Written evidence submitted by the Leeds Sustainability Institute, Leeds Beckett University, to The All Party Parliamentary Group for Excellent in the Built Environment's Inquiry into the Quality of New Build Housing in England.

Professor Christopher Gorse
Leeds Sustainability Institute, Leeds Beckett University, Leeds, United Kingdom.
c.gorse@leedsbeckett.ac.uk

Leeds Sustainability Institute Building Performance research team
Malcolm Bell, David Johnston, Fiona Fylan, Dominic Miles-Shenton, David Glew, James Parker, David Farmer, Martin Fletcher and Felix Thomas.

Central themes to assure the quality of new housing:

1. **Standards to sustain long term economic value and address performance gaps**
    a. Establishing an acceptable performance tolerance: Energy testing, assessment and certification.
    b. Assuring building performance: Evidence of assembly, commissioning and performance.
    c. Evidencing build, function and performance with geo and date tagging to each dwelling.
    d. Prototyping for systematic research and development: Engineering repeatable solutions.

Introduction

The Government's National Productivity Plan has an ambitious target to build in excess of one million homes in England by 2020, ensuring the gap between supply and demand is reduced (HM Treasury, 2015). With a focus on affordable homes, it is important that the effort to adopt measures, to ensure an effective delivery, do not compromise build standards. With a programme of such scale, it is particularly important that new homes sustain their economic value, remain affordable to operate and are robust. Most buildings are with us for some time and their sustained value is important. Economic sustainability is a product of build quality, functional value and operational efficiency.

To increase productivity without compromising quality, the findings of recent research on the performance of building fabrics will prove important in future decision making. The recognition of a performance gap between the designed intent of a building and that actually achieved in practice is of notable concern. Evidence suggests that some current build processes are flawed and susceptible to variation in quality and performance. Attention needs to be directed at design, construction and commission practice to ensure all new building forms are robust.

Some of the gaps are small, within an acceptable level of tolerance, and can be put down to expected variation in field based performance and the sensitivity of assessment. However, some test results are well outside any normal tolerance or acceptable practice and are indications of inadequate, specification, design or construction. Agreement on acceptable tolerance and meaningful certification is essential.

A few concerns identified in early research have been recognised by regulatory bodies and are now incorporated into building standards, for example the party wall bypass. However, a considerable number of issues are unresolved. Insight gained through the investigations into thermal performance have revealed whole building assemblies that are a potential concern with regard to fire safety, resilience to moisture related degradation, problems of air tightness, thermal/acoustic bypass and bridges. The integrity of the external envelope and effective interfaces between components affect many aspects of performance. Most of the problems identified can be addressed by good practice, changes to design, workmanship and an evidence based quality processes.

Much of the research provides evidence of missing or ill-fitting components and assemblies that are different to that designed and cannot be put down to acceptable error. The unregulated assemblies that differ from design or are not adequately specified and are compromising fire, acoustic and thermal performance. A growing body of evidence identifies non-compliance and failure to adhere to test and commissioning process. A simple, standardised evidenced based method for building compliance is required. With current technology, evidence of build quality can be assured and cross checked to buildings by geo and date tagging. Such building information will ensure future maintenance is appropriate.

A number of low energy new build properties have achieved their performance targets. As the number of schemes that achieve such status are few, attention should focus on how they achieve such status and which techniques can be adopted at scale. A few organisations are investing in prototypes schemes where they learn, develop and improve their design and construction process. Such systematic improvement is good development that can inform large scale programmes and incremental development of build and manufacturing processes. Prototype and version development adopted by many other industries should be encouraged within house building sector.

The domestic home, in whatever form, represents a significant investment. Evidence of practice that assures build quality could have a significant impact on the energy efficiency and future value of the building. Affordable energy efficient homes are most likely to be delivered through quality driven standardised or manufactured processes. Bespoke, or what might be described as the limited edition run of homes, will become less common inevitably being more expensive and only available to the affluent or those interested in self-build. Focus should be on the mass build market and how to drive up standards of quality and build in this sector.

Achieving performance and the performance gap

Whole building heat loss test were first used to identify a performance gap, between the predicted performance and that achieved when the buildings were measured ‘as-built’ in the field (Wingfield *et al.,* 2011). Such testing has also been used to discuss acceptable degrees of tolerance, offering a suggested method of regaining confidence in thermal building performance measures (Stafford *et al.,* 2012a; 2012b; CEBE, 2015).

Currently there are no formal agreements on acceptable variation in performance. The accuracy of the prediction does have an impact on the performance gap. The information that is fed into the models can skew a potential difference. A cautious approach, where designers adopt conventions that assume greater heat loss serves to limit a potential negative gap, while assuming that all component assemblies perform as expected, based on information taken from models and laboratory tests, would normally result an increased exposure to a performance gap. In most cases performance gaps are not a result of optimistic or cautious design approaches, buildings are designed using the knowledge and product information available and expected to perform. In most cases the information available is sufficient, but small discrepancies in prediction are expected as there are no acceptable margins of tolerance. Even when the accuracy of testing and analysis are considered, the scale of variance in many of the buildings tested is of concern. Such buildings with lower thermal resistance than expected will consume more energy and be more costly to operate.

The results reported here show that for some buildings have a considerable discrepancy in the predicted and actual performance (Figure 1). It is important to note that the results also show a few energy efficient buildings that achieved their design intent. The dwellings with the lowest Heat Loss Coefficient (HLC), shown to the right of the graph, were built to Passivhaus or what may be considered Nearly Zero Energy Building fabric standards.

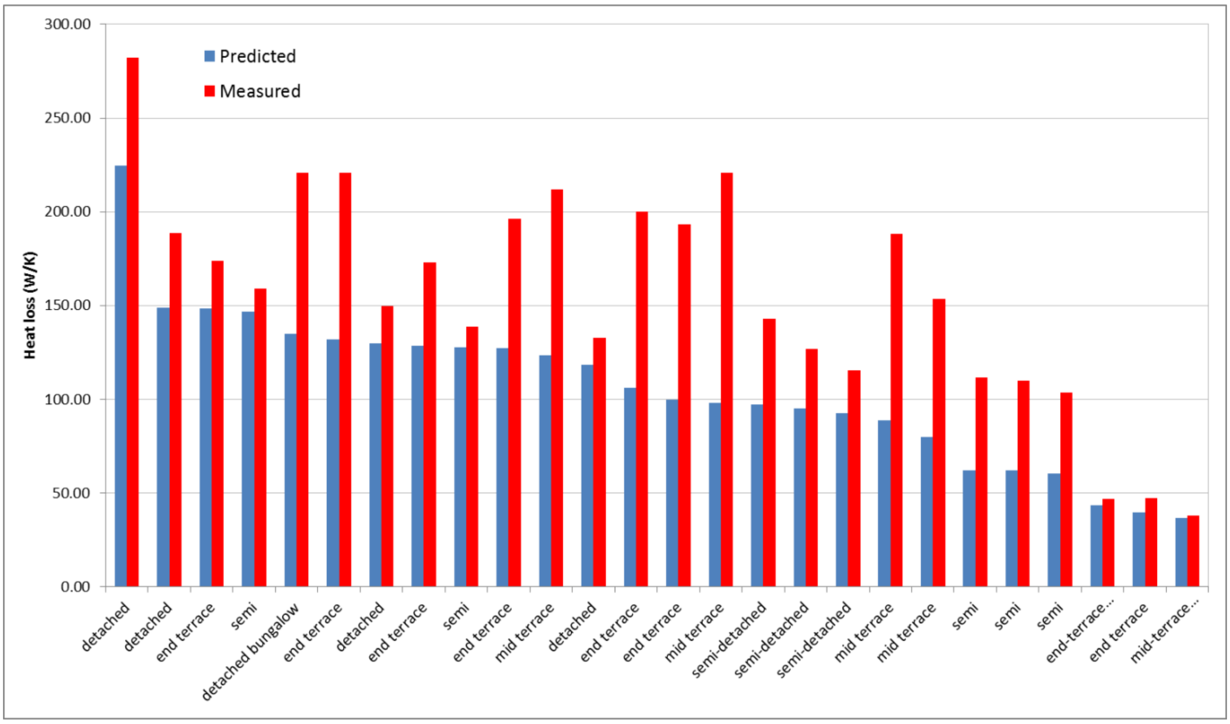

Figure 1 Whole building heat loss new building predicted and as measured (Leeds Beckett University: CEBE, 2015)

Standards and build quality

High thermal performance targets can be met where quality control is exercised in order to ensure that design targets are reached, the heat loss tests reported here confirms this and supports earlier assumptions made on smaller sample (see initial work by Stafford *et al.* 2012a. 2012b). One of the main findings of the building forensic analysis undertaken is that the most common faults occur where the integrity of the air and thermal barriers are breached or discontinued. Thus, the interface and continuity of the thermal envelope and the air barrier must be maintained in design and when built. The work of Johnston *et al.* (2014; 2015) highlights buildings that have achieved high standards of energy performance in design and construction.

Buildings that meet their design standard show limited evidence of unintended bypass, air leakage and thermal bridging. However, some test results in figure 1 show a considerable discrepancy between design intentions and as-built performance, which are seldom accounted for by margin of error alone. It is evident that buildings that offer effective thermal barriers resist provide more consistent and reliable behaviour.

Fire Safety and acoustic control

While failing to achieve zero energy targets affect our future aspirations to reduce emissions and be more sustainable, there are some important concerns regarding current build quality that have implications for the fire safety of buildings. The variations in thermal performance can often be an indication of non-compliant build standards, with buildings also failing to properly address acoustic and fire standards (Littlewood & Smallwood, 2015). Littlewood *et al.s* research noted that air permeability and smoke tests, used for air tightness compliance, found air leakage paths resulting from breaks in the insulation and penetrations that connected to neighbouring properties, which allowed the passage of smoke from one property to the next. Such paths also penetrate the acoustic and thermal barriers. The photographic evidence and thermal surveys collected by the research team at Leeds Beckett University also show problems of component interface, ill-fitting seals, breaks in construction and missing insulation that contribute to variations performance and also expose bypasses and interconnecting voids that may compromise fire safety. Ensuring components are properly fitted and installed is essential to ensure whole building integrity. Evidence of construction assemblies in the field is now relatively easy to collect.

Assembly evidence and monitoring of energy efficiency

As the cost and availability of photographic and thermal image technology is within site reach, it is not unrealistic that evidence of build quality could be provided for each property. Simple geotagged images could replace signatures of compliance, reduce bureaucracy and improve conformance. Smart phones, tablets and their apps can all record such data.

As there is a considerable increase in the technology that can be readily accessed to monitor and measure building energy performance, consumers have greater power to understand the behaviour of their homes and the degree to which they respond to environmental change and user requirement. Energy assessment tools are now available to consumers and they are steadily becoming more sophisticated as intelligent algorithms are developed to interpret and separate out energy data. As researchers develop the ability to disaggregate building fabric, system and occupant data, the home owner will soon have the power to determine whether the building fabric is fit for purpose.

The processes and measures used by industry must ensure that the quality of the building is fit for purpose, robust, ensures the government's carbon commitments are not compromised and meets the demand required by its clients.

Economically viable homes and long term consequence of poor performance

For most, fuel and power represent the largest proportion of expenditure (Office for National Statistics, 2014) and the places we live our largest investment. The purchase price or rent, operation and maintenance costs are a foremost concern for a large proportion of the population. However, and rather surprisingly, where buildings are poorly constructed, being energy and resource intensive to operate, the evidence of rebuild or remedial correction to address the operational cost is relatively thin. The building industry does not have a reputation of recalling and systematically correcting faults related to energy consumption.

Once buildings are occupied and classed as home, the ability to undertake systematic improvement can be difficult. The social values linked to buildings are complex and can sometimes be at odds with economic viability (for example, see Crawford *et al.* 2014 work on the choices associated with demolition or refurbishment of social housing).

If new homes continue to be poorly constructed the UK will bear the operational and maintenance costs for some time. Such costs are borne by the nation as many of those that live within fuel poverty brackets are unable to support living costs unaided (evidence of this can be found in MacInnes *et al.* 2015 report on poverty).

During the last five year for many groups access to housing has got worse (MacInnes et al. 2015). While the demand for housing has steadily inflated the purchase price, this is not necessarily reflected in the quality of build. Evidence of under performance is consistently found in new buildings (Gorse *et al.* 2015; Littlewood & Smallwood 2015; Johnston *et al.* 2015). Building performance and integrity are likely to affect value as the operational cost become a burden and remedial costs are incurred.

Immediate industry consequences of poorly performing homes

Ensuring the fabric and services are fit for purpose, in new building is important if the occupant is to adopt cost effective and energy efficient behaviour. Currently, much of the new building stock suffers from conditions that prevent them being operated as expected. The evidence reported would suggest that parts of the industry are not able to build to designed and regulated standards. The success of new build programmes are measured by output, performance and on the ability to meet client expectations. Where buildings do not perform as expected local authorities and developers may be held to task with residents seeking financial redress through media exposure as well as legal redress (for example see Griffiths, 2013). The Sunday Times recently questioned the value of Energy Performance

Certificates for some houses and suggested that the building industry could face an emissions scandal (Lonsdale, 2015).

The benefit of exemplars and prototypes

While underperformance of dwellings is common in the research reported, there are exemplars that demonstrate the possibility to deliver buildings that are comfortable, robust and can be operated within low income budgetary constraints. Some examples of prototyping leading to repeatable solutions suitable for volume house-building have achieved success. Joseph Rowntree Housing Trust with the Temple Avenue 54 & 69; Hill with BeZero Concept House and CITU with Little Kelham all use the information from prototypes to inform large scale building projects (CEBE, 2015). Such projects provide a more systematic approach to achieving nearly zero energy building than is generally found.

The UK has extended the timeline for adopting the measures required for new building to meet energy efficiency targets (HM Treasury, 2015); however, as part of the European Energy Performance of Buildings Directive, the UK remains committed to delivering NZEB by 2018 (public buildings) and 2020 for all other new buildings (EPBD 2010). Systematic research and development projects are required to improve the quality of build and performance.

Conclusion

Attempting to close the gap between designed and actual energy consumption in buildings requires a whole systems approach to construction. In our research we have shown that dwellings and elements within dwellings can be designed and constructed to perform consistently within an acceptable range of tolerance. The performance of buildings is not conventionally recorded and has not previously been a fundamental part of the house building process and so it is reasonable to predict that a great deal of variation exists in the UK housing stock. The implication of this is that a large amount of energy may be being unnecessarily and unaccountably consumed by the UK housing stock.

The development of testing and energy monitoring protocols that demonstrate building performance is developing at a pace (see the work of Leeds Beckett University and International Energy Agency, Annex 58 work on performance testing, also Knauf Insulation's work on the Energy Performance Challenge). Some simple monitoring tools are starting to enter the commercial market. Both the industry and its clients should now have the ability to determine which buildings perform as expected and those that don't. Quality systems are essential to ensure the industry assures the performance of its products for a scaled up delivery.

References

CeBE (2015) T*echnical Reports:* Centre for the Built Environment, Leeds Sustainability Institute, Leeds Metropolitan University (renamed Leeds Beckett University) <www.leedsmet.ac.uk/as/cebe>[accessed 2015]

Climate Change Act 2008 (c.27) London: The Stationery Office.

Crawford, K., Johnson, C., Davies., Joo, S., and Bell, S. (2014) Demolition or Refurbisment of Social Housing: A review. 27th October 2014. UCL http://www.engineering.ucl.ac.uk/engineering-exchange/files/2014/10/Report-Refurbishment-Demolition-Social-Housing.pdf [accessed 2015]

EPBD (2010) Energy Performance Building Directive, 2010/31/EU, Directive 2010/3/EU of the European Parliament and of the Council, 19 May 2010, Official Journal of the European Union. < http://eur-lex.europa.eu> [accessed 2014].

Gorse, C.A. Thomas, F, Miles-Shenton, D. Farmer, D, Glew, D and Johnston, D. (2015) Understanding Building Performance: *Implications of heat loss and air permeability on building control,* ***Journal of Zero Carbon Building****, Vol 4,* *<http://zcb.hkcic.org/Eng/InformationCentre/Publications.aspx>*

Griffiths, K (2013) Bills shock for families as West Bowling eco-friendly homes project fails to live up to promise, Telegraph and Argus, < http://www.thetelegraphandargus.co.uk/news/10203659.Energy_bills_shock_for_families_as_multi_million_pound_homes_project_fails_to_live_up_to_eco_promise/?ref=rss> [accessed 2015]

HM Treasury (2015) Fixing the foundations: Creating a more prosperous nation. Presented to Parliament by the Chancellor of the Exchequer by Command of Her Majesty CM 9098, July 2015. <https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/443897/Productivity_Plan_print.pdf> [accessed 2015].

Johnston, D and Farmer, D and Brooke-Peat, M and Miles-Shenton, D (2014) *Bridging the domestic building fabric performance gap.* Building Research and Information.

Johnston, D. Miles-Shenton, D and Farmer, D. (2015) Quantifying the domestic building fabric 'performance gap', Building Services Engineering Research & Technology, 36 (5) p,614-627

Littlewood, J.R. and Smallwood, I (2015) Testing building fabric performance and the impacts upon occupant safety, energy use and carbon inefficiencies in dwellings, 7th International Conference on Sustainability in Energy and Buildings, Energy Procedia, Elsevier

Lonsdale, S. (2015) A load of hot air. The Sunday Times, 22.11.2015 Home. p. 7 < http://www.thesundaytimes.co.uk/sto/style/homes_and_gardens/article1635150.ece> [accessed 2015]

MacInnes, T., Tinson, A. Hughes, C., Barry Born, T. and Aldridge, H (2015) Monitoring poverty and social exclusion, Joseph Rountree Foundation, https://www.jrf.org.uk/mpse-2015. [accessed 2015]

Office For National Statistics (2014) Family Spending, 2014 Edition, 2nd Dec 2014, Office for National Statistics, London. http://www.ons.gov.uk/ons/rel/family-spending/family-spending/2014-edition/index.html [accessed 2015]

Prism Environmental (2012) Construction Sector Overview in the UK, report for the European Commission <http://www.prismenvironment.eu/reports_prism/UK_PRISM_Environment_Report_EN.pdf > [accessed 2015]

Stafford, A., Johnston, D., Miles-Shenton, D., Farmer., D., Brooke-Peat, M. and Gorse. C. (2014) Adding value and meaning to co-heating tests., *Structural Survey,* Vol 32, (4), pp 331-342

Stafford, A, Gorse, C. and Shao, L (2012a) The Retrofit Challenge: Delivering Low Carbon Buildings, Report no. 4. Energy *Saving Trust & Low Carbon Futures* <[www.lowcarbonfutures.org>, March 2012 [accessed 2014]

Stafford, A, Bell, M. and Gorse, C.(2012b) Building Confidence: A Working Paper, Report no. 8. Energy Saving Trust & Low Carbon Futures, <www.lowcarbonfutures.org>, March 2012, [accessed 2014]

Wingfield, J., Bell, M., Miles-Shenton, D., South, T. and Lowe, B. (2011) Evaluating the impact of an enhanced energy performance standard on load-bearing masonry domestic construction, Understanding the gap between designed and real performance: Lessons from Stamford Brook. London: *Department for Communities and Local Government*