Challenges building service engineers can help overcome to assist the large-scale delivery of whole house energy retrofitting to achieve Net Zero

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Abstract
To achieve UK Net Zero targets by 2050 whole house energy system retrofits need to delivered across the 29.8 million existing homes in the UK. Significant financial input is required as well as close collaboration and communication between all stakeholders to enable a high-quality transformation. The Low Carbon Built Environment Team at the Welsh School of Architecture at Cardiff University have delivered more than 40 whole house energy systems over the past 15 years collaborating closely throughout the decision-making process with a broad range of stakeholders including residents, social landlords, local authorities, designers, manufacturers and installers. This paper presents key lessons learnt associated with different challenges faced when undertaking whole house energy system retrofitting relevant to building service engineers to achieve the urgent targets set.

Keywords
Retrofit, housing, challenges, energy systems, Net-Zero.

1.0 Introduction
There are 29.8 million homes across the UK (1, 2, 3, 4). To achieve the Net Zero targets set by UK Government by 2050 (5), these homes must be transformed – to be more energy efficient and energy self-sufficient. The benefits of making this transformation to our existing housing stock goes way beyond carbon emission reductions, with the potential to create 500,000 jobs and deliver economic growth across the UK (6, 7) as well as reducing fuel poverty and the health impacts of poor-quality homes as well as the associated costs of poor health (8).

Delivering the scale of change needed is possible – in 1970 only 30% of the UK housing stock in the UK had a central heating system (approximately 5.5 million homes), by 1980 this had increased to 59% (approximately 12.6 million) homes – 7 million installations in 10 years (9). By 1990 a further 6 million households were benefitting homes central heating systems (79% of total housing stock) (9).

The Centre for a Low Carbon Built Environment (LCBE) have applied a 'whole building energy systems' approach to more than 40 typical Welsh new and existing homes in Wales, UK (10,11,12,13, 14). Collaboration with all necessary stakeholders has taken place to deliver appropriate, affordable and replicable energy demand reduction, renewable energy supply and energy storage solutions in the real world (Figure 1). This has been made possible through funding bodies including as Higher Education Funding Council for Wales (HEFCW), the Welsh European Funding Office (WEFO), Innovate UK, the Welsh Government and the Engineering and Physical Sciences Research Council (EPSRC).

Figure 1 – Delivering a whole house energy system retrofit – before and after

Discussions between LCBE team members together with semi-structured interviews with 11 key stakeholders involved in the retrofits have identified key lessons learnt. Those that are specifically relevant to Building Service Engineers are presented below. They are grouped into 8 different themes, describing the challenges faced and providing examples where relevant.

1 Data and Information

1.1 All homes are different

Some solutions work well in some homes and not in others, this needs to be recognised at the planning stage. Basic data about the home including building location, surroundings and microclimate, building construction, ventilation, heating, appliances and lighting, energy bills, potential for retrofit, occupants and layout need to be known (15). This information can be collected quickly and will ensure that other stages are easier to deliver. For example, battery storage may not be the optimal solution if orientation limits the generation potential of the PV to generate enough energy for storage. This is also the case if residents are at home all day and are using larger amounts of energy. Having this information available early on helps to inform the decision-making process and prevents investment in solutions that do not provide value for money.

1.2 Value of monitoring data - providing evidence

Monitoring for a whole year before the installation of solutions in retrofits or a sample of similar retrofits and for at least 2 years beyond completion provides valuable information on how individual technologies and the system as a whole performs as well as the conditions the occupants are experiencing. This evidence helps to identify performance gaps and support action on inefficiencies in the performance of solutions.

1.3 Occupants need to understand how to make the most of their systems

Clear guidance and instruction need to be provided to residents on numerous occasions in a range of formats including paper, digital and verbally to ensure solutions are used effectively. This needs to be communicated by someone the residents trust and who understand what they are talking about. Information should be provided on the solutions within their home, how to 'use' them and how to keep track of what energy they are using and where it is being used. The resident should be provided with contact details for who to contact if issues arise and formal documentation from the supply chain on the equipment installed.

2 Technical

2.1 South facing roof is not essential to benefit from PV panels

Integrating solar PV panels on east and west facing roofs generates slightly less energy (5-10% in South Wales, UK) than the same size south facing roof. However, with east and west facing PVs, maximum generation potential occurs when energy is often required most - early morning and early evening. This helps to increase self-sufficiency as occupants can use energy as it is available. Many homes in the South Wales valleys are located on either side of south to north running valleys. East and west facing PV is the only option and has been shown to perform well.

2.2 Ventilation helps to provide a healthy home

By improving building fabric to a point where air leakage is minimised (<5m3/hr/m2 @50Pa) energy demand is reduced as the home is more airtight. Additional ventilation is necessary to control whilst enable the introduction of fresh air. Positive Input Ventilation (PIV) and MVHR have worked well, improving air quality and reducing condensation, damp and mould by reducing humidity. In more than one home residents reported improvements in respiratory health and asthma.

2.3 Flexible whole house energy systems

A whole house energy system needs to be flexible to enable components to be replaced as new solutions come onto the market or end of life is reached. As an example, early-to-market batteries were not particularly efficient and were large in size. As the market has developed batteries have been replaced with, smarter, efficient alternatives. As the sector continues to develop, replacement may be necessary which can increase the efficiency of system but will incur cost. Time spent identifying the of most appropriate components of a system needs to be spent to minimise costs.

2.4 Limitations of existing homes and the need to compromise

It can be just too difficult to install some solutions in some homes due to space limitations, layout, fabric or just too much disruption. For example, joist layout can prevent the installation of complex ducting for an MVHR system in some properties. Positive Input Ventilation (PIV) can provide an alternative, requiring less associated infrastructure and a single, smaller unit in the loft.

3 Supply Chains

3.1 Aggregated contracts for associated works

Using the same contractor for multiple tasks, where possible, supports communication, maximises efficiency and reduces costs. For example, if electrical works, including installation of the PV panel, battery and replacement of the distribution board are carried by one electrical company, installation was less challenging, more efficient and costs were reduced. The use of multiple contractors can confuse and delay communications and therefore progress.

3.2 Gap between specification and design

Even when very clear specifications were prepared and written with the whole house energy system in mind, the supply chain often did 'what they know' or what fits current practices rather than develop skill sets and adapt processes. This can lead to errors in what is designed and installed on site. For example, a heat pump was incorrectly sized as processes within a tendering company did not allow for the much higher performance of the fabric of the home, which was also part of the whole house energy system, to be considered in modelling. Heat pump sizing was based on ‘as built’ rather than actual performance. This created delays and a lack of trust between the team.

3.3 Detailed specifications for warrantee in procurement to protect owner

When installing new to the market technologies, there is a risk that performance may not meet expectations. Owners need to be reassured that they will be protected in case of a lack of performance or technical issues. Case studies of previous relevant works should be provided to enable contractors to demonstrate relevant experience. During the procurement process requirements should be clearly stated, for example kWp, panel warrantee details and performance warrantee to allow clear comparison. Warrantees need to be provided for new to the market products, to lower risk for those prepared to experiment with innovative solutions and provide reassurance that if issues arise, help will be available to rectify them.

3.4 Forward thinking supply chains

Projects can really thrive when supply chains are engaged/embedded within projects and have vision to understand the benefits of delivering low carbon housing. SMEs are often in a position to know local markets and skills and can really help to solve unforeseen challenges. For example, increased reassurance around the security of batteries was required when fitted externally. The electrical contractor on site was able to secure a skilled local manufacturer to produce a robust and cost-effective floor mounted cage that could be replicated at relatively low cost across other sites.

3.5 Commissioning at appropriate point/s

Commissioning is a critical part of the installation process. Once the supply chain has left site and moved onto the next project, it is very difficult to rectify any issues that may exist. Commissioning should take place immediately at the end of the installation process and rechecked just before occupants move in. Technologies can be impacted by snagging activities. For example, an MVHR was clogged with debris following the making good process that had taken place after the initial commissioning process.

4 Skills

4.1 Management on-site

A construction manager should be onsite regularly and should have the technical and communication skills to manage the schedule of works liaising with all stakeholders frequently and when necessary. The construction manager should be involved as early as possible, preferably in the planning process so they have ownership of the project and understand why the whole house energy system approach is being taken. Commitment by the construction managers can ensure a project is successfully delivered, rectifying issues as they arise, reducing costs and improving the efficiency of the installations. This helps to ensure occupants remain happy.

4.2 High quality design to be followed through to installation

Mechanical and electrical services need to be designed by skilled staff with a clear set of priorities that can range from minimising carbon emissions to reducing energy bills for residents. Designs need to be communicated clearly, preferable through clear drawings and specifications, to ensure the installation process provides an as designed performance. Designs should also consider all other components of the whole house energy system.

4.3 Impact of poor workmanship

Heat loss through poorly fitted or damaged windows and doors, air vents, uninsulated loft hatches, gaps around pipework can be significant. Installation should be as high quality as possible. In existing homes, making repairs and insulating these areas, energy used to heat can be significantly reduced.

4.4 Trust and support from the supply chain

The specification in the procurement process should be as clear and comprehensive as possible and applicants should respond accordingly. The supply chain should ensure compliance with Building Regulations and that quality is maximised. For example, in one project the specification omitted that a FENSA accredited company or Building Regulation check was necessary, as this was assumed. The successful company should have ensured this took place, however, this was not the case and additional costs were incurred at a later date to recall Building Regulations to approve window installation.

5 Behaviour change and occupants

5.1 Prevent the need to decant residents

Decantation is expensive and very disruptive for the daily lives of residents. Careful planning and scheduling to select solutions that allow residents to remain living in their homes is preferable. Disruption is inevitable, but if residents are kept well informed, they are generally more accommodating. High levels of communication by construction manager and other members of the delivery team to ensure that residents are kept well informed and as comfortable as possible during the whole process, even when delays or issues occur.

5.2 Providing residents with useful and appropriate information about systems

Maintenance requirements for all components of the system should be part of the handover process to the resident. Clear guidance should be provided to the owners and the residents in a format that is easy to understand and can be referred back to. This will enable maintenance regimes to be followed, such as replacement of filters to optimise performance. Information on the impact that behaviour may have on the performance of the system should also be provided, such as closing vents on an MVHR unit or drilling into external wall insulation.

5.3 Resident comfort benefits

Pre and post retrofit monitoring of people, the environment and the solutions enabled confirmation that comfort significantly improved across all projects. For example, monitoring provided evidence that damp and mould was removed and relative humidity was reduced to comfortable levels in all homes where MHVR was installed.

6 Financial and monetary

6.1 Scaling up innovative technologies to introduce economies-of-scale

Innovative solutions can be applied at scale at an affordable cost if carefully planned and designed. The cost to implement innovative solutions at an individual building or small-scale project, particularly in retrofits, can be prohibitive due to variation of many factors across homes. However, energy reductions can be significant, and cost to deliver projects lowered when applied at scale. Examples of solutions where economies-of-scale can be applied include transpired solar collectors and Structural Insulated Panels (SIPs).

6.2 Using highly innovative technologies can become cost effective over time

Solutions are evolving rapidly and key stakeholders need to keep on top of the changing market. Independent training should be available to provide an appropriate level of knowledge to all stakeholders involved in the process. Innovative high quality and high-performance solutions should be considered wherever possible to optimise systems and futureproof homes. For example, the cost to install an exhaust-air heating system is much higher than a traditional gas heating system but not that much more expensive that an air or ground source heat pump. The advantages of an exhaust-air heat pump include higher Co-efficient of Performance (COP), combined hot water and heating and cooling all located in one unit and air heating rather than room-based heating such as radiators, therefore maximising space. These also require only one level of maintenance.

6.3 Sharing components to minimise costs

Modelling research indicated that sharing solutions between homes can reduce capital costs whilst still fulfilling the energy needs of residents. For example, PV panels can be optimised if they overlap property boundaries, as size limitations can be overcome. Capital and installation costs of ground source heat pumps and batteries could be reduced if shared between 2 or more homes whilst still fulfilling the needs of the occupants. However, concern over long term ownership and maintenance, associated potential future legal costs and a lack of reliable controls to manage sharing need to be carefully considered.

7 Collaboration and decision making

7.1 Communication within supply chain

Clear communication is essential throughout all stages of the process to prevent mistakes being made and whole energy systems not performing as designed. For example, bringing all suppliers and installers together on site before any works start and agreeing a full delivery plan as a team will help to ensure efficiency and establish good communication channels. This will help to overcome any challenges that arise during the process.

7.2 Space availability for equipment and infrastructure

The location and size of equipment and infrastructure associated with a whole house energy system needs to be carefully planned including engagement with residents. This is particularly important when space is limited but the performance of technologies may be impacted by location. A heat pump, MVHR unit and associated ducting, battery and a hot water tank all take up precious space, most have to be installed internally. Agreeing the location of the equipment, discussing requirements to maximise performance and safety whilst minimising disruption is essential between all stakeholders.

7.3 Combining active and passive measures to maximise benefits

A significant increase in energy costs was experienced in homes where the installation of an electric hybrid heat pump was not accompanied by fabric upgrade or renewable energy supply. Carbon emission reductions were the priority and energy costs were not a key part of the decision-making process. The additional 'retrofit' of a PV and battery enabled onsite electricity to be generated alongside fabric improvements, significantly reducing bills by reducing overall demand and import from the grid.

7.4 Clarity in fulfilment of common tasks within a project

Responsibility needs to be clearly defined for elements of the system where an overlap between different stakeholders may occur. For example, responsibility for the grid connection application needs to be clear as multiple trades on site could fulfil this particular role.

8 Policy and Regulation

8.1 High-quality long-term commissioning

Commissioning needs to be carried out accurately and outcomes should be acted on. Poor or a complete lack of commissioning can lead to ongoing poor performance and therefore a lack of trust by residents in the whole house energy system. This has to be prevented through understanding of the whole house system interactions, more accurate commissioning and higher levels of accreditation through Regulations.

8.2 Connecting to the national network

A range of issues were faced at the point of contact with the local Distribution Network Operator regarding connecting to the electricity grid. Different costs were provided to carry out works by different members of staff for the same project. There was a lack of ability to understand what was being carried out and a lack of flexibility to try to accommodate solutions. These challenges seemed to be driven by a lack of knowledge, data and long-term planning processes as well as willingness to evolve to allow progress.

8.3 Widening the market

Effort was taken to increase awareness of opportunities to support SMEs. SMEs should be encouraged to join procurement portals such as Sell2Wales to help support long term sustainable supply chain development. Complex tender processes can be prohibitive to organisations with small numbers of staff, busy with other projects and not routinely using portals. Some tender documents were poorly completed and had to be discarded, leaving few to select from. Support and training is essential to help overcome this issue.

Conclusions

LCBE research has shown that investing in whole house energy systems across housing stock significantly reduces carbon emissions, supporting the drive towards Net Zero carbon targets. Co-benefits are also provided including reduced energy bills and therefore a reduction in fuel poverty, more consistent internal temperatures and the removal of damp and mould which help to improve health together with a higher quality and attractive internal and external built environment.

Key lessons learnt include it is essential that commitment to delivery is followed through all stages of the process from planning, design, procurement, installation and maintenance and operation. This requires clearly defined, tailored, yet holistic priorities, close collaboration and knowledge exchange between all key stakeholders. In most cases consideration of each of the lessons listed above need to take place as early as possible within the process, preferably at the planning stage. If this does not take place, delivery will not be as successful as it could be, and in some circumstances, may well have a detrimental impact, not only on the individual home where work is carried out but across the sector more widely.

Building Service Engineers (BSE) can play a key role in pushing forward whole house energy system retrofits in the UK and internationally. Being aware of, and enabling knowledge exchange to help overcome the lessons presented above would make a significant difference in the long-term implementation of whole house energy system delivery. Some of the challenges can be directly influenced by the BSE sector whereas others can be supported and encouraged throughout the process alongside other stakeholders.

Developing wider skills beyond more traditional technical skills is critical to enable this, particularly to allow clear communication and collaboration to deliver at scale. This helps to generate trust across all stakeholders which is critical for successful high-quality delivery at the scale needed. The opportunity to take a proactive approach in driving forward change is significant for those within the BSE sector but also the opportunity to inspire change for all stakeholders involved across the whole process from planning, design, procurement, installation and maintenance and operation.

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Acknowledgements

This research has been made possible through funding bodies including as Higher Education Funding Council for Wales (HEFCW), the Welsh European Funding Office (WEFO), The Technology Strategy Board, Innovate UK, the Welsh Government and the Engineering and Physical Sciences Research Council (EPSRC).

The Low Carbon Built Environment (LCBE) projects could not have been delivered without the support of staff at the Welsh School of Architecture, Cardiff University particularly those within the Centre for a Low Carbon Built Environment, together with the many colleagues in partner organisations who have worked with them to deliver the projects, particularly Swansea Council and Wales & West Housing.