the aim of "assisting institutions of the developing world with their communication needs" (DWB,). The same year The Massachusetts Institute of Technology (MIT) founded Design that Matters (DtM) with the idea that that "the university system could become a catalyst for the creation of new tools to better serve basic needs in developing countries" (DtM 2012).

More recently the Cooper-Hewitt, National Design Museum (2007) curated *Design for the other 90%.* The exhibition and accompanying catalogue were "intended to draw attention to a kind of design that is not particularly attractive, often limited in function, and extremely inexpensive" (Cooper-Hewitt 2007: 5). Exhibited were products such as a solar-powered hearing aid, the controversial „One Laptop per Child" project and Q-Drum, a water container that can be rolled and so avoids heavy lifting. The exhibition has received criticism as its audience and to a large extent the designers involved are westerners (Chick & Micklethwaite 2011: 155). Nevertheless *Design for the other 90%* and the follow up exhibition *Design with the other 90%: Cities* which was shown at the United Nations in New York, has created an ongoing debate about the role of design amongst design professionals and organisations working in international development. Similarly, *Design Like You Give a Damn* edited by AfH (2006) and *Design Revolution* (Pilloton 2009) showcased design interventions in developing countries. Furthermore, international design consultancy IDEO developed the *Human-Centred Design Toolkit*. The free document was developed to support "NGOs and social enterprises that work with impoverished communities in Africa, Asia and Latin America." (IDEO 2012) and offers advice on human-centred design methods (Chick & Micklethwaite 2011: 159).

Tim Brown, the head of IDEO is a prominent proponent of *design thinking*. He states: "Design thinking takes the next step, which is to put these tools into the hands of people who may have never thought of themselves as designers and apply them to a vastly greater range of problems" (Brown 2009: 4). IDEO have used design to explore *how design thinking transforms organizations and inspires innovation* (Brown 2009).

The UK Design Council has applied design thinking to public services such as the NHS and prisons (Cottam & Leadbeater 2004a; Cottam & Leadbeater 2004b; Burns et al 2006) and insights gathered led to the articulation of transformation design as a new discipline.

These explorations do not mean that every design graduate is on her way to become a sustainable designer or even a designer interested in sustainability. It is also clear that designers and design thinkers are not necessarily in agreement over strategies. David Stairs of DWB said in an interview that "Architecture for Humanity ... has evolved into little more than an emergency relief agency (Chick & Micklethwaite 2011: 69)." Nevertheless, what all of these works and movements have in common is a recognition of designer"s "social and moral responsibility" as well as the notion that the holistic and creative capabilities that designers have previously used to create new forms, can indeed be applied to foster positive social change. In the words of Bruce Mau Design and the Institute without Boundaries (n.d.), design is "no longer associated simply with objects and appearances, design is increasingly understood in a much wider sense as the human capacity to plan and produce desired outcomes".

TRANSFORMATION DESIGN IN RURAL GAMBIA

The research proposes to apply transformation design as a design methodology for energy systems in rural Gambia, a West African country located on the Atlantic cost.

Proponents of transformation design and design thinking accentuate the importance of "empathy" which is the foundation for user-centred design. Akin to other areas in the sub-Saharan region, The Gambia has witnessed a significant population increase over the past few generations. In 1950 the population was estimated at 271 000 (UN 2010). Current levels are around 1.8 million and rising (FCO 2011). The drastic rise in numbers is putting pressure on available resources such as forests that provide primary energy for the majority of Gambians. Wood fuels are used by up to 90% of the population for domestic cooking and also find application in small industries such as rural bakeries and fish smoking in coastal villages (NEA n.d.: 3). This illustrates that the design of energy systems has to be informed by an additional qualitative dimension that measures available biocapcity and maps out resource flows (Desai & Riddlestone 2007). In rural Gambia this data is not readily available, therefore methods and tools from a broad spectrum of disciplines may be adopted.

Brown (2009: 145) states that: "an integrated program of design thinking, relies on two critical moments: the beginning and the end." However, there is arguably no end to the design of a system that has to adapt to changes such as increasing population outlined above and shifts in consumption. In fact, energy systems in rural Gambia may require frequent and perhaps drastic adaptations over a relatively short period of time. An example is the wide spread usage of mobile phone technology since the turn of the century. RED recognise the design process as continuous and propose to "leave behind not only the shape of a new solution, but the tools, skills and organisational capacity for ongoing change" (Burns et al 2006: 21)

As outlined above RED have identified *looking*, *making things visible* and *prototyping* as fundamental skills of the transformation design process. In rural Gambia additional skills and knowledge may include learning a local language and deep cultural understanding which requires time. John Ballyn who has extensive experience in working with artisans in developing countries stresses “a designer has to be prepared to learn additional skills, study a wide range of new and sometimes challenging information and, most importantly, learn to play a supporting rather than a leading role” (Chick & Micklethwaite 2011: 165).

CONCLUSION

The literature does not explore the international development discourse in relation to design approaches such as past and present participatory practice of NGOs operating in The Gambia. It does however demonstrate an ongoing zeitgeist shift from designing *for* to designing *with* and to an extent designing *by* users which is central to transformation design. Furthermore the study highlights additional skills and knowledge required to aid the design process of sustainable energy systems in rural Gambia.

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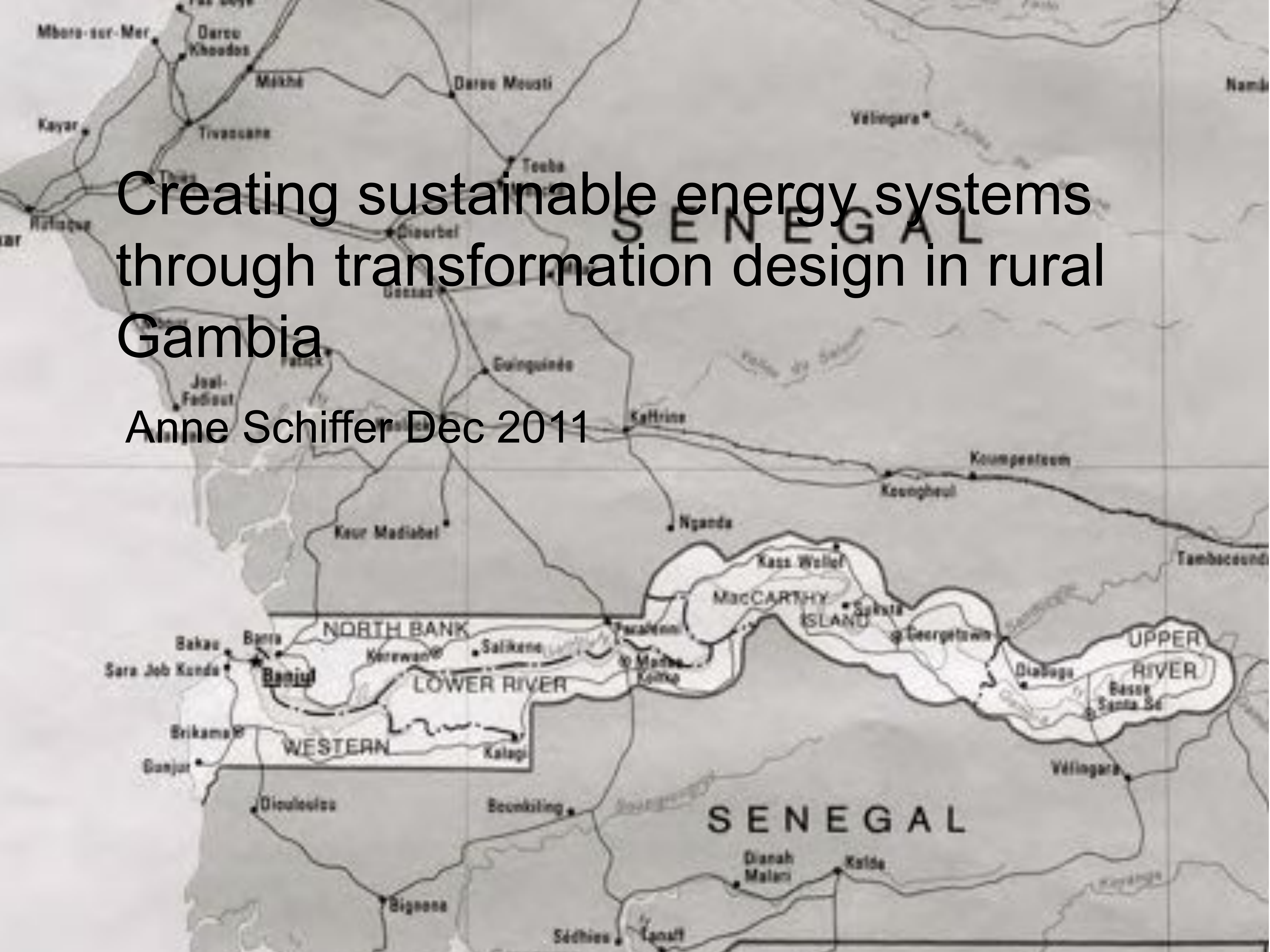
Creating sustainable energy systems through transformation design in rural Gambia

Anne Schiffer Dec 2011



1900
2 billion

1900
2 billion

2000
6 billion

1900
2 billion

2000
6 billion

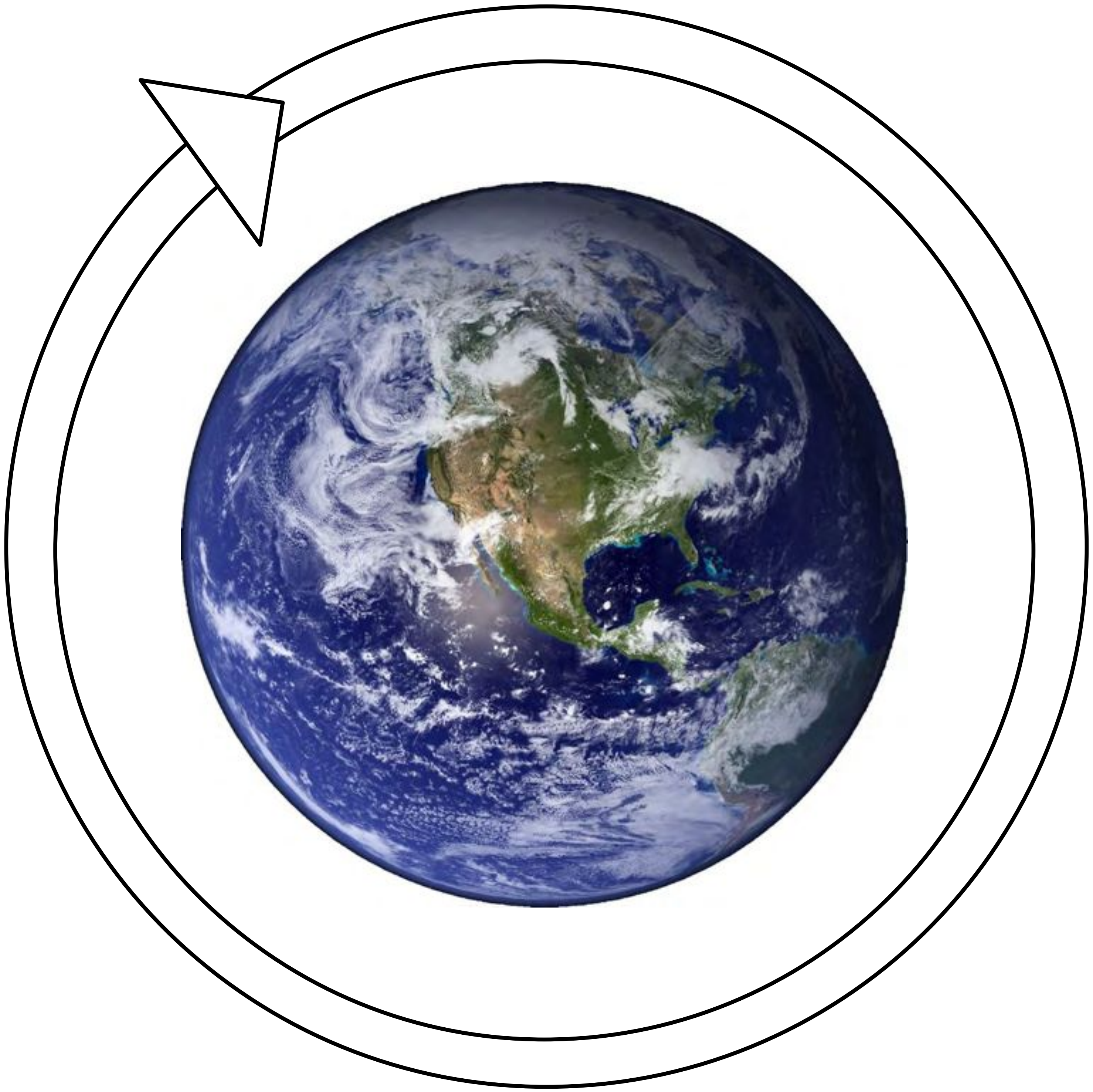
2050
9 billion


GAMCEL
MU MOO BEE
LE TAA TI

Efficiency approach

less extraction - less usage - less waste

Cradle to cradle



McDonough;
Braungart

Why design?

What is design?

- discipline
- drawing, proposal or plan
- outcome
- **design process**

(Chick & Micklethwaite 2011, p.15)

What is design?

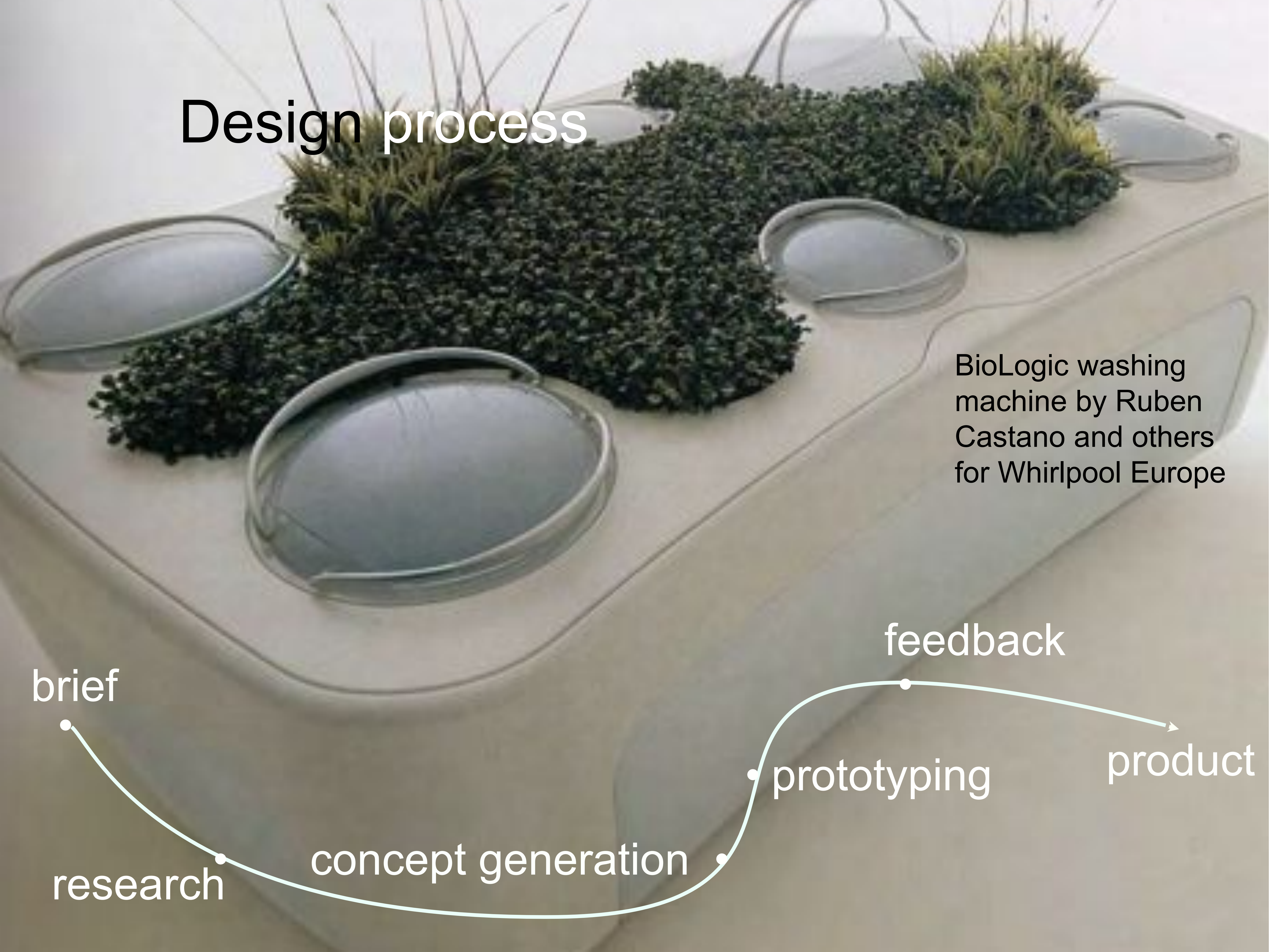
- discipline
- concept, proposal or plan
- outcome
- **design process**

creative

holistic

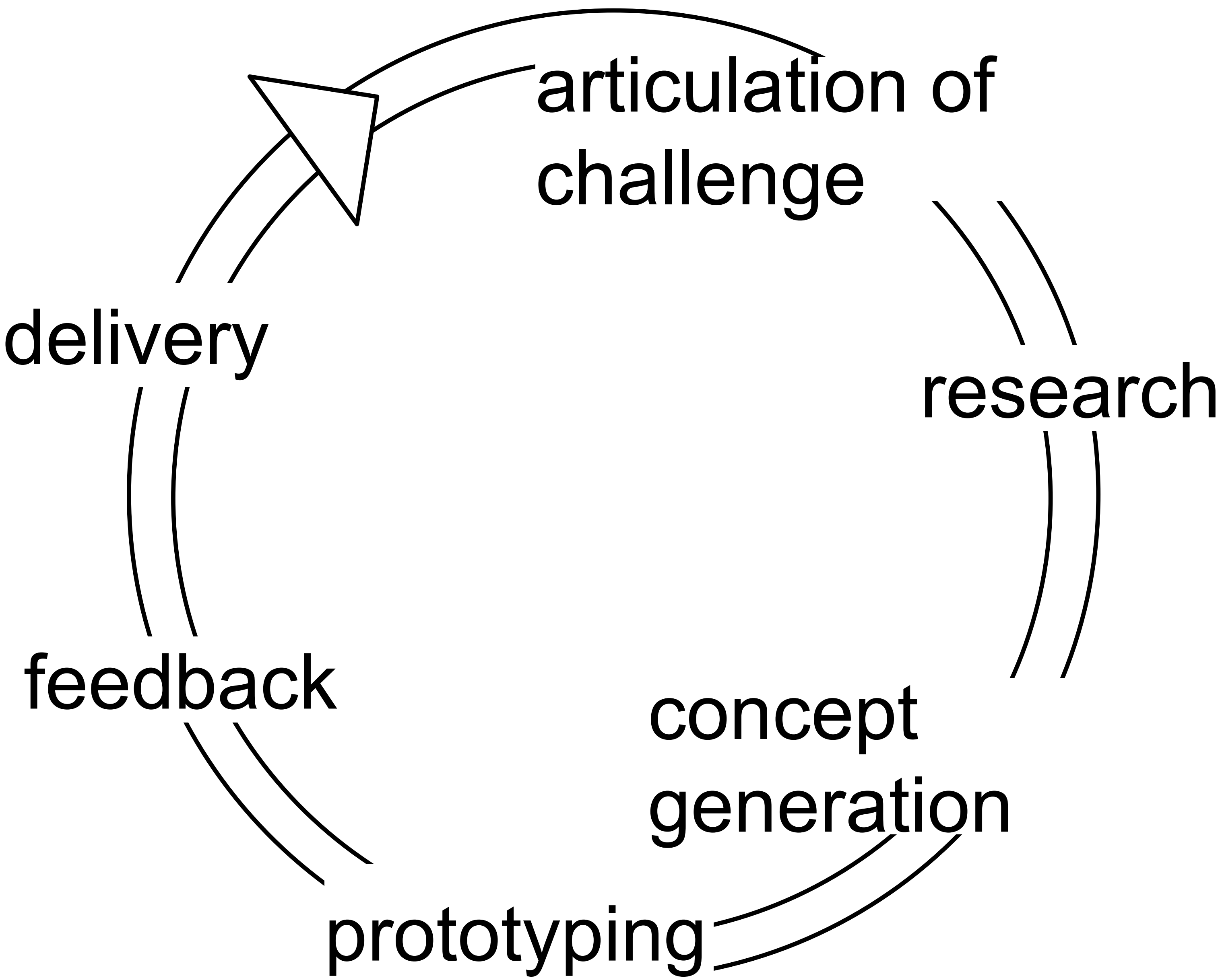
user-centred

Design process



BioLogic washing machine by Ruben Castano and others for Whirlpool Europe

Transformation Design

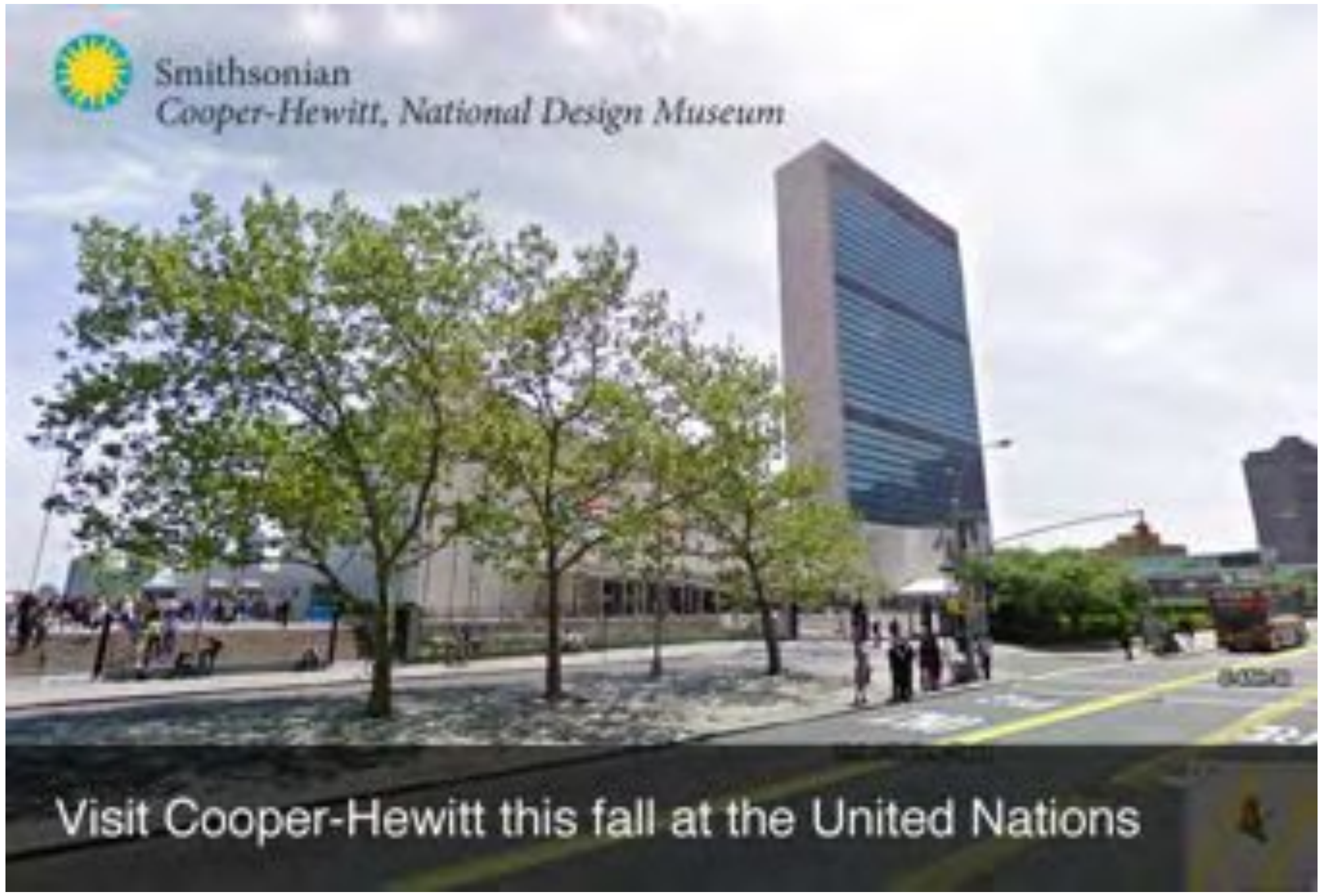


- anyone can design
- capacity building
- collaborative
- behaviour v. form
- ambitious
- continuous

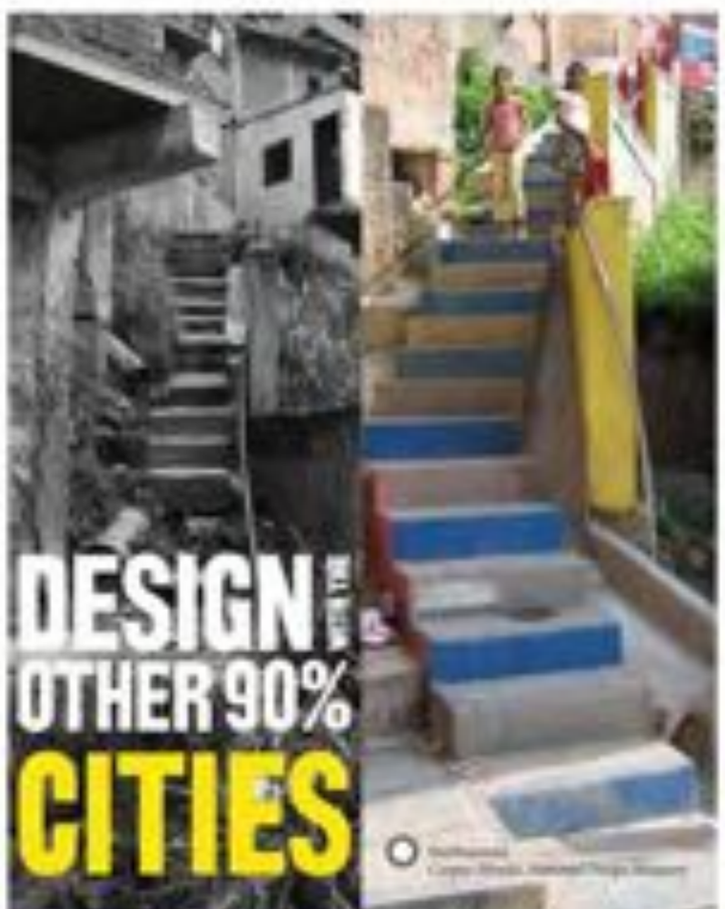
(Cottam et al, 2006)

IDEO - Human Centred Design Toolkit

http://www.ideo.com/work/human-centered-design-toolkit/


Smithsonian
Cooper-Hewitt, National Design Museum
Visit Cooper-Hewitt this fall at the United Nations


Design Like You
Give a Damn


DESIGN
OTHER 90%
CITIES


DESIGN FOR THE
OTHER 90%


Design
Revolution


In The Gambia
visualisation
immersion
observe v. interpret
interviews
Co-design
prototyping
feedback
disseminate methods
brainstorming
identifying opportunities
identifying capabilities...

LEEDS METROPOLITAN UNIVERSITY
Leeds Sustainability Institute

CeBE Centre for the Built Environment

Heat Pumps

A Low-Carbon Technology?

Anne Stafford
1st December 2011

Policy Interest in Heat Pumps

- Ground Source Heat Pumps are an eligible technology for RHI (possibly ASHPs in future)
- Also eligible for RHI premium payments
  - £ 1,250 for GSHP
  - Off gas-grid dwellings only
- Considerable interest from DECC
- UK Renewable Energy Roadmap
  - Need to understand performance variation (only CoP $\geqq$ 2.9 eligible for RHI)
  - Need for improved standards of installer training under MCS.
- Status as a low carbon technology likely to improve with decarbonisation of grid.

CeBE and Heat Pumps

- CeBE interest is *in-situ performance measurement, fabric-technology interactions and technology-social/behavioural interactions and control systems.*

Harrogate B.C.:

- Analysis of Existing Data
- Carbon, Control & Comfort

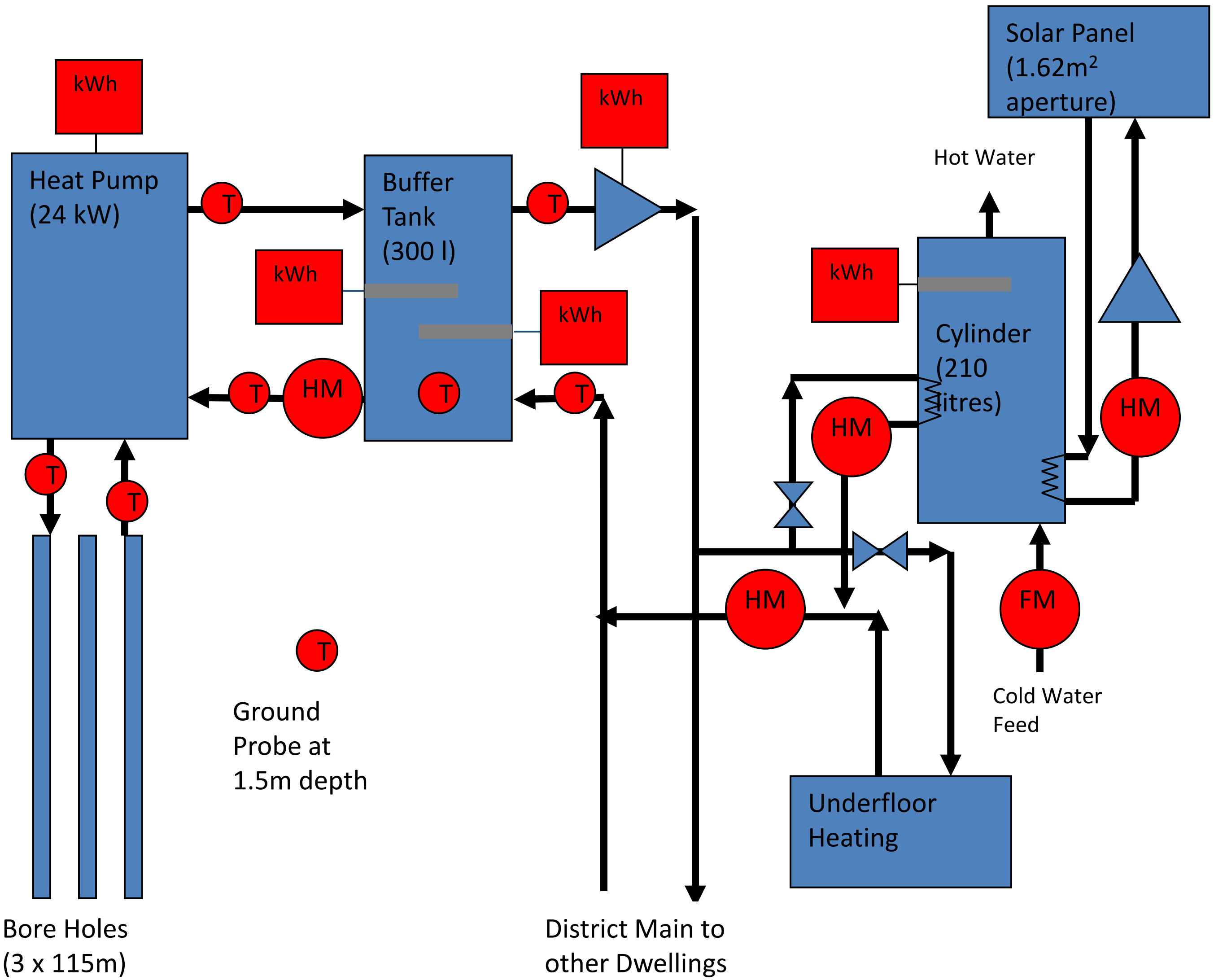
JRF:

- Elm Tree Mews

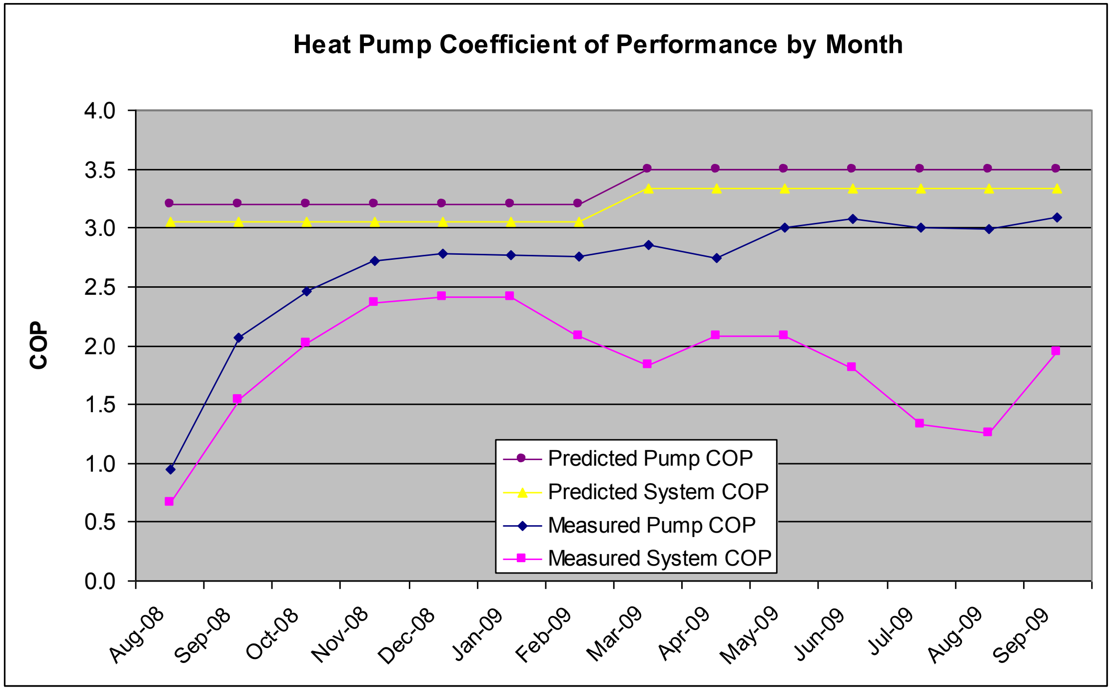
10x individual GSHPs

1x communal GSHP

Elm Tree Mews - Monitoring

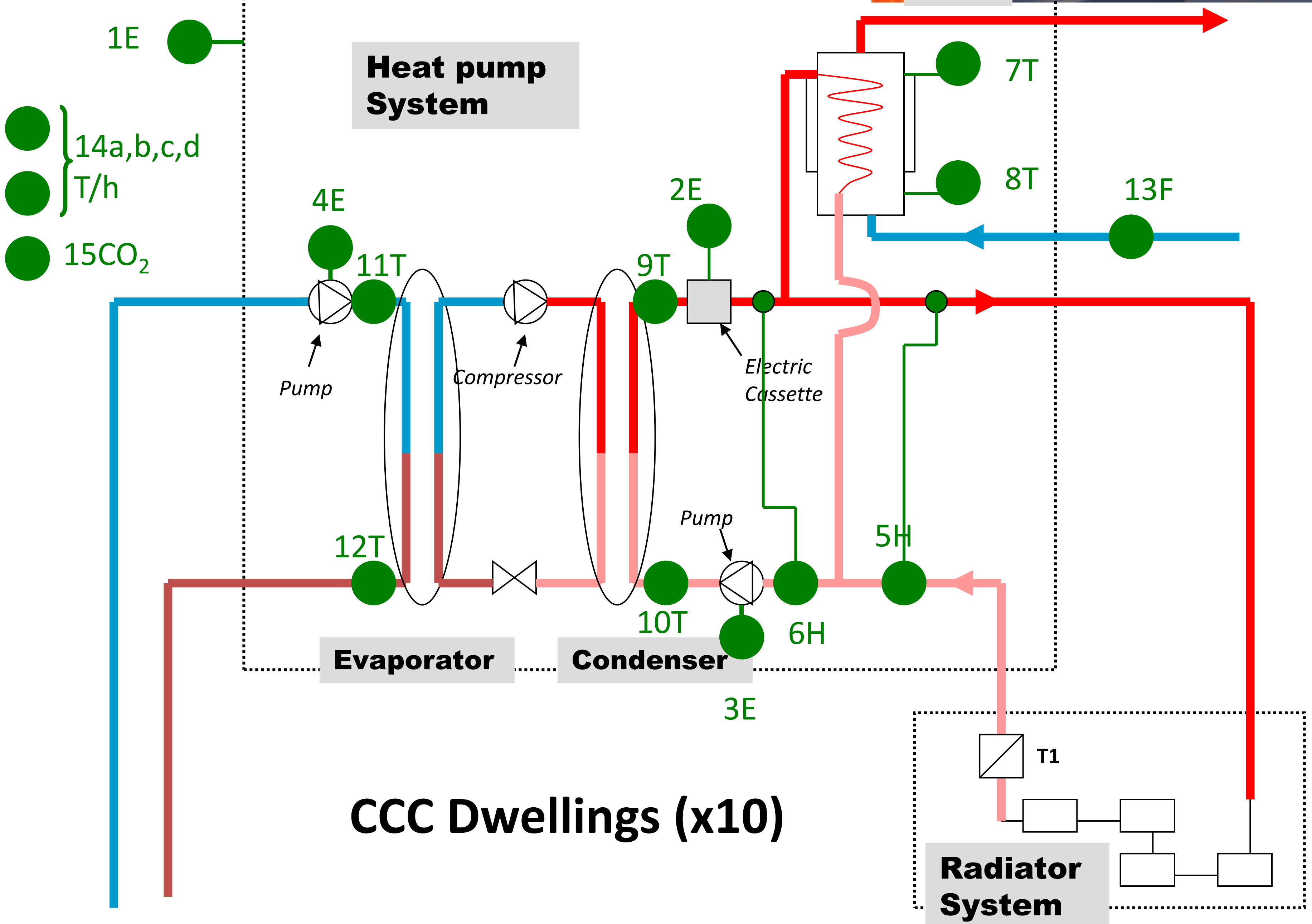


Elm Tree Mews – Some Results



Problems identified:
Hot-side pump replaced
Buffer tank thermocouple replaced
Commissioning problems with SWH.

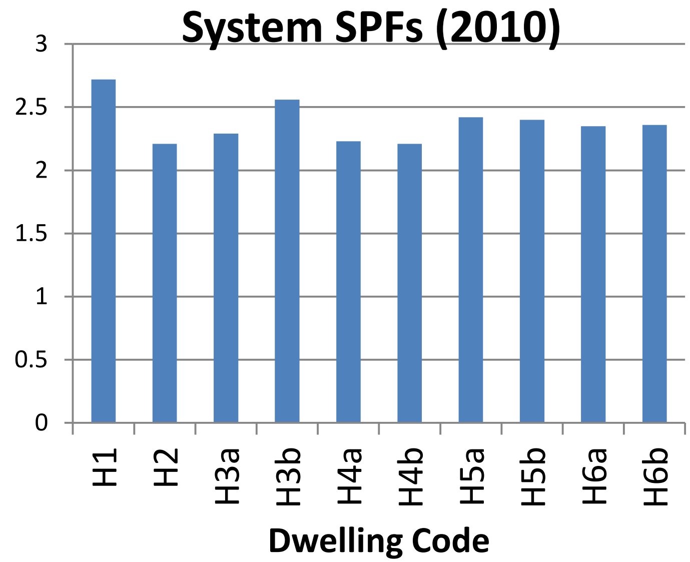
Heat Pump CoP not achieving $\geq$ 2.9 until after modifications.
System COP still much poorer than predicted.



CCC Dwellings (x10)

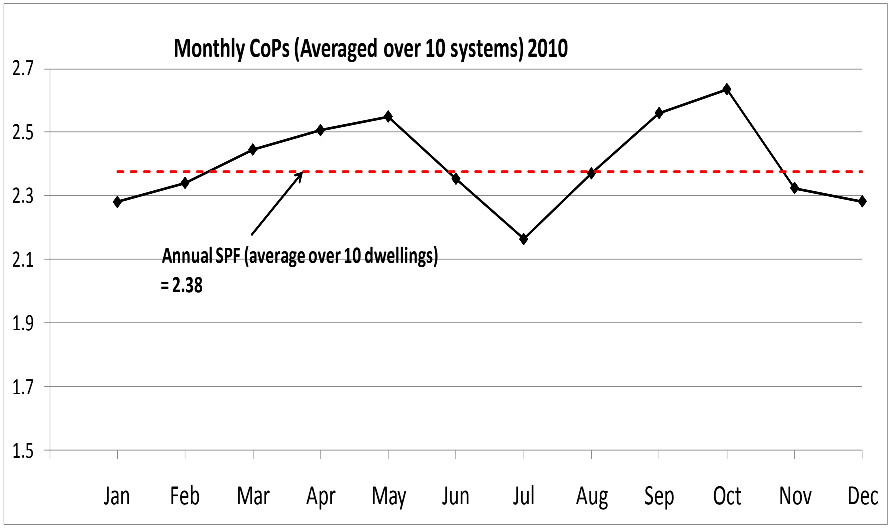
CCC - Results

System Performance

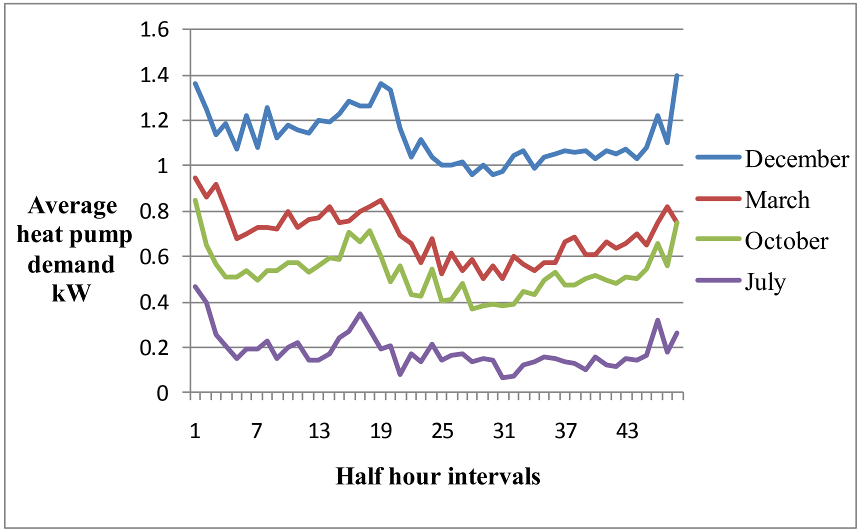


Affected by:
Settings: temperature/DHW set-point and use /cycling/summer setback etc.
Building fabric/radiators
Ground loop characteristics
User behaviours

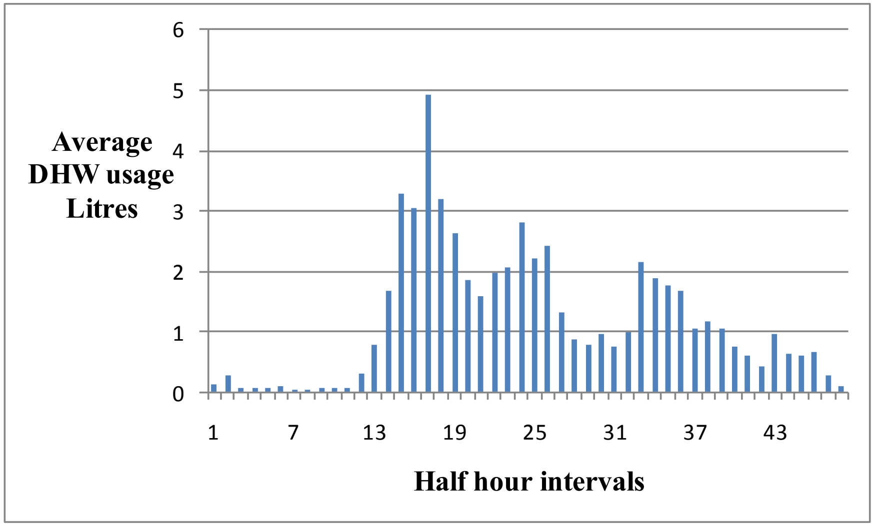
Average SPF over all 10 dwellings over annual cycle is 2.38



CCC - DHW

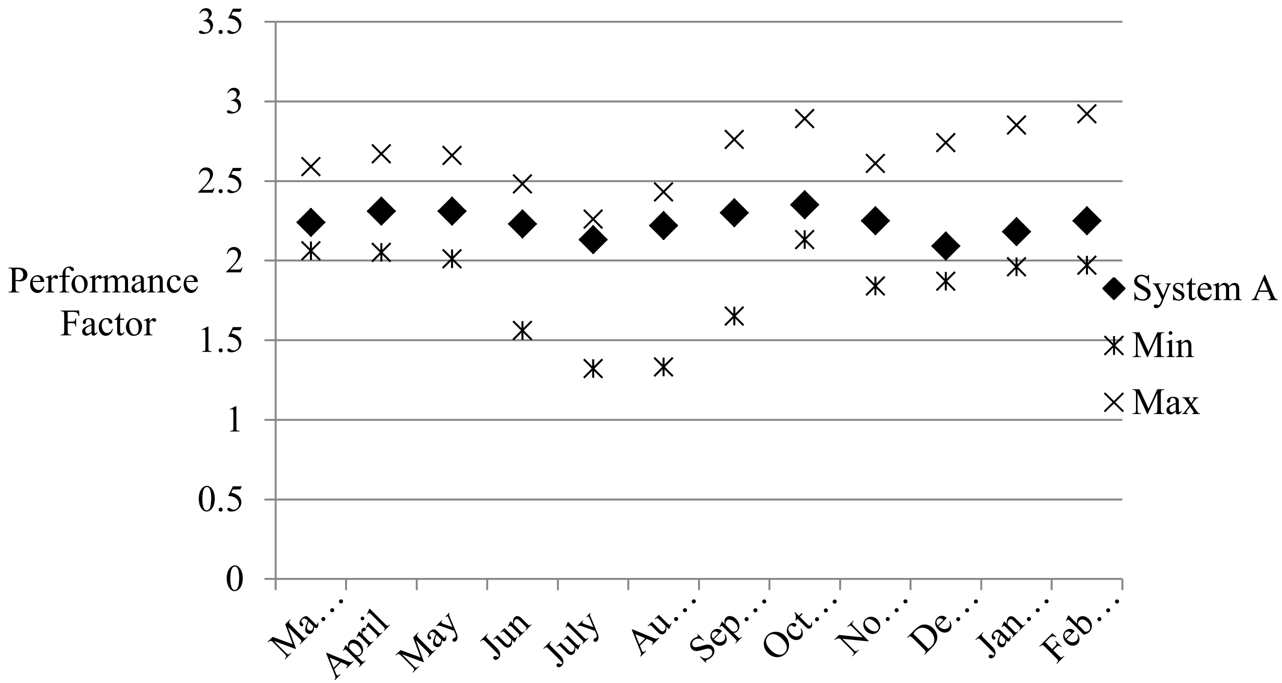


Electricity Demand correlates well with DHW consumption patterns



This is a function of the demographic, but demonstrates there may be some scope for demand management.

CCC – Individual Variations



Able to explain performance in terms of:

- DHW settings
- Compressor cycling behaviour
- Fabric & behavioural practices

CCC - Wattbox

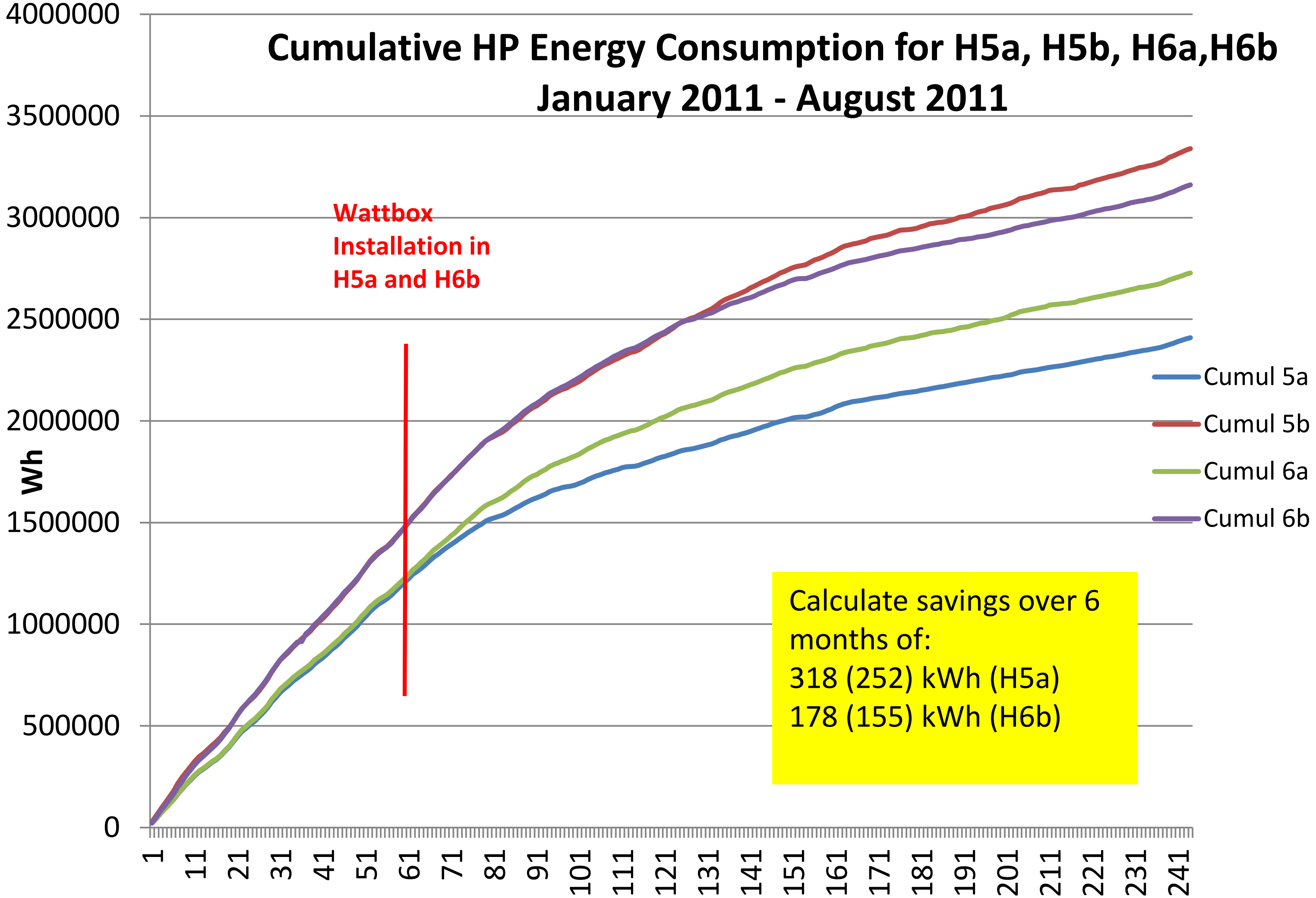
Participants advised to operate HP constantly.

- Some did not like constant temperatures (too warm at night).
- Most were reluctant to engage with controls (complex interface).

Calculations show that:

- ***It is sometimes possible to allow the HP to "back off" at night without energy penalties.***
- ***Needs to calculate a switch-on time to get up to temperature by preferred getting up time.***
- ***Easier to get energy gains by this method in low thermal mass buildings.***

CCC - Wattbox



Calculate savings over 6 months of:
318 (252) kWh (H5a)
178 (155) kWh (H6b)

CCC – Research still on-going

Carbon, Control and Comfort

An EPSRC-E.ON strategic partnership consortium (EP/G000395/1)

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