HOUSE BUILDING IN SCOTLAND: THE SUSTAINABILITY PERFORMANCE GAP

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The construction of very low carbon new homes in Scotland is soon to be mandatory. Despite considerable investment, numerous reports and a deferment, there remain serious question marks over the domestic sector's capability, capacity and motivation to deliver as standard very low carbon homes. The difference between low carbon design and actual building performance has arguably dominated the debate. The 'performance gap' as it has commonly become known, is only one measurement of industry readiness. For successful design and delivery of very low carbon homes, a holistic evaluation of house building in Scotland is required. This is a position paper, exploring the challenge of constructing very low carbon housing. Contrary to the traditional interpretation, the performance gap in the delivery of sustainable domestic construction is arguably threefold; (1) Environmental: the difference between fabric design, thermal performance and resultant energy consumption, (2) social: the gap between supply and consumer demand and (3) economic: the disparity between the economic rewards and the incurred cost of sub-standard delivery. Evidence from previous studies indicates that whilst the notion of very low carbon housing is widely commended and has generated many successful design strategies, the best ways for the industry to deliver the build to the required level remains highly debatable. The low carbon challenge is frequently expressed in 'green', 'sustainable' and 'environmentally friendly' vernacular. Reviewing the literature, this is arguably misleading and a rather gracious evaluation of current industry performance. If, in essence, sustainability ideals are quality ideals then questions need to be asked about construction procedure, process and performance. Addressing the environmental, social and economic performance gap(s) will in all probability require further government intervention, but it may also require a fundamental re-evaluation of sustainable domestic construction and the evolving role of legislators, designers, contractors, consumers and end-users.

Keywords: sustainability, performance, domestic construction.

INTRODUCTION

The construction of very low carbon homes in Scotland is soon to be mandatory (Sullivan, 2013). Despite the imminent requirement to deliver as standard very low carbon homes, there remain serious question marks over the industry's capability, capacity and motivation to realize this level of performance. Key areas of concern include building fabric and energy performance, supply and demand, affordability and client satisfaction to name a few. It is has been argued that by taking advantage of synergies between sustainable construction design and parallel initiatives such as smart materials, integrated supply chain management (BIS, 2013) and post occupancy

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energy performance evaluation, the design and construction of very low carbon homes will be achievable.

Sustainable domestic construction is not a new concept. Over the past two decades, this aspiration has been a significant part of the industry improvement agenda. Early emphasis was placed upon the building fabric, exploring ways to reduce heat loss and energy consumption, the challenge now is much broader with the focus firmly on delivering very low carbon homes from 2016 / 2017. But, despite considerable investment, recent studies suggest (Gorse *et al*., 2011, Gorse *et al*., 2012) that there remains a 'sustainability performance gap' between the promise of a zero carbon home and the actual performance of the dwelling as built.

The term 'performance gap' typically refers to the difference between sustainable domestic design (theory) and carbon performance in practice (Zero_Carbon_Hub, 2014). This has stimulated extensive research and development in the technology and science of domestic construction and the need to develop robust models for the design and post-evaluation of the building fabric (Zero_Carbon_Hub, 2014). However, the notion of a sustainability performance gap in domestic construction is not confined to the building fabric and energy consumption.

There is also a 'social' performance gap, this relates to market supply and demand for very low carbon homes. Although the dynamics of the housing market are likely to alter due to direct government intervention, the attractiveness of owning a very low carbon home still has to be promoted as a desirable proposition for new home-buyers. Dependency on the ethical argument, i.e. ‘it’s the right thing to do’ is unlikely to shift consumer perception and create notable demand in the short-term (Fewings, 2009). On the other hand, success also brings tensions. Increasing volume is also likely to put pressure on resources and build quality.

In addition to the ‘environmental’ (fabric) and ‘social’ (supply and demand) performance gap there is also an ‘economic’ performance gap (Craig *et al*., 2010). The economic performance gap refers to the apparent disconnect between the commercial performance of a house builder and the profit implications (penalty) of delivering less than standard. At present there is little recourse for home buyers dissatisfied with the quality of build and energy performance of their new home and the extended time between taking ownership and a full evaluation makes remedial work even less likely.

Whilst several of the ‘performance’ problems are scientific and technological in character, others are arguably rooted in the traditional behaviours, culture and structure of an industry largely impervious to substantive change. It is suggested that a mandatory post occupancy evaluation procedure is needed in order to help ensure that low carbon new housing targets are achieved.

This paper is a holistic review of housebuilding in Scotland in the context of the challenges set by performance evaluations. Following a brief overview of sustainable house building objectives in Scotland, the challenges associated with the housing 'performance gap' is reviewed. Three perspectives are presented; (1) an environmental performance gap; (2) a social performance gap and (3) an economic performance gap. The following section outlines the research strategy. The discussion section explores potential corrective measures and suggests that many of the sustainability ideals demanded by government and policy makers are very often quality ideals. The paper concludes with some reflections and identifies avenues for future research.

SUSTAINABLE HOUSE BUILDING IN SCOTLAND

This paper asks a basic question about the holistic sustainability gap between the theory and practice of very low carbon homes in Scotland. Given the imminent legislative requirement to design and deliver zero carbon housing, this is a potentially thorny question for industry stakeholders including government authorities, building design consultants and construction professionals. But, asking this question in the Scottish context in 2015 is pertinent in two related ways that could be applied to other countries. First of all the difference between the high building heating load caused by Scotland's climate and the legacy technical standards that prevailed until fairly recently means that heating energy use, costs and associated carbon emissions in the country are high. Secondly, as a counterbalance to the historical situation, the Scottish legislative aspiration for the very near future is amongst the most demanding in Europe.

The European Commission (EC) has a 20:20:20 vision for the year 2020 in the Energy Performance of Buildings Directive (EPBD) (OJEU, 2010). Key targets for new domestic buildings include a 20% reduction in energy demand, a 20% reduction in carbon emissions compared to 1990 levels by 2020 and a 20% target for renewable energy to be supplied to buildings. To meet the 20:20:20 EPBD commitment, the UK government Standard Assessment Procedure (SAP) (BRE, 2012) is used to evaluate the energy demand of buildings. Adopting this widely accepted algorithm will permit an objective statement of energy performance efficiency over time. Whilst the aspirations of zero carbon housing is driven by the EC, the UK strategy for achieving the 20:20:20 vision is set out in two key documents, the Callcutt Review (2007) in England and Wales and the Sullivan Report (2007) in Scotland.

The Scottish domestic construction industry is guided by the aspirations set out in the government commissioned Sullivan Report (2007) on measures to improve the energy performance of new housing and other buildings in Scotland: ‘net zero carbon buildings by 2016/2017, if practical’ and, to include eventually the materials supply chain, ‘the ambition of total-life zero carbon buildings by 2030’. Of importance, the report makes it clear that the achievement of ‘net zero carbon’ is to be evaluated using the Scottish building standards requirements for space and water heating, lighting and ventilation, which makes explicit use of the SAP methodology (BRE, 2012). This supports the objectives of the EPBD (OJEU, 2010).

The Sullivan Report (2007) for 2016/2017 recommended a two stage strategy in the design and delivery of sustainable housing in Scotland. The first stage was to amend Scottish energy standards to achieve ‘low carbon buildings’ in 2010, the second stage was to further revise the Scottish energy standards to achieve ‘very low carbon buildings’ in 2013. In order to give the domestic building industry adequate notice to prepare for the proposed changes, the Sullivan Report (2007) strongly emphasised the need for information to be disseminated as soon as possible from the date of publication.

In accordance with recommendations set out in the Sullivan report (2007) the Scottish energy standards were changed in 2010 (see Table 1) to deliver a 30% reduction in carbon emissions compared to the 2007 standards. But the second stage (very low carbon buildings) scheduled for 2013 was postponed indefinitely. In response, the Sullivan panel (see Sullivan, 2013) was reconvened for an updated report in May 2013.

The economic downturn that began in 2008 had a negative impact on the construction output in most countries in Europe, including Scotland. The acute economic correction meant that it was necessary to re-think the timetabling for the Scottish energy standards to implement 'very low carbon buildings'. Despite the delay, government resolve and ambition continues to endorse full implementation of the Sullivan 2007 recommendations and indeed are closely linked to the legally binding carbon emissions reduction targets set out in the Climate Change (Scotland) Act 2009 and the overarching EC EPBD 2010.

New energy standards for housing will be in place in October 2015 (see Table 2). The revised technical standards aim for a 45% reduction in carbon emissions compared to the 2007 standards. Interestingly, Sullivan (2007) had previously targeted a 60% reduction compared to 2007, in carbon emissions by 2013.

Table 1: Current Scottish Building Standard Section 6.0: Energy

Scottish Building Standards Section 6.0 Energy 2010 and unchanged in 2013		
Element or System	U-Value (W/m2.K)	Air infiltration through the building fabric (m3/m2h at 50 Pa)
Walls	0.19	7.00
Floors	0.15	
Roofs	0.13	
Openings	1.50	

Table 2: Proposed Scottish Building Standards Section 6.0: Energy

Scottish Building Standards Section 6.0 Energy proposed for October 2015		
Element or System	U-Value (W/m2.K)	Air infiltration through the building fabric (m3/m2h at 50 Pa)
Walls	0.17	7.00
Floors	0.15	
Roofs	0.11	
Openings	1.40	

Table 1 shows the U-value and air infiltration key performance indicators implemented in the Scottish energy standards in 2010 as recommended by Sullivan (2007) and remained unchanged in 2013, missing the Sullivan (2007) proposed upgrade. Table 2 shows the same energy performance KPIs to be introduced in October 2015. It is worth stating that the 2015 proposed thermal transmittance (U-value) standards are comparable to those required for passivhaus certification.

The Scottish Government ambition for very low carbon housing is commendable. The potential benefits are both local and global. At a local level household energy consumption will be significantly reduced, leading to lower energy costs and improved living standards. At a global level, CO_2 emissions will be reduced and have a positive impact on UK Government carbon emission targets in both the short and longer-term. However, with only a limited amount of time before very low carbon homes become the industry standard for domestic construction in Scotland, many design, build and delivery challenges remain unresolved.

THE SUSTAINABILITY PERFORMANCE GAP

In theory, the design and construction of low and zero carbon housing is both achievable and realistic (Gorse *et al*., 2011). In practice, the delivery of zero carbon dwellings remains problematic. The success of zero carbon house building is dependent upon three critical aspects of pan-industry sustainable performance; namely, (1) the environmental performance, (2) the social performance and (3) economic performance of the house building sector (see Figure 1).

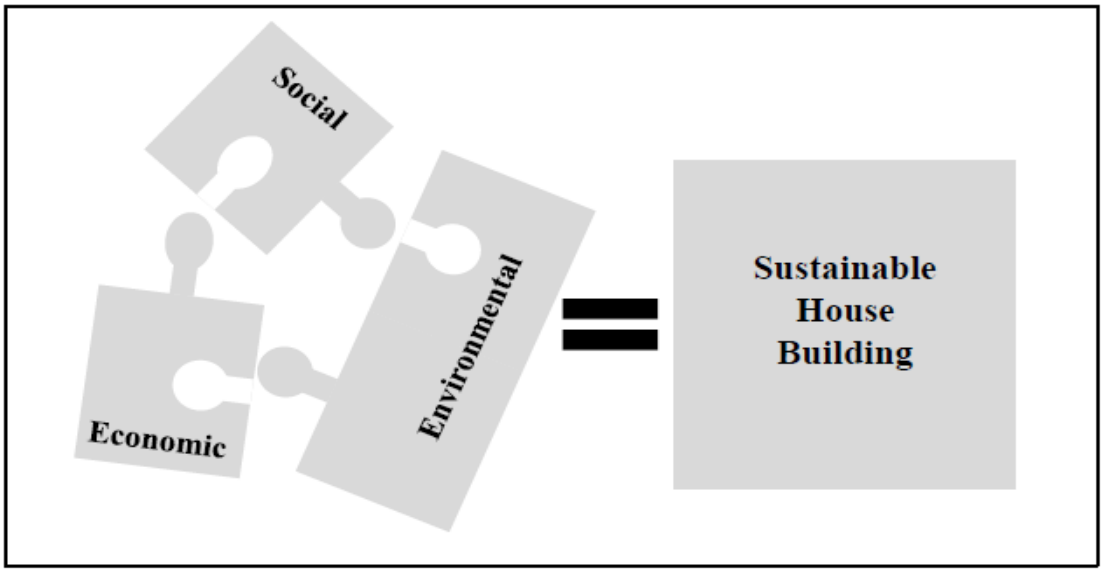

Figure1: Key components in the delivery of sustainable house building

THE 'ENVIRONMENTAL' PERFORMANCE GAP

Since the publication of carbon targets for housing (Callcutt, 2007, Sullivan, 2007) there has been growing interest in the environmental 'performance gap'. The performance gap refers to the difference between the theoretical performance and the actual performance regarding energy efficiency in domestic construction (Zero Carbon Hub, 2014). For many, *"the foundation for any zero carbon home must be to ensure that the fabric is delivered to a standard that minimises energy consumption,"* (BIS, 2010). Whilst the specification and design of energy and carbon efficient housing is arguably 'academic' and founded on widely respected technological and scientific principles, the 'actual' construction process introduces complex variables beyond the scope of laboratory testing. In fact, 'in-situation' testing and performance evaluation of house building and energy efficiency remains extremely rare in the UK.

Reasons for the environmental performance gap are both complex and diverse. Location, design, construction and occupancy behavioural patterns all contribute to the net energy efficiency of the house. In addition to design, recent findings suggest the performance gap is compounded by a range of buildability issues including careless detailing, poor workmanship, lack of applied knowledge and inadequate management / supervisory procedures (Gorse *et al*., 2012). Given the regularity of sub-standard performance in the domestic construction sector (Craig *et al*., 2010), it may be argued that sustainable construction ideals are merely high quality ideals. Both (sustainability and quality) contribute to fabric performance that is beneficial to the home owner and government environmental targets.

Exploring reasons for poor quality, as opposed to poor sustainability, highlights the pivotal role of the house builder and the domestic construction industry in general. Many of the underlying causes of poor energy efficiency can be attributed to site practices that are simply sub-standard and unacceptable regardless of the sustainability objectives. Findings from Gorse *et al* (2012) underscore the extent of the problem; 'insulation displaced', 'insulation discontinuity', 'failure to inspect', 'insulation not properly reinstated', 'gaps in party walls', 'incorrect use of tapes and sealants', 'cold bridges', 'incorrect expansion strips', 'junctions not sealed' and 'air leakage around service fittings'. Therefore, to suggest that the performance gap (building fabric) is simply a 'zero carbon challenge' is arguably misleading and also a rather gracious evaluation of current industry build standards.

THE 'ECONOMIC' PERFORMANCE GAP

The economic performance gap refers to the difference between the motivation and capacity of house builders to deliver zero carbon homes and the market value of the industry product. Reviewing recent evidence of fabric performance studies, confidence in house builders and construction contractors in general would appear justifiably limited, but this does not correspond to changes in consumer demand. From an economic perspective, the performance gap is presented as a disconnect between corporate profits and construction standards. As noted in the Review of Housing Supply (Baker, 2004 p.111), *"house builders do not have to deliver a good product, or high levels of customer service, to win market share"*.

The growing popularity of off-site construction and innovative design for manufacture and assembly (Dfma) is arguably trying to tackle key issues regarding technical standards and build quality. Promoting the 'industrializing' of the house building process addresses many technological issues but arguably ignores the root cause of poor quality construction. Construction is a people industry. If those with responsibility do not deliver on technical quality, then regardless of its design stage potential, the final product will exhibit failings and defects. As highlighted in previous sustainability studies, damaged panels continue to be installed, construction joints are incorrectly finished and supervisory levels onsite remain inadequate. The pertinent question is why are these practices tolerated? Why are damaged panels installed when it is obvious prior to assembly that they are damaged? Why are assembly joints left open when it is clearly a problem? And why do house builders provide limited supervision on their construction sites when quality standards are widely acknowledged as variable? Admittedly, domestic construction is very difficult to monitor with any degree of confidence. House builders and home buyers arguably accept this. For example, the all too familiar snagging list is simply an expression of sub-standard construction and/or workmanship and/or supervision.

Unfortunately, many of the defects that impair the sustainability values of a low or zero carbon home will be hidden from view and therefore unavailable for detailed inspection from third party regulators and home owners. At present there is very limited post occupancy review of new dwellings, no 'fit for purpose' testing and client feedback to industry bodies appears to be administrative and largely symbolic.

THE 'SOCIAL' PERFORMANCE GAP

Social performance refers to the housing market and the enthusiasm of home buyers to purchase low or zero carbon homes. A number of studies have explored green marketing strategies for sustainable domestic construction (Bevan and Lu, 2013) and

consumer appeal of owning a sustainable, environmentally friendly home (Callaghan, 2014). Frequently, the desire to own a sustainable home is calculated in monetary terms and largely based on an estimate of how much extra money a house buyer is prepared to pay for a zero carbon home. Consequently, the social performance gap is the discrepancy between consumer desire to own a zero carbon home and the financial premium incurred when electing to purchase a sustainable house.

To date, there has traditionally been an upfront financial cost to purchasing and owning a zero carbon home. The upfront build costs are arguably more expensive due to housing developers having to change standard designs, introduce zero carbon technologies (ZCT), hire specialist skills and purchase high specification materials. House builders simply pass any additional expenditure on to the house buyer. The current lack of demand for energy efficient homes (Callaghan, 2014) has arguably compounded the price differential between traditional methods of domestic construction and sustainable techniques and technologies.

The social performance gap is twofold. First, potential home buyers do not regard energy efficiency as a priority when looking to purchase a new home and second, they are not prepared to pay inflated prices, (Callaghan, 2014). House builders have failed to adequately address the problem by continuing to adopt traditional sales strategies. The responsibility for seeking information about energy efficient homes still resides with the consumer (Bevan and Lu, 2013). Given that energy efficiency is not a marketing priority, prospective home buyers are largely left to their own devices regarding salient technical information they require to make an informed judgement. In short, there would appear to be a performance gap between those that produce and those that wish to purchase very low carbon homes.

RESEARCH STRATEGY

This is a position paper. The objective is to explore key challenges facing sustainable domestic construction in Scotland and in particular the performance gap that exists between the theory of very low carbon homes and current industry practice. The spotlight is on house building within Scotland and in particular volume house builders and their construction practices.

The review explicitly excludes contributions from all non-domestic construction, infrastructure (civil engineering), builders' merchants and domestic construction outside Scotland. It is pertinent to note that within the UK, Technical Standards (Scotland) for domestic construction differ from England and Wales. Despite variations, the overarching ambition of both UK and Scottish Parliaments is to deliver very low / zero carbon housing in the short-term. Consequently, many of the issues facing the design and delivery of low carbon homes in Scotland will be representative of challenges experienced in the rest of the UK.

The research method relies primarily on a literature review. The narrative draws on findings and discussion from previous industry studies. Secondary data is provided via anecdotal evidence gathered from recent discussions with a SME house builder and new home-buyers. It is envisaged that further empirical studies will be undertaken to explore the scale of the challenge facing sustainable domestic construction and correction strategies to close the sustainable performance gap.

DISCUSSION

The discussion section explores the readiness of the domestic construction sector in Scotland to deliver very low carbon homes. Addressing the environmental, social and economic sustainability performance gap outlined earlier, three initial strategies are proposed; namely pre and post occupancy certification, quality considerations and improving consumer understanding of low carbon domestic construction. Whilst it is convenient to disaggregate the design, build and delivery of very low carbon domestic construction in to three distinct streams, they are not necessarily mutually exclusive.

PRE AND POST OCCUPANCY CERTIFICATION

Over the past decade, the majority of research interest has concentrated on the environmental performance gap, namely the difference between the theoretical performance and the actual performance regarding energy efficiency in domestic construction. It is therefore fundamental in the delivery of very low carbon homes to fully understand and develop control and correction mechanisms that will permit (1) evaluation of actual performance against the design requirements and (2) raise the knowledge, understanding and profile of very low carbon home ownership.

A key recommendation is the introduction of mandatory post occupation certification for very low carbon homes. This would be an extension of the current building warrant and completion certificate issued by Building Control. Post occupation would allow an independent evaluation of energy performance over an extended period. In Sweden, post occupancy energy efficiency valuation is carried out after two years of new home ownership (Heffernan *et al*, 2012). Results could be collated nationally, energy performance tolerances established and deviation outwith expected energy consumption referred to a ‘sustainable housing’ industry regulator. The regulator would have license to instigate investigative reports, order remedial work and where appropriate assist with compensation claims for new home-owners. They would also establish a register of repeat offenders.

In the longer-term, the concept of post occupancy certification has a fundamental contribution to make in tackling the environmental performance gap. In the short-term, new home-owners remain vulnerable to energy ‘inefficient’ housing. As a stop-gap measure and just prior to owner-occupation, building control (or the National House Building Council (NHBC)) could introduce simple non-contact thermometers and thermal imaging to quickly establish thermal performance weak points.

SUSTAINABILITY IDEALS ARE QUALITY IDEALS

Reviewing typical new home-owner defects and snagging lists, it becomes obvious that many of the 'thermal weak points' relate to sub-standard workmanship and inadequate supervision. A significant contributor to poor build quality is the way mass house building in Scotland is structured and subsequently managed. The Scottish construction industry like the rest of the UK is unregulated at the point of entry and in the case of house building very often self-regulating at the point of delivery.

In contrast to many local house builders, very few national house builders directly employ their workforce; as a result house building companies frequently rely on site supervision that is frequently understaffed and over-dependent on the good-will, face-value and honesty of their unregulated / self-regulating subcontractors and suppliers. It remains highly debatable if 'light-touch' regulation can provide the level of product quality and service satisfaction necessary for a very low carbon built environment.

Whilst the list of defects is both familiar and depressing, the perpetrators remain largely unaffected. It may be argued that changing construction industry attitudes regarding quality are greater than the technological and scientific challenges posed by the design and construction of very low carbon housing. Without redressing the balance in favour of the consumer, very little is likely to change. Only at the point where the economic risk associated with poor quality becomes financially punitive will house building companies start to engage seriously with quality build initiatives.

CONSUMER AWARENESS

Much has been made of the construction skills gap in relation to design and delivery of quality sustainable homes (Glass *et al*., 2008). Whilst not discounting the requirement for greater construction skills training, consumers also require knowledge. Many potential home-buyers are either unaware or currently disinterested in the sustainability credentials of their new home and consequently do not perceive the value of a very low carbon house as a priority. For home-owners it remains the financial cost of a house and potential resale value that dominates the purchasing decision-making process (Fewings, 2009).

The market persuasiveness of *"location is still king"* (Sullivan, 2013 p.17), continues to distort the commercial relationship between cost and quality and energy consumption. A recommendation set out by the Sullivan update (2013) was the requirement to recognize monetary savings attributed to very low carbon construction within property evaluations. Whilst this may reinforce the economic rationality of low carbon home ownership, on its own it is unlikely to alter buyer perceptions.

In addition to house valuations that reflect low carbon construction, consumers also need to better understand the design specifications and technical standards of the house they are buying. This requires home-buyers to become pro-active in seeking information and house builders engaging with potential consumers to disseminate technical information and the performance benefits of very low carbon home-ownership. Without an exchange of technical knowledge, consumer behaviour is unlikely to alter and house builders will continue to exhibit a casual attitude towards quality standards and client satisfaction (Craig *et al*., 2010).

The supply and demand challenge of the very low carbon home is likely to be exacerbated by recent Scottish Government appeals for ever greater numbers of homes to be built year on year. The surge in the demand for housing units will create tensions within the construction community, stretch regulatory bodies and potentially limit the development and diffusion of technological innovation. In short, significant market demand for new homes may impede industry supply, drive and desire for sustainable house building in Scotland.

CONCLUSION

The Scottish Government ambition to deliver very low carbon housing is both commendable and soon to be mandatory. However, the capacity, capability and motivation of the house building sector to deliver sustainable, energy efficient, high performance homes as standard remains debatable. The challenge is not simply technological, stakeholder expectations of the construction industry need to be raised and a superior quality of service and products demanded and delivered.

There is undoubtedly a requirement for more research and better understanding of the technology and science connected with sustainable domestic construction. The design

and the integration of energy efficient services have a notable part to play but many of the findings cited in recent studies frequently refer to basic failures in construction technology. Defects such as missing insulation, insulation incorrectly placed, gaps not properly sealed, poor workmanship, inadequate supervision, carelessness and misuse of materials are first and foremost exemplars of sub-standard quality. Indeed, many are hopeful that Dfma will help address these issues since sustainability ideals are frequently quality ideals.

Building companies need to take greater responsibility for the delivery and evaluated performance of very low carbon homes. To help achieve this mandatory post occupancy auditing and industry certification should be introduced. Until the sustainability performance gap is addressed in an integrated manner, the construction of sustainable homes in Scotland will probably remain an objective only in theory.

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