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Proceedings

Adaptive Re-Use in the London Market

The influence of technical constraints on project feasibility

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Abstract

There is an increasing requirement to provide new housing stock in London. Coupled with the short life-cycles of commercial space, the opportunity exists to exploit ‘adaptive re-use’ i.e. change of use from office to residential by means of refurbishment. Literature exists which explores the drivers and barriers for this and identifies that one of the main challenges is cost certainty. Is it possible to make a preliminary assessment of the conversion potential of a building, prior to spending time and effort on extensive survey work?

A review of the literature has generated a consolidated list of building attributes, which are proposed as critical factors in assessing conversion potential. The model has not been reviewed for London in 20 years, during which time a new generation of buildings has been added and building performance regulations have become increasingly onerous. This study tests the model in the current London market for adaptive re-use. The research draws on the experience of technical practitioners to validate and supplement the list and further test it against the perceptions of the wider construction industry: developers, cost consultants and architects, each of whom is involved at feasibility stage.

An updated list of the building attributes, which are most influential upon project feasibility is presented at the end of the study. The final list incorporates input from both technical and non-technical participants in the research.

An important theme to emerge from the study's interviews, is the importance of transfer of knowledge through the construction industry concerning adaptive re-use.

Introduction

London is experiencing economic and social pressures similar to many other cities across the UK and the world. The population in London has been increasing since the 1980s and despite a net increase in the number of dwellings, house-building has not kept pace with the growth and households are now larger than a decade ago (GLA, 2014). Net increase includes for the effects of a reduced rate of demolition and also for the conversion of existing building stock from office to residential. Consequently, the most recent data available shows that the real number of new houses constructed lags even further behind the increasing demand. The British government introduced new planning policy in May 2013: a three-year trial of extended Permitted Development Rights, during which time change of use from office to residential would not require submission of a formal planning application (DCLG, 2014). Some conditions and limitations apply but the intended effect of the proposal is:

“… to support an increase in housing supply, encourage regeneration of offices and bring empty properties back into productive use.” (DCLG, 2013)

The term ‘adaptive re-use’, has come to encapsulate the process of conversion to an altogether new purpose, where the particular function is no longer relevant or desired (Langston, 2008). Advances in technology, commerce, automation and demands on comfort mean more buildings are obsolete and there is an abundance of buildings available for rehabilitation and reuse (Johnson, 1996). In commercial terms, it is important to differentiate between available and suitable. The planning framework in London may exist to facilitate change-of-use, but a wealth of factors influence the commercial viability of the refurbishment of any given building.

In addition to current planning incentives, the benefits of refurbishment of existing building stock are recognised: it can offer a cost-effective alternative to demolition and re-build. The capital outlay required to build new building stock exceeds that required for all but the most complex modifications to an existing building albeit that the refurbished building may offer a lower operating return (Highfield, 2000). Furthermore, a successful refurbishment marries value to the developer with significant environmental, social and heritage benefits. Retention over demolition and new-build represents project embodied carbon savings of up to 70% (Derwent London plc, 2012). This is a key metric in environmental performance terms; reducing embodied carbon minimises material resources and associated costs as well as alleviating longer term risks around resource availability (UKGBC, 2015). Regeneration of existing building stock can engender a positive change in attitudes within communities (Ball, 2001). The preservation of our most significant buildings permits us to continue to live, breathe and enjoy the architecture and history of past generations (Brand, 1994).

There are, however, challenges to overcome. Refurbishment carries inherent risks of existing constraints and historical unknowns. No two projects are the same and external influences will vary. So how can we draw the line between the art of the possible and the impossible?

At a crude commercial level, whether we change or whether we don’t is a matter of ease of implementation. It may be the simplest buildings, which are easiest to refurbish. However it is often the more complex and ‘characterful’ buildings that we wish to preserve. Comparing buildings across this spectrum is part of the challenge faced in evaluating suitability: is it worth the risk and how can this be quantified? Giebler (2009) identifies the concept of ‘conversion potential’ as a comparative measure. In order to assess the conversion potential, however, he advocates early investment of time and money: the antithesis of industry norms, where early input is limited. The opportunity to make decisions, which will significantly affect capital cost is greatest early in the project life cycle but fees expended at this point are low.

This problem is encountered across all refurbishment projects, not only adaptive re-use, and financial risk is magnified at a commercial development level. Landlords and developers have to make the most important decisions regarding project feasibility often even before land acquisition. An assessment of cost is required, within which an allowance is made for risk. In determining commercial feasibility, this figure must be lower than the potential future value of the development. This study focuses upon the factors which most strongly influence the cost side of this equation in the context of advocating adaptive re-use as a sustainable means of adding to London’s housing stock at the pressure continues to mount.

Research Aims

Wilkinson (2010) and Gann (1996) both propose lists of specific building attributes, which should be considered at the point of the initial commercial appraisal for an adaptive re-use project. These building attributes were considered to define the technical constraints with the greatest influence on project feasibility. This study builds on the work of Gann and Wilkinson to test, evaluate and develop their findings in the context of the present-day London residential market. The research aims to develop a new validated list for the London market, to inform a more technically robust feasibility study for adaptive re-use projects. Such a list, encapsulating the most influential and high-risk project attributes for adaptive re-use projects, could provide an early indicator of the degree of commercial exposure for a developer whilst also providing a focus for design effort and creative thinking at the project outset.

Research Method

The research aim was achieved through a two-stage research method.

During Stage 1, research by Gann and Wilkinson was compared and consolidated to generate an 'original' list of building attributes, to be tested for completeness and relevance in the context of the current London market. The primary research then commenced with a workshop, held with practising structural engineers, all of whom had experience in the adaptive re-use sector to review, critique and supplement the consolidated list. They were asked to add to the list with any 'new' attributes and then rank the most influential overall. Ranking using a top five scoring system (5= most influential) allowed results to be combined and an updated list to be generated.

However, the nature of a building project is that it is a collaboration between multi-disciplinary professionals. Stage 2 of the primary research therefore explored whether the list of attributes and ranking was an accurate representation of the perception of the wider industry. Semi-structured interviews were conducted with other professional stakeholders: the client, cost consultant and architect, on three live projects in London. The opening portion of the interviews established the relevant experience of the participant. The latter portion of the interviews focused on the attribute list from Stage 1. Participants were asked to rank using the same system. The final list of attributes was developed by combination of Stages 1 and 2.

The research is designed to reflect the human involvement in the assessment of conversion potential through primary research involving workshops and semi-structured interviews. Both are used to achieve a depth of understanding not possible through a questionnaire or a survey. The semi-structured interview balances flexibility with structure to obtain the best quality data in the short time available. (Gillham, 2005)

Results and Analysis

Stage 1

This section presents the results and analysis of Stages 1 and 2 of the primary research, including the original list of attributes generated from the literature review and upon which the primary research builds.

The Stage 1 workshop was based around a consolidated list of Wilkinson and Gann's original attributes. Following discussion amongst the ten participants, based around their own experience, a number of additional attributes were added to the list. Table 1 illustrates both the original and new attributes.

	Original Attributes (Wilkinson 2009, Gann ,1996)		**Additional Attributes (Gosden Thesis workshop 02/02/15)**
1	Internal layout and access (inc. vertical circulation)	17	Structural Redundancy
2	Site Boundaries	18	Foundations
3	Vertical Services Distribution	19	Future Tenant Profile (Mixed Use? High end / Affordable?)**
4	Historic Listing	20	Column Sizes
5	Fire Safety and Means of Escape	21	Existing Tenants Insitu**
6	Acoustic Separation	22	Past Modifications and Maintenance
7	Typical Floor Area	23	Condition
8	Size and Height of Building (w.r.t. density)	24	Load Capacity

9	Depth of Building (Daylight)	25	Deleterious Materials
10	Age	26	Floor to Ceiling Heights
11	Building Structure (Type of Frame)	27	Party Walls**
12	Existing Building Services and distribution	28	Lift Configuration
13	Building Envelope and Cladding	29	Archive Information
14	Site Access	30	Structural Fire Resistance
15	Parking		
16	Aesthetics		
Wilkinson 2010 not included: gross floor area, PCA grade, street frontage; location			

** Additional attributes from the workshop which are considered non-technical but with a bearing on the technical

Table 1: Outcomes of Stage 1 workshop on technical constraints and building attributes

The main tendency seen here is a focus on an increased level of detail in the structural frame. Wilkinson and Gann included ‘Building Structure’ in the context of the type of frame. They elaborated only in material and grid spacing. The technical professionals added specifics, a number of which are interrelated, which came out in the discussions and are presented below:

- Foundations, columns sizes and load capacity are all inherently linked and the presence of comprehensive archive information will have an impact on the ability to assess residual capacity in the frame.
- More broadly, past modifications (documented or otherwise), presence of deleterious materials (such as asbestos), structural fire resistance and the existing condition of the structural material were identified as risks. It was noted in each instance that these can present ‘hidden problems’ or latent issues within the building, often not apparent without an investment in surveys.
- Tenants and neighbours formed a third category, with the prospect of decanting tenants insitu or awaiting tenancy expiries noted, as was a need to understand the future tenant profile, which may dictate the standard of the end product. Party wall issues, particularly in central London where an island site is the exception rather than the rule were also highlighted.

Floor to ceiling heights and lift configurations were the remaining two items, both of which can be established at appraisal stage.

That some of the items above are not directly ‘technical’- by the definition of influencing engineering design principles and assumptions – does not mean that they do not have indirect effects. The examples identified in the workshop are those listed under the third bullet point above and indicated with a ** in Table 1. Each was discussed in the workshop during the concluding stage with the researcher to test reasoning and understanding and included on the basis of arguments made that:

- Future tenant profile will often influence client aspirations for floor to ceiling heights and also the level of servicing required
- Tenants in situ can not only influence the overall project programme but also lead to the delay in survey information pending vacant possession of the site
- Party wall constraints can be onerous, particularly where basement excavation is involved and they dictate the permissible ground movement and hence influence design.

Therefore although not ‘technical’ each of the above were deemed to be valid building attributes to add to the list because of the indirect effect on the design.

Each participant was then asked to rank their top 5 from the new, combined list in descending order. The responses were then collated and scored as follows:

Number 1 on a participant’s list = 5 points, number 2 = 4 points and so on to number 5 = 1 point. Those attributes not appearing on a participant’s list = 0. The top ten list is presented below (O = original attribute set, N = new attribute set).

Position	Building Attribute	N/O
1	Availability of archive information	N
2	Condition of existing structural frame	N
3	Party wall issues	N
4	Existing floor to Ceiling Heights	N
=5	Redundancy within the existing frame	N
=5	Foundation type and capacity	N
7	Past modifications and maintenance	N
=8	Age	O
=8	Future Tenant Profile	N
10	Internal space, layout and access (including vertical circulation)	O

Table 2: Most influential technical constraints for adaptive re-use conversion potential assessment (by technical professionals)

It is interesting to note that only two of the top-weighted attributes for projects in the London adaptive re-use market, were part of the original list. This supports the theory that a new generation of buildings across London, as well as changes to regulations, have caused a shift in the most influential considerations. Stage 2 of the research permits us to test this with wider design team.

Stage 2

Whilst the technical constraints on a project are rightly considered by those professionally qualified to best-assess them, there is a possibility of a very narrow perspective on the issue of ‘conversion potential’. Whilst a problem may be very complex to overcome structurally, the resolution may deliver value which outweighs the complexity in the view of other stakeholders. An example of this might be a complex party wall constraint, where extensive underpinning and temporary works are required, but the implementation of this may unlock the whole site for development. The benefit may outweigh the cost.

In order to validate the list with an audience beyond the technical experts and to understand the perceived importance of these issues in the broader context of a commercial appraisal or feasibility study, interviews were undertaken with key stakeholders on three current projects. Each participant was again asked to rank the combined list of new and original attributes generated during Stage 1. The top-ten weighted list is shown below (O = original attribute set, N = new attribute set).

Position	Building Attribute	O/N
1	Existing Floor to Ceiling Heights	N
2	Condition	N
3	Depth of Building	O
=4	Internal space, layouts and access (inc. vertical circulation)	O
=4	Historic Listing	O
6	Building Structure (Type of Frame)	O
=7	Building Envelope and Cladding	O
=7	Load Capacity	N
=9	Typical Floor Area	O
=9	Party Walls	N

Table 2: Most influential technical constraints for adaptive re-use conversion potential assessment (by non-technical professionals)

Items in green, also appear in Table 1.

In this list, more attributes are from the original list of Wilkinson and Gann. On the one hand this supports the idea that Wilkinson's study, based on results of completed projects from a large sample and which represents the reality of decisions made in a given geographical environment, may be transferable to London. However, Wilkinson's study used a more cross-discipline approach, which matches the Stage 2 sample. It is noted that the top 2 on the weighted list from the wider project stakeholders are new attributes, indicating that there is was a requirement to review the relevance in the London market of 2015.

Four of the attributes appear on both lists, indicating some degree of alignment in thinking between the engineers and the rest of the project team. This is encouraging but that more do not match, even on such a small scale sample, could indicate that as profession, the engineers have some way to go in understanding the motivations of the rest of the team and what they perceive to be influential in delivering a successful project.

The final consolidated top ten list from Stage 1 and 2 is presented in Table 3. The scores have been normalised to allow the two list to be merged and it combines the input of both the technical and non-technical design team stakeholders. That so many top-ranked attributes were 'new' also supports the theory that a new generation of buildings across London, as well as changes to regulations, have caused a shift in the most influential considerations.

Position	Building Attribute	
1	Condition	N
2	Archive Info	N
3	Floor to Ceiling Heights	N
4	Party Walls	N
5	Depth of Building	O
=6	Internal space, layout and access (inc. vertical circulation)	O
=6	Historic Listing	O
8	Building Structure (Type of Frame)	O
9	Load Capacity	N
=10	Redundancy	N
=10	Foundations	N

Table 3: Most influential technical constraints for adaptive re-use (by wider design team)

Discussion and Conclusions

The research aim was to develop a new validated list for the London market to inform a more technically robust feasibility study for adaptive re-use projects. The list will serve as a prompt for both technical and non-technical design team members to ensure that the most influential building attributes and their associated technical constraints have been duly considered. At this early stage there is limited time and money available to expend so the list will help to focus the available resources.

The lists generated separately from the Stage 1 (technical) and Stage 2 (non-technical) ranking exercise show a degree of alignment. However, the perspectives of the wider team gained during Stage 2 of the research place importance on some concepts that were not ranked as highly by the engineers. These are important to consider in the context of their work and in gaining an enhanced understanding of commercial drivers.

My final list, externally validated by non-technical stakeholders, is presented in Table 3 and includes 11 building attributes. The list is a mixture of attributes from the historic studies and new attributes with a strong tendency towards the new attributes, which the technical participants themselves generated. This points to a perceived gap in the existing research and reflects not only the challenges brought about by the newest generation of buildings, but also the changing, and increasingly onerous regulatory requirements surrounding building performance today. Some of the items appearing, such as redundancy of the existing frame and foundation type and capacity are particularly pertinent in the consideration of the newest generation of buildings - Gann’s most recent study in London concluding with the 1980s building stock – because it is in recent years that, with the computational power now available to engineers and architects alike, the most complex buildings have begun to be designed. In a world where every part of the design can be rationalised, there is limited scope for future change. Building performance requirements, particularly for residential developments have also become more onerous. Although they did not all make it into the top-weighted list, the new attributes added such as floor to ceiling heights, structural fire resistance and lift configuration reflect the increasing pressure to upgrade existing buildings to meet new codes and regulations. A good example of this from my recent experience is the requirement to justify existing floor slabs to 120 minute fire resistance when the codes of practice at the time of design were far more lenient than the current Eurocodes or even the preceding British Standards.

The research also drew out a difference between the best intention to consider these constraints and the situation in practice where finances are often prohibitive to early investment in detailed technical assessment. This highlights the potential benefit of such a list, which will help to focus attention on the most critical areas on what can often be extremely complex projects. The list will serve as a prompt for the design team: an innovative approach to managing design risk and ensuring that the most influential building attributes have been duly considered.

Opportunities for Further Work

An opportunity has been identified for further research: to try to develop the new list into a 'tool' which could itself provide quantitative outputs. This would inevitably require an even greater degree of engagement with industry and would need to consider cost. Cost bench-marking for refurbishment projects is notoriously difficult – and was highlighted as such by two cost consultants in the Stage 2 interviews – and part of the challenge is the lack of transfer of knowledge in this sector of the industry. A solution may be developed to overcome a particular technical challenge on one project, but because the design is typically non-standard and not codified, it is either not thought appropriate to apply elsewhere or it is simply not recorded and distributed as useful. Finally therefore, a key challenge that the industry faces is the transfer of the knowledge with respect to adaptive re-use projects. This would be a rich and rewarding focus for future research.

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Energy renovation: it is time for a paradigm shift in policy design

Yamina Saheb

OpenExp

Abstract

The *"Clean Energy for All Europeans*" package confirms the pivotal role of the EU building stock in meeting EU 2030 climate and energy targets. In fact, the projected decarbonisation of the EU energy system is mainly based on the renovation of existing buildings and the increased penetration of renewable energies in heating, cooling and power generation. This paper analyses the expected impacts of the *''Smart Finance for Smart Buildings''* initiative and the proposed changes to the Energy Performance of Buildings Directive and the Energy Efficiency Directive on the emerging energy renovation market. The French energy renovation market is used to illustrate the weaknesses of the proposals. The author concludes by the need for a paradigm shift in policy design and funding allocation to meet Europe's obligations under the 2015 Paris Climate Agreement.

Keywords: Clean Energy Package, Smart Finance for Smart Buildings, EPBD, EED, Zero Energy/Carbon Building, Paris Climate Agreement, Efficiency First,

Introduction

The ''*Clean Energy for all Europeans package''*, also known as a ''winter package'', released by the European Commission on November 2016, anticipates the leading role of the building stock in the decarbonisation of the EU energy system [1]. Compared to the baseline scenario (EUCO27), which aims at 27% energy savings by 2030, greenhouse gas (GHG) emissions are projected to fall by 9% in the residential sector and by 7% in non-residential buildings if a 30% energy savings target (EUCO30 scenario) by 2030 is adopted jointly by the European Council and the European Parliament. Emissions reduction must go further down if a 40% energy savings target (EUCO+40 scenario) by 2030 is adopted, as the European Parliament and some stakeholders call for. Compared to the EUCO27 scenario, emissions in the residential sector would have to be reduced by 48% while in the non-residential sector, the projected emissions reduction is at 36% (Figure 1).

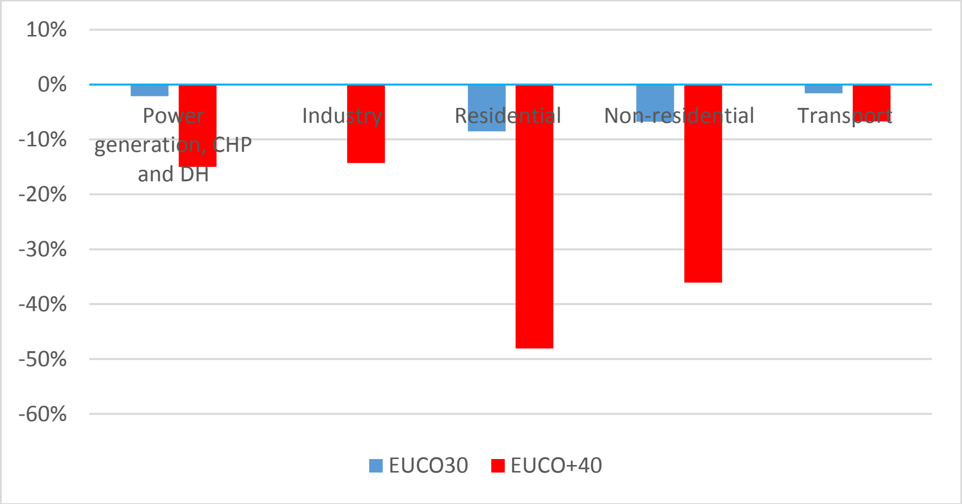


Figure 1: Percentage change of GHG emissions per sector compared to the baseline scenario, EUCO27. Source: PRIMES 2016

The projected decarbonisation of the EU building stock results from the assumption that annual renovation rates will increase over time leading to reduced energy consumption and increased integration of renewables in buildings. Consequently, this would facilitate the shift to electric heating systems leading to further integration of buildings to the grid. Moreover, the *''Winter Package''* proposes changes in both the Energy Performance of Buildings Directive (EPBD) [2] and the Energy Efficiency Directive (EED) [3]. The package also includes a non-legislative proposal, known as *''Smart Finance for Smart Buildings''* (SFSB) initiative [4]. The aim of the SFSB initiative and the proposed changes to the existing legislation is to accelerate the energy transition of the EU building stock from being an energy waster to being highly energy efficient and energy producer by removing the identified barriers to ambitious energy renovation and mobilising private finance.

This paper assesses whether the SFSB initiative and the proposed changes to the EPBD and the EED will create enough demand for energy renovation and make existing finance ready to trigger ambitious large-scale renovation projects allowing for costs and burden reductions. The analysis shows that ambitious energy renovation is unlikely to happen without requiring building owners to renovate their buildings at a certain level of performance and defining the level of ambition to achieve after renovation. With the entry into force of the Paris Climate Agreement, the cost-optimum level of energy performance for renovated buildings should be set at zero energy ideally for each building if not for cluster of buildings.

The SFSB initiative proposes to bundle funding dedicated to energy renovation from the European Structural and Investment Funds (ESIF) with those of the European Fund for Strategic Investment (EFSI) within the national/regional investment platforms to be set by member states. Revenues from energy taxes, Emission Trading Schemes (ETS) and Energy Efficiency Obligations (EEOs), which are important funding sources for energy renovation, are not considered for bundling by the SFSB initiative. The expected impacts from the investment platforms might, therefore, be limited, as shown by the French case study.

Moreover, the bundled funding will be made available for Energy Services Companies (ESCOs) and/or third-party financing which would play a role of one-stop-shops and make finance available for individuals. However, experiences from the field show that existing ESCOs and third-party financing schemes do not trigger zero energy/carbon renovation nor have they been successful in scaling-up existing projects at regional/national levels [6]. Prohibitive costs of ambitious energy renovation and the mitigation of the financial and/or technical risks by existing ESCOs and third-party financing are major barriers to the expected role the one-stop-shops would play in scaling-up ambitious energy renovation projects [7]. Likewise, member states may decide to not set up the investment platforms and/or the one-stop shops as the SFSB is a non-legislative proposal and thus there is no legal obligation to do so.

Above all, the SFSB initiative and the proposed changes to the EPBD and the EED assume that individuals will take the initiative to renovate their homes and financial institutions would provide finance for energy renovation if they are both well-informed about the benefits of energy renovation. The ''*De-risking Energy Efficiency Platform, DEEP*'' was developed at EU level for this purpose. However, existing similar tools at national level [8] have, so far, failed in shifting the component-based energy renovation market which is financed, mainly, by grants to a self-financed energy renovation market delivering cost-effective and holistic energy renovation aiming at zero energy/carbon buildings.

Overall, the impact of the *''Winter Package''* on energy renovation might well be limited, as shown in the following sections, unless the European Parliament asks the European Commission to further strengthen existing instruments keeping in mind that energy renovation is a societal issue, which cannot be addressed by individuals.

Analysis of the proposed changes to the EPBD and the EED

The proposed changes to the EPBD, which will have a direct impact on energy renovation, include measures to link financial incentives provided by public funds with the energy savings achieved. However, the calculation of the savings will be based on the cost-optimum methodology, which does not lead to ambitious energy renovation. In fact, using this methodology, the cost-optimum level ranges between class C and class B (Figure 2). In most member states, energy consumption of buildings in class B and C is far from zero energy consumption and might well lead to lock in the savings potential until the next round of renovation. Literature suggests a renovation round of 30 years for residential buildings and 15 years for non-residential ones [9]. In practice, shallow renovation puts Europe at risk of not meeting its 2050 decarbonisation objective.

The proposed changes to the EPBD do not require building owners to renovate their buildings at a certain level of energy performance. It is, therefore, assumed that energy renovation is required only if buildings undergo major renovation as defined in the current version of the EPBD [2]. The major renovation concept applies if '*'the total cost of the renovation relating to the building envelope or technical systems is higher than 25% of the value of the building, excluding the value of the land upon which the building is situated; or if more than 25% of the surface of the building envelope undergoes renovation*" [2]. Based on this definition, the number of residential buildings undergoing renovation to be considered for setting minimum energy performance requirements will be limited [10]. Overall, linking finance to the achieved energy savings is a good practice. However, the impact of this measure will be weakened by the lack of requiring an ambitious energy performance target for the renovated buildings.

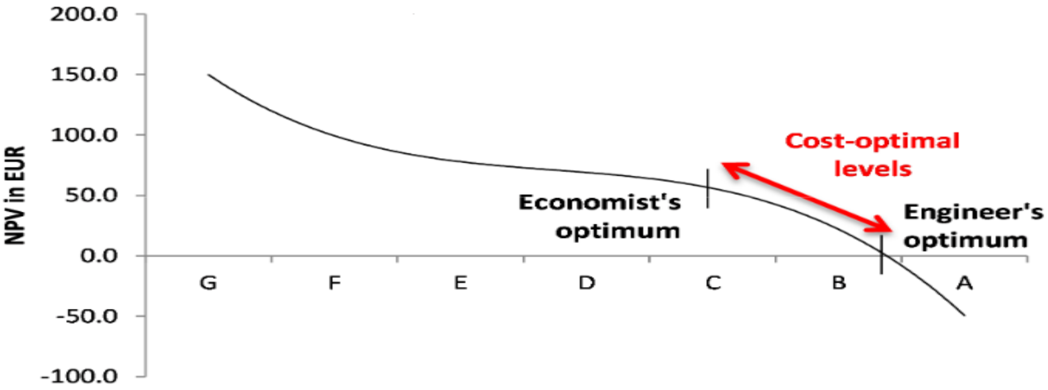


Figure 2: Net Present Values for different optimums. Source: EiB presentation at EEFIG workshop in 2017

Among the proposed changes to the EED, the continuation of Article 7 of this directive with its Energy Efficiency Obligation Schemes (EEOSs) will have a direct impact on energy renovation. For the current period, member states' reporting shows that 42% of the overall savings under Article 7 will take place in the building sector [11]. With savings from financing schemes and grants estimated at 19% out of the total and those from taxes at 14% out of the total [11]. The share of savings from energy renovation using EEOSs varies across member states. The United Kingdom expects 100% of the savings to take place in buildings [12], followed by France with 67% [13] while in Slovenia this share goes down to 7% [14]. Consequently, total public investments through EEOSs in energy renovation varies across member states. It is estimated for 2015 at €1.072 million in the United Kingdom, against €657 million in France and only €2 million in Slovenia [15]. While, the implementation of EEOSs has led to the emergence of a new market and new actors in the building sector, existing literature does not provide evidence about the contribution of EEOSs to ambitious energy renovation. In fact, EEOSs allow for providing grants to purchase energy efficient products. However, the amount of each grant is too low to trigger ambitious energy renovation, especially if the grant cannot be combined with other incentives such as tax credit, tax reduction and eco-loans.

Analysis of the ‘’*Smart finance for Smart Buildings’’* Initiative

The SFSB initiative is a non-legislative proposal included in the ‘’*Clean Energy for all Europeans package*”. The initiative is a de-risking framework, articulated around three pillars where each pillar addresses one set of risks. SFSB is based on lessons learnt at EU and national level in mobilising private financing to accelerate energy renovation of existing buildings by removing the identified barriers. The initiative builds on existing EU financing strands and instruments that support energy efficiency and deployment of small-scale renewables, such as the European Structural and Investment Funds (ESIF) which allocates around €18 billion for energy efficiency (out of which €13 billion are allocated to buildings) over the period 2014-2020 and the European Fund for Strategic Investments (EFSI), where energy efficiency projects represent more than 10% of the EFSI guarantee usage so far [1].

The first pillar of the initiative aims at financial de-risking by merging EU funds to provide an easy access to EU finance and a guarantee mechanism, which would lower interest rates of energy renovation. This would reduce financial costs of energy renovation and would be implemented through national/regional investment platforms. These platforms have been inspired by the Private Finance for Energy Efficiency (PF4EE) scheme funded by the EU and managed by the EIB and the scheme implemented in Germany via KfW. The platforms will ensure an effective combination of European funds from the European Structural and Investments Funds (ESIF) and the European Funds for Strategic Investments (EFSI). They would play the role of a risk sharing facility, allowing for mitigation of the risk of financial intermediaries and will also encompass technical assistance for the rolling out of lending programmes [1].

The second pillar of the initiative aims at technical de-risking by providing technical assistance to allow for aggregation of small projects. This would reduce technical costs of energy renovation and would be implemented through local one-stop-shops, which are inspired by the existing ESCOs/Third-party financing models. The aim is to reduce the transaction costs, address operational obstacles, and develop project pipelines of bankable projects allowing for economies of scale [1].

The third pillar of the initiative aims at behavioural de-risking by providing accurate and detailed information on energy consumption, energy savings and the cost of energy renovation to various market actors. The objective is to change the perceived risk of energy renovation and to trigger renovation work. It will be implemented through various EU/national/regional information platforms [1]. The DEEP database and the European building observatory were developed for this purpose.

The proposed instruments under the SFSB initiative is a valuable step forward. However, the initiative would succeed to mobilise private financing at the scale needed only if the regulatory framework is strengthened by requiring building owners to renovate their buildings at an ambitious level of energy performance (see previous section). Furthermore, the initiative is unclear about how EU funds will be bundled with ETS, EEOSs and tax revenues, despite the high share of these revenues in the overall public funding allocated to energy renovation as shown by the French schemes below, and if the investment platforms will have the technical capacity to bundle all the funds available for energy renovation. It is only through the bundling of all those sources that there would be sufficient funds for an ambitious renovation.

Moreover, the initiative does not address the technological costs which makes the pay-back time and the costs of zero energy renovation prohibitive and shallow renovation cost-effective in the short-term (Figure 3). The SFSB initiative will reduce the financial costs by lowering the interest rates of renovation loans while reducing the technological costs requires moving away from step by step renovation towards an integrated and holistic renovation [7,10].

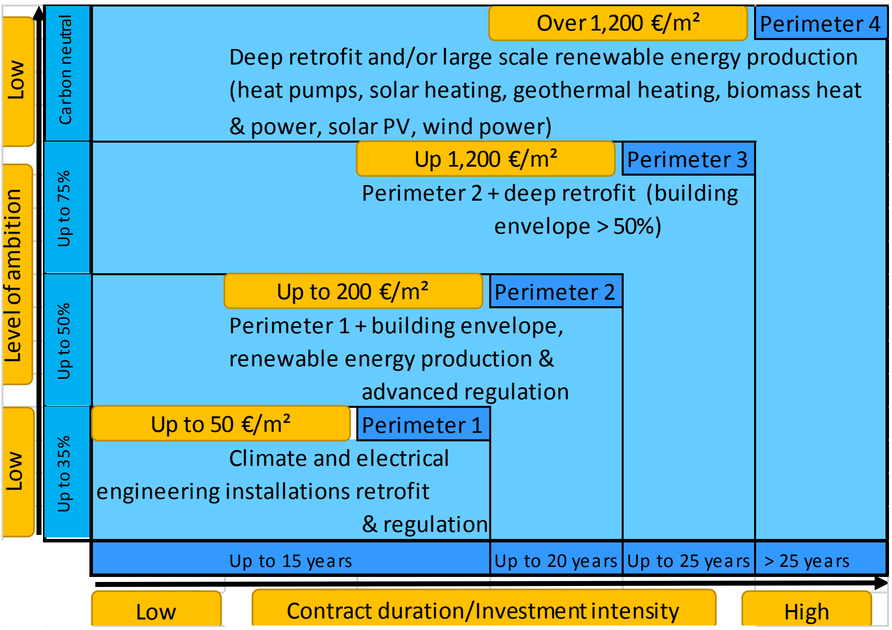


Figure 3: Energy renovation costs and pay-back time based on the quality of the renovation. Source [6]

Achieving this objective necessitates "industrialising" the development of energy renovation kits for each climate zone, building type and construction period and the automation of renovation tasks [10]. Large-scale projects should make the industrialisation of energy renovation cost-effective and more attractive to the industry [7]. Unfortunately, it is unlikely that the SFSB would lead to the industrialisation and the modernisation of energy renovation given the identified weaknesses of the initiative (Figure 4). The SFSB proposal also suffers from the uncertainties about the availability of EU funds for the period 2021-2030. This may increase the perceived risk by investors and put the overall *''Winter package''* at risk of failure.

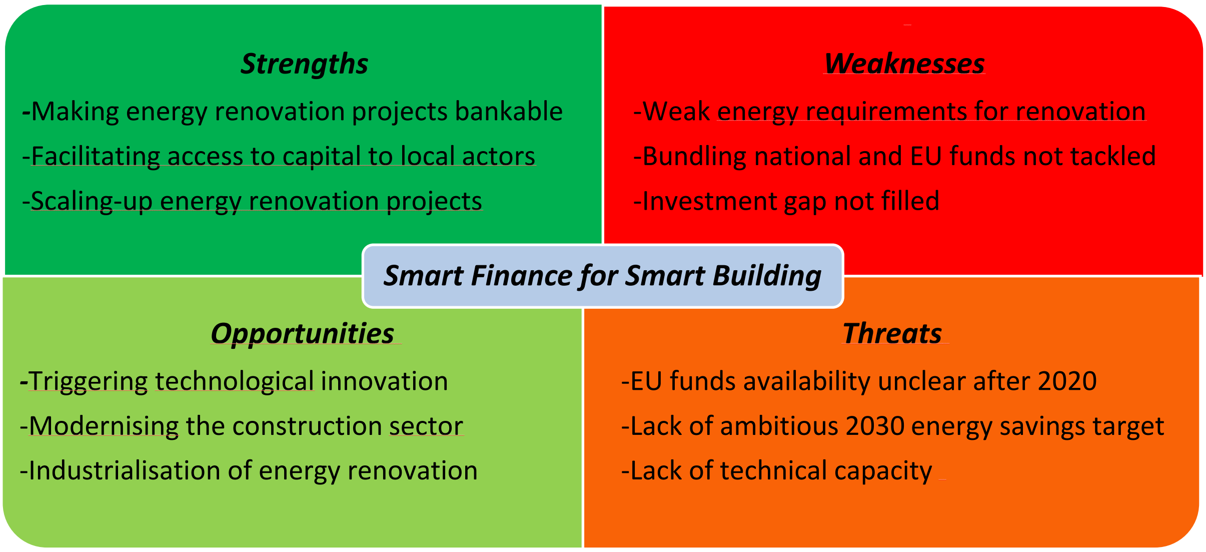


Figure 4: SWOT analysis of the SFSB initiative. Source [1]

Impacts of the SFSB and the proposed changes to the EPBD and the EED on the French energy renovation market

The impacts of the SFSB and the proposed changes to the EPBD and the EED on the energy renovation market are assessed for France. The French energy renovation market is the third largest in Europe after the German and the Italian markets. The French energy renovation market was estimated at € 13 billion in 2015 [7]. The same year, the French government adopted an energy transition law for green growth [16] which sets a target to make the French building stock low energy consumption by 2050. The government must report annually to the parliament on the progress made on the implementation of the renovation plan as set in the energy transition law.

The French energy renovation plan aims at renovating, starting from 2017 and every year, 500000 homes out of which half should be homes occupied by low-income households. Several decrees have been adopted to ensure a smooth implementation of the energy transition law. A decree which requires setting minimum energy performance requirements for buildings undergoing renovation of the façades (which is required by law in France since the 19th century) and/or extension was adopted a year later [17]. This decree goes beyond the current definition of major renovation included in the EPBD (see section on EPBD changes) to include all buildings undergoing renovation and/or extension.

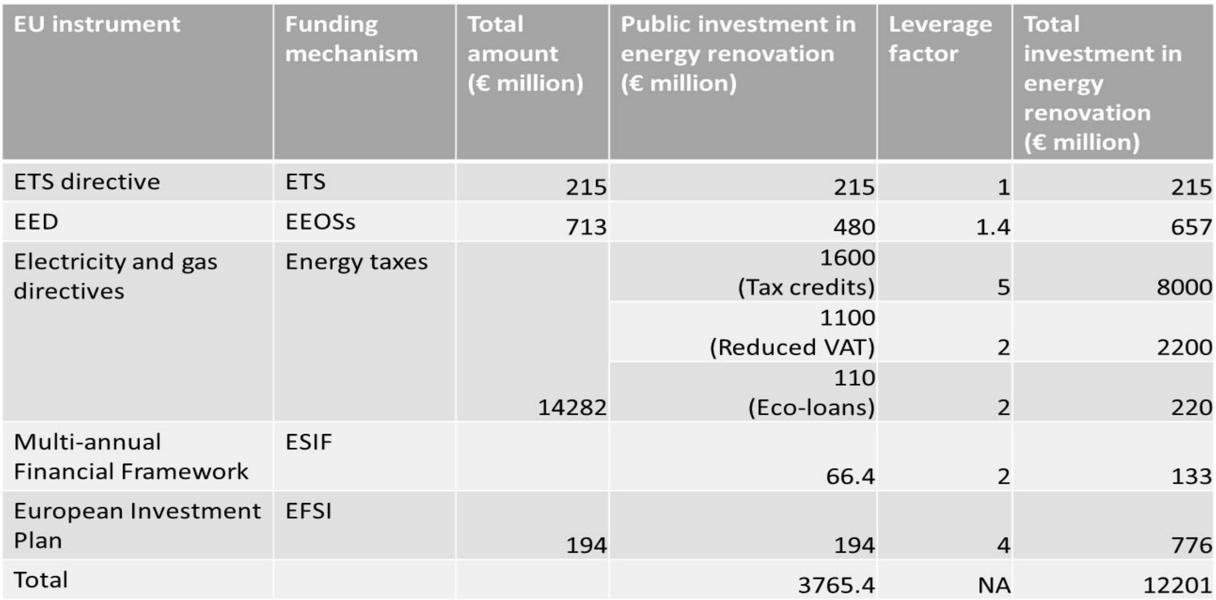
The French building energy code for existing buildings, however, is not as ambitious as the one for new buildings [18]. In fact, while for new buildings, energy consumption for regulated loads (heating, cooling, ventilation, lighting and hot water) is set on average at maximum 50 KWh/m².yr of primary energy for all buildings, for existing building, requirements are set based on the size and the construction period of each building. Energy consumption for existing buildings, with more than 1.000m² and/or built after 1948, is set on average at a maximum ranging from 80 to 195 kWh/m².yr of primary energy for residential buildings and for non-residential buildings, the requirement is to reduce energy consumption by 30% compared the current consumption. Furthermore, the energy consumption to consider under this requirement relates only to heating, cooling and hot water contrary to the regulated energy consumption for new buildings which includes also electricity consumption due to lighting and ventilation. For existing buildings with less than 1.000 m² and/or those built before 1948 requirements are not set for the overall consumption. Instead the French building energy code includes minimum energy performance for each component and energy system which could be renovated separately. In practice, this means that residential buildings do not have to be fully renovated which increases the lock-in effect risk.

From a financing perspective, France could be considered as a champion in the use of all existing funding mechanisms for energy renovation (Table 1). In 2014, France reported to use 100% of its ETS revenues, which is equivalent to €215 million, for energy renovation of buildings occupied by low-income households [19]. Regarding EEOSs, the share of energy savings from energy renovation out of the total savings is estimated, in 2014, at 67% which is equivalent to €480 million of public investment through EEOs in energy renovation [15]. By assuming a leverage factor of 1.37 for EEOSs [13], this leads us to a total investment in energy renovation of €657 million through EEOSs in 2014 [15].

The same year, total energy taxes paid by households reached € 14282 million [20]. The breakdown of the use of the taxes is not reported by the French government. However, the updated National Energy Efficiency Action Plan (NEEAP), submitted in 2017 to the European Commission, shows that i) €1600 million were spent through tax credits used for energy renovation with a leverage factor of 5, ii) €1100 million were spent on reduced VAT related to energy renovation work and iii) € 110 million were spent for the eco-loans scheme [21]. The French survey *OPEN 2015* about energy renovation shows that tax credit and reduced VAT for energy renovation work are the two most used measures by households [21]. The funding mechanism related to these governmental expenditures is not mentioned in the NEEAP. However, if we assume that energy taxes paid by households is the funding mechanism used by the French government for these incentives, this would imply that at around 20% of energy taxes paid by households were used in 2014 for the renovation of their homes. Similarly, if we consider a leverage factor of 5 for tax credit as reported in the NEEAP and assume a leverage factor of 2 for reduced VAT and eco loans, total investment generated by energy taxes paid by households, in 2014, would have been €10420 million.

Regarding EU funds, the French projects signed, so far by the EiB for the use of EFSI, are all related to financing the existing French one-stop-shops and funds dedicated to energy renovation such as Energie Positif and EIFFEL Energy Transition Fund [22]. The total support provided to France by EFSI is €194 million and the leverage factor considered by EiB is 4 [22]. Similarly, the reporting available on the use of ESIF shows a financial support to energy renovation in France of €464,5 million over the period 2014-2020 [23]. This is equivalent to €66,4 million per year if it is equally distributed over the seven-year period. Considering the leverage factor of 4 for EFSI as suggested by the EiB and a leverage factor of 2 for ESIF, this would lead to a total investment in energy renovation in France of € 909 million that would have been triggered by the bundled EU funds, in 2014. Summing all the investments made in France in 2014 for energy renovation leads us to €12201 million (Table 1).

The French government reported that 388000 homes had been renovated in 2014 with approximately 100000 occupied by low-income households [21]. If the calculated total investment in energy renovation would have been distributed equally among the renovated homes, this would mean an investment of €31400 per renovated home (Table 1). Given that energy renovation costs range from €50/m² for shallow renovation to over €1200/m² for zero energy renovation (Figure 3), it will be impossible for France to achieve its target of making all its building stock low energy consumption without drastic reduction of energy renovation costs.



EU instrument	Funding mechanism	Total amount (€ million)	Public investment in energy renovation (€ million)	Leverage factor	Total investment in energy renovation (€ million)
ETS directive	ETS	215	215	1	215
EED	EEOSs	713	480	1.4	657
Electricity and gas directives	Energy taxes	14282	1600 (Tax credits)	5	8000
			1100 (Reduced VAT)	2	2200
			110 (Eco-loans)	2	220
Multi-annual Financial Framework	ESIF		66.4	2	133
European Investment Plan	EFSI	194	194	4	776
Total			3765.4	NA	12201

Table 1: Investment in energy renovation in France in 2014

The way forward

The French example should be a wake-up call for the way forward. The analyses of the SFSB and the proposed changes to the EPBD and the EED show a very low impact of the ‘*’winter package”* on the energy transition of the EU building stock. The proposed bundling of EU funds within the investment platforms, to be set by member states, would be equivalent in the case of France to 6.9% of total public funding allocated to energy renovation or 7.5% of total investments in energy renovation in 2014. France is one of the leaders and yet we see the difficulties that lie ahead given the prohibitive cost of energy renovation. Beyond France, the EU is at serious risk of not meeting its energy and climate targets and consequently its obligations under the Paris Agreement without a serious cut in energy renovation costs which should go beyond the 40000€ per home targeted by Energiesprong. The existing legislative and non-legislative proposals still on the table should be complemented with a proposal to accelerate the industrialisation of energy renovation.

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Governance of Low-carbon Innovation in Domestic Energy Retrofits in the UK

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Abstract

Pioneering case studies of housing renovation show that 80-90% emissions reductions are achievable using existing technology, but the task requires very high standards of design, installation and integration of energy system components. The often-observed design-performance gap is related to how the industry is structured and construction projects are managed, not because of a fundamental lack of products and technologies.

Many disciplinary studies have investigated aspects of the problem: technical potential, management practice, estimates for ‘green’ jobs, policy appraisal. However, little work has been done to understand the construction sector as potential agents of change in delivering and maintaining a low-energy housing stock.

An inter-disciplinary approach is needed to understand the practices and processes of the institutions and firms in the market for repair, maintenance and improvement (RMI) of housing. RMI firms are incumbents in the housing-energy system in the sense that they are uniquely placed to reach and influence retrofit projects at scale. They make physical changes to buildings and also have influence on decisions through their everyday dealings with people.

Four key questions are proposed to better understand the industry, the policy context, and the real nature of the low-carbon challenge for existing housing. How can the risks of doing retrofit badly (under-performance and unintended consequences) be better managed? What is the real economic opportunity of mass-scale housing retrofit? How well are supply chain actors and the vocational training system equipped to support the low-carbon challenge? Are the institutions of government and industry well aligned to support this transition?

Introduction

Studies based on computer models and scenarios show that the UK’s 2050 emissions reduction targets are achievable, but there is little or no room for trade-offs between sectors: targets for buildings, transport, industry and agriculture are all extremely challenging (Skea et al 2011, DECC 2011). Challenges also exist at the scale of individual building projects: low-carbon deep refurbishment is achievable, but only if there is high quality in design, installation and integration of energy system components, and good communication between different key actors (Institute for Sustainability 2012, TSB 2013, Topouzi 2015). New technology may help the situation to some extent, but technology alone cannot resolve the underlying structural problems in the industry: a lack of technical knowledge; poor communication skills on project teams; and unclear boundaries between roles and responsibilities (ZCH 2014).

Where scenario-based studies focus on technology-related questions (what technologies, how much of each, and by when?) our focus is on industry-related questions about deployment: how might the technology be installed, and to what extent is the industry prepared and able to deliver this work in sufficient quality and quantity? Despite the broad research consensus that deep emissions reductions in the buildings sector are important for the overall energy system, very little work has been done to understand the construction sector as agents of such a profound change.

This focus on the role of the construction industry is rooted in the idea that these industry stakeholders are ‘middle actors’, operating in the space between top-down policy ‘push’ and bottom-up market ‘pull’ (Janda &

Parag 2013). They have their own preferences, practices and motivations, which can be better understood through research. Middle actors have influence both upstream to policy (e.g. through lobbying activity by trade bodies) and downstream to project clients (e.g. through formal and informal influence over design, specification and installation of technology). Through their daily working lives, construction firms have access to property owners at multiple points of decision-making on projects, and they use a variety of tactics and strategies to influence those decisions (Killip 2013). The skills and capacities of these firms are therefore an important part of the 'soft infrastructure' of decision-making, which helps shape future energy demand in buildings.

By focusing on the industry as potential agents of change, we seek to move the debate on from the questions about technology (the 'what' question) and towards questions about capacity to deliver (the 'how' and 'by whom' questions). The existing industry is also important in terms of sheer scale and reach to customers. The UK housing RMI sector is dominated by some 50,000 small and medium-sized enterprises (SMEs), delivering projects to the value of £26.23bn in 2015 (ONS 2016). These small firms are highly influential in whether or not partial or whole house energy retrofit opportunities are realised (Owen et al, 2014). RMI projects are typically motivated by goals other than energy efficiency, but they can nonetheless provide important intervention opportunities (Maby & Owen, 2015). For example, a project to replace a kitchen involves removing furniture, fixtures and fittings; and that is also good preparation for insulating the floor and walls. Conversely, if a new kitchen is fitted without insulation in floors and walls, the opportunity to insulate the building fabric may be lost for many years. This 'room by room' or 'over time' approach can achieve significant carbon reductions, and is a strategy to consider alongside 'whole house' or district-scale approaches (Fawcett 2014).

Governance

'Governance' is used here to mean the patterns of influence over decisions at multiple scales, from the negotiations on a single building project, to more strategic processes in government and business. It is not intended to be synonymous with 'government', although policy is clearly one of the influences to consider. Nor does our use of governance refer to the internal management of a firm or organisation, although business management and strategy are also clearly valid influences. Instead, our focus is on systemic issues across an entire business sector (i.e. residential RMI), and across an entire sub-set of the national building stock (i.e. existing UK housing). Governance can relate to decisions on many aspects of the retrofit agenda: the specification of renovation projects, business strategies, policy design, project finance, education and training. It therefore operates across a whole system.

Innovation for low-carbon outcomes

Relevant innovations include technologies (e.g. heat pumps, photovoltaics, insulation products), working practices and skills (e.g. 'multi-skilling' of on-site workers to reduce industry fragmentation), and business processes (e.g. new business models for better quality assurance and customer service). Most innovations in the construction sector are incremental, seeking to give advantage to individual firms; much rarer are examples of systemic innovation (Winch 1998). In his 2002 industry review, Sir John Egan characterised the construction sector as 'a series of sequential and largely separate operations undertaken by individual designers, constructors and suppliers who have no stake in the long term success of the product and no commitment to it' (Egan 2002, 13). The low-carbon agenda is profoundly disruptive because it requires a shift of attention away from mainstream inputs (e.g. known materials, conventional job roles) and onto critical outcomes (performance of the resulting building in occupation). It also calls for creative collaboration in finding workable solutions, rather than the current culture of limiting liability and avoiding risk, often enshrined in adversarial contractual relationships.

Researching the housing retrofit market as a complex system

By taking a broad view of these issues and treating governance as a systemic issue (i.e. not just at the level of a single firm or policy, but as a complex whole), a very different set of questions for researchers begin to emerge compared with conventional approaches based on modelling or case studies of good practice. For example, system-level questions might include the following:

- How can the risks of doing retrofit badly (under-performance and unintended consequences) be better managed?
- What is the real economic opportunity of mass-scale housing retrofit?
- How well are supply chain actors and the vocational training system equipped to support the low carbon challenge?
- Are the institutions of government and industry well aligned to support this transition?

Each of these questions is discussed in more detail in the following sections.

Quality & risk management

Pioneering case studies have shown that ambitious retrofits are possible using existing technology and materials, but that they also represent a major challenge for quality assurance and integration between good design and good implementation,(InstituteforSustainability 2012, Walker, Lowery et al. 2014, Johnston, Farmer et al. 2016). Quality assurance is needed to mitigate two types of risk: under-performance (the 'design-performance gap'); and unintended consequences (e.g. structural damage and mould growth arising from interstitial condensation in insulated structures). Risks and potential innovations can be identified at the level of individual projects and within the different stages of retrofit from design to installation; from installation to client hand-over (where issues like continuity of personnel can be important). The management of these risks and innovations may require different approaches in different circumstances, but common themes can also be discerned, such as the need for a commitment to monitoring and learning about technology performance rather than a 'fit and forget' approach (Killip et al 2014).

Macro-economics

Most economic studies of retrofit focus on the micro-economics of individual projects, the costs and paybacks. Once the focus moves beyond the level of individual projects to a contemplation of industry-wide change, macro-economic questions become more relevant. These include issues such as labour productivity improvement, which might be achieved through strategic investment in training and innovation (Green 2016). Investment in low-energy renovation of housing has been identified as a route out of economic recession (Bowen et al 2009), but its role in other parts of the economic cycle is under-researched. Macro-economic models often use quite crude assumptions about the cost and deployment of technology; and engineering studies normally relate to micro- rather than macro-economics. A more rigorous assessment is needed of the real benefits, costs, risks and uncertainties of pursuing mass-scale retrofit in terms of the number and quality of jobs involved, and the knock-on effects across the wider economy.

Supply chains and training

Despite having a deserved reputation for conservatism, the construction industry can innovate when conditions are right (Killip 2013). Innovation may be instigated at a project level by firms and/or clients, but projects can be seen as 'end-of-pipe' with possible constraints on innovation further upstream. Sources of innovation also exist upstream from the project level, including the system for vocational education and training, and product supply chains. Training has a clear role to play in improving technical understanding, reducing the energy-performance gap and reducing risks, but general pleas for more and better training lack specificity. Over several decades the UK's vocational training system has seen a decline in the technical content of courses and the numbers in training compared with European neighbours (Brockmann et al. 2008). The UK tends to focus on training supply (new courses), rather than on the real needs for training or the effective application of training in the workplace (Keep 2016). Similarly, while it is possible to envisage new and better products entering the retrofit market, the process of decision-making among supply chain firms about routes to market for new products needs to be understood, rather than assumed.

Multi-sector networks

We are careful to emphasise the potential nature of the construction industry's role in creating and maintaining a low-carbon housing stock. The bulk of economic activity in the RMI market lies in projects where energy is of little or no concern. The challenge of energy retrofit at mass scale lies in brokering a workable marriage of quality outcomes and a massive increase in the quantity of work undertaken. This means not just the adoption of 'best practices' but the development of new 'next practices', for which new partnerships and networks are required (Berkhout & Westerhoff 2013). Relevant organisations include government departments and quangos (such as the sector skills councils, which operate under licence from government, but which are industry-led), local authorities, trade associations, professional institutions, and representatives of property owners and residents (public and private sectors; rented and owner-occupied tenures).

Implications for policy, research and practice

The study of innovation from the perspective of a mainstream, incumbent industry may at first sight be unpromising. Where innovation is needed, surely there is more to learn from engagement with high-profile innovators? However, the real problem is not in identifying examples of innovation, but in devising a strategy by which innovation can diffuse across the industry to a scale where long-term climate change targets have a chance of being met. The diffusion of innovation is widely acknowledged as the hardest part of the innovation process. Successful diffusion will have to not only increase the quantity of work done, but also the quality of that work.

The focus on mainstream construction firms and their institutions turns the challenge of widespread, deep retrofit away from purely technical or micro-economic effects, and moves it onto processes, strategy and public policy more generally. Plenty of studies have made a case for what needs to be done and how much; rather less attention has been paid to the questions of who can do the work, and how it might conceivably be organised on a grand scale.

This shift of focus has the potential to be disruptive for policy, research and practice. It calls for institutions to assess their own contribution as part of a wider system, and it raises the possibility that the system may be inadequately governed. It also raises the prospect of solutions needing to be found in domains which are often ignored or under-represented in studies of climate and energy policy.

If the challenges of governance for low-energy renovation are either ignored or unresolved, the prospects for climate and energy policy are quite stark: failure to meet (or even get close to) climate targets, with the increased risks of climate chaos that that suggests; or a reliance instead on pathways to a low-carbon future which downplay the potential of building stock renovation. The costs (social and economic) of either option may prove to be very high.

If, on the other hand, the governance issues are taken seriously, a different set of priorities begins to emerge to do with innovations for quality assurance and management. There would be costs, risks and benefits in attempting to transform the housing RMI sector so that it can deliver low-carbon retrofits at scale; but not attempting that transformation also carries risks and uncertainties.

Ways forward

The pursuit of low-carbon outcomes requires a ‘whole-project’ approach that involves new combinations of people, technology, knowledge and behaviour. Some of these are fairly well understood in isolation, but none of them is well understood in combination with all of the others. For this reason, a way forward could be a coordinated series of field trials, in which real renovation projects are undertaken, the outcomes monitored and honestly reported, feeding back new lessons for the development of the next round of trials. In some respects, the Retrofit for the Future (RfF) programme could be viewed as a first round (TSB 2013), although there is no coordinating organisation to analyse the results from that programme and devise a second round of projects. Where the RfF programme tested the most ambitious technical design standard, other approaches can easily be devised: e.g. setting a financial budget and challenging project teams to make best use of the money; or, assigning a project team to carry out multiple retrofits with a remit to report and learn from mistakes, leading to a record of accumulated learning and experience at the end. Such a programme would need national coordination but would probably operate best at the scale of city-regions: large enough to attract and mobilise a range of stakeholders, but small enough to be nimble, while also reflecting regional diversity in property markets and socio-economic conditions.

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Housing Estate Regeneration using the Passivhaus EnerPHit Retrofit of Wilmcote House in Southsea, Portsmouth

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John Pratley [1], Alex Baines [2]

[1] Gardner Stewart Architects, [2] Encraft

Gardener Stewart Architects are the Lead Designers and Encraft, the Passivhaus Consultants for Engie Keepmoat Regeneration Contractors of the largest Passivhaus EnerPHit Retrofit in the UK; comprising over 100 social housing flats within three, eleven-storey, tower blocks in Southsea, Portsmouth – known collectively as Wilmcote House.

Introduction:

In Jan 2016: UK Government policy announcement for the Regeneration of Council Estates based on Savilles Report “Completing London’s Streets”

The Report outlined how the regeneration and intensification of housing estates could increase London’s supply of homes and benefit residents by knocking down the existing housing stock and starting again. This regeneration approach was to be rolled out nationwide, but did not include the decant & demolition business case for existing residents (as Saville’s indicated in the small print of their report).

The intention of this presentation is to describe an alternative approach to housing estate regeneration, with a focus on refurbishing existing buildings and upgrading them to modern, energy efficient Passivhaus standards – allowing the residents to stay in their homes during the refurbishment process.

The presentation will describe the journey from the original public sector landlord aspirations to extend the life of the existing tower blocks and the initial design proposals following resident consultation, to the design development and project delivery by the contractor team.

The presentation will discuss the following approach to sustainable refurbishment of the UK social housing stock:-

- Integrated EnerPHit approach: holistic environmental approach incorporating thermal performance, air-tightness & ventilation
- Building to Passivhaus Build Quality: extending the life of an existing building
- Resident Benefits: very low energy bills, improved health & comfort
- Business Case: retrofit build cost rate, comparable with new-build housing
- On-site Regeneration: with residents remaining in their home

Pre-Retrofit:

Wilmcote House comprises the following:-

- 3 x 11-storey blocks connected by horizontal open balconies with vertical lift and stair access
- 100 3-bed maisonettes + 7 1-bed flats – all social housing, no leaseholders
- Owned and managed by Portsmouth City Council
- Bison Reema pre-cast concrete panel construction, built in 1968
- Electric hot water and space heating (original gas supply removed due to risk from panel construction in 1990)

Pre-Retrofit Condition:

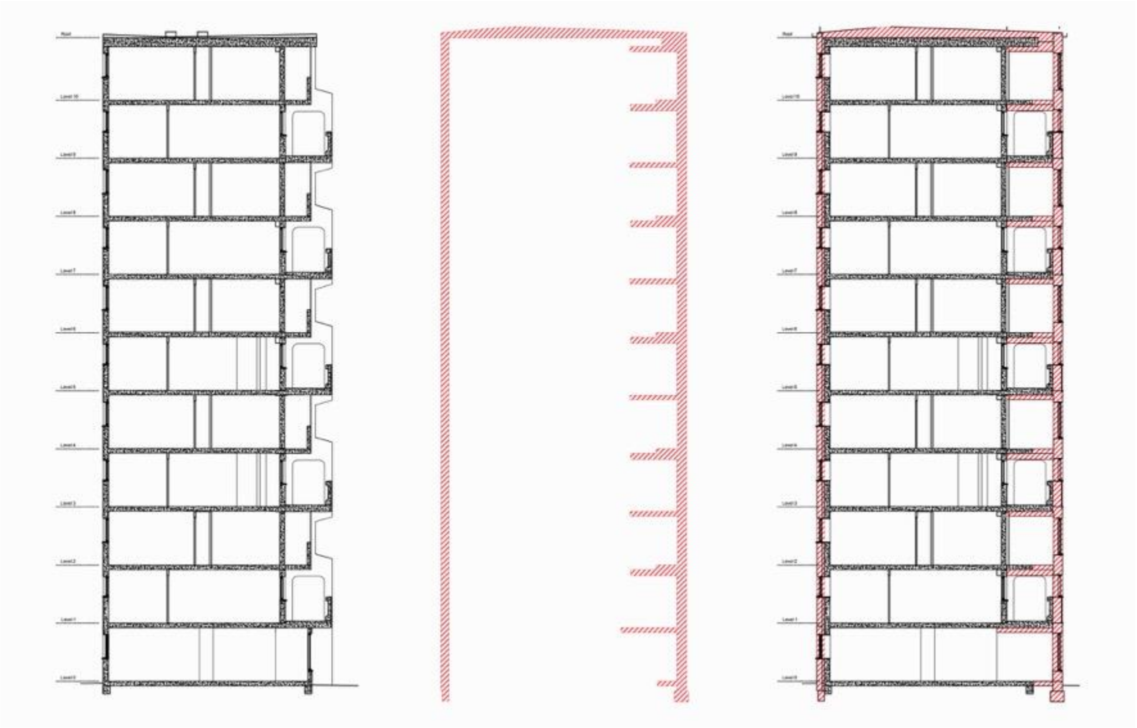
Wilmcote House building condition was deteriorating even though there had been regular maintenance and refurbishment cycles carried out by the Portsmouth City Council landlord:-

- Cold and damp internal living conditions created by 1960's design & construction – almost no insulation in the external fabric construction
- All-electric heating at high costs – creating fuel poverty
- Maintenance costs driven by condensation & water ingress
- Concrete repairs to existing panels if left exposed to weather
- Security problems open deck, balcony arrangement – difficult to re-decorate
- Regeneration opportunity created by the Area Housing Office re-location from ground floor
- Decant & demolition considered too expensive for Portsmouth Council and too disruptive for the residents

Retrofit Proposals:

Advanced Deep Retrofit ‘Over-warp’ strategy considered which could properly extend the life of the existing building and transform the living conditions for the existing residents while they remained in-situ:-

- Fabric First, super-insulated thermal and weather-proofing over-cladding concept
- Improved Air-tightness
- Efficient mechanical ventilation with heat recovery (MVHR)
- Integrated Passivhaus approach incorporating thermal performance, air-tightness & ventilation
- Enclosed secure balconies and walkways
- Retained, reduced electric heating
- Resident Benefits: extra space, very low bills, health & comfort



Resident Consultation:

The Passivhaus EnerPHit retrofit proposals would address the residents' concerns:-

- Residents can't afford to heat - EnerPHit fabric reduces space heating demand by 80-90%
- No control over temperature - EnerPHit stabilises temperature
- Mould in wardrobes/poor health - Heat recovery ventilation and warm internal surfaces
- Drying clothes a problem - Flexible balcony/sunspace design
- Falling objects/child safety - Enclosed walkways
- No hot water when needed - Add showers and well-insulated HW system
- No security - Controlled access to enclosed walkways (shared private space)
- Unloved visual appearance - “Like living in a new building”

Overall Retrofit Proposals:

Portsmouth City Council decided to progress with the following retrofit proposals (by the original design team ECD Architects and Carter Clack Structural Engineers):-

- External wall insulation and new pitched roof supported on ‘exo-skeleton’ steel frame
- Air-tight envelope: parge-coat to road-side elevations, ply-supported membrane to garden-side
- Triple-glazed windows and doors
- Efficient mechanical ventilation with heat recovery (MVHR)
- Enclosed secure balconies and walkways creating extended living space
- Retained, reduced electric heating with new hot water cylinders & showers

Building Procurement:

Portsmouth City Council awarded the construction contract to Keepmoat Regeneration Ltd in March 2014

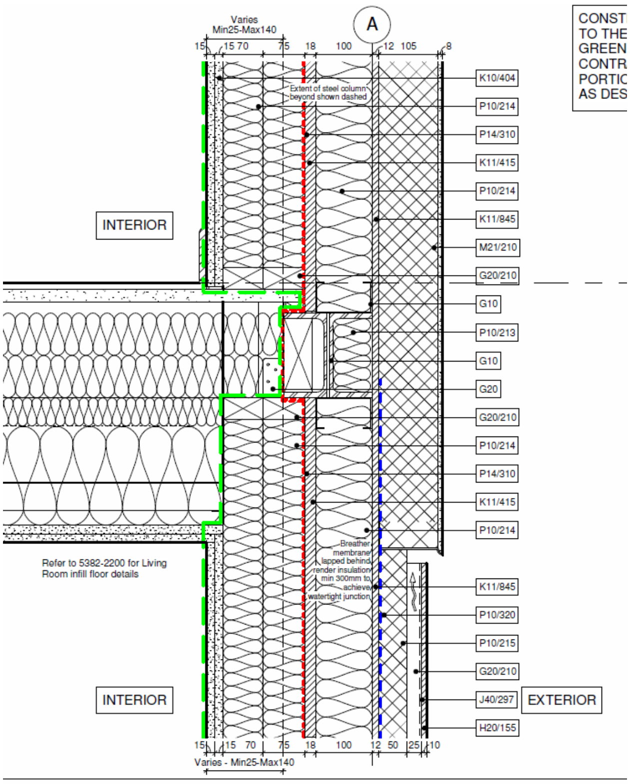
- Contract Sum: £12,927,456
- Construction Programme: August 2014 – November 2016
- JCT SBC/Q 2011 Standard Building Contract with Quantities
- with Contractor Design Portion

Contractor Design Responsibility:

- All new and modified structural works
- External building fabric
- Air barrier implementation & Air testing
- MVHR installation
- EnerPHit compliance

Contractor Design Responsibility:

- Gardner Stewart Architects: Lead designer
- Encraft: Passivhaus consultant
- Curtins: Structural engineer
- Greenwood: MVHR design



Designing and Building to Passivhaus Standards:

Gardner Stewart Architects and Encraft have staff trained as Certified European Passivhaus Designers and Consultants who have experience of designing and building to the Passivhaus energy efficiency standard within the UK.

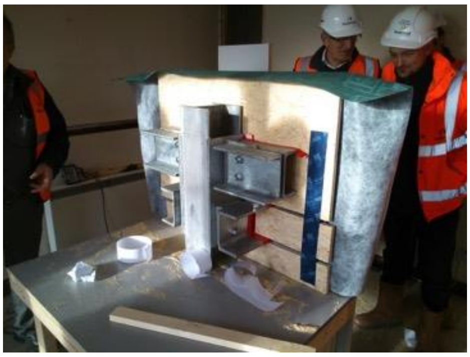
The Contractors, Keepmoat Regeneration have never built to these standards. At the project outset, no-one in the UK has retrofitted an existing residential building of this size and complexity.

The Project Team sought guidance from the Passivhaus Trust:-

- To illustrate the need for formalised quality assurance tools and methods
- To demonstrate examples of tools and techniques
- To confirm and clarify the requirements of the Passivhaus standard with regard to workmanship and liability as they relate to site teams and managers

Contractor Team Passivhaus Up-Skill:-

- EnerPHit Risk register
- Design stage evaluation
- Project management checklists
- Desktop buildability reviews
- Buildability workshops, mock-ups
- Quality assurance champion training
- Tool box talks to provide basic training for site trades
- Change management sign-off
- Intermittent site inspections and site inspection reports
- Contractors declaration proforma



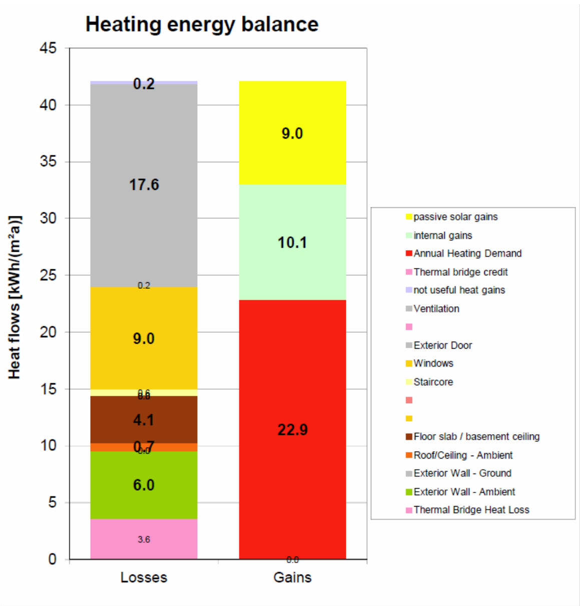
Contract Design Evaluation: Testing the Design in PHPP:

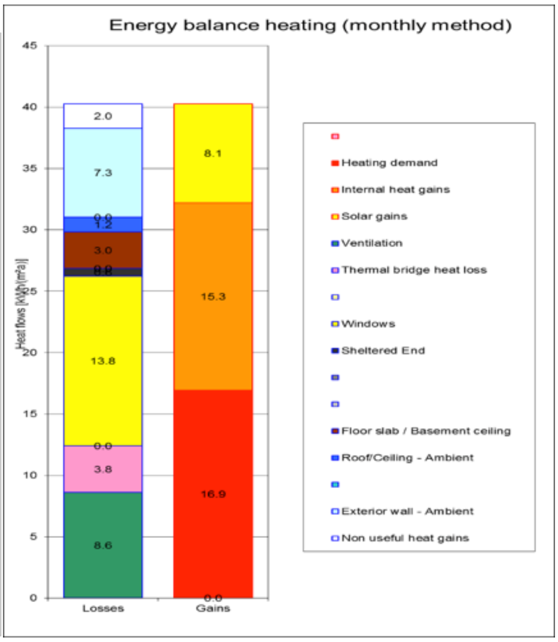
First task for the Keepmoat Design Team

From simplified Pre-tender model to Post-Tender model summary Heating Energy Balance bar graph.

- Bar on the left highlights differences within the 45 KWh/m2a heat loss
- Bar on the right highlights differences within the 45 KWh/m2a heat gain
- Solar gain (yellow), internal heat gain (cyan to orange) leaving heating demand down at 16.9 KWh/m2a

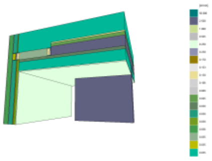
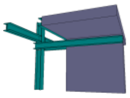
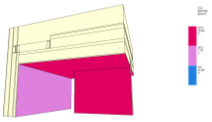
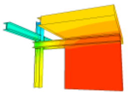
– well within the EnerPHit target of 25 (not 15 for PH)





Thermal Bridge Modelling

- To provide more detailed input into the PHPP model.
- Essential for building with this much steel in the overcladding and not able to insulate over the existing ground floor slab – so having to insulate on the perimeter.

Detail Ref **M4**	Two tie back beams at eaves level – infill timber roof over balcony	Modelled U_{wall}	Modelled $U_{main\ roof}$	ξ-value
		0.138 W/m^{2}K	0.060 W/m^{2}K	0.092W/K fo
 Full model showing all materials			 Model showing only steel and concrete	
 Full model showing boundary conditions			 Model showing heat flow	

EnerPHit Fabric Specification

End up with final fabric breakdown windows, walls, rood and floor slab.

Core gable wall onto the stair cores.

Building Fabric	**Average U-Value[W/(m²K)]**
Windows	0.928
External walls	0.139
Roof	0.127
Ground floor slab	2.447
Core gable wall	0.337
Thermal bridges:-	Y-Value [W/(mK)]
Ambient	0.029
Perimeter	- 0.348

The Primary Energy Challenge

One of the difficulties of achieving the Passivhaus standard in the retrofit of an existing building is determining which elements can be replaced to the higher standard within the time constraints of the refurbishment works.

Although the new Space Heating demand was under 25 kWh/m2/yr and the Heating Load at 12 W/m2 (to comply with EnerPHit)

But we cannot get primary energy down without full replacement of the existing electric heating system.

EuroPHit (of which this project is UK example) allows for staged EnerPHit certification but does not ‘reward’ a fabric-first approach

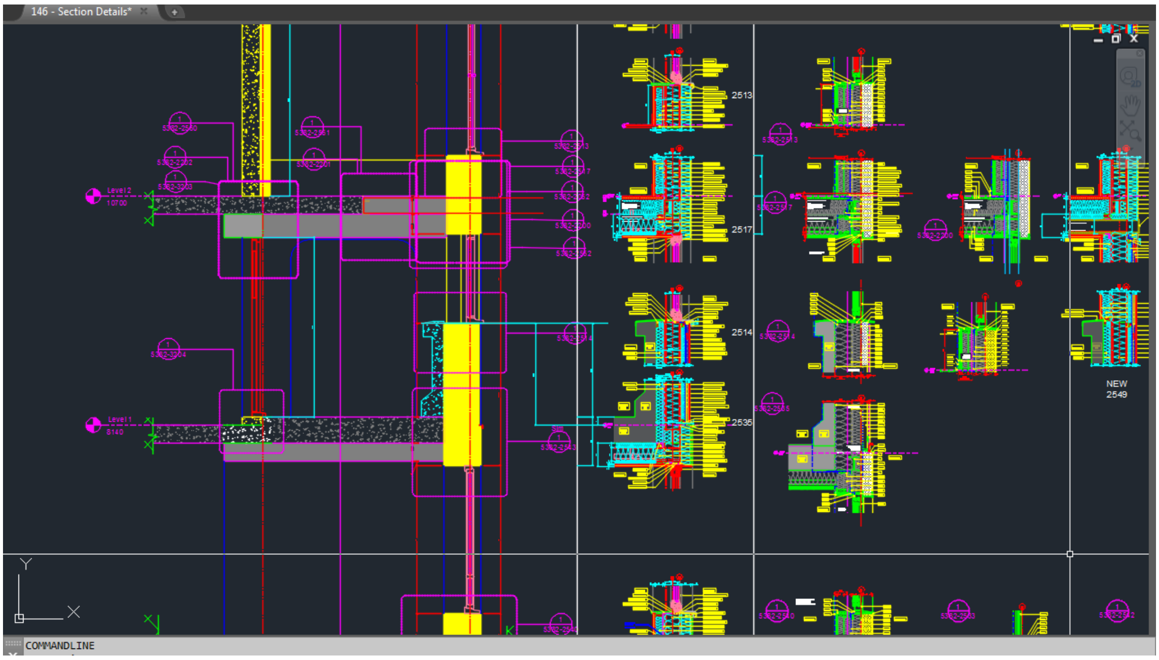
Future alternatives could be district heating (unlikely) or on-site renewable energy generation (PV on the roof).

“In individual cases where a very high primary energy demand is necessary, this limit value can be exceeded after agreement with the Passive House Institute. For this, evidence of efficient use of electrical energy is necessary, with the exception of existing electricity uses for which an improvement of the electrical efficiency by means of upgrading or renewal would prove uneconomical over the lifecycle.” iPHA

Contract Design Evaluation: Design Development

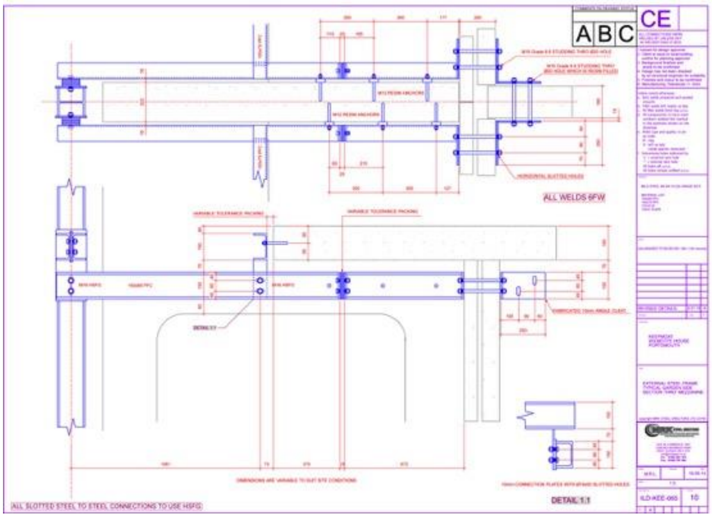
Architecture:

- CAD transfer of tender drawings (BIM model would have helped)
- Re-inserting the details, getting to know the existing building once the contractor takes over the site
- Not just detailing – re-think the air-tightness strategy, re-think the sequencing



Structure:

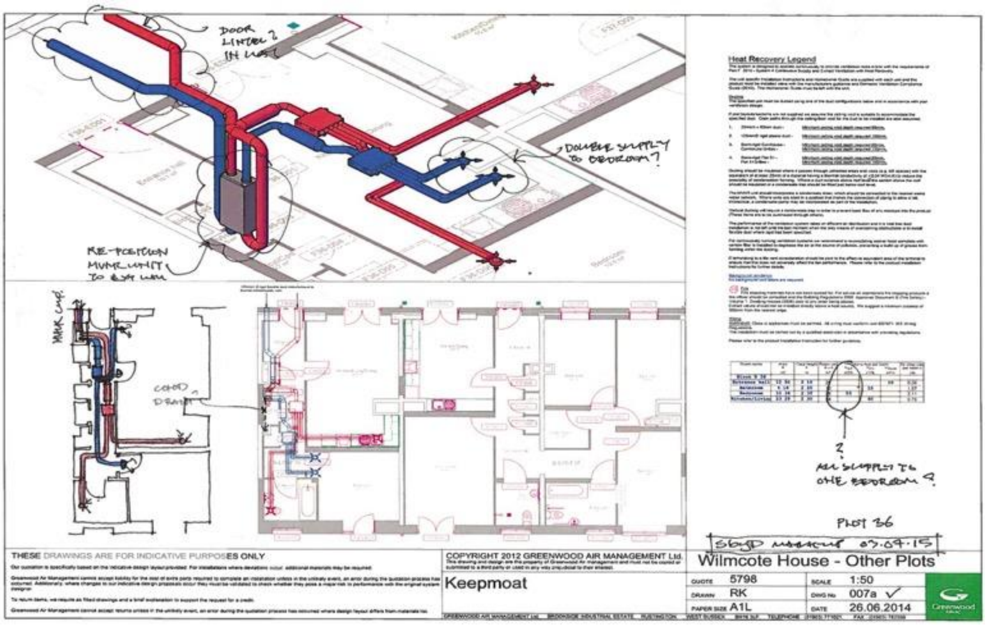
- Steel frame manufacturer’s design, test bolt fixing into the existing building, windows in different locations – add tolerance to the design
- How close can we build to the original building envelope (which isn’t straight plan and section)?



Ventilation:

MVHR efficiency:

- Greenwood Zhender components – contractor has to absorb last minute change at tender to different components – Paul Focus 200 unit with Lindab rigid ductwork to Zhender Comfo-air 200 unit with semi-rigid Comfotube ducts and manifolds – radial system. Advantages: more flexible, cheaper installation in tight locations but insulated in/out ducts longer needing spiralite insulation to keep design efficiency under 75%.



Kitchen Ventilation Upgrade:

- Portsmouth client conscious of residents’ use of kitchens once the access deck enclosed – now no external wall/window: how do you purge vent?
- Encraft demonstration ‘proved’ (tested in void flat) that the MVHR on boost would eventually bring the kitchen moisture/temp down - but not for a few hours.
- Had to provide non-pH, independent kitchen vent system which greater vent purge (also tested in void flat) – requires ‘air-tight’ dampers on the ducts when not in use.

Air-Tightness Strategy:

Through Further Air Testing Encraft/ALDAS were able to isolate an individual maisonette via a co-pressure test for the first time in order to record the background leakage of the existing building fabric alone.

- (7 No. previous existing building air leakage tests which averaged at 3.7 AC/hr @ 50 Pa)
- Previous tests had shown air leaking up & down the internal riser between maisonettes.
- The co-pressure air leakage result of approximately 1.0 AC/hr @ 50 Pa (with not all external openings properly sealed) led them to conclude that the fall back EnerPHit airtightness target of <1.0 AC/hr @ 50 Pa within the Wilmcote Contract should be achievable by using the existing concrete construction and that the parge coat may not be necessary.

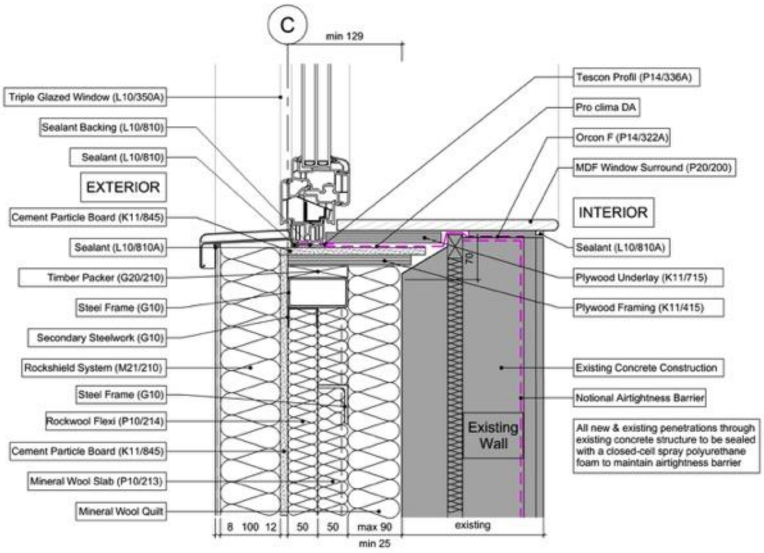
- Air test volumes double-height maisonette terrace, separated stair cores, air-tightness layer not necessarily following the thermal envelope line.
- Additional taped laps at compliance air-test junctions.
- Interim air-testing required before construction areas covered up

Detail Design Development:

2 over-cladding strategies;

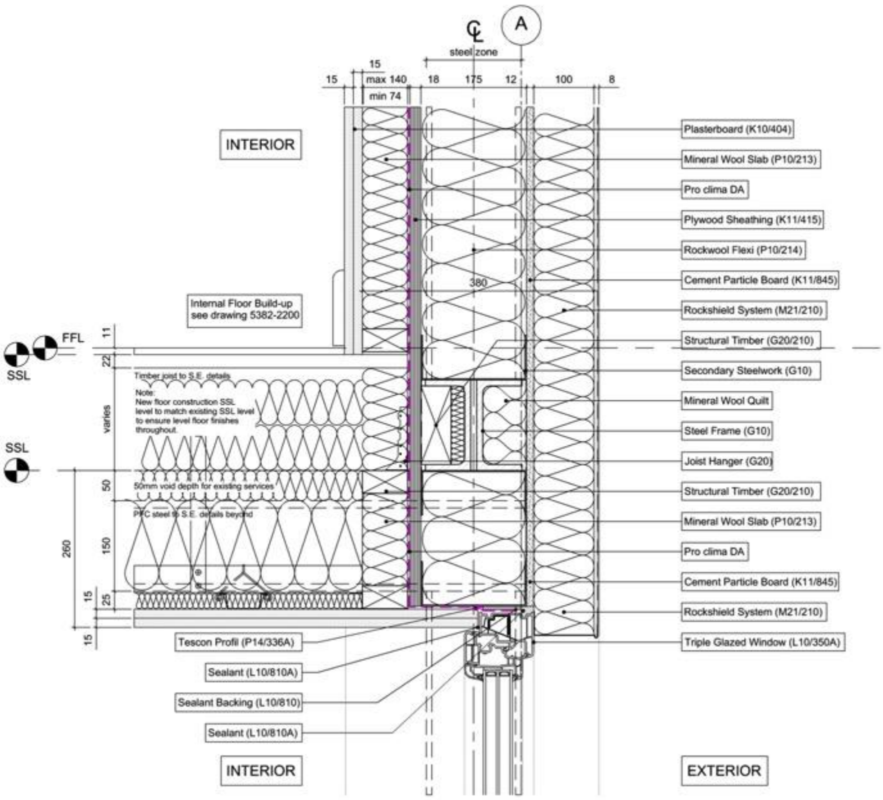
Road-side:

- Review construction sequencing – for construction and interim air testing
- Increase tolerance zone to existing building openings – as window/panel locations not consistent
- Simplify air-tightness taping at window installation – to allow standard Internorm pre-taped window installation
- Utilise existing concrete air tightness – no need for parge coat
- Wrap weather-proof board around reveal to temporarily protect insulation during works. Also more robust DA membrane spec rather than Intello Plus
- Review construction sequencing!



Garden-side:

- Review construction sequencing – for construction and interim air testing
- Increase tolerance zone to existing building – to allow membrane installation to back of ply sheathing
- Straighten up, simplify air-tightness membrane – not in and out as tender design
- Over-size secondary steel to simplify construction – straightens sheathing boards on both sides
- Additional air-tightness tape for testing volumes
- Insulation within steel channels – continuity of insulation
- Review construction sequencing! Again and again – if the subcontractors can't build it then it won't happen/shortcuts



On-Site Progress:

Building the Exoskeleton - substructure

Reinforcement cages 4 x piles for cantilevered ground beam/pile caps supporting each column

Building the Exoskeleton – 1st steel

Road side primary steel bolted through cladding panels to party floor slabs.

New columns support the mast-climbers!

Building the Exoskeleton – 2nd steel

2nd steel 'metsec-like' cladding frames between columns

Residents In-Place

Advantage of over-cladding strategy means less disruption to residents living on the inside.

Spiderman (!) reminds us that there are families with young children inside the flats while we are working on the outside.

Residents In-Place

Where construction works are close to residents we have to provide temporary screening

Living Room Extensions

.....such as where we are crunching the existing wall to allow the extension of the living rooms

Enclosing the Deck

This shows the steel ties beams spanning across the ceiling from the new structure on the outside of the deck to the party wall on the inside.

Also, timber joists show the living room extension above

Internal works: MVHR installation

Spiralite pre-insulated air in/out ducts from the MVHR unit the outside over the existing flat door.

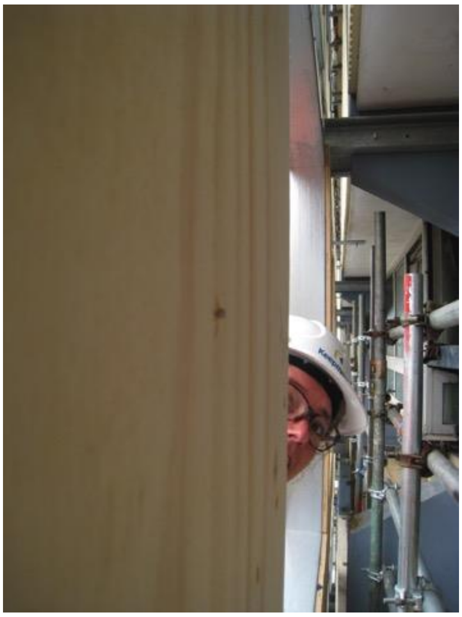
Internal radial-system semi-flexible ducts with manifolds – 1 for supply, 1 for extract

Zhender Comfo-air 200 MVHR unit fits snug into existing hall cupboard

IPassivhaus Inspecting & Checking

Garden-side plywood needs to be free from fixing protrusions prior to Pro-clima DA membrane installation.

Road-side windows DA membrane stuck to existing concrete panel reveal with Pro-clima Orcon line (in addition to Orcon



Rockwool mineral wool thermal insulation to road-side facade – specification adapted from quilt, flexi and slab to slab throughout as easier to work with. Thermal conductivity Lambda values checked with PHPP first. Insulation continuity – some metsec sections had insulation slid into the steel C-section before fixing to the frame.

Residents reporting already feeling the benefits of the thermal over-cladding as the outside temperature dropped over winter.

Window Installation

Internorm triple-glazed, PH-certified windows now weather-tight sealed on the outside with the taped particle cement board

And on the inside with the DA membrane – awaiting the mdf surrounds

Block A Over-Cladding Roof Insulation

Block A Garden-side overcladding progressing

Block A Overcladding nearing completion: white externally insulated render (EWI) with blue coloured cladding – all low fire risk non-combustible insulation and limited combustible finishing materials

Block A Road-side overcladding nearing completion: white externally insulated render (EWI) with blue solar shading fins– all low fire risk non-combustible insulation and limited combustible finishing materials

Internal Corridor overcladding and enclosure

Summary Conclusions:

The intention of this oral presentation is to describe an alternative approach to housing estate regeneration with a focus on refurbishing existing buildings and upgrading them to modern, energy efficient Passivhaus standards – with residents in place.

Internal radial-system semi-flexible ducts with manifolds – 1 for supply, 1 for extract

- Integrated EnerPHit approach: better thermal performance, air-tightness & ventilation
- Building to Passivhaus Build Quality: extending the life of an existing building
- Resident Benefits: very low energy bills, improved health & comfort
- Business Case: retrofit build cost rate, comparable with new-build housing to similar density & quality
- On-site Regeneration: difficult with over 400 residents on site, but no community displacement caused by decant and demolition

Increasing the local consumption of solar PV electricity using smart storage

Professor Rajat Gupta, Dr Adorkor Bruce-Konuah

Oxford Brookes University

Abstract

This paper examines the increase in local consumption of solar photovoltaic (PV) electricity achieved in a social-deprived community in Oxford, through deployment of decentralised renewable generation (solar Photovoltaic systems) and smart storage at an individual household and aggregated community level, as part of a new community energy research project (called ERIC – winner of Energy Awards 2016). The overall aim is to demonstrate how smart home batteries in a local community can help in reducing average peak load and doubling self-consumption of local PV electricity. The research project brings together solar PV power and (behind the meter) smart energy storage across a cluster of 82 households and community centre to create a virtual localised energy grid within the existing infrastructure. The batteries are linked to solar PV in each house, and also have internet connections allowing them to be virtually coupled, so as to ensure that the maximum amount of solar generated electricity is used within the community.

The methodological approach of the evaluation comprises dwelling surveys, energy audits, householder interviews, monitoring and evaluation of high frequency household electricity consumption, PV generation, battery charge and discharge data. In the monitored households, average daily electricity consumption ranges from 2.9kWh to 21.7kWh, and is found to be positively related with dwelling size, number of occupants and number of appliances used. Although 120MWh of solar PV electricity has been generated within a year across 54 households, electricity consumption and generation profiles show that in most households, generation exceeds consumption, but peak generation does not match peak consumption. Analysis of the contribution of smart batteries show that self-consumption increases on average by 6% and 7% on household and community level respectively. Ultimately the study seeks to demonstrate the case for building localised energy grids that empower communities and remove dependence on fossil fuels.

Keywords: Energy flexibility, smart storage, electricity consumption, solar PV, households, community

Introduction

Domestic electricity consumption accounts for over a third of the UK's electricity use (DECC 2015b). Over the years, the potential of the domestic sector to contribute towards the reductions in energy consumption and greenhouse gas emissions has been recognised and there is a pressing need to transition to a low carbon economy. To achieve this, an energy system consisting of a significant proportion of decentralised renewable energy sources and a decarbonised power system will be required. This energy system should also be resilient and so planning and preparing for energy flexibility is becoming increasingly important. The transition to a low carbon economy is well on its way in the UK. Between 2014 and 2015, electricity generation from renewables increased by 29% and amongst all the sources, solar photovoltaic (PV) generation increased by 87% in 2015 (Waters & Hemingway 2016). However renewable energy generation is most often stochastic and always intermittent in nature and although the intermittency may be predictable (e.g. PV electricity generation), peak output periods do not usually match peak energy demand periods in domestic buildings. This is why the UK Government is pushing smart meters and batteries to balance demand and supply by adding flexibility to the electricity grid.

The current power system is therefore envisaged to evolve in response to the growth of distributed generation (Howard & Bengherbi 2016). The elements of the future power system will include a much more complex network of renewable energy sources, both small and large scale, and most importantly storage facilities also on different scales. Storage refers to the processes and technologies which have the capacity to capture energy and release it for consumption later, e.g. during a blackout. They provide further flexibility in their ability to divert generated renewable energy from the exiting ageing energy infrastructure, reducing export of generated renewable energy. Great attention is already being paid to large scale energy storage systems for the grid (Kim & Powell 2011). Power output from renewable sources cannot be controlled and hence storage plays a vital role in improving their overall stability and reliability. Energy storage capabilities have been identified as one of the physical means to achieving flexibility (Roege et al. 2014).

Storage at household level enables householders to have more control over how they use electricity, reducing their electricity bill (Crespo Del Granado et al. 2014; Hoppmann et al. 2014). When used in combination with distributed generation systems, theoretical study results have shown that storage can increase consumption of renewable energy (Crespo Del Granado et al. 2014; Luthander, Lingfors, et al. 2015; Widén & Munkhammar 2013). The upward trend in the uptake of small scale renewable energy systems and the established benefits of domestic storage technologies combined with the falling incentives for generation and export of renewable energy (Ofgem 2017) means that it now makes more sense for energy to be generated, stored and used at a localised level, i.e. domestic and/or community level (Gupta and Bruce-Konuah 2017). As identified by Luthander et al (2015), storage technology is one of the options to improve self-consumption of PV electricity, however, more research is needed to further demonstrate their potential. The field study described in this paper is a domestic solar PV and storage (home batteries) project, called ERIC, using monitored household and electricity consumption, PV generation and battery electricity (stored surplus PV electricity) to evaluate the contribution of internet-enabled home batteries in increasing the local consumption of solar PV electricity, thereby introducing energy flexibility.

Methodology

A socio-technical evaluation approach was adopted to combine assessments of dwelling and household characteristics with assessment of high-frequency data on electricity consumption, PV electricity generation and storage of surplus PV electricity. Table 1 presents the details of the methodology for the evaluation of ERIC. The different sample sizes in each method is due to recruitment of households and availability of data. The installed batteries are connected to the internet to transmit data on electricity consumption and generation and contribution of storage.

Table 1 Methods for evaluation ERIC

Method	**Source of data**	**Sample size**
Dwelling survey	Data obtained from energy performance certificates to assess the physical conditions of the dwellings.	82
Household survey	Assess the household characteristics. Data obtained from the householders.	60
Assessment of household electricity consumption	Baseline electricity consumption obtained from meter readings	54
	After installation of systems, electricity consumption data obtained remotely at 5-minute intervals for a one-year period	Variable in each month
Assessment of PV electricity generation and consumption	5-minute interval data obtained remotely for a one-year period	
Assessment of the contribution storage	5-minute interval data obtained remotely for a one-year period	

ERIC Households

ERIC households are in a community in the south-east region of England. It is predominately a socially-disadvantaged community with a significant number of socially-rented households. In recent years the community has been the focus of many regeneration initiatives, including a new community centre and the ERIC project. ERIC brought solar PV systems and storage technology to 82 households in the community. All the case study households have solar PV systems ranging from 1.5kWp to 4kWp and a 2kWh battery unit for storage of excess PV generated electricity installed. A household survey was conducted with a sample of 60 of the households. Table 2 presents the dwelling and the household characteristics of the households. The results from the dwelling and household characteristics show that there is a range in dwelling types, ages and household types. All the dwellings have double-glazed windows and are all gas heated.

Table 2 Dwelling and household characteristics of ERIC households

Dwelling characteristics		
Dwelling type	Terraced house	58
	Semi-detached house	10
	Detached house	2
	Bungalow	4
	Flat	8
Dwelling age	Pre 1944	10
	1945 – 1990	46
	Post 1990	26
Dwelling size	Under 100m^2	70
	101 – 149m^2	7
	Over 150m^2	2
Household characteristics		
Household type	One-person household	20
	Two-person household	11
	One family (children under 18)	21
	One family (children over 18)	5
	Two or more unrelated adults	3
Number of occupants	1 or 2	36
	3 or more	24
Employment status	Working (full time)	18
	Working (part time)	6
	Retired	21
	Other (e.g. unemployed, carers, disabled)	33
Occupancy pattern	Always occupied	39
	Evenings and weekends	15
	Afternoons, evenings and weekends	5
Number of electrical appliances used	≤19	16
	20 – 29	24
	30 – 39	11
	≥ 40	1

Baseline household electricity consumption

Before the use of the storage units, average household electricity consumption was assessed for 54 ERIC households. This represents the baseline electricity use and it was estimated from historic household utility bills and meter readings. Figure 1 presents the range in the daily average electricity use. Average daily electricity consumption ranges from 2.9kWh to 21.7kWh with a median of 6.9kWh and an average of 7.5kWh. Figure 1 also shows the UK's average daily electricity consumption for domestic households (DECC 2015b) and it shows that ERIC households are on average low electricity consumers.

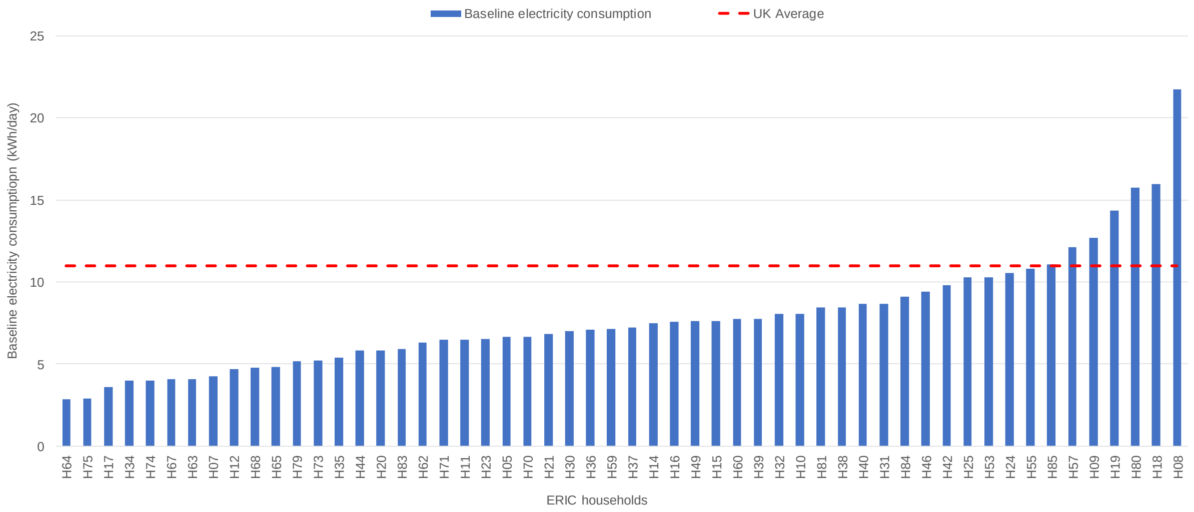


Figure 1 Baseline electricity consumption (n = 54)

From the dwelling and household characteristics, differences in household electricity were found between the different dwelling sizes, number of occupants and number of electrical appliances used. The differences were positive and significant at 0.05 significant level but with varying strengths (Table 3). The positive correlations show that as dwelling size, number of householders and number of appliances increase, daily average electricity consumption increases. The results confirm the findings from previous studies that have investigated the dwelling and household characteristics that are related to with household electricity consumption (Jones & Lomas 2015).

Table 3 Correlation coefficients for dwelling and household characteristics

Dwelling and household characteristics	**Correlation coefficient**	**Strength**
Dwelling size	0.35	Weak
Number of occupants	0.48	Moderate
Number of appliances used	0.61	Strong

Solar PV electricity generation and consumption

Solar PV systems were installed in households as part of the project. The installation process was staggered due to the recruitment process. PV generation data for one year before use of the batteries is available for 54 households (Figure 2). From these systems, a total of 120,242kWh of electricity was generated.

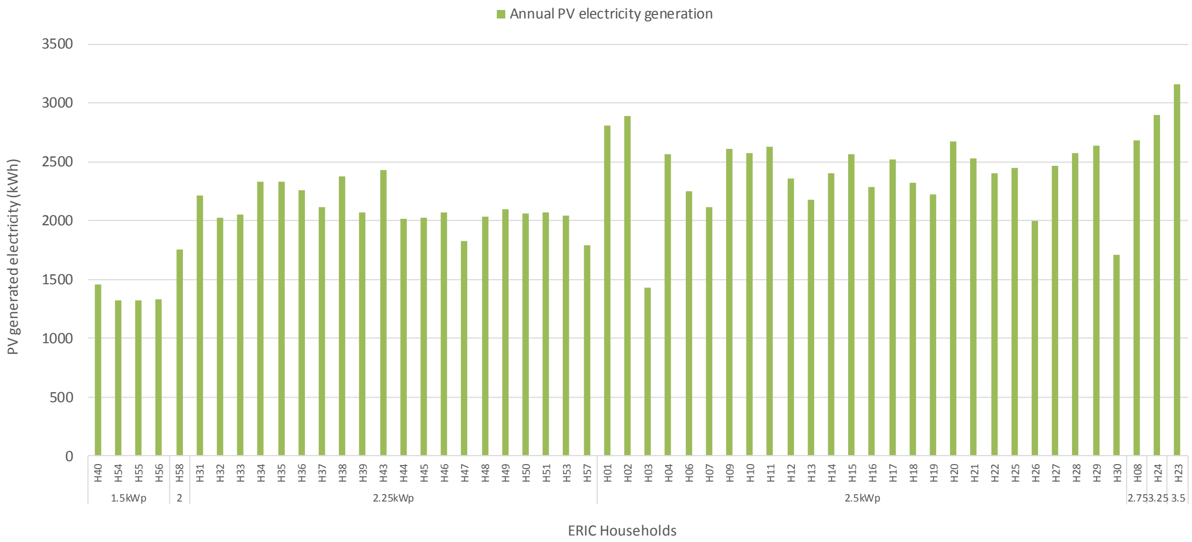


Figure 2 PV electricity generated from June 2015 to May 2016 in ERIC households (n = 54)

Half hour data on PV generation is available for 46 out of 54 households and from these, daily average PV electricity can be estimated for the different seasons. The figures presented in Table 4 show that in the solar PV generation has the potential to meet a significant amount of the household's daily electricity demand. This is especially true in the summer and spring from system sizes 2.5kWp and above.

Table 4 Seasonal breakdown in average daily PV electricity generation (n = 46)

System size	Number of systems	Daily average PV electricity generation (kWh/day)			
		Summer	Autumn	Winter	Spring
1.5kWp	10		1.0	0.8	2.4
2.0kWp	2		1.8	1.2	3.6
2.5kWp	31	5.0	2.4	1.5	4.4
2.75kWp	1	5.2	2.7	1.8	4.8
3.25kWp	1	6.3	2.6	1.3	5.6
3.5kWp	1	6.6	3.7	2.2	6.4

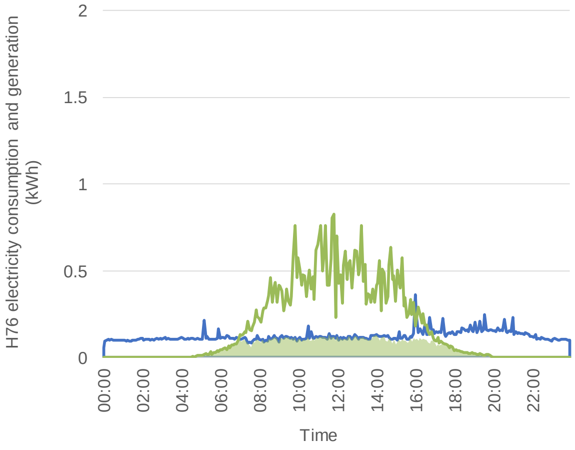
Self-consumption of PV generated electricity

From the batteries, high-frequency data is recorded for total household electricity consumption, PV electricity generation, grid electricity consumed, and battery electricity consumed. Self-consumption is explained as the proportion of the PV generated electricity that is consumed by the household in the house in which the system is installed. The battery electricity consumed is the increase in self-consumption of PV generated electricity. From the high-frequency data, electricity consumption and generation profiles can be plotted for each household. Figure 3 shows the consumption and generation profiles for a low, medium and high consumer household. The classification of consumer type is based on Ofgem's[1] values for typical domestic consumption (Ofgem 2015).

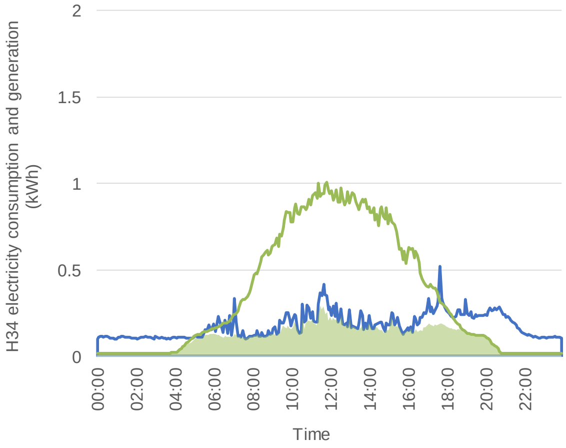
▭ Total electricity consumption — PV electricity generation 🟩 PV electricity consumption

Low consumers

H76: 2.9kWh/day, 1.5kWp PV system, 30% of PV electricity consumed

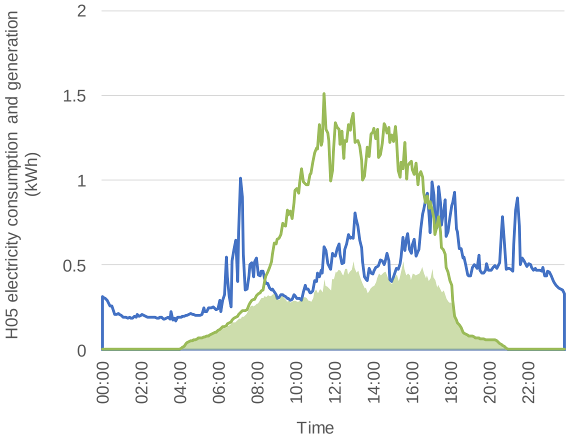


H34: 4.3kWh/day, 2.25kWp PV system, 30% of PV electricity consumed

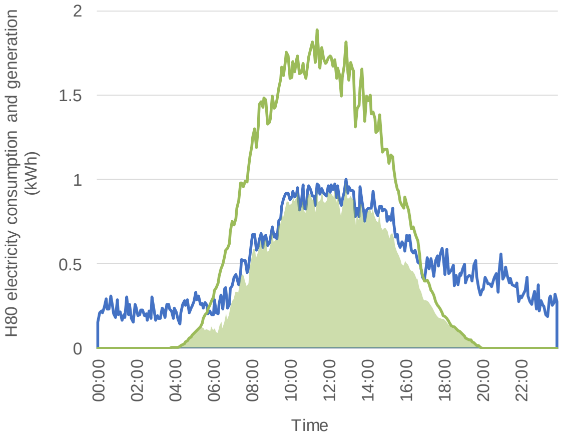


Medium consumers

H05: 10.6kWh/day, 3kWp PV system, 43% of PV electricity consumed



H80: 12.0kWh/day, 3.8kWp PV system, 52% of PV electricity consumed



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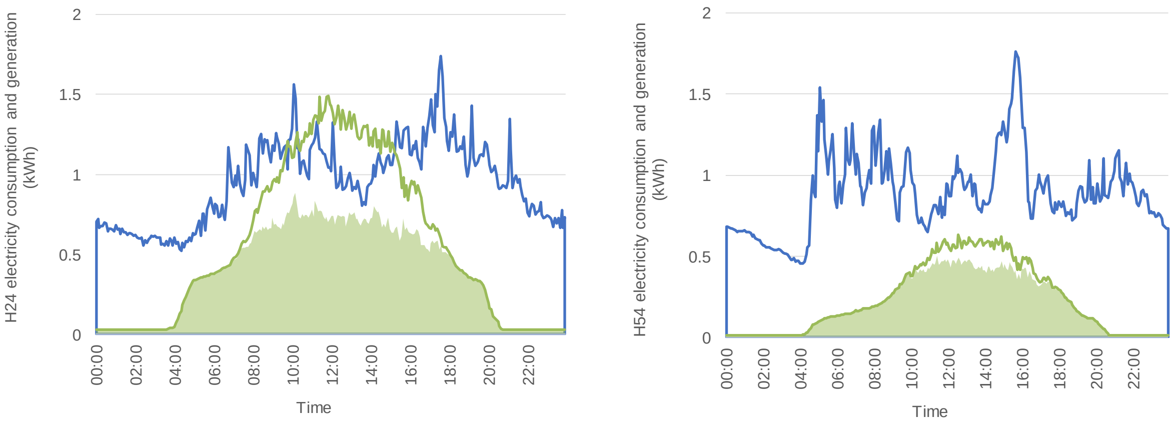
[1] Ofgem – Office of Gas and Electricity Markets, is the UK's government regulator for electricity and downstream natural gas markets in the UK.

High consumers



H24: 22.2kWh, 3.25kWp PV system, 70% of PV electricity consumed

H54: 21.3kWh, 1.5kWp PV system, 87% of PV electricity consumed

Figure 3 Average daily electricity consumption and generation profiles in low, medium and high consumer households

In Figure 3, the area under the graph shaded green represents the amount of PV electricity consumed during generation and the area above that is the surplus electricity which will be exported to the grid. For self-consumption of PV generated electricity, a strong, positive correlation was found between household electricity consumption and the amount of PV electricity consumed instantaneously (*r=0.73, n=64*). As household electricity demand increases, the proportion of PV electricity consumed during generation increases, so in these households, there will be minimal surplus PV for storage. It is important to also note that the PV system size will have an influence on the amount of PV consumed and what is left as surplus.

The daily average PV electricity generated in February 2017 and May 2017 are presented in Figures 4(top) and 4(bottom) respectively for a sample of the ERIC households. The daily average generation is split into PV system size, PV electricity consumed instantaneously, (i.e. during generation) and the excess PV. These bar charts show that in both periods of high and low sunlight, there is excess PV (an average of 1.3kWh in February and 4.9kWh in May). From across the ERIC households and over a one-year period (Jun-16 to May-17), self-consumption of PV generated electricity ranges from 22% to 96% with an average of 53%. This means that across the year, about 56,514kWh of generated renewable electricity is not consumed in the community and it is exported to the grid to be sold back at the usual price to households. This surplus electricity can be stored and used by the households, increasing the self-consumption of their PV generated electricity and further reducing their demand of grid electricity.

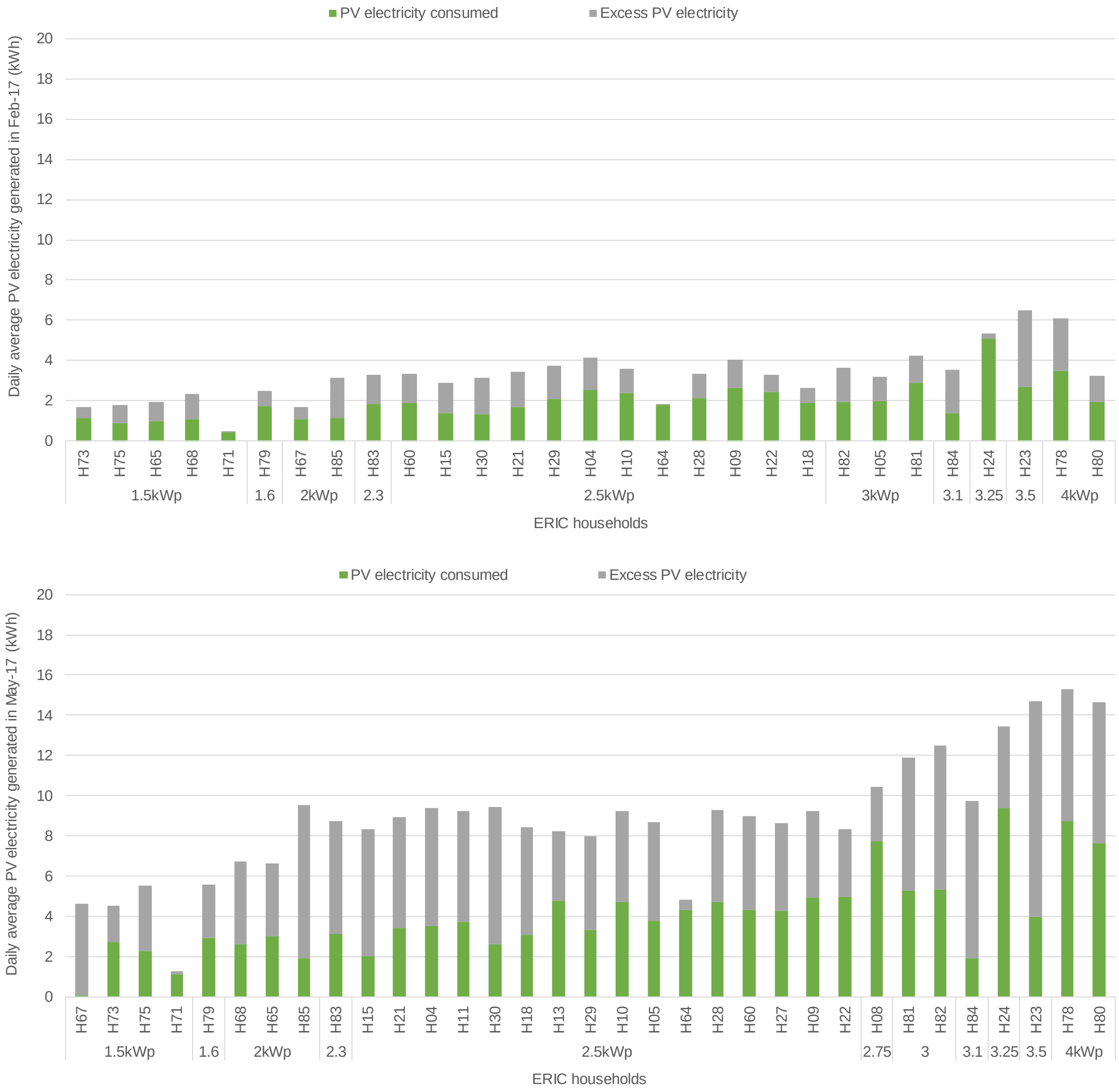


Figure 4 Daily average PV electricity generation in (top) February 2017 (n=29) and (bottom) May 2017 (n=33)

Contribution of storage in self-consumption of PV generated electricity

In the batteries, the charge and discharge models are based on PV electricity generation and household electricity consumption. The batteries are charged only when PV electricity generation is greater than household electricity demand with no more electricity than the difference between electricity generation and consumption. The batteries are never charged from grid electricity. They are discharged when household demand is greater than generation, hence mainly in the early mornings and/or in the evenings when there is very little or no sunlight. Across the households and over the one-year period, percentage increase in self-consumption of PV generated electricity ranges from 0% and 22% with an average of 8.4%. The maximum amount of PV electricity that was discharged was 1.5kWh, however, the average amount discharged was marginal at 0.5kWh. Figure 5 shows profiles of household electricity consumption and this is split into electricity from the grid, instantaneous consumption of PV electricity and PV electricity from the battery in May 2017.

H35: Daily generation 8.0kWh from 2.25kWp system

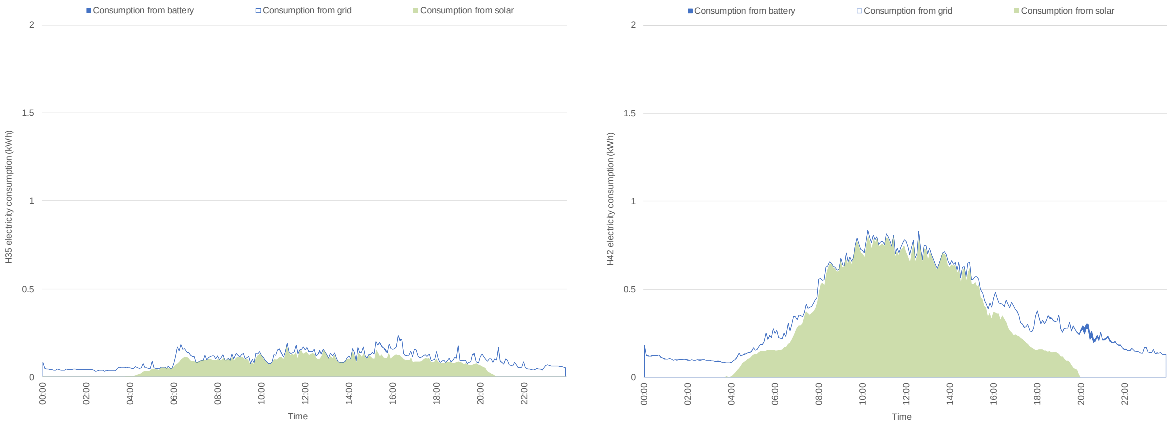
PV electricity consumed instantly: 20%

Increase in self-consumption: 0.1%

H42: Daily generation 8.4kWh from 2.25kWp system

PV electricity consumed instantly: 80%

Increase in self-consumption: 0.4%



H06: Daily generation 8.2kWh from a 2.5kWp system

PV electricity consumed instantly: 43%

Increase in self-consumption: 11.8%

H65: Daily generation 6.6kWh from a 2kWp system

PV electricity consumed instantly: 45%

Increase in self-consumption: 12.5%

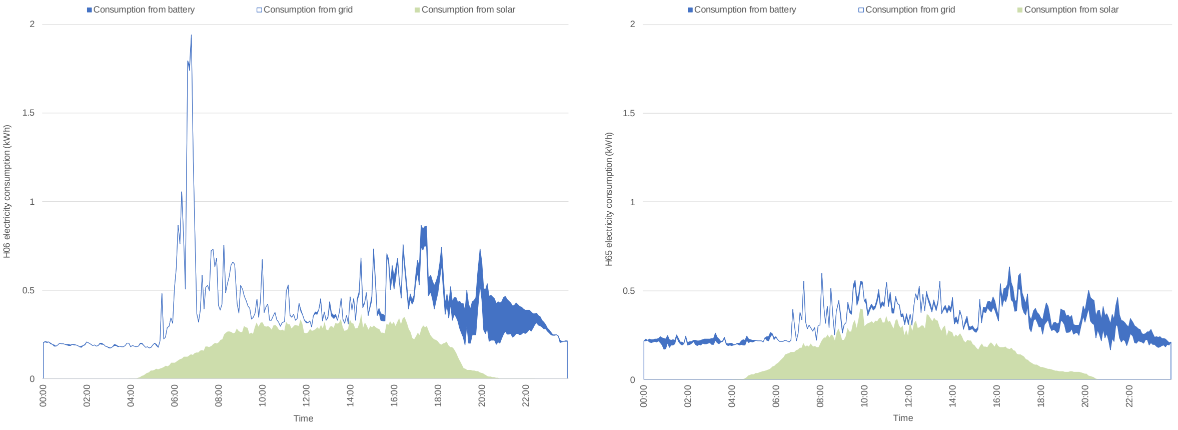


Figure 5 Household electricity consumption from grid, PV and battery

The top two households (H35 and H42) make very little use of the battery. H35 is a low electricity consumer (daily average consumption of 2.3kWh) and the household's electricity baseload is very low (less than 100W), hence the battery is not fully discharged. For this household's electricity demand, 67.8% is PV electricity, 0.3% is stored electricity and 32% is grid electricity. In H42, the installed PV system is also 2.25kWp and the household's daily electricity demand is 8.2kWh. A significant proportion of the PV generated is consumed and a very small amount is discharged from the battery. The household's demand is 75.6% PV electricity, 0.4% stored electricity and 24% grid electricity. The bottom two households (H06 and H65) make good use of the battery. Like H42, H06 and H65 are average electricity consumer (9.9kWh/day and 8.1kWh/day respectively), however, bigger PV systems are installed, generating more electricity (8.2kWh/day and 6.6kWh/day respectively). In H06, 35% of the household's total demand is PV electricity, 10% is stored electricity and 55% is grid electricity and in H65, 37% is PV electricity, 10% is stored electricity and 53% is from the grid.

In Figure 6 the daily average PV electricity generated in each household is shown in the proportion consumed instantaneously and through storage and the excess. After storage, there is still some PV electricity which is not consumed in most of the households. In the low consumer households (≤ 6.0kWh), instantaneous PV electricity consumption offsets a significant amount of grid electricity however contribution of storage is minimal in most of these households. Average self-consumption before storage is 32% and this is increased by 2% with storage. In medium consumer households (6.1-12kWh), amount of PV electricity consumed increases, both in instantaneous consumption and storage. Average self-consumption is 47% and this is increased by 6% with storage. Also in the high consumer households (≥ 12kWh), average self-consumption increases by 6% but consumption before storage is higher at from 58%.

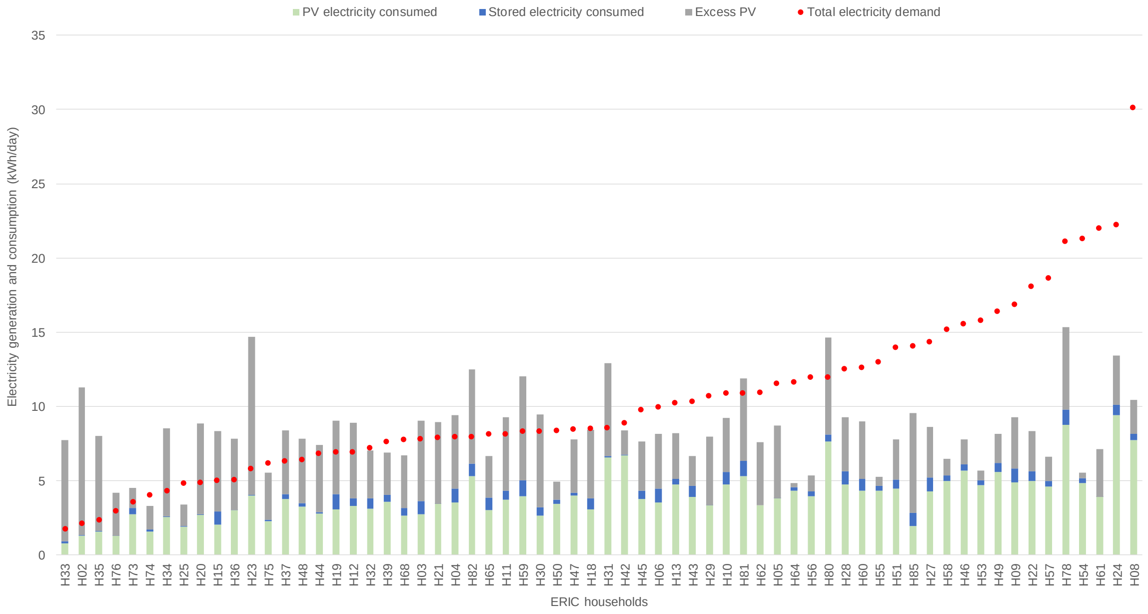


Figure 6 Electricity consumption and generation in May 2017

Contribution of storage at community level

For the summer period in 2016, total electricity consumption, PV electricity generation and battery discharge from 42 households were aggregated to represent a small community. Figure 7 presents the average consumption and generation across the community. There is a smoothing effect in the consumption profile as electricity consumption varies in all households however the peaks which are evident in the consumption profile is still mismatched with the peak in generation and there is a significant amount of excess PV electricity. In this summer period, total electricity demand across the community was 45,078kWh and 36,951kWh of PV electricity was generated. Across the community, 17,780kWh (48%) of the PV electricity generated was consumed instantly. From the remainder, 2480kWh was charged and discharged from the battery. This proportion of PV electricity stored increased self-consumption by 7%. Hence 55% of the PV generated electricity was consumed, saving approximately £3,039. During this period, PV electricity made up 39% of total demand, storage contributed 6%, while 55% was drawn from the grid.

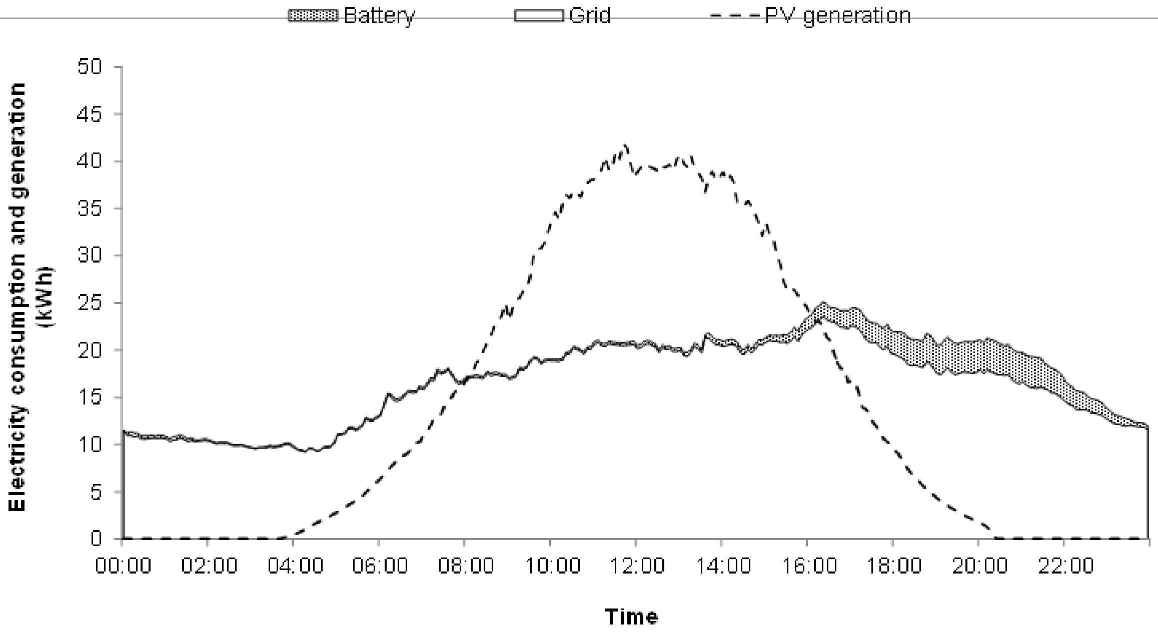


Figure 12 Mean aggregation for 42 households: electricity consumption, generation and battery discharge

Discussion

Assessment of the electricity consumption of the ERIC households showed that there is a wide range in household electricity use and there are differences between households with similar dwelling and household characteristics. Household electricity consumption profiles differ from household to household due to differences in electricity use behaviour and household characteristics which have an impact of electricity consumption.

A significant amount of PV electricity was generated during the monitored year offering great cost savings to the households and environmental savings to the community. The daily average PV generation in the summer and from system sizes 2.5kWp and above is close to the daily average consumption across the households. Due to the difference in electricity use behaviour within the households and the different PV system sizes, self-consumption of PV electricity during generation varies from household to household. In high consumer households and in households where peak consumption matches peak generation, a substantial amount of the generated PV is consumed instantaneously. In most other households, there is a mismatch between peak demand and peak generation and so only a small amount of the PV electricity is consumed resulting in surplus PV electricity. This mismatch in consumption and generation peaks and the wide range in household consumption means that even in the months with reduced sunlight there is still surplus PV electricity. This indicates that there is potential of meeting a substantial proportion of household electricity by adding storage to the distributed generation scheme.

On the contribution of storage in increasing self-consumption of PV electricity, the amount of stored electricity consumed also varies across the households although all households have the same battery capacity. Low consumers tend to have very little or no contribution from storage. From their profiles, a large amount of their total demand is met by instantaneous consumption of PV electricity and because they tend to have low baseloads, their batteries are not discharged (due to the discharge model of the battery). In these households, self-consumption is very low and surplus PV electricity is high. The other group of households having minimal impact from the batteries are those with high self-consumption before storage (because of high consumer/small PV system sizes or matching peak consumption and generation). In these households, most of the PV electricity is consumed (> 70%) with little surplus for storage and discharge. The group of households who seem make good use of storage are the medium consumer/big PV system size or having the mismatch between peak consumption and generation and considerable baseloads. In these households, an average amount of PV is consumed during generation (~ 45%) leaving sufficient surplus for storage which is discharged later (evenings and mornings). Here self-consumption can be increased by up to 22%. In the households where storage is contributing, self-consumption can further be increased with a larger battery capacity. The results also indicate that there is a potential to increase self-consumption of PV electricity through a sharing scheme. Households with PV systems can benefit from the surplus PV which is stored in a networked battery system or a large-scale battery. A future development for the PV-battery concept should therefore include the idea of a community sharing scheme where not all households will have PV systems but rather have storage facilities connected to their neighbours PV systems. Currently, the savings achieved from the use of solar PV systems far outweighs the savings achieved from the use of a home battery, which is why savings from the batteries are significantly improved when integrated with solar PV systems.

Conclusion

The main conclusions of this study can be summarised as follows:

- There is a wide range in household electricity consumption even across households with similar dwelling and households' characteristics.
- The solar PV systems are successful in generating a significant amount of electricity and offsetting the household's grid electricity demand, however, there is substantial surplus PV across the community which is not consumed.
- Increase in self-consumption of solar PH through storage is affected by the amount of surplus PV electricity as well as the household's electricity load and profile.
- The potential of storage technology will be enhanced when aggregated on a community level through a sharing scheme.

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Serious games as an instrument to support energy retrofitting

Lessons from the Go2Zero City-zen Game

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Abstract

This paper presents the serious multi-player tabletop game GO2Zero and explores how such games may contribute to overcoming barriers to local energy retrofitting. The game lets actors involved in local energy retrofitting, experience the multi-actor decision-making context. In half a day, about twenty participants play a role. Roles defined are: local authority, housing corporation, tenant, homeowner, local sustainable energy supplier, grid operator, local renewable energy supplier, or a contractor offering retrofitting measures and technologies. Within the game, participants are requested to determine their energy goals, and the strategies to be used to achieve them. In four consecutive rounds, each representing several years, participants have to decide which retrofitting investments they will make, if any. They can choose from a number of retrofitting measures, and have to get an understanding of the pros and cons of each. They are confronted with the consequences of their decisions over the years, in terms of individual and collective goal achievement, carbon reduction, security of supply (network instability), land use, and affordability.

After playing the game, the participants have more insight in the different opportunities for retrofitting, the effect of different retrofitting strategies, and the dynamics of the institutionally fragmented decision-making context. The paper will report on the experiences of sessions played with local stakeholders involved in energy retrofitting in the cities of Dubrovnik, Amsterdam and Delft. The game development and sessions played have been part of the EU FP7 supported project 'City-zen, new urban energy'. The game has been developed in collaboration with DNVGL.

Introduction

The transition towards renewable, non-carbon based energy resources is a global challenge involving all industries and sectors. In search for achieving the UN climate goals, the residential sector needs to contribute as well (Ballarini, Corgnati and Corrado 2014). In the European Union (EU-28), the households are responsible for 25,4% of final end use of energy use in 2015. The contribution is even expected to rise due to global warming and continued urbanisation, leading to increased (peak) energy demand for cooling and in turn contributing to increased pollution and global warming (Ascione et al. 2017). Whereas many efforts have been put in the successful development of energy neutral and zero emission concepts for new housing, the existing building stock turns out to be resistant to many of the policies and innovations supporting the reduction of carbon-based energy and increasing the use of renewable energy (Trencher et al. 2016). In the period 2007-2015, the EU-28 final energy consumption for the residential sector fell by -3,9% compared to -15,5% by industry (Eurostat 2017). This poor result can be explained by a number of factors: high upfront investment costs, lack of awareness and knowledge by residents, home owners, but also amongst professional stakeholders as contractors and local policy makers, disruption for residents, uncertainty of return of investments, uncertain energy performance and the fragmented institutional setting, with many small stakeholders, split incentives, absence of a directing actor and of enforcement capacity (Van Bueren and De Jong 2007, Sunnika-Blank and Galvin 2012, Baek and Park 2012, Zuo and Zhao 2014, Caputo and Pasetti 2015).

In the EU FP7 project 'City-zen: new urban energy' (Cityzen-smartcity.eu 2017) the cities of Amsterdam and Grenoble took on the challenge to develop best practices for improving the local energy performance of buildings, districts and cities. The Go2Zero game has been developed as part of this project, acknowledging that many of the challenges in urban retrofitting are of a non-technological nature, requiring stakeholder interaction.

This paper presents the Go2Zero game, developed by TU Delft in cooperation with DNV GL in the context of the City-zen project, and the results of the first sessions played. The following sections first explain the complexity of the challenge of energy retrofit or energy renovation of the existing homes, followed by a description of the GO2Zero game and the results from the first sessions played and conclusions.

Energy retrofitting challenges

Cities, including the energy system and the housing system, can be considered as complex socio-technical systems consisting of an intractable number of variables and relationships which are difficult to control. The socio-technical complexity is recognizable in the case of energy retrofitting. There is a large variety of technological solutions to choose from, ranging from energy saving measures to the adoption of renewable energy technologies to produce energy on a household scale (e.g. through heat pumps, PV panels) and on district scale (e.g. PV farms, wind farms, and using industrial waste heat), or changing the energy mix (e.g. to use electricity instead of natural gas). This results in a large number of options to choose from, without clear indications of costs and benefits in terms of finances and energy use. The costs and benefits of options are often interdependent, making it even more difficult to determine these and to make a choice. For example, a well-insulated home reduces the return on investment of alternative forms of heat supply. Also, costs and benefits tend to be based on reference buildings, with reference occupants with reference behaviour, lifestyles and preferences. Another, often disregarded, but complicating factor is the relationship between the use of renewable energy technologies in homes and the grid changes it requires, bringing in the grid operator as another stakeholder. Grid operators might need to invest in additional infrastructure and in the capacity and balancing of the network to secure supply.

Main actors on a district level are the municipality, inhabitants of the district, the social housing corporation, businesses, but also the energy network operator and energy companies. These stakeholders operate on different levels and make decisions based on different values and act according to different regulatory frameworks. Whereas a resident mainly focuses on the direct living environment, a network operator or energy supplier acts on a larger geographical level. Although, in general, the actors would agree that the energy transition is important, the ways in which this can be achieved varies from high-level, top-down interventions to small-scale, bottom-up initiatives. Decisions of cities to expand heat grids limit the options of residents; decisions of many individual residents for decentralized technologies together demand additional investments by grid operators; subsidies from a municipality steer the selection of measures causing different performances of the system. These interactions may lead to emergent system behavior on the level of the district and consequently on the national and international scale.

Municipalities, who have an important role to play in promoting the energy retrofitting or energy renovation of the existing housing stock, thus face a difficult task. They have to encourage citizens to invest in their homes, without being able to supply them with a customized action perspectives and without significant enforcement capacities. In addition, the level of knowledge and awareness amongst municipalities is generally quite low, often concentrated in the hands of a few experts (Caputo and Pasetti 2015). It is for this setting that the Go2Zero game has been developed, as a serious role playing game to make stakeholders involved in the energy retrofitting at a local level aware of the complexities involved and possible actions and their effects. Also, it offers an environment to experiment with coordinated action strategies.

The Go2Zero game

Serious games are games developed for other purposes than mere entertainment. Simulation games offer participants a representation of a real world complex system in a simplified way (Bekebrede 2010). Participants can experience situations that are difficult to experience otherwise, and can learn from it. In the multi-player, roleplay settings, such as Go2Zero, games also offer participants the opportunity to freely experiment with different strategies and experience and reflect on the consequences of one's actions (Duke and Geurts 2004). Due to the complex nature of climate change and urban development, serious gaming is a useful support tool in this area (Mayer et al. 2005, Kwok 2017).

GO2Zero is a multiplayer tabletop game. The development followed the game design approach of Duke and Geurts (2004). The main objective of the game is to offer participants a better understanding of the challenges of the transition process towards zero carbon emissions by residential buildings and to provide an experiential space to explore different technological options and transition strategies. The game development started with a thorough analysis of the local energy system, from the energy system of individual households to the local energy infrastructure and supply. This was based on a knowledge available amongst the participants in the City-zen consortium and on interviews with different stakeholders in Amsterdam and Grenoble, to understand the main variables, relationships and challenges in energy retrofitting and the main actors involved. To make the game more playable and more focused, some simplifications were made, such as the choice for an average, mono-functional suburban residential (small) district, and the exclusion of the transportation sector.

The game GO2Zero simulates the energy transition process of existing dwellings. Multiple players, divided over different roles need to take actions to reduce energy consumption by 50%, to produce all renewable energy locally and make the district CO2 free. On a card board the residential district is represented, consisting of twelve houses with their families and gas and electricity networks. Each household has three pillars of coloured fiches representing the energy consumption (heat and electricity), the energy production, and the CO2-emissions. The potential areas for local energy production also have a place on the map showing the capacity realised.

The roles included in the game are home-owners, tenants, a housing corporation, the municipality, the grid operator, contractors supplying the energy retrofitting measures and a local energy company. A role is preferably played by 2 persons, giving them the opportunity to brainstorm, exchange ideas and discuss decisions. At the start of the game, all households have a grey energy contract with a national energy company, played by the facilitator. The grid operator is responsible for ensuring sufficient capacity on the grid. The needed capacity will change due to the actions of the families and the housing corporation, but also by newly installed production capacity of the local energy company. The participants are placed at different tables in the room, with a placemat containing information about their individual financial situation, energy contract, and assets. They are allowed to move around and communicate with each other.

A GO2zero gaming session starts with an introduction to the game after which participants have time to read the information and develop a strategy. The game takes place in maximum four rounds consisting of three steps: 1) payments, 2) negotiation, and 3) consumption. In the first step, households receive their salary and they have to pay their rent or mortgage, energy bills, grid costs and local taxes. During the second step, all stakeholders can buy technological energy measures from the contractors, negotiate about costs, make appointments, change contracts, and organize community meetings (Figure 1 left). In the third step, the district map is adapted to the new situation: based on the transactions, the pillars of fiches are reduced (Figure 1 right). A complete gaming session has four rounds, after which the final score is registered and all participants have to count their money and to produce an overview of their situation. During the debriefing, participants share and discuss their results, followed by sharing of emotions surfaced during the game, and reflect on the overall outcomes of the game. Further, they discuss what has happened and how this could be done differently. Finally, together they look forward to what this could mean for their local energy transition challenge and possible strategies.

Figure Discussion amongst participants (left) and the card board (right)

Results

The game was play-tested with stakeholders from the Amsterdam region in the Netherlands and from the city of Dubrovnik in Croatia, leading to some improvements. The final design has been validated by 3 sessions with students from Tilburg University.

Game outcomes

Households in all sessions started from the same position: residents live in houses with a low energy label (G or H) and use fossil-based energy sources. We observed different strategies and results between the three sessions. Table 1 shows the outcomes on the three main objectives in the game. In none of the sessions any of the final objectives were achieved. This was hardly possible, as the game has been designed for four rounds of playing and due to time limitations, we played two rounds.

In the first session the participants clearly focused on reducing CO_2 emissions by changing the grey energy contracts to a contract with energy generated by nuclear power. This had a large impact on CO_2 emissions, but introduces another dilemma. Also, the households focused on energy reduction and local production via PV panels. They did this without any communication with the grid operator. Consequently, the network had insufficient capacity to deal with the new production, leading to energy loss and network instability. In the second round, the grid operator invested in increasing the grid capacity while the households invested in energy reduction measures. This led to an over dimensioned network and a waste of resources.

In the second session the participants strongly focused on the reduction of energy. Together with some local renewable energy contracts, they were about halfway the CO_2 reduction targets and reached the highest reduction in energy use of the three sessions. In this session, the grid operator was also not part of the discussion on how to achieve the objectives. In the debriefing, the grid operator explained that it thought it could only react on the actions of others and need to follow the dynamics.

In the third session there was a strong grid operator, who took the lead. To survive as a company, it had the strategy to focus on production of renewable energy on the district level instead of on the individual household. The students playing this role actively discussed with the local energy company the additional investments needed in the grid resulting from the increased local production. In this session, the households had less influence and paid the higher grid costs. In the results, this is not yet visible, as the installed power was not connected to the grid when this game ended. If it had been connected, the energy from local production would have been 52%, which would have been substantially higher than in the other sessions. However, the energy consumption in this third was overall higher.

The debriefings led to two general observations. First, aligning strategies amongst the participants was not easy. Although they shared ambitions, investments discussions led to a deadlock. For example, everybody had agreed that implementing a heat grid was a good solution, but nobody wanted to invest and the heat grid could not be realized. A second general observation was that stakeholders focused on the well-known measures as PV panels, insulation and double-glazing. They did not research other opportunities.

Game Experience

In the postgame survey, we asked for players' experiences while playing this game. The number of responses of the postgame questionnaire was 24 (51%). The participants agree that the game was relevant (M = 3.9, SD = 0.5) and they put themselves into their role (M = 3.9, SD = 0.6). Further, they slightly agree on the clarity of aim, the level of detail, and the realism of dynamics. In the debriefing, we observed that the students were surprised that in reality stakeholders often do not communicate well and believed that you could take decisions only with complete information. Further, they slightly agree that they enjoyed playing the game and they would like to play again. From the reactions in the open questions, we conclude that a better introduction of the different roles is needed as students lack knowledge about different roles. In addition, they asked for more time, so they would have the opportunity to finish the game. Both points influenced their experiences. In the oral debriefings of the game sessions in Amsterdam and Dubrovnik the participating professionals emphasized that the resemblance with the real-life complexity of local energy transition processes, making them realize that the complexity of the challenge is even higher than they realized.

Conclusions

The GO2Zero game achieved its goal to give participants more insights in the challenges of a transition process towards sustainable cities by focusing on the local energy transition and energy retrofitting of housing in particular. Our observations, coupled with the results of the sessions played, show that the game also provides room for testing a variety of strategies and related outcomes. Further observations showed that coordinated decision-making between different stakeholders is necessary to achieve objectives and to optimally use limited resources. Especially the role or involvement of a grid operator seemed critical in the process – a role that is not often considered in discussions on energy retrofitting. Finally, well known and easy to apply measures had been taken, while participants did not invest in other, less known measures.

Based on the results, we conclude that a game such as the GO2Zero is capable of a whole representation of a complex system, thus providing stakeholders a more profound understanding of the complexity and the need to collaborate and coordinate actions. Playing more sessions in different institutional contexts will result in better understanding of strategies used by the participants. Improvements of the Go2Zero game could be in several directions. It would be interesting to use it as an environment for experimenting with different predefined retrofitting strategies and incentives. Also, new roles, such as an energy advisor and energy service company, could be included, and new technologies could be introduced.

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Seven myths of building retrofit

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Abstract

This paper identifies seven widely-respected myths in the retrofit debate, which need to be debunked if retrofit is to have a chance of achieving its potential.

Myth 1: Retrofit is a ‘fit and forget’, once-only intervention.

Buildings need upkeep and they change over time in response to user needs. Energy retrofits need to be similarly maintainable and adaptable.

Myth 2: Low-energy retrofit happens independently of repair & maintenance cycles.

The service providers with the potential to deliver retrofit at scale are in construction, not energy .

Myth 3: Off-site methods can industrialise all retrofit activity.

The unpredictable nature of retrofit work means that it will always involve labour-intensive tasks and on-the-job problem-solving.

Myth 4: The only useful innovations are in technology.

The construction industry needs support to trial processes and practices which do not show up in conventional metrics of innovation (R&D spending; patents).

Myth 5: Regulation is bad for business.

Well-designed policy provides a level playing field for business activity. Businesses need policy support to prevent being undermined by poor-quality competitors.

Myth 6: Retrofit policy should promote specific measures.

Engineering and economic assessments of retrofit give insights into what needs to be done by when, but they are poor predictors of how the work is to be achieved and by whom.

Myth 7: Real-life retrofit decisions are based on cost-benefit analysis.

Buildings serve many more functions than providing energy services, so assessments of energy costs and savings are too narrow to drive investment decisions.

Introduction

Retrofit – the renovation of existing buildings in order to reduce their energy demand - is consistently identified as a priority for action, using the familiar argument that existing buildings account for a significant share of energy-related GHGs, while the potential for improvement using current technology is also very large (IPCC 2014, Skea et al. 2009).

Assessments of future potential based on engineering and economics are ubiquitous and widely respected in policy and strategic industry debates. And yet the cost-rational take-up of available technology to reduce energy use has not happened at anything like the scale expressed in those assessments. Many different arguments have been put forward as to why that might be the case, including the concepts of non-financial barriers (Eyre 1997), high applied discount rates (Sutherland 1991), and a general observation that consumers have other priorities (Wilson et al, 2013).

We argue here that the techno-economic paradigm of discourse around energy efficiency is too narrow, and that its over-use leads to a collective failure of imagination and curiosity about what retrofit actually means in the real world. The way in which the expert energy community has presented the issue to itself, to policy-makers and, to practitioners is at fault. In this we echo some of the arguments of Lowe and Oreszczyn (2010) that this community has spent so long arguing that improving building energy efficiency is cheap and easy, that they (we) have been convinced by their (our) own rhetoric. Despite all the evidence to the contrary, the same arguments continue to be made, as if the desired change will emerge through sheer repetition of why it makes sense.

We are essentially arguing here that answers are being sought in the wrong place: that, like the person searching for a lost key under a street-lamp, we are confusing our ability to see with an unjustified confidence that we are looking in the right place.

The arguments presented here have emerged through years of research and practice, as well as participation at numerous meetings, conferences and consultations. Our deliberately provocative assertion is that energy experts both inside and outside government have fallen into a trap of believing their own arguments. The point is made by selecting seven widely-respected myths, which we believe need to be debunked if we are to start focussing attention in more productive areas, enabling retrofit to have a chance of achieving its true potential.

Myth 1: Retrofit is a ‘fit and forget’, once-only intervention.

Evidence of the myth: Calculations of annual number of retrofits required are typically based on total building stock figures divided by the number of years left to 2050. While the figures are successful in conveying the scale and urgency of the issue, the simple arithmetic also betrays an assumption that each home will experience the process of retrofit just once in the run-up to the arbitrarily chosen end-date of mid-century.

Counter-arguments: Buildings change over time in response to user needs, and the very adaptability of buildings partly ensures their longevity (Brand 1996). Extensions, conversions and other physical changes to buildings – internal and external – are an established process in the steady evolution of the housing stock. The energy retrofit agenda needs to be compatible with changes that may take place for reasons other than energy, because if it is incompatible, the likely effect is a loss of energy performance each time those changes occur. Also, buildings start to fall apart without repair and maintenance. Buildings which have undergone an energy retrofit need to be maintainable and adaptable over time.

Myth 2: Retrofit policy should promote specific measures.

Evidence of the myth: Policy documents frame the problem of energy efficiency for housing in terms of individual technology options, e.g. solid wall insulation, heat pumps.

Counter-arguments: As the technical standards for energy retrofit get more ambitious, so the need for well-integrated solutions becomes more important. The interfaces between elements are often where problems occur, because physical joints are not well made, or because the installation practices of one person create problems for the next person trying to carry out another part of the work. Some combinations of technology may simply not work well – for example, a heat pump may struggle to heat a building with an inefficient fabric (Fawcett et al 2014). Similar problems can occur between design and installation, where oversights and misplaced assumptions on either side can lead to messy compromises being made. This lack of integration underlies much of the design-performance gap (ZCH 2014).

Policy on building energy performance needs to be expressed in relation to design standards and compliance regimes, not in terms of prescriptions for technology: it is the project team's job to design and install materials which meet the energy objectives, not the policy-maker's job.

Myth 3: Low-energy retrofit happens independently of repair & maintenance cycles.

Evidence of the myth: The lack of customer demand for energy retrofit is cited as a barrier; the legacy of policy approaches based on individual measures has led to energy efficiency being viewed as a specialist, stand-alone job.

Counter-arguments: Pioneers of retrofit have often seized an opportunity; that is, when contemplating major works to a building, they have integrated the energy-related works with the rest of the project (Fawcett and Killip 2014). The service providers with the potential to deliver retrofit at scale are in construction, not energy; the technical potential of projects on a room-by-room 'over time' basis is slightly lower than for whole-home approaches, but the market potential is much greater than for whole-house approaches (Fawcett 2014). The concept of 'trigger points' for retrofit captures the idea that the cost and disruption of energy-related works (especially fabric improvements) can be significantly reduced if it is carried out alongside other works for general repair, maintenance or improvement (EST n.d.). Conversely, where such opportunities are not taken (which is mostly the case in the current market), the next realistic opportunity may be many years into the future.

Myth 4: Off-site and modular methods of construction can industrialise all retrofit activity.

Evidence of the myth: The Farmer Review (Farmer 2016) argues that the labour model of UK construction needs wholesale reform with a focus on mechanisation and digital technology; because quality assurance is seen as easier to manage in a factory than on a construction site, debates on housing refurbishment include comparisons with manufactured consumer goods (cars, domestic appliances).

Counter-arguments: Refurbishment is different from new construction because of the constraints of working in a pre-existing building, not on a vacant plot of land. On-the-job problem-solving is an inherent part of the work because not all of the starting conditions can be known before work begins; it is commonplace for unexpected problems to be found after work begins, and for the detailed running of the refurbishment project to need to be adjusted accordingly. While it is tempting to assume that similar buildings are essentially identical (e.g. a row of houses in a terrace), there are always physical differences that matter to some extent.

That does not mean that solutions will necessarily require new and different products every time, but rather that the preparation work and detail of the installation is likely to be different in each building. Where off-site techniques can help improve the speed and quality of installation, they can be used to good effect. An example is the WHISCERS™ service, where laser measurement and off-site cutting of insulation panels helped increase accuracy of fit and reduced time spent on site. Even so, the final result still also relies on the practical skills and care of installers (NEF n.d.).

Myth 5: Innovation means new technology.

Evidence of the myth: Assessments of whether economies or sectors are 'innovative' typically rely on two metrics: dedicated R&D budgets; and patent applications. Other types of innovation are 'hidden' as a result (Harris & Halkett 2007).

Counter-arguments: The deep emissions reductions assumed in scenarios to 2050 are based on mature and near market-ready technologies. The fact that they are not deployed at scale is the real issue: there is no evidence to suggest that new technologies would be deployed any better. The problem of inertia in the system has been termed ‘carbon lock-in’, and overcoming it is a challenge of market breakthrough, not technology breakthrough (Unruh 2000). More promising innovations focus on organisation, management and new business models, precisely because they address technology in relation to a market, not in isolation. New technology should not be ignored, but it needs to be seen as one element of a complex system that co-evolves with other elements – notably policy, user practices and business strategies (Foxon 2011). Some of the most promising examples of new technology for retrofit have been where the technology is used in the service of new business models, e.g. in providing monitoring tools and feedback mechanisms on building performance (Killip et al 2014).

Myth 6: Regulation is bad for business.

Evidence of the myth: Regular media reports of lobbying against regulation by bodies representing UK business claiming that regulation adds a cost burden for business.

Counter-arguments: Well-designed policy provides a level playing field for business activity; the CBI campaigns for ‘stability, simplicity and certainty in tax policy and regulation’ (CBI n.d.). Small construction firms stated that where energy policy was concerned they would welcome consistent, long term regulation that set a floor rather than a ceiling as long as such regulation was enforced and supported by advice (Maby & Owen 2015). There is a long history of minimum energy performance standards being applied as part of a wider policy approach across the EU, covering domestic appliances and lighting. In many instances, standards which were initially resisted by industry stakeholders were met and exceeded relatively quickly. There are many components to good policy design, but one common theme is a regulated minimum standard, announced in advance to give industry time to adapt and innovate. Businesses need policy support to prevent being undermined by poor-quality competitors, ensuring there is not a ‘race to the bottom’ in terms of quality.

Myth 7: Retrofit decisions are based on cost-benefit analysis (CBA).

Evidence of the myth: CBA is enshrined in policy impact assessment methods internationally. Even when cost-rational decision-making is not observed, weight is given to economic reasons (such as high applied discount rates) in an attempt to restrict the debate to discussions about money.

Counter-arguments: Buildings serve many more functions than providing energy services, so assessments of energy costs and savings are too narrow to explain investment decisions. Energy spending is largely unquestioned by all but the poorest (estimated bills, strong social norms about modern life and consumption), so the economic benefit of reduced spending is not very salient. The benefits of retrofit which are salient and valued include: improved comfort, indoor air quality, daylight, better views out, noise reduction (e.g. from better-fitting windows), aesthetic appearance, improved security, greater user control of energy systems. Equally, where retrofit causes problems they are typically on related topics: overheating (lack of comfort), stuffiness (poor air quality), noise nuisance (e.g. from ventilation fans, heat pumps), lack of user control of energy systems. All of these issues matter to residents/users but they are not easily amenable to monetisation.

Reframing the problem of retrofit

The de-bunking of these myths helps to construct a new narrative for retrofit, which can then inform new debates and proposals for future policy. We have argued that retrofit has several inalienable qualities with important implications for future strategy:

- It is a repeating process not a one-off, so interventions need to be adaptable and maintainable

- It is not helpful to focus on specific energy efficiency measures, but rather on solutions with an emphasis on good quality design and installation of technologies to provide a well-integrated result
- The real opportunities for retrofit lie in the existing RMI market, not outside it
- Retrofit is not and never can be a wholly mechanised process carried out in a factory. Expertise in energy-literate problem solving must be developed in practitioners, while some off-site techniques can be helpful in supporting new business models
- New technology in itself does not overcome the problem of 'lock in', so a broader focus on innovation is needed, including new process and practices, not just new products
- Regulation has an important role to play in providing a level playing field, avoiding a 'race to the bottom', and providing the certainty needed for industry to invest in education and innovation
- The salient attractive features of good retrofit for consumers are not easily monetisable, and stimulating genuine market demand hinges on promotion of these benefits to consumers, not framing the argument in terms of costs and paybacks

There is a strong agenda for innovation here. Step change reductions in building energy demand will requires innovative solutions, particularly in the practices and processes of construction projects. Accelerating the creation and diffusion of such innovations requires a regulatory framework and systems for compliance-checking, which lead the construction sector to focus on outcomes and performance, not just volume of installations. The long-term goal should be to transform the construction industry so that it is fit to rise to the low-carbon challenge of the 21st century build and maintain low-carbon building stocks as the rule, rather than the exception.

Implications for policy, research and practice

For policy, there are two main insights, which are worth emphasising because they would mark a significant divergence from current policy discourse. Firstly, while there may be good reasons for cost-benefit analysis to be part of the policy process (for example in policy impact assessments), there needs to be a very different underlying logic when it comes to stimulating the market for retrofit. The salient benefits for householders are comfort, improved health, and a generally better quality indoor environment. Environmental concerns may also figure, but there is little resonance in the arguments around energy costs and payback on their own. The arguments made to justify policy need not be the same as those used to implement policy. Secondly, a regulated minimum standard is an essential part of the policy mix. The market breakthrough required for retrofit will involve stimulating demand and supply (capacity to deliver) in equal measure. There is a long history of successful policy interventions to improve environmental standards in product markets, and all of them include minimum energy performance standards. There is no reason to think that it will be any different for housing retrofit.

The models and scenarios used to estimate the technical and economic potential for retrofit all broadly agree that deep emissions reductions are possible. Research needs to move beyond statements of modelled potential and engage more fully with other aspects of the problem if it is to contribute new and valuable insights. Inter-disciplinary research across the social and physical sciences is needed if we are to understand better how to reduce and manage the environmental impacts of people living in buildings in which new, complex systems of energy provision are installed.

Our main insight for industry practice is the need for new business models built around outcomes (building energy performance) rather than inputs (materials, labour, pre-defined job roles). The function of 'integration' is essential for retrofit, but it is not assigned unambiguously to the job description of any trade or profession. It may not need to be assigned to the same job role on every project, but the responsibility for overall results does need to be taken on, individually or collectively, by project teams. How the industry could achieve this from its current position of widespread fragmentation and risk aversion is a huge part of the overall challenge.

Our critique of the seven myths shows that the dominant techno-economic discourse around energy efficiency is too narrow. We need new, broader perspectives on how to deliver retrofit at scale. Our experience leads us to conclude that it could be done through engagement with existing actors, notably the construction industry. The industry is ill-prepared currently to take on the work, but there are some pioneers showing a lead in the UK and elsewhere.

And if that seems too implausible, we would welcome the debate on how else it might be done. It is time to hunt for the keys outside the streetlamp's circle of light.

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Upgrading the UK Housing Stock

Insights into the Performance of Ready for Market Retrofit Solutions

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Abstract

While the UK government withdrew from the zero carbon building agenda, the need to provide a high quality, controllable and comfortable internal environment remains. Regardless of the shifting government sands, the thermal performance and energy efficiency of new buildings has improved, creating a gap between new and the 28 million existing properties in the UK. In Britain, many of the existing buildings are draughty and poorly insulated, making the buildings difficult to control and condition; positioning the UK housing stock amongst the most expensive to heat in Europe. Uninsulated thermal elements, bypassing of the insulation layer, and excessive thermal bridging, are present in many of these properties. The resultant cold temperatures and risk of condensation and mould have an impact on the health and wellbeing of the occupants, contributing to excessive winter death rates. To achieve thermal upgrade at scale, affordable and reliable 'off-the-shelf' solutions are required. This research provides the results from a deep retrofit project, where off-the-shelf measures were introduced in stages, under controlled conditions, on a hard to treat property. At each stage, significant reductions were achieved in the energy required to heat the property. The whole retrofit provided a more air-tight, thermally efficient fabric that brings many of the environmental benefits associated with new builds.

Keywords: building fabric, building performance, health and wellbeing, retrofit

Introduction

The Paris Agreement (UNFCCC, 2016) reaffirms the position that reducing carbon emissions remains a global priority. Notwithstanding the recent departure of the USA (Merica, 2017), the position from the United Nations is clear, emissions must be significantly reduced to limit global warming and anthropogenic climate change (IPCC, 2014). However, the possible departure from the European Union and recent policy changes make UK's commitments to a reduction in building emissions uncertain (Watson, 2017).

Regardless of the changes, there are significant problems with the UK's aging building stock. While the sustainability arguments continue, the issues associated with current housing are acute. Many of the properties tested are difficult to heat, with occupants experiencing draughty dwellings and problems of condensation (Fylan et al. 2016; Gorse et al. 2015). The fabric condition of the most existing houses are far from that regulated for new build. Some buildings are so cold and damp due to their fabric thermal performance that they represent a health risk to the occupant. In winter, a cold home impacts on a wide section of the community. Of the 40,000 excessive winter deaths in the UK, 9000 are associated with cold homes (ACE, 2015; NEA, 2016). Over a five-year period (up to 2015) 46,716 deaths were attributed to cold dwellings, with the annual death rate similar to that caused by alcohol, and almost as high as breast cancer (ACE, 2015). Yet, mortality is a weak indicator of the impact of cold homes on the occupant; the years of healthy life lost and illnesses related to living in cold damp environments have much wider impact on society; ill health caused as a result of the living conditions costs the NHS £1.36 billion per year (NICE, 2015).

The recent changes to legislation are also having an impact on UK markets, leading firms, - including Kingfisher, BAM and ARUP - have lobbied the UK Government to use its Clean Growth Plan to tackle emissions from buildings (refer to the letter to Greg Clark Secretary of State, WWF,2017). The Head of Energy and climate change at WWF, called for clarity to enable UK business to invest in appropriate technologies (Bairstow, 2017).

As one third of anthropogenic greenhouse gas emissions world-wide are attributable to the built environment (UNEP, 2012), it provides a significant opportunity to reduce emissions. For new build dwellings in the UK, the Building Regulations have been used as the main tool for reducing emissions. And, in a direct response to the UK climate conditions, emphasis is placed on a fabric first approach, reducing space heating energy needs. However, little is regulated with regard to fabric retrofits. The Green Deal failed to incentivise the fabric retrofit market. The economic benefits and piecemeal voucher approach did not capture sufficient interest. The Energy Company Obligation scheme delivering carbon savings through cost effective measures, is in a period of transition and from 2018 the Minimum Energy Performance Standard (Private Rented Sector) will only require landlords to ensure rented properties achieve E or above.

What is lacking is the potential to demonstrate what a fabric first approach can achieve in terms of comfort, wellbeing and energy related savings. The research undertaken here sought to measure the improvement in thermal performance that could realistically be achieved using standard ‘off-the-shelf’ products to retrofit a solid wall terrace considered typical of the UK’s “Hard to Treat” (BRE, 2008) housing stock.

Research method and experimental set up

The Energy House, a full scale test facility at the University of Salford consisting of a replica pre-1919 solid-wall Victorian end-terrace house constructed inside an environmental chamber, was used to test the retrofit measures. The Salford Energy House test facility was selected as it provides a controlled environment in which a steady-state can be achieved and maintained and replication of test conditions. Such an environment enables any change in thermal performance resulting from retrofit to be measured with a higher degree of confidence than in the external environment. The test house was built using reclaimed materials and methods of the time. Table 1 provides the construction details of the test house prior to retrofit (baseline test stage). Figure 1 shows an image of the Salford Energy House.

Table 1. Baseline test house construction details

Thermal element	Construction assembly and components
External walls	222.5 mm brick arranged in English bond with 9mm lime mortar and 10.5 mm British Gypsum Thistle hardwall plaster with a 2mm Thistle Multi-Finish final coat.
Roof	Purlin and rafter cold roof structure. 100 mm existing mineral wool insulation (λ 0.044 W/mK) between 100x50 mm ceiling joists running parallel to the gable wall at 400 mm centres above lath (6 mm) and plaster (17 mm) ceiling. 3 uninsulated timber loft hatches.
Floors	Suspended timber ground floor, with underfloor vented void. 22 mm floor boards fixed to 200 x 50 mm floor joists at 400 mm centres. Ground and intermediate floor joists run between the gable and party wall with joists ends built into masonry walls.
Windows	Double glazed in PVCu frames with trickle vents. Typical 1980’s replacement double glazing (single glazed timber sash windows)
Doors	UPVC, typical of a 1980’s replacement (uninsulated timber doors units with single glazing)
Party wall	Solid wall construction, unplastered on the Guard House side.

Figure 1. The Salford Energy House

The retrofit process involved thermally upgrading either one, or a combination, of its thermal elements. Table 2 presents the configuration of the test house at each stage of the experiment.

Table 2. Test construction at each test stage of the experiment

Test stage	Construction of element at each test stage (shading denotes intervention & upgrade)			
	External wall	Roof	Glazing	Floor
1 Full retrofit	Hybrid solid wall insulation system 90 mm EPS EWI to gable and rear walls 80 mm PIR IWI to front wall	270 mm mineral wool	A+++ glazing, argon fill, low e	200 mm mineral wool + membrane
2 Full retrofit with original floor				Uninsulated suspended timber (original construction)
3 Solid wall retrofit		100 mm mineral wool (original construction)	1980s style double glazing units (original construction)	
4 Glazing retrofit	Uninsulated solid wall - (original construction)		A+++ glazing, argon fill, low e	
5 Loft retrofit		270 mm mineral wool	1980s style double glazing units (original construction)	
6 (Baseline)		100 mm mineral wool (original construction)		

At each stage of the experiment the following measurements of thermal performance were obtained:

- Heat loss coefficient (HLC) – The HTC (also referred to as the heat transfer coefficient) is the *"heat flow rate divided by temperature difference between two environments"* (BSI, 2007). It represents the steady-state aggregate for the total fabric and background ventilation heat loss across the entire thermal envelope of a building in Watts, per kelvin of temperature difference between the internal and external environments, expressed in W/K. The HLC was measured using an electric coheating test (Johnston *et al*., 2013).
- *In situ* U-values - The thermal transmittance of a building element (U-value) is the "Heat flow rate in the steady state divided by area and by the temperature difference between the surroundings on both sides of a flat uniform system" (BSI 2017; ISO 7345:1987), expressed in W/m^{2}K. *In situ*, U-value measurements were undertaken in accordance with ISO 9869:1994 (BSI, 2014).
- Air permeability - Blower door tests in accordance with Technical Standard L1 (ATTMA, 2010) were performed to measure the air permeability (q_{50}) of the test house, expressed in m^3/(h.m^2) @ 50 Pa.

The thermal performance attributable to a retrofit thermal upgrade was calculated as the measured change from the baseline value. Figure 2 shows an image of the experiment set-up in the test house.

Figure 2. Typical experimental set up in the test house (red disks show in situ U-value measurement locations)

A mean internal air temperature of 20 °C was maintained during each test stage, which represents the average central heating thermostat set-point for homes in England was set (Shipworth *et al.*, 2010). The chamber (external) air temperature was held at 5 °C. This setting was considered optimum for the chamber HVAC system while close to the mean external air temperature (6.6 °C) for North West England during the October to May heating season (Standard Assessment Procedure, BRE, 2012).

Results

The full retrofit resulted in reduction of 63% heat loss through the fabric (Figure 3). Solid wall insulation was the thermal upgrade measure which resulted in the largest reduction (46%) from the baseline (Figure 4) representing 72% of the total heat loss reduction in the retrofitted house.

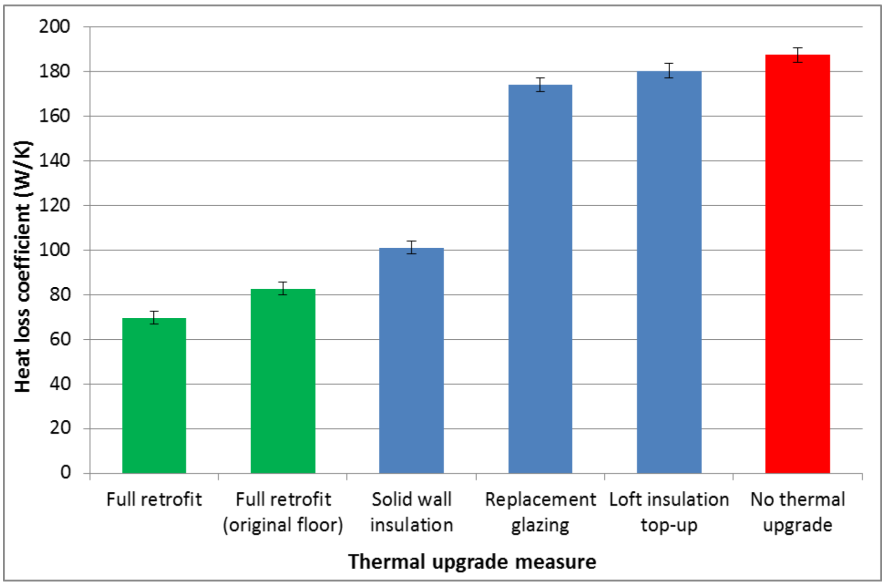

Figure 3. Measured HLC of the test house at each test stage (blue bars represent the test house heat loss following a single thermal upgrade measure, green bars represent thermal upgrade measures in combination)

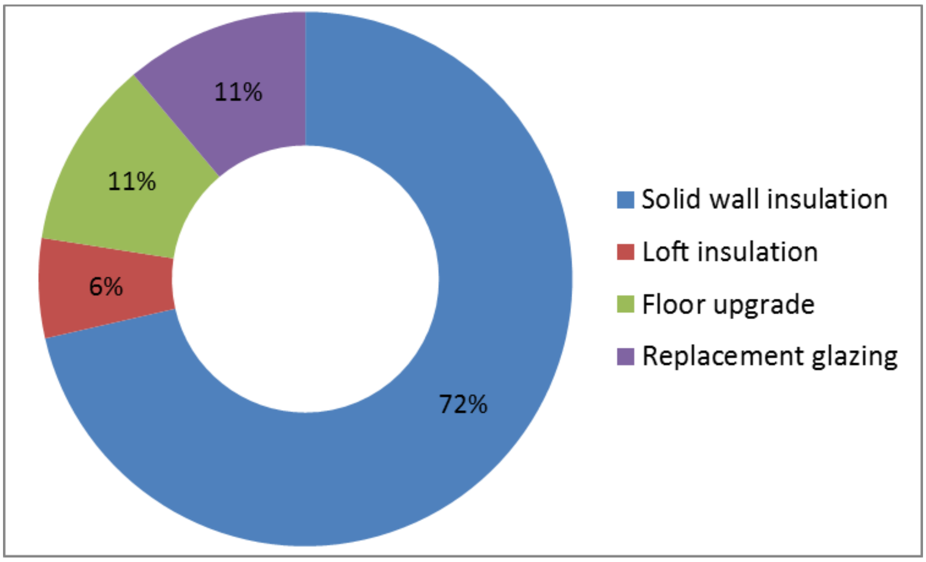

Figure 4. Contribution of each thermal upgrade to the reduction in whole house heat loss of the fully retrofitted test house

Based on the assumptions provided in Table 3, a notional dwelling of similar heat loss characteristics, subject to a similar thermal upgrade programme, could reduce annual space heating costs from £554 (no thermal upgrade) to £206 (full retrofit) with annual CO_2e emissions associated with space heating reducing from 2.31 tonnes (no thermal upgrade) to 0.86 tonnes (full retrofit).

Table 3. Impact of thermal upgrades on a similar house in the external environment located in Manchester, UK (annual space heating demand and cost, and CO_2 equivalent emission reductions)[1]

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[1] All values calculated for reduction in annual heat demand are based on the 5 years prior to the experiment (2008 – 2012) mean annual heating degree day value of 2297 measured at Manchester Airport (base temperature 15.5oC). Assumes average UK condensing gas boiler efficiency of 82.5% (EST, 2009). Cost based upon average gas price for Manchester during 2012 of 4.42p per kWh (data sourced from DECC, 2013). Based upon June 2013 value for natural gas of 0.18404 kgCO2e per kWh (data sourced from the Carbon Trust, 2013).

Thermal upgrade measure	HLC (W/K)	Reduction on baseline (W/K)	Annual space heating energy reduction (kWh)	Annual space heating cost reduction (£)	Annual space heating CO_2e reduction (kg)
Full retrofit	69.7	117.8	6497	348	1449
Full retrofit (original floor)	82.7	104.8	5777	310	1289
Solid wall insulation	101.2	86.4	4761	255	1062
Replacement glazing	174.2	13.4	737	39	164
Loft insulation	180.5	7.1	390	21	87
No thermal upgrade	187.5	n/a	n/a	n/a	n/a
Floor upgrade	n/a	13.1	720	39	161

Results from the *in situ* U-value and air permeability measurements provide greater insight as to how the reductions in HLC were achieved.

Figure 5 illustrates the reductions in heat loss from each thermal element following retrofit. The greatest reductions were measured from the hybrid solid wall insulation system which involved the application of internal wall insulation (IWI) to the front external wall and external wall insulation (EWI) to the rear and gable external walls. The relatively modest reduction in heat loss from the roof can be explained by the pre-existing insulation contained within the loft of the baseline house reducing its potential for improvement.

The only retrofit measure where there was a significant difference between the calculated improvement in thermal performance and that measured was the EWI. However, the underperformance was the result of the temporary nature of the installation meaning an adhesive coat could not be applied to the EWI, this allowed air movement between the EWI and outer leaf of the gable wall, and bypassing of the insulation layer.

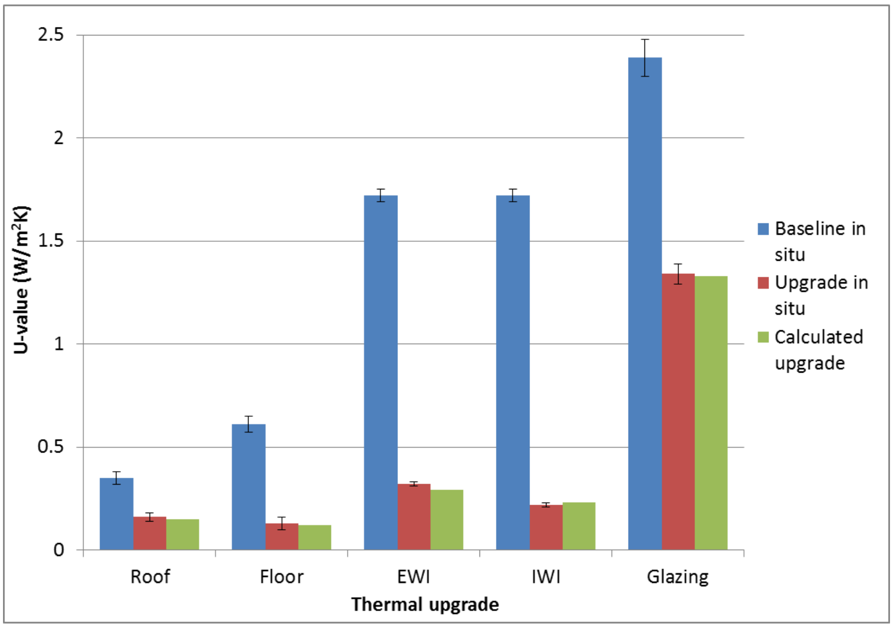

Figure 5. Summary of the in situ baseline and upgrade U-value measurements. Upgrade U-value measurements are compared to those predicted by U-value calculations

Table 4 shows that all the retrofitted thermal elements performed within the in-use factor applied by UK Government funded retrofit schemes to account for underperformance.

Table 4. Measured in situ U-value performance vs. in-use factors

Thermal upgrade	**Calculated upgrade U-value (W/m^{2}K)**	**Measured upgrade *in situ* U-value (W/m^{2}K)**	**Discrepancy from calculated upgrade U-value (%)**	**In-use factor (DECC 2012) (%)**
Roof	0.15	0.16 (± 0.02)	+ 7	35
Floor	0.12	0.13 (± 0.03)	+ 7	15
EWI	0.29	0.32 (± 0.01)	+10	33
IWI	0.23	0.22 (± 0.01)	- 4	33
Glazing	1.33	1.34 (± 0.05)	+ 1	15

The full retrofit of the test house resulted in a 50% reduction in air permeability from its original condition. From Figure 6 it can be seen that the upgrade measures to the floor provided the greatest increase in airtightness, a reduction of 42% from the baseline value. The increase performance can be primarily attributed to the airtightness membrane.

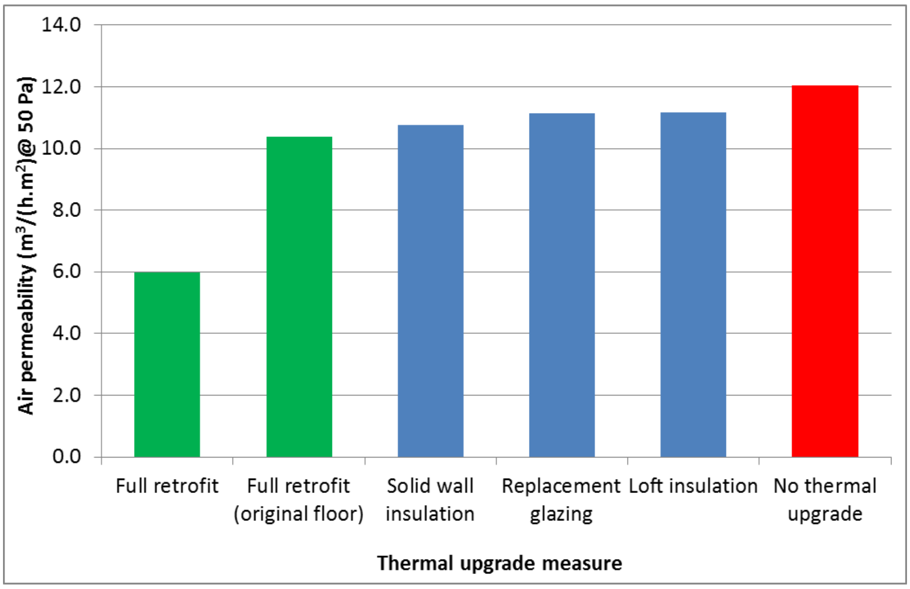

Figure 6. Air permeability value of the test house in each condition (Blue bars represent the test house following a single thermal upgrade measure, green bars represent thermal upgrade measures in combination

Conclusion

The research presented in this paper has demonstrated that dwellings of this type, which represent a significant proportion of the UK's hard to treat housing stock, have the potential to be retrofitted using off-the-shelf thermal upgrade measures to a standard which can significantly reduce their requirement for space heating and currently associated CO_2 emissions.

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What is holding back energy efficiency financing in G20 countries?

Ada Ámon, Ingrid Holmes, Pedro Guertler

E3G – Third Generation Environmentalism

Abstract

In 2015, E3G launched an initiative linked to the G20 that had two aims. The first aim was to reach out to energy efficiency campaigners and experts in each of the G20 countries, plus Central and Eastern parts of the European Union. This was in order to understand the current state of play on energy efficiency and the political barriers to increasing levels of energy efficiency investment. The second aim was to seek support for a statement calling on G20 countries to make energy efficiency an infrastructure priority, as a means of 'getting to scale' on financing. This presentation shares the initiative's findings.

Introduction

In 2015, E3G launched an initiative linked to the G20 that had two aims. First, to reach out to energy efficiency campaigners and experts in each of the G20 countries plus Central and Eastern parts of the European Union in order to understand the current state of play on energy efficiency and the political barriers to increasing levels of energy efficiency investment. Second, to seek support for a statement calling on G20 countries to make energy efficiency an infrastructure priority as a means of 'getting to scale' on financing.

Energy efficiency has been a long-term area of work for E3G. Through this project we wanted to expand our traditional focus on Europe to look more widely at global energy efficiency financing challenges. By consulting with experts in G20 countries we aimed to better understand how energy efficiency is seen by both energy policy and wider political decision makers. We focused on the potential size of the market, the targets and ambitions of each country in this area. We also looked to better understand the opportunities to make a stronger political case for energy efficiency to be treated on an equal basis as other forms of energy infrastructure. Finally, we focused on the political barriers and gaps we would need to address to move forward with scaled ambition on financing and policy asks.

We were able to talk to experts from 15 of the G20 countries. We gained a great deal of valuable information directly from experts - and from wider research in cases where we were not able to make direct contact. We found that overall there has been a significant increase in both funding and policy support to energy efficiency in G20 countries over the last decade. This has been driven mainly by energy security concerns. The emphasis now placed on energy efficiency is seen by the experts E3G consulted as unprecedented in scale particularly when compared to where it was in, for example, the 1990s. However, this is mainly because in the 1990s support was almost completely absent in many countries. For example, in the two countries likely to dominate the future shape of the world's energy demand - China and India – energy efficiency targets have increased and so too has the amount of publicly sourced funding to support investment in this sector. The multiple benefits of energy efficiency are acknowledged in many places. For example in the UK there is an acknowledged benefit from energy efficiency to improving fuel poverty. In China it is expected that energy efficiency will play a key role in controlling both future demand and urban air quality – and so it has been featured in two of the last Five Year Plans. Despite this progress, according to all experts consulted, the levels of energy efficiency financing – and in particular public financing – are still far below the critical mass of capital needed to unlock the full potential of energy efficiency in G20 economies.

This paper summarises and discusses the findings from our survey in three broad categories and presents some high-level conclusions and recommendations.

Data gaps abound

Energy efficiency is cheap but not free - are we framing the arguments the wrong way?

One of the key political barriers to scaling up energy efficiency is a misunderstanding of what it takes to drive forward energy efficiency financing. Because some studies show that energy efficiency makes economic sense and will pay back in a relatively short period of time, many politicians believe that investments will happen regardless of governmental intervention or major financial support. Thus government spending programmes to support investment remain relatively small compared to other public infrastructure investment priorities. Where decision-makers have begun to consider what needs to be done to drive investment, they have concluded it will be too hard to deliver on a large scale and won’t save enough money to justify the effort. This is the case even in countries where money is available and decent progress has been made (for example Germany).

Core data to empower energy efficiency financing campaigns are often missing

There are significant research gaps that make it difficult for campaigners to drive a credible discussion on what more needs to be done to close the energy efficiency financing gap. In two thirds of the countries E3G included in this study, there were no public data available on the comprehensive energy saving potential. This includes India, Japan, Turkey, South Africa, Mexico, Argentina, Australia and France. E3G has seen modelling for China but it is unclear whether this is publicly available in China. Consequently, for these countries we do not know how much public and private finance is needed to close the energy efficiency financing gap. In at least a quarter of the G20 countries consulted there were no data on what barriers need to be addressed and what reforms are needed to unlock investment. This included developed countries such as France and Japan - but also China, Turkey, Mexico, Argentina and South Africa. Some countries - Germany, UK, USA, Italy and EU – had undertaken analyses on the macroeconomic case for energy efficiency, but elsewhere this economy-level analysis has not been done.

Political support from economic decision makers is weak

Public funds for infrastructure investment is not lacking – rather, energy efficiency quite simply does not feature among national level capital expenditure choices

While there is a strong focus on driving growth through energy and wider infrastructure investment in G20 countries, energy efficiency is not touched upon. In different countries there are different focuses to public infrastructure financing discussions:

- In emerging G20 economies the focus of the discussion on public spending is on access to energy, renewable energy integration, connecting regions, converging GDP/capita, and overall modernization of the country.
- Within debates on infrastructure financing, governments are mainly focused on the classical network infrastructure investment, such as roads, networks, and power plants.
- In developed countries there is a focus on innovation, growth, maintaining levels of public infrastructure services, and smart systems.
- Both in emerging and developed economies energy security is the main driver behind the discourse on energy infrastructure development. Solutions centre on the need to diversify energy imports and build more renewable energy rather than ramp up energy efficiency investment.

In addition, in many G20 countries there is little constructive debate on infrastructure choices – choices tend to be imposed on populations rather than being the subject of public debate. This can result in both national populations and local communities taking a ‘not in my back yard’ position on projects they do not like (e.g. new nuclear or coal plants or gas pipelines) and creates political barriers to deploying that infrastructure. This could be a useful opportunity to promote better debate.

Lack of clear public value offer combined with ‘austerity politics’ means that as operational spending budgets shrink, energy efficiency financing programmes become vulnerable

Across the G20, energy efficiency financing programmes are fragmented and therefore lack impact. The budgets (which are relatively small compared to those available to support supply side investment) are often mismanaged by public authorities. This is most obvious in countries such as Turkey, Russia and many central and eastern EU member states. Energy efficiency financing programmes are usually targeted not to the sectors of the economy where the highest value energy savings can be achieved but to those sectors believed to be most rewarding politically in the short-term. For example programmes are targeted to support lightbulb or refrigerator replacement or targeted to highly vocal members of the population such as affluent and retired people. With the rise of austerity measures in some countries, energy efficiency programmes are especially vulnerable to cut backs. For example in 2015 in the UK the underperforming Green Deal Programme has been abandoned while a new nuclear plant is being planned at vast cost. In Russia, also in 2015, the energy efficiency support budget was cut back entirely as a “natural” part of austerity policies, while wider capital spending on infrastructure has been retained. In Russia, this single action has wiped out approximately $1.5bn in investment.

Fragmentation of governmental departmental responsibility means efficiency lacks champions

Across G20 countries a range of government departments are involved in energy efficiency policy decisions. The number of ministries and institutions involved in energy efficiency policy design and implementation is higher than in other policy areas. Coordination and harmonization within the government and with other policies is very time consuming and complicated – adding another layer of challenge to scaling up energy efficiency ambition.

This means that the benefits of energy efficiency are widely recognized but no one invests in driving the agenda. All the G20 country experts interviewed agreed that of the key decision makers involved, regardless of department, none would deny the importance of energy efficiency. But all the experts also said there is a significant gap between verbal support and practical support for the sector – in terms of securing sufficient finance, enforcing the law and driving forward the reforms needed to create markets. For example, in countries such as France, Italy, Turkey and Germany binding regulations to improve energy efficiency levels – which are a key market maker for energy efficiency – are actually seen by the same decisionmakers as working against market forces.

Energy efficiency is not politically contextualised

Framework-based policy innovation is needed to make energy efficiency visible

New framework-based legislation to deliver low carbon energy transitions has been passed recently in several G20 countries, including Germany, France and Mexico. The legislation sets a new direction for energy policy making by including energy efficiency as a key source of energy. The EU is also discussing this kind of framework for its 2030 energy targets.

Putting energy efficiency on an ‘equal footing’ with other conventional energy sources in legislation is a step forward – however it has yet to be translated into equal support in terms of access to finance. Other countries continue to look at energy efficiency policy in isolation from wider energy policy, and in doing so miss opportunities to look at the wider context of how energy efficiency policy can reduce the need for supply side investment. That said, some countries including India and Turkey have developed detailed action plans and sectoral targets for energy efficiency and have ambitions to improve efficiency levels in the target sectors. China has also developed detailed action plans and sectorial targets for energy efficiency and some sectors – for example steel-making – are highly efficient. China is different to India and Turkey however, in that in its Five Year Plan reflects an integrated view of how energy efficiency can deliver on China's overall energy needs.

A framework approach can also help address political barriers in the form of incumbents

In many G20 countries the (incumbent) energy utilities, which are often publicly owned, have a significant influence on governmental energy policy decisions, thus blocking wider energy efficiency programs, which can limit future demand. This is the case in Japan, France, South Africa, central and eastern European EU Member States and Latin America.

Household energy subsidies – solutions need to be found

Subsidized energy consumption is widespread and a major disincentive to energy efficiency investment. Household energy price subsidies are a particular issue: for example in Mexico, 90% of households are subsidized. It is a particular issue among emerging G20 economies – including all of the Latin American countries, South Africa, many central and eastern European countries, Russia, Turkey, India and China.

Conclusions and recommendations

Education and capacity building is needed to educate policy makers on what needs to be done. Credible analyses of the economic case are needed – along with credible delivery strategies to support decision-makers in moving this complex agenda forward. This is an area where NGOS and think tanks can make a big difference.

In many G20 countries, key data to enable credible economic arguments to support increased energy efficiency financing are missing. A further capacity gap analysis is needed to set out what research would be useful to empower campaigners to target messages, set out core asks for scaling up energy efficiency investment and engage in core economic debates on infrastructure and public finance choices.

While energy efficiency fits with the infrastructure investment themes being discussed both in developed and emerging G20 economies, it is not included in those discussions. There is a need to enable campaigning groups and think tanks to engage with the broader debate of security and infrastructure choices. This would need significant resources and preparation – for example enabling local groups to undertake like-for-like analysis of the costs and benefits of energy efficiency investment programmes compared to other energy infrastructure investment choices to build the energy security and/or economic case. It would need to be combined with a campaigning narrative on how energy efficiency can deliver high value public infrastructure investment but also deliver on energy security/fuel poverty/air quality/health benefits etc – according social concerns and debates that are nationally relevant.

Stronger NGO scrutiny of public budget management will be needed to give a strong voice to campaigners. Positive propositions will also be important. NGO capacity needs to be strengthened to (i) build more positive narratives for how public funds can be better targeted to drive energy efficiency and generate economic growth and convergence across regions, deliver security, resilience etc; (ii) build the evidence base for how ambitious energy efficiency schemes can be developed, delivered and financed with public and private funds.

Cross-government stakeholder engagement will be important and calls for a coordinated approach by campaigning groups in each country to bring together different parts of government and reconcile the different elements of the debate – which are likely to encompass impacts on energy, health, housing, and economic policy. This will require strong external leadership from campaigning NGOs. It again argues for research and advocacy capacity to be deployed to support NGOs to build better understanding of how improved energy efficiency in different sectors of the economy can create wealth through turning wasteful energy use into job creation and increased economic output/productivity, security etc. Analytical research can help build the legitimacy for campaigners to lead externally. It can also be reinforced through strong and effective country-level low carbon business voices to build a counter narrative on the positive role energy efficiency can play in the economy by harnessing market forces to do more with less.

The shift in some countries towards a framework approach to making decisions about energy policy that includes energy efficiency as an energy source needs to be encouraged. It can help push energy efficiency up the political agenda by facilitating a side-by-side comparison of the costs of delivering on energy goals through supply side versus integrated supply and demand side investment. Energy efficiency campaigners need to have capacity to engage in the wider energy debate – and work to bring the two together in crafting policy solutions. This in turn will help empower campaigners to hold governments to account on how they allocate funding – including promoting more transparent financial decision making - to support energy infrastructure.

In this context, incumbents can act as a powerful block on more ambition – which is another key issue that will need to be addressed when developing effective campaigning strategies. Litigation could be a good forward strategy to support this area of work.

Political strategies need to be developed to address the issue of energy subsidies. This would be a high value area to pursue – and will need to focus both on practical solutions (e.g. using a framework approach to phasing out subsidies while phasing in increased energy efficiency measures in homes so that bills remain around the same level) and on a political narrative to support this transition.

Author and Presenter Biographies

Ms. Helene Gosden [1]

1. University of Cambridge / Ove Arup & Partners

Adaptive re-use in London: The influence of technical constraints on project feasibility

Lead Author & Presenter Biography

Helene is a chartered civil engineer, who seeks to create elegant, sustainable engineering solutions to functional problems. She has experience in the education, healthcare and aviation sectors and more recently in residential and prime London commercial development. She has a strong interest in refurbishment projects; in overcoming technical challenges to unlock the potential and value in existing assets and to extend their useful life. Helene recently completed a part-time masters, sponsored by her employer Arup, at the University of Cambridge. Her masters thesis research explored two of her passions, multi-disciplinary collaboration in design and adaptive re-use of existing buildings.

Dr. Yamina Saheb [1]

1. Openexp

Energy renovation: it is time for a paradigm shift in policy design

Lead Author & Presenter Biography

Yamina Saheb is a Senior Energy Policy Analyst at Openexp. Prior to this position, Yamina was Policy and Scientific Officer at the Renewables and Energy Efficiency Unit at the Institute of Energy and Transport of the Joint Research Centre (JRC) of the European Commission (EC). Before joining the JRC, she worked as senior buildings energy efficiency policy analyst at the IEA. Yamina holds a Ph.D in Energy Engineering, Master's degrees on Landscape Architecture and Development Economics and an Engineering degree in Building technologies.

Dr. Marina Topouzi [1]

1. University of Oxford

Governance of Low-carbon Innovation in Domestic Energy Retrofits in the UK

Lead Author & Presenter Biography

Marina Topouzi has been an interdisciplinary researcher with the Lower Carbon Futures group at the ECI since 2009. She has strong background in building energy use and demand, and her main research interests concern the 'building/user' system, focussing on the factors that affect buildings' energy performance. She holds an undergraduate degree in architecture from Aristotle University of Thessaloniki School of Architecture and Universita degli Studi di Firenze; an MSc in Energy Efficient and Sustainable Buildings from Oxford Brookes University; and a DPhil from Oxford University ('Occupants' interaction with the UK's low-carbon retrofitted homes and its impact on energy use'). She has worked in research projects at Oxford Brookes University and at Oxford University. Prior to starting academic research on energy efficiency and buildings, she worked since 2000 as a professional architect in a wide range of projects for the public and the private sector.

Mr. John Pratley [1]

1. Gardner Stewart Architects

Housing Estate Regeneration using Passivhaus EnerPHit Retrofit of Wilmcote House, Portsmouth

Lead Author & Presenter Biography

John Pratley BA(Hons) DipArch CEPHD FRSA, is an associate at Gardner Stewart Architects, an award-winning architecture, master planning and urban design practice based in London. It has successfully delivered many benchmark projects across more than three decades, in all sectors including residential, mixed use, commercial, education, conservation, regeneration and leisure. John has nearly 25 years of experience working on public and private housing sector projects, including challenging and complex regeneration and refurbishment projects, urban extensions and smaller scale infill site housing schemes. He has been involved in many of the practice's major projects, providing early conceptual thinking and contributing to internal design reviews. His versatility and expertise in delivering projects from concept through to site, his ability to motivate successful teams and his practical approach to project delivery perfectly complements the management group. John has a particular interest in social, community responsibilities and energy-efficient, ecological design. He is a Certified European Passivhaus Designer.

Prof. Rajat Gupta [1]

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Increasing local consumption of solar electricity through smart storage

Lead Author & Presenter Biography

Professor Rajat Gupta is Director of the multi-disciplinary Oxford Institute for Sustainable Development (OISD) and Low Carbon Building Research Group at Oxford Brookes University, where he also holds professorial chair in sustainable architecture and climate change. He developed the RIBA award-winning DECoRuM model for carbon mapping communities. Rajat's research interests lie in scaling up energy retrofits and monitoring, and evaluating impacts of community-led retrofits. As Principal Investigator, he has won over £8 million in research grants from ESRC, EPSRC, EU, Innovate UK, World Bank, UNEP, RICS and British Council. Recently Rajat was PI on a ESRC/EPSRC funded £1.14 million EVALOC project on evaluating the impacts of low carbon communities on localised energy behaviours. Rajat has also been lead academic on several Innovate UK funded projects under the Retrofit for the Future and Invest in Innovative Refurbishment competitions, as well as a LEAF project on carbon mapping communities.

Prof. Ellen van Bueren [1]

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Serious games as an instrument to support energy retrofitting

Lead Author & Presenter Biography

Ellen van Bueren is professor of urban development management at the Faculty of Architecture and the Built Environment at Delft University of Technology, and Principal Investigator at the Amsterdam Institute for Advanced Metropolitan Solutions (AMS). In her research and teaching she focuses on the governance challenges of today's urban areas, many of which require a transition towards sustainable urban systems.

Dr. Gavin Killip [1]

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Seven myths of building retrofit

Lead Author & Presenter Biography

Gavin had ten years' experience of energy efficiency and renewable energy projects in the voluntary and public sectors before turning to research in 2004. His current research interests are on possible delivery mechanisms for a low-carbon housing stock, and the 'multiple benefits' approach to energy efficiency. Gavin takes an inter-disciplinary and 'whole systems' approach to research, combining insights from engineering, design, economics, history of technology, sociology and innovation studies. His work on retrofit is characterised by ongoing engagement with institutions, construction firms and supply chains. Gavin has refurbished his own 1908 house in Oxford to achieve a 65% reduction in CO2 emissions, as well as reducing other environmental impacts.

Prof. Christopher Gorse[1]

1. Leeds Beckett University

Upgrading the UK housing stock: Insights into the performance of 'ready for market' retrofit solutions

Lead Author & Presenter Biography

Christopher Gorse is the Director of the Leeds Sustainability Institute and a Professor of Construction and Project Management at Leeds Beckett University. He is a Chartered Builder, Engineering Professors Council Member, with over 20 years industrial and academic experience in buildings, materials, management and construction law. He has written extensively on the construction of buildings and the processes required to deliver them successfully and measure their performance. Chris is keen to push the boundaries of research. As Vice Chair of the Association for Researchers in Construction Management and Sub Task Lead on three International Energy Agency projects he not only assembles expert research groups, but is active in developing a better understanding of how buildings behave, can be made more efficient, controllable and how they play their role in the energy flexibility that is required to deliver a cleaner network of energy.

Mr. Pedro Guertler [1]

1. E3G

What is holding back energy efficiency financing in G20 countries?

Lead Author & Presenter Biography

Pedro Guertler is a Senior Policy Advisor in E3G's London office. His work focuses on advancing the case for a coordinated and ambitious approach to low carbon heat and energy efficiency investment – particularly as an infrastructure priority in the UK, and more broadly as integral to delivering many of the benefits of the low carbon transition cheaply, quickly, evenly and tangibly.

Prior to joining E3G, Pedro was Research Director at the Association for the Conservation of Energy, leading a team of experts in the development, delivery and dissemination of energy policy design and evaluation research projects.

Pedro is a UK ambassador for the European Council for an Energy Efficient Economy, was a Trustee of the Eaga Charitable Trust and a member of the London Borough of Islington's Climate Change Fund advisory panel.

Dr. David Tetlow [1]

1. University of Nottingham

Innovative retrofit strategy application in Nottingham social housing using historic planning documents and mapping

Presenter Biography

David Tetlow is a research fellow based in the Architecture, Energy and Environment (AEE) Research Group in the Department of Architecture and the Built Environment. He has been involved in research projects for seven years involving low carbon technology application in the built environment in both UK and European based projects. He specializes in domestic retrofit in the UK, and works with both public and private organisations in the development of innovative technologies and methodologies. His main interest is in research into resolving the problem of slow uptake of retrofit measures in the UK housing stock, and all related subjects pertaining to this.

Dr. Ronald Rovers [1]

1. International Advisor on Sustainability

Retrofit Europe: concepts and experiences

Presenter Biography

Ronald's main focus is developing closed cycle approaches for the built environment. He is currently involved in developing concepts for large scale renovation of houses towards 0-energy performance, as well as working on projects focussed on climate neutral buildings and city development. Ronald's research concentrates on Zero Impact Built Environment (ZIBE), with a special focus on the material impacts of construction and renovation, as well as on processed bamboo as a construction material. He has launched a 'closing cycles' calculation tool, under the MAXergy methodology (maximising energy and mass exergy, with 'Embodied Land' as denominator) and is the developer of Urban Harvest + model which evaluates 0 impact urban areas.

Since 1998, Ronald has also been involved in organising and chairing a number of conferences dedicated to a low energy refurbishment for a sustainable future. Some of his most notable past conference include:

- SBE16 Conference Transition Zero
- SB2000 Maastricht 1st World Conference Sustainable Building
- EU Housing Ministers Conference
- PLEA 2004 Eindhoven

Ronald is also a founding board member of iiSBE, the international initiative for a Sustainable Built Environment.

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