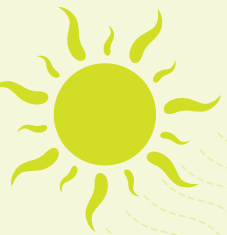



Whole House Solutions

Transforming Northern
Ireland's domestic energy
efficiency landscape

Christine Liddell, Barbara Gray and Anna Czerwinska





“Energy transitions are determined by the dynamic interconnections between the national landscape made up of climate change, fuel prices and policy initiatives, and local contexts as defined by levels of deprivation, building stock, geography and local government initiatives.”

(Lemon et al., 2015).



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Executive Summary

This report outlines the case that can be made in Northern Ireland for adopting a new domestic energy efficiency ethos. This would be centred on whole house solutions, with retrofit completed as a single programme of works, and encompassing both state of the art technical innovations and wrap-around customer advice and support.

The report details why this new ethos seems particularly apposite in Northern Ireland, and goes on to explicate what such a transformation of ethos would require in terms of multi-level stakeholder engagement. Commensurate with a whole house approach, it also argues that a *single agency* is likely to provide the most optimal business solution for delivering such a complex and coordinated retrofit strategy, with an initial requirement for work in 130,000 homes.

The report outlines why the present time seems especially apposite for the adoption of a *whole house solutions approach* in Northern Ireland, providing a wide-ranging evidence base that focuses not simply on financial benefits to householders, but also on co-benefits for households (which customers often seem to value more than money saved on energy bills), co-benefits related to fiscal stimulus, and the increasing availability of reliable technologies. These new innovations, in particular, have the capacity to transform the extent of energy savings which customers will be able to lever in, whether through their own actions or through customised automation.

In the foreseeable future, as energy prices rise, so these benefits are set to transform a previously negative business model associated with whole house solutions into a positive one. Through intelligent market segmentation in particular, the report argues, *customised* whole house solutions will be capable of ensuring that all retrofitted households are able to maximise savings, not only the able-to-pay.

The evidence base reviewed in this report points consistently to the need for a local approach to whole house solutions in Northern Ireland, supported from above by key institutions, energy policies, and capital investment. A trusted concierge service, which looks after each household from first conversation to two-year follow-up, has the capacity to provide Northern Ireland households with a systems-based energy efficiency package of measures, installed to the highest standards, and coupled with an unprecedented wraparound energy advice and support service.

Introduction

In the past, energy efficiency improvements in the UK and Ireland have generally been installed in a piecemeal fashion. This has often required repeat installation-related visits by a wide variety of agencies including advisers, plumbers, electricians, specialised fitters, and building control teams. They have sometimes improved the efficiency of space heating, sometimes lowered electricity consumption, and occasionally tackled both at the same time. Loft insulation was an early adoption, both by the able-to-pay and subsidised markets. Low-energy lighting followed, incentivised by the widespread distribution of free lightbulbs and the gradual withdrawal of less energy efficient options. Over time, the purchase of more energy efficient appliances grew in popularity, through a combination of trusted energy efficiency ratings and a lowering of price differentials between A+++ and other grades of white goods. Presently, investment in newer (and more costly) measures – such as condensing boilers, solar energy, and heat pumps – is growing gradually, and the current rollout of smart meters in GB and Ireland is enabling households to reduce their energy consumption still further through a combination of:

- real-time feedback leading to
 - behavioural change
 - and savings-based decisions to make further investment in energy efficiency measures
- (Darby et al., 2014).

Investment in energy efficiency has resulted in substantial savings for households, particularly loft insulation, cavity wall insulation, and condensing boilers. However, when installed piecemeal, these are still classed as *shallow retrofits*, because they fail to achieve the full potential of a system-wide energy efficiency package. This sets the UK and Ireland apart from many countries in Europe which have a similar temperate climate – such as Germany and Italy. In these countries, retrofit programmes have aimed to ensure that any and all potentially energy saving interventions are carried out at the same time. The German development bank KfW is perhaps the best known underwriter of such programmes:

“The bank was formed as part of the Marshall Plan to assist with reconstruction following World War II. With half a trillion euro in assets, it is roughly twice the size of the World Bank. Between 2009 and 2011, KfW spent €24 billion on energy efficiency in homes. Its program promotes energy-efficient housing for owner-occupied houses as well as for landlords, for new houses and for retrofits. Its key to success is very low interest rates, currently 1–2%. German homeowners can borrow up to €75,000.” (Brown, 2014).

These alternative European approaches aim to leave a home proofed against both cold and rising energy costs.

What is a whole house solution?

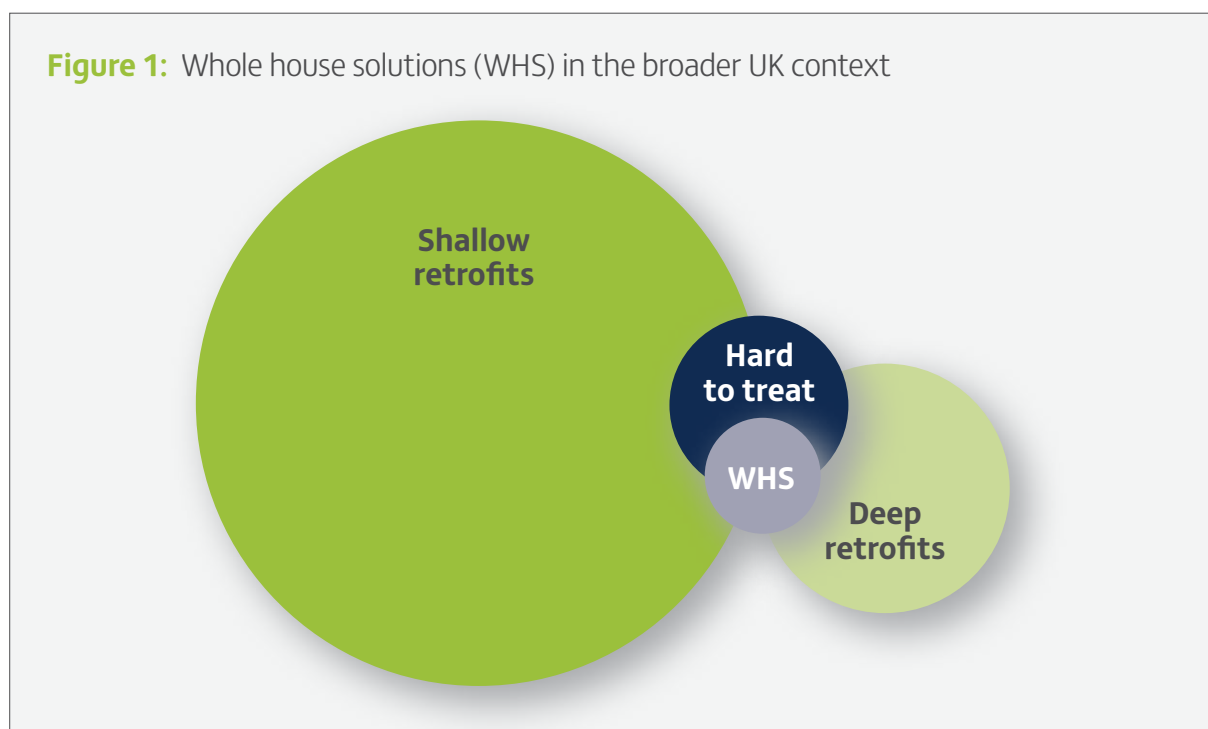
Whole house solutions are not synonymous with major works, although most commonly they do require deep retrofit. In some instances the combination of energy efficiency measures required may simply involve a comprehensive package of conventional and relatively low-cost measures, such as cavity wall insulation, top up of loft insulation, draught-proofing, a new boiler with simultaneous conversion from oil to gas, and the fitting of new radiators and pipe-work. However, even in these instances, a variety of *additional* measures are generally considered ideal, including features which

can attain high standards of airtightness, air quality and moisture levels (Gupta et al., 2015). Usually, therefore, a whole house solution achieves not only substantial savings on energy consumption, but also a root and branch reform of a home's composite energy performance.

They also require a range of new skills for energy efficiency teams, not least of all a *systems thinking approach*, which jointly considers the building, its orientation, the people who need to use it, and the environment in which it is located. They can be an especially effective solution to energy efficiency needs in houses which are hard to treat since these are homes which cannot be adequately retrofitted through a "staple" package of conventional measures. The Building Research Establishment defines 4 categories of hard to treat homes namely properties which:

- have solid walls
- are off the gas grid
- have no loft capacity for insulation
- are high-rise flats (BRE, 2008).

Figure 1 outlines the relationship between whole house solutions, deep and shallow retrofits, and hard to treat homes.



Whether deep or shallow, whole house retrofits can achieve much greater *cost-efficiency and energy efficiency* by taking a whole-building approach, addressing many elements of a home's energy system at once. Since the building fabric and energy systems of any house are generally installed at the same time (i.e. when the house is built), both often merit major overhaul at roughly the same time, making a whole house approach apposite, though (as illustrated in Figure 1) still rare in the UK. This rarity is largely a result of government policies in the UK having long supported piecemeal solutions, in both the fully subsidised and the able-to-pay markets.

Whole house solutions are much easier to design into new buildings than they are to create in ones which were built many years ago. But even new-builds with a whole house energy system remain rare, despite longstanding positive outcomes for carbon footprints and energy costs. BedZed in London, which was completed in 2002 (see Figure 2) has been the focus of repeated energy audits, all reporting positive outcomes.

Figure 2: BedZed, South London



Similarly positive results, based on smart meter data, have recently been reported in NI's first evaluation of whole house solutions in newly built properties in Belfast (see Figure 3; Liddell, 2015). This evaluation investigated the experiences of 5 low-income families in Northern Ireland who moved into new homes built using an innovative building design that dispensed with central heating. The design was able to achieve high standards of energy efficiency through raised standards of insulation, airtightness, and a heat recovery system. At the same time, the design of these homes ensured they fitted well into the existing traditional architecture of the Belfast street in which they were located (unlike BedZed and many other innovative designs), which the owners who purchased them felt was an important consideration in their decision to purchase.

Figure 3: High-specification energy efficiency housing in Belfast



Compared with the average cost of powering a more conventional home in Northern Ireland at that time, smart meter data indicated that energy consumption in the first year was 20% less than in the average newly built gas-fired home, and 34% less than the average oil-fired new build. When followed up after a second winter, the households had achieved improved levels of thermal comfort, whilst reducing their winter energy costs by a further 9%.

The Northern Ireland context – scope of need for whole house solutions

As previously noted, the Building Research Establishment's definition of homes which are "hard to treat" includes all homes which are off the gas grid, rendering roughly two-thirds of all homes in Northern Ireland classifiable as hard to treat. Added to a regional fuel poverty rate of more than 40%, the scale of what the region requires in order to provide standards of housing that meet the levels of energy efficiency which many parts of Europe are already achieving seems formidable.

Bryson Energy recently commissioned an evidence-based assessment of what would be required to achieve acceptable levels of energy efficiency in all of NI's housing stock, and how much this would cost (*Morris, 2014*). Based on the analyses undertaken for that report, we can reasonably assume that substantial retrofits are likely to be needed in at least 70% of all NI homes. Assuming that a quarter of these would merit a whole house solution on the basis of passing a cost : benefit ratio test, this suggests that more than 130,000 homes in Northern Ireland could be eligible for whole house solutions.

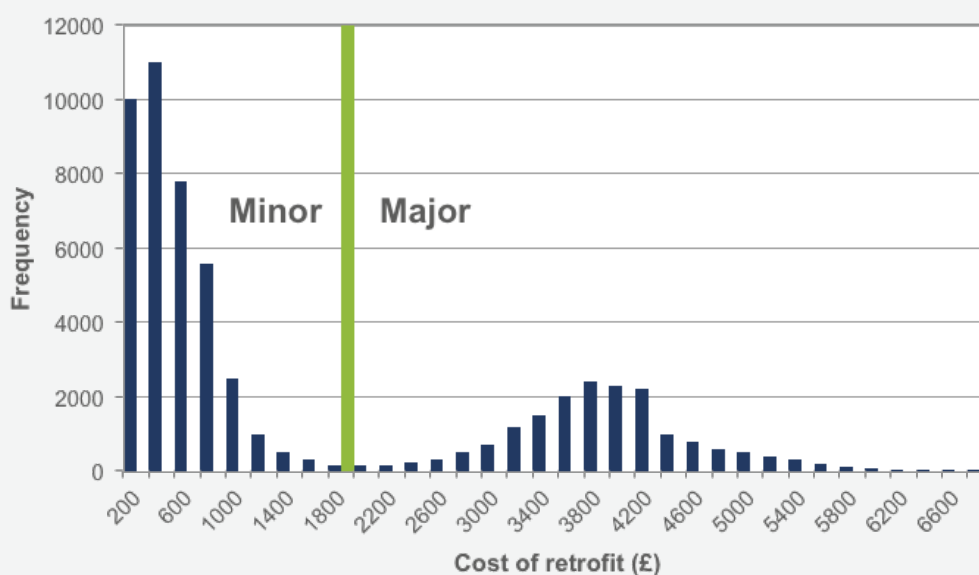
When averaged over the whole of Northern Ireland's housing stock, the Morris Report estimated an average retrofit cost of £5,000 per property. This would allow each household to achieve a SAP rating of 78, which underachieves what is thought to be required to "fuel-poverty-proof" a home i.e. SAP 85 (*Boardman, 2010*).

This more limited goal has to do with NI's climate and the incremental cost of SAP gains. The sheer demand for heat in Northern Ireland, whilst not dramatic even in deep winter, lasts all year. The average local home requires more than 2,000 degree days of heating every year and there is no month in the average year when indoor temperatures in Northern Ireland stay above minimum safe temperatures each day if they are not heated. In theory at least, every household in Northern Ireland should be running some form of heating system during every month of the year in order to maintain temperatures which the World Health Organisation endorse as safe for human health. The health risks associated with living with colder temperatures is illustrated by the fact that, while Northern Ireland averages almost 1,000 cold temperature-related deaths per year, almost 50% of these do not happen in winter (*Liddell et al., 2015*). The region does not *become* cold in winter, it is almost always cold; cold enough for a lack of affordable warmth to present an enduring, year-round health risk.

This level of heating demand means that the sort of fuel poverty proofing which Boardman aspires to for England through a SAP of 85 will require something akin to SAP 90 in Northern Ireland. Such deep retrofits would mean increasing the SAP of the average NI home (currently SAP 59) by more than 50%. The economic conditions prevailing in the region limit what can be reasonably expected, and Morris illustrates helpful tipping points: a basic retrofit taking a home from SAP 59 to SAP 77, rather than SAP 89 would cost £1,000 per SAP point gained and provide three-quarters of the energy savings of a SAP 89 retrofit.

A more pragmatic retrofit program for NI is, therefore, to aim for a SAP of 78, balancing impacts against costs. To set this amount in context, the per property investment made by the Warm Homes scheme (2002 – 2009) was less than one third of this amount (*Walker et al., 2013, see Figure 4*).

Figure 4: Retrofit costs for Warm Homes assisted households in Northern Ireland 2002 – 2009 (n = 58,868 homes)



If present levels of investment in the homes of the fuel poor continue at similar rates, there may be considerable difficulty in making deep impacts on fuel poverty.

Morris makes a similar point when referring to the current boiler replacement programme in NI. At past rates of replacement, it would take 70 years to “get around” all of those presently in need of replacement. During which time, the first boiler installed would have required replacing again a further 5 times. On the same point, the Energy Saving Trust note that homes in the UK typically undergo major refurbishment once every 50 years (*in Simpson et al., 2014*), and refurbishments are seldom modelled as having a lifetime of more than 30 years – here too, the future under a business as usual model is one in which housing standards will regress rather than improve.

Examples such as these highlight a consistent message: *radical reform is the only feasible option for Northern Ireland, and wherever feasible and cost-effective, this should include whole house solutions.*

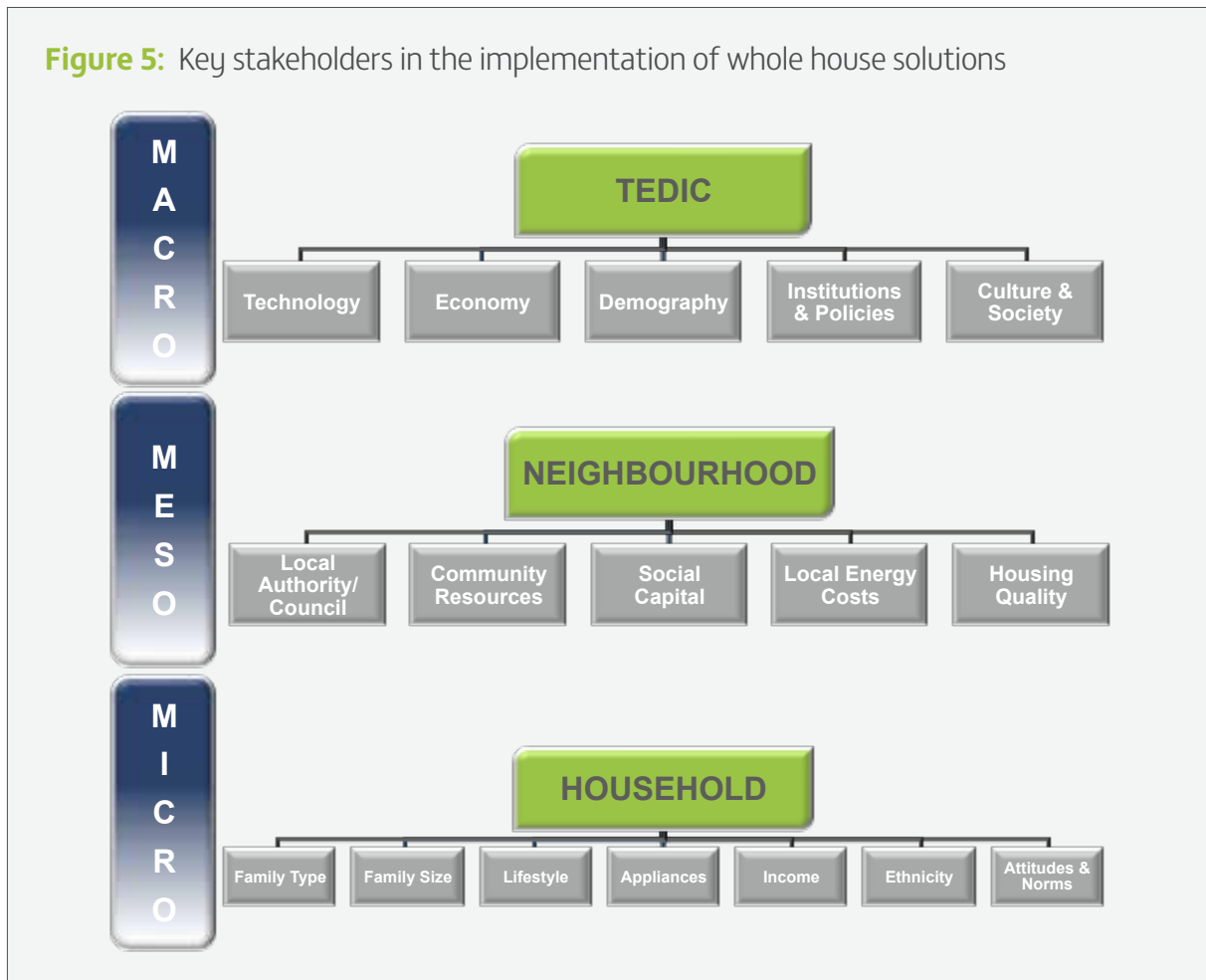
Whole house solutions and multi-level stakeholder engagement

As this report will show, whole house solutions are complex enough in their own right, but they also require embedding in the activities and policies of a wide range of indirect stakeholders in order that they can achieve maximum efficiencies. These can be broadly divided into three levels: macro-, meso- and micro-levels, as illustrated in Figure 5. Whilst support from TEDIC contributors is fundamental to success, the evidence base so far suggests that whole house solutions have usually returned greatest benefits and stakeholder satisfaction when they have operated at the meso- or neighbourhood level.

By contrast, macro-level strategies have failed to gain the confidence of households (*Marchand et al., 2015*), have been unable to generate capital investment (*Brown, 2014*), and have not been successful in developing integrated design and manufacturing infrastructures (*Gupta et al., 2015*). Single household designs have often been experimental and costly, not always delivering high levels of customer satisfaction (*Liddell, 2015*). Neighbourhood-level schemes, on the other hand, seem to work best because local teams are more fully conversant with local conditions and local design archetypes, rely

more on maintaining their local reputation, and have a greater stake in the sustainability of their neighbourhoods (Crilly et al., 2012).

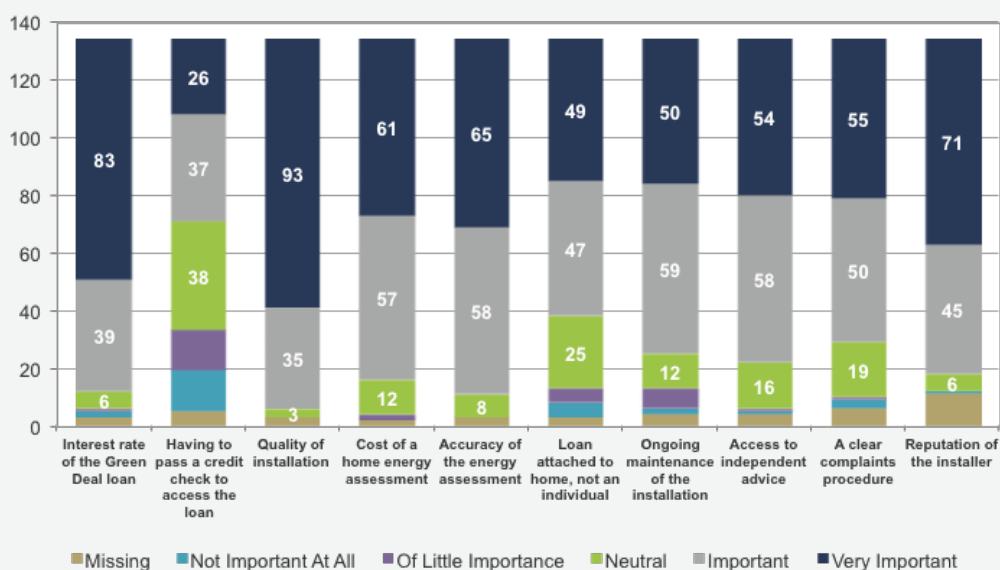
Figure 5: Key stakeholders in the implementation of whole house solutions



Whole house solutions = one trusted service provider

Research involving small builders in GB who were engaged in Green Deal installations revealed relatively low levels of knowledge regarding sustainable building, and conflicting attitudes towards the concept of sustainability (Sun et al., 2015). Perhaps not surprisingly, then, Figure 6 illustrates the concerns of customers who were considering taking up a Green Deal solution in England. The item most frequently rated as *very important* by those surveyed was the quality of the installation (93% rated this as very important), with 71% also rating the reputation of the installer as *very important*. By March 2015, these concerns and other barriers meant that – among households who undertook the preliminary inspection for Green Deal – only 1.2% took the offer up; intensive additional investment aimed to increase uptake to 30% in a small geographical area, but resulted in no uptake at all (Marchand et al., 2015). Despite being envisioned as a long-term government-subsidised energy efficiency scheme, capable of transforming the housing stock owned by households able to pay, the scheme opened in June 2014 and was terminated a year later.

Figure 6: Perceived importance of ten potential concerns with receiving a Green Deal (number of responses)



As noted in many critiques of whole house solutions (e.g. Crilly et al., 2012; Gupta et al., 2015) one of the main weaknesses of previous installations has been the lack of an integrated service, in which a single trusted provider has led the process from start (initial engagement with householder) to finish (extended after-care and support service). Taken together, these findings point towards the need for a concierge-level service in which a trusted local provider undertakes all aspects of the process.

The range of expertise which a whole house performance contractor requires means that there are relatively few existing agencies in the UK who are capable of delivering solutions in the round. Table 1 provides details of some of the skills sets that are required in order that a whole house solutions agency can deliver across all operational areas.

Ensuring an integrated supply chain, particularly for the sort of innovative projects which whole house solutions can entail, creates challenges in many of the operational areas listed on the table, including training, procurement, sub-contracting, and strategic planning; it requires unusually complex logistics, risk management strategies, and financing. Table 2 provides a more detailed breakdown of the requirements for just one of these operational areas (Burdick, 2011).

The efforts required to develop and deliver *each* of these functions are considerable; for example, in launching the Kirklees area-based scheme in Yorkshire (which was free to all householders), the local authority estimated that 3 key personnel spent the majority of the first year delivering on PR and advertising (Liddell et al., 2011):

“A total of 43,000 lofts were insulated as well as 21,000 cavity walls, and levels of take-up were even across lower, middle and upper income areas. But this level of participation and take-up was only secured through sustained marketing and repeated household visits from a trusted provider that placed great emphasis on customer care and the quality of installations.”

In reviewing the outcomes of the Scheme some years later, garnering household participation in the Scheme emerged as only one of a range of formidable barriers: on the one hand technical, financial and economic, on the other the deeply embedded social practices around domestic energy use and “entangled cultural practices, norms, values and routines” that made persuasion and behavioural changes difficult to achieve (*Webber et al., 2015*).

Even within one aspect of Customer Interaction, advising the customer on what solutions are optimal, the demands and skills sets required are significant since:

“research in behavioral economics and psychology has shown that consumers are quite limited in their decision making. They systematically confuse known information for important information, seek confirmation, ignore relevant information, rely on norms, seek to keep the status quo, are averse to the possibility of losses, are creatures of habit, display intransitive preferences, and grossly discount the future, among other evidence of bounded rationality.” (*Brown, 2014*).

Ensuring that customers are advised what to expect, ahead of retrofit, in terms of energy outcomes is also an important element of early Customer Interactions. This requires yet another set of skills, namely maintaining a watch on emerging research and evaluation studies, as these are published in scientific journals. Staying with the Kirklees example, evaluators reported consistent differences in outcomes for lower income and higher income segments. Among lower income households retrofit works led to comfort-taking through raised indoor temperatures, rather than saving money on energy bills – these were households who spent more rather than less on energy post-retrofit, but did so because they now considered the expenditure as value for money, rather than “money up the chimney”. Among higher income households, these had been able to afford warmth before retrofit, and so energy efficiency measures led to bill reduction since they did not need to raise indoor temperatures (*Webber et al., 2015*). Ensuring customers are prepared for likely outcomes post-retrofit, based on matching current research evidence to what is known of people’s unique pre-retrofit energy practices, is a vital element on enshrining customer satisfaction.

There are also many softer elements to best practice in providing energy efficiency advice to customers, which require in-depth knowledge of some areas which can change rapidly, but which can lever in significant benefits for households if they are put to best use. These include tariff switching, benefit checks, budgeting options, and community buying schemes.

Such a complex array of diverse skills sets means that few local enterprises are presently set to launch an initiative such as this, although Bryson Energy is perhaps best positioned to do so. Even for an agency like them, adopting the sort of whole house solution approach outlined here requires transformation in perspective and agenda: a repositioning of the organisation so that it becomes situated in the combined framework of domestic energy systems analysis and state-of-the art product testing/installation.

Table 1: Typical business operations profile of a Whole House performance contractor

Operational Area	Business Planning/ Processes	Marketing/ Customer Contact	Assessment	Sales	Contract Administration
Business Functions	Training	PR Strategies	Customer Interaction	Proposal	Contracting
	Employee Relations	Advertising Strategies	Whole House Assessment	Sales Presentation to Customer	Customer Financing
	Procurement	Customer Referral Strategies		Closing	Rebate and Incentive
	Subcontracts	Call Management			Accounts Receivable/ Payable
	Strategic Planning	Lead Management			

Table 2: Operational areas for initial customer contacts

Operational Area	Marketing/ Customer Contact				
Business Functions	PR Strategies	Advertising Strategies	Customer Referral Strategies	Call Management	Lead Management
Work Activities	Newspaper	Newspaper	Community Engagement	Call Scripting (Inbound & Recurring)	Sales Coordination
	Local TV/Radio	Local TV/Radio	Social Media	Inbound Call Process (New Leads)	Lead Database & Tracking
	“Local Expert”	Billboards	Direct Referral Programmes	Recurring Call Schedule (Service Appointments)	Lead Qualification
	Customer Education	Neighbourhood Saturation	Newsletter/ (e- or paper)		Scheduling
	Demonstration Homes	Website	Service Tech Referrals		Appointment Verification
		Search Engine Optimization			
<i>Internal Lead</i>	<i>Marketing</i>	<i>Marketing</i>	<i>Marketing</i>	<i>Operations</i>	<i>Sales/ Operations</i>
<i>External Lead</i>	<i>PR Agency</i>	<i>Ad Agency/ Designer</i>	<i>Ad Agency/ Designer/ Community Groups</i>	<i>Customer Advice Consultant</i>	<i>Project Management Consultant</i>

Barriers to public engagement with whole house solutions

Studies which have examined the pace and pattern of home refurbishment undertaken by UK householders illustrate how rarely they opt for whole house solutions. In almost all cases where homes have achieved a high standard of energy efficiency in an existing house, this has been achieved in a piecemeal fashion, step-by-step, over a number of years; more than a third of whole house solutions took owners longer than 5 years to complete (Fawcett et al., 2012). Few households are seasoned managers of major refurbishment works that focus on energy efficiency, and most seek to undertake such works at a relatively gradual and controlled pace.

Whole house solutions are also best undertaken with residents “decanted” from the property. This can add significantly to costs both in terms of removal and storage of people’s belongings, and in the rental of temporary accommodation, since most will be required to live away from their homes for at least 4 weeks (Gupta et al., 2015).

It has also been difficult to persuade people to undertake major energy-related retrofits in the past because there is, as yet, insufficient evidence that retrofitting homes *reliably* pays for itself during the lifetime of the refurbishment (Davies et al., 2012). Almost perversely, having completed *some* retrofitting at an earlier date can increase the payback time of installing other measures later on. For example, fitting a new boiler first and then later investing in cavity wall insulation means that the boiler is active for longer in the first years than it would have been if both measures were installed together. As more expensive measures are generally added later, so their payback time increases substantially beyond what would have been required in a whole house refurbishment (Simpson et al., 2014).

Whilst the net present value of refurbishment vastly outstrips demolition and rebuilding in terms of the returns on investment, payback periods can sometimes be very long indeed. Table 3 illustrates an example from a refurbishment scheme in Lambeth, London, which included internal wall insulation, floor insulation, window replacements, and a new district heating system.

Table 3: Cost : benefit analysis of refurbishment and rebuilding under stable and rising energy price scenarios – the Clapham Park model (Crawford et al., 2014)

	Refurbishment	Rebuilding
Best NPV		
Second Best NPV		
Worst NPV		
Second Worst NPV		
Investment (£2010/m ²)	847.4	1678
Annual energy saving from consuming less gas (kWh/m ²)	81.49	111.49
Annual saving on gas bills in 2010 prices (£/m ²) Year 0	2.702208	3.697008
Simple Payback Period (years) (no inflation)	314	454
30 Year NPV (£2010)	-787	-1592

As Brown (2014) notes, it is not only cost : benefit scenarios such as this which make householders cautious, they make investors cautious too:

“Financial barriers can prevent the introduction and widespread penetration of EE technologies. High-efficiency products and systems tend to have inherently higher up-front costs, which can increase the ratio of capital to operating expense. This up-front hurdle is exacerbated by the concurrent technical and market risks associated with advanced technologies. As a competing option among a multitude of investment choices, businesses and consumers are looking for a greater-than-average return on investment from EE projects because of the perception of greater uncertainty.”

The passage of time and its impacts on barriers to public engagement

There are six caveats to offer at this point. Taken together, they may very soon have the potential to transform the negative cost : benefit ratios that have, thus far, hampered investment in whole house solutions requiring deep retrofit.

1. Non-financial co-benefits to householders are considerable, and include more modern and aspirational standards of living, better aesthetics, and the protection of family health and wellbeing. It may not be too difficult to communicate these advantages to people, for whom they may already be uppermost in their minds. In a recent study by Scott and colleagues (2014), residents of Yorkshire and Humber estimated they would save £300 a year from deep retrofits involving external wall cladding, energy efficient gas boilers, fuel efficient central heating systems and controls, loft insulation, cavity wall insulation, UPVC windows, heat meters, and photovoltaic panels. However, they were more attracted by the aesthetics of refurbishment, and the potential it created for neighbourhood renewal, pride in their home, and a raising of their community's status within the wider area. Similarly, independent evaluators of Glasgow's GoWell programme (a major housing refurbishment scheme among fuel poor households) reported significant savings on energy bills, but that residents rated their new front door as a more salient positive feature of the scheme (Bond et al., 2013).

Added non-monetary value can also be achieved through improvements in thermal comfort. This is a particularly strong incentive in Northern Ireland where a recent QUB survey explored what residents thought were the most fundamental essentials for a decent life (Kelly et al., 2012). The top two items nominated were:

- A damp-free home
- Heating to keep adequately warm.

Both outranked “the ability to afford two meals a day”. People of all ages, both genders, and all incomes gave the same high priority to these top 2 nominations.

2. Co-benefits at a societal level are considerable. Any financial savings that are made on energy give households the opportunity to invest their money elsewhere – usually on other products and services – potentially stimulating the local economy whilst at the same time improving the region's energy security.

Moreover, the Institute for Public Policy Research (2014) estimates that some of the most costly measures which whole house solutions can require (e.g. solid wall insulation) can become major

catalysts for job creation, and can also generate significant income from VAT and corporate tax. *Ürge-Vorsatz (2010)* reviewed several empirical studies on the employment effects of energy efficiency measures as a result of buildings retrofit activities inside and outside the EU, and concluded that (on average) 17 jobs are created per million euro invested. Applying these results to the Hungarian context the study concludes that ‘deep renovations are one of the most employment intensive interventions for climate change mitigation or other economic recovery attempts’ (p23).

The Energy Bill Revolution is calling for a radical new approach to home energy efficiency, in which all low income homes are provided with whole house solutions by 2025, to bring them up to EPC Band C standard, and for all other households to be offered 0% interest loans to improve them to an equivalent EPC standard by 2035. In costing this proposal, *Cambridge Econometrics and Verco (2012)* concluded that such a programme would return £2.27 for every £1 invested by national government, which classified the proposal as “High” Value for Money when compared with other national infrastructure business models.

3. Whilst an energy performance gap, in which installed measures failed to deliver modelled energy savings, has been a sustained problem for most deep retrofit programmes in the past, causes for these failures have been comprehensively analysed and sometimes effectively resolved. Gupta and colleagues (2015) provide a useful account of the typology of these failures, some technical, and some simply incurred by failing to support the home-owner in using newly installed equipment¹:

“An energy performance gap can occur at any stage of retrofit delivery as follows:

- *During the design and specification stage, there can be a lack of understanding regarding the impact of early design decisions on energy performance, and lack of communication of design intent through all work stages. Also domestic energy modelling software, such as the Standard Assessment Procedure (SAP) in the UK, is reliant on the expertise of the user, quality of data input and appropriateness of the model to the particular context.*
- *During the construction stage, substitution of specified products with products of inferior performance due to supply chain issues and inadequate on-site understanding of the performance implication of different products also contribute to the performance gap. This is further compounded by poor workmanship and lack of quality assurance procedures on-site. In retrofit, during the design and construction stages, an insufficient understanding of existing conditions can result in a failure to integrate new measures and technology appropriately.*
- *Finally at handover, delivery from the retrofit team is usually piecemeal with no formal aftercare arrangements, which lead to unfamiliarity amongst residents to operate, control, and maintain new and unfamiliar technologies resulting in suboptimal use, settings or unexpected behaviour. As a solution, retrofit work in Denmark, Portugal, Latvia and Belgium, has found that knowledge networks were beneficial in providing advice and help for homeowners, both before and during the retrofit work.”*

4. There is an increasingly viable array of affordable new technologies; these are entering the energy efficiency market at an unprecedented speed. Many have the potential to radically transform levels of saving which households will be able to lever in from reducing their energy consumption, often with little or no effort on their own part. This could boost the returns on investment sufficiently to yield, at least, a neutral NPV in the foreseeable future.

¹ A primary cause of early teething problems in the Belfast Homes (Liddell, 2015).

5. As these innovative new products are trialled, improved, re-tested and revised, they become capable of manufacture to scale. This significantly lowers both unit prices and the cost of bulk purchasing; these in turn have significant impacts on the cost element of the cost : benefit ratio. For example, moving from small-scale retrofitting programmes to city-wide level roll out in Chicago has been recently estimated to reduce the payback period for deep retrofits from 25 years to 17 years (*Leinartas et al., 2015*).
6. As energy prices rise, so the sheer amount of money returned to customers from energy efficiency investments rises too. Using 5% less of an expensive commodity results in more money saved than using 5% less of a less expensive commodity, altering the *benefit* element of the ratio. In this context, Table 4 provides details of how gas and oil costs associated with maintaining a 3-bedroomed home in Northern Ireland have altered since 2010 (*Sutherland Tables 2010-2014; DECC, 2015*). As costs for installations reduce, and designs become more reliable, so too customer savings boost through rising energy prices, altering both sides of the cost : benefit ratio simultaneously.

Taken together, these considerations led the International Energy Efficiency Agency to endorse the principle of *Energy Efficiency First* in early 2015:

“**Energy efficiency first** is the principle of considering the potential for energy efficiency first in all decision-making related to energy. Where energy efficiency improvements are shown to be most cost-effective, considering also their role in driving jobs and economic growth, increasing energy security and reducing climate change, these should be prioritised. Applying the principle will start to redress the historic bias towards prioritising increasing supply over saving energy – a bias which still persists.” (*Coalition for Energy Savings, 2015*).

Table 4: Cost of energy for a 3-bedroomed home with condensing boiler in NI

Date	Oil	Change from previous year	Gas	Change from previous year	Electricity	Change from previous year
October 2010	£973		£800		£571	
October 2011	£1278	31% increase	£1099	37% increase	£606	6% increase
October 2012	£1333	13% increase	£1088	1% increase	£648	8% increase
October 2013	£1348	1% increase	£1136	4% increase	£634	2% increase
October 2014	£1132	16% increase	£1093	4% decrease	£685	8% decrease
4 year change		16% increase		37% increase		20% increase

From innovation to implementation – making intelligent choices

Northern Ireland has long been at the forefront of small-scale early adoption and trial in the energy efficiency and fuel poverty landscape (*Walker et al., 2014*). Monitoring the outcomes of recent and ongoing trials of whole house solutions and tools that can contribute to these could be expanded with a view to investing strategically in the most successful of these. This could dismantle barriers to public acceptance quickly and convincingly. In this context, the outcomes associated with projects funded by the UK's Technology Strategy Boards via their £17M Retrofit for the Future Programme (2009-2013) are already yielding positive solutions. As is the UK's DEFACTO project, which is investigating the extent to which digital heating control and feedback devices can reduce energy consumption (*Mallaband et al., 2015*). Devices such as the Whole House Switch, which disables all selected standby devices at the same time as a room's main light switch is turned off, may hold significant promise² (*Burgett, 2015*). The rapid uptake of remote home heating control apps, installed in mobile devices at low cost, is a useful illustration of how effective technologies that save both energy and money are often very quickly normalised.

These innovations are no longer *visions of the future*. Digital heating control and feedback systems, such as those being trialled in DEFACTO, are already available in local DIY stores across Northern Ireland. The company manufacturing one of these systems (see Figure 7) was recently bought out – and not by another energy efficiency stakeholder, but by Google (for \$3.2bn). The potential embedded in a household's simple broadband connection for full-scale home energy systems management should not be underestimated – it includes not only the option for fully intelligent and automated control³, but also for dynamic purchasing of energy (from any supplier on any day depending on when and where the most competitive market price is offered). As Smith notes in a seminal 2015 editorial:

“firms such as Google and Apple may be the new interface between electricity customers and electricity generators. It does not take a great imagination to foresee a world where Google, Apple and other companies not traditionally affiliated with energy management for consumers move into and take over this role. Consequently, today's utility companies may simply be relegated to the business of generating and transmitting electrons that are then managed by another firm.”

² Households frequently resent fully automated systems which do not allow them choice over what standby devices to disable.

³ Where and when customers want it – which is not generally *everywhere and always*.

Figure 7: NEST energy system – feedback unit and temperature control wheel



The introduction of smart metering could offer another potential opportunity for intelligent metering and feedback. It may be introduced in Northern Ireland in the foreseeable future under EU Electricity and Gas Directives, but this is not yet certain. Recent GB estimates suggest that smart meters which are accompanied by tools that give customers real-time feedback can help them save around 5% on their gas and electricity consumption (Darby *et al.*, 2015).

However, even if local policy decisions are taken to opt out of smart meter rollout, viable options for allowing households rich information on their energy usage and costs are already commercially available. Figure 8 illustrates some feedback alternatives from a recent paper published in *Nature* (Kelly *et al.*, 2015). This system is not reliant on a smart meter (which of itself does not yield appliance-specific usage data).

Figure 8: A 24 hour profile of household energy use

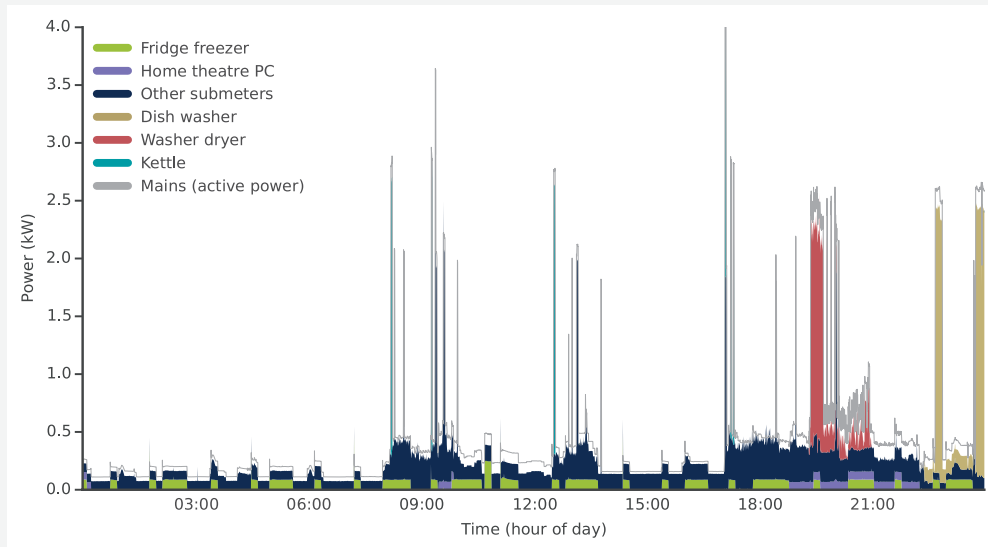
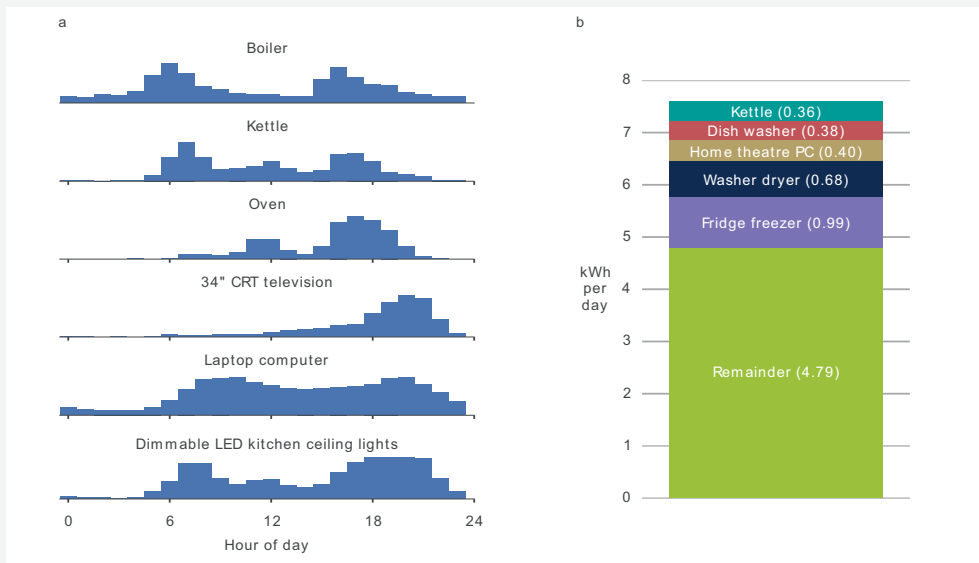


Figure 9 provides a more detailed breakdown of 24 hour profiles for some core electrical items.

Figure 9: Key appliances and their 24 hour profiles



Of particular note in Figure 9 is the extent to which the “Remainder” consume a large share of a day’s consumption; these are all the other electrical devices installed in the home, other than those itemised in Figure 8. In the household shown here, and during this particular 24 hour period, the residents’ remainder appliances consumed almost two-thirds of all their electricity usage. These richer information sources assist in understanding how a *whole house* functions, enabling analysts to identify all areas in which either automated controls and/or user behaviour changes could yield energy savings.

As Koksal and colleagues (2015) have recently noted:

“For both the homeowner and the system operator, the availability of more detailed information will allow them to act upon their respective goals. Perhaps assisted by entrepreneurs of some kinds (for instance, data analytics or energy informatics companies), they will be able to understand better specific opportunities and problems and to act accordingly. For the homeowner, for instance, this may involve promptly discovering and replacing a defective, inefficient, and/or older appliance (as revealed by an unusually large level of consumption). For the system operator, meanwhile, this may entail identifying a disproportionately large end-use demand during its peak demand periods and devising an energy conservation education campaign accordingly.”

Intelligent market segmentation

“In reality, many case studies in retrofitting residences attest to the dominance of overly technical interventions and ways of trying to cut down on household energy use. With few exceptions, strategic advice has been targeted at the individual householder, and thus at properties rather than structures. Often such properties have themselves been considered merely as the separate building elements of wall, floor, roof and services. However, an integrated project is different from a series of incremental actions, and more complex in practice. For example, designing for optimal energy performance is dependent upon demographic variations and levels of occupancy levels. The ethnic profile of tenants is also important, since in some cases two sitting rooms may be required (one for each gender); in other cases, extended and stepfamily arrangements may vary the occupancy between two and five people at different times.” (Crilly et al., 2012).

If a whole house package of traditional and innovative solutions is tailored to the needs of residents, as well as to the building fabric, this will help ensure that investments have the potential to achieve an optimal cost : benefit ratio. As illustrated earlier when comparing lower and higher-income households post-retrofit, innovations can yield different outcomes for different income groups. But the potency of market segmentation stretches far beyond simple considerations of income and affordability. For example the programmable systems which the DEFACTO programme is trialling appear to be *least* beneficial for households who are at home most of the time. They are *most* beneficial for families who are at work or school during the day, and then tend to move through zones of their home when they return (gathering in the kitchen first, moving into a TV room and study next, then ending the evening upstairs in a bathroom and bedrooms); for these households, zonal control systems can save households an average of 12% on their heating costs – more than double what can be levered in through smart meters (see Table 5; Beizae et al., 2015).

Table 5: Estimated gas use for heating the test house, with the same occupancy, in seven different regions of the UK, using either ZC or CC for a basic system

Region (Weather station)	Annual heating energy use CC ^a (kWh)	Annual heating energy use ZC ^b (kWh)	Reduction in heating energy use (%)	NPV after 15 years: Basic system ^b (£)
London (Gatwick)	15685	13839	11.8%	£971
East of England (Hemsby)	15696	13848	11.8%	£972
Northwest (Aughton)	15805	13936	11.8%	£985
West Midlands (Birmingham)	16354	14379	12.0%	£1047
Northern Ireland (Belfast)	16374	14395	12.1%	£1050
Yorkshire (Finningley)	16507	14503	12.1%	£1065
Scotland (Aberdeen)	17346	15180	12.5%	£1160

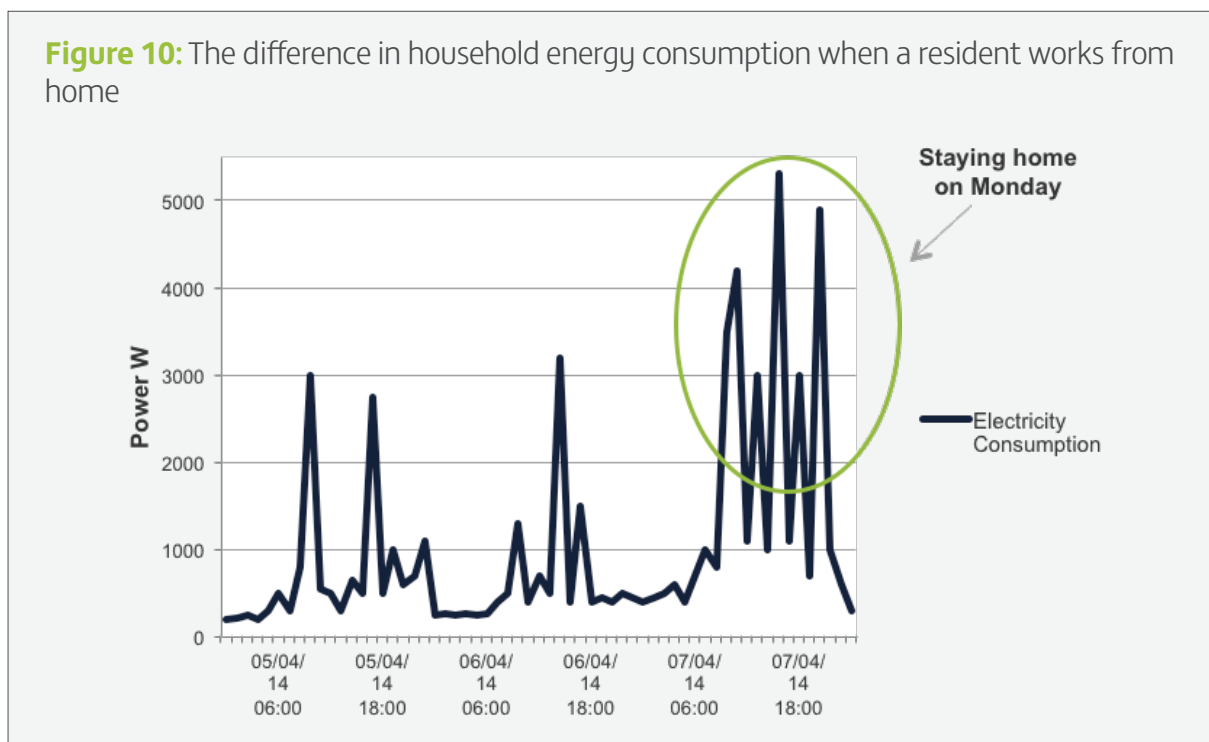
Note: Calculated based on HDD base temperature of 17.8°C.

^a For a typical weather year with heating months being October to April.

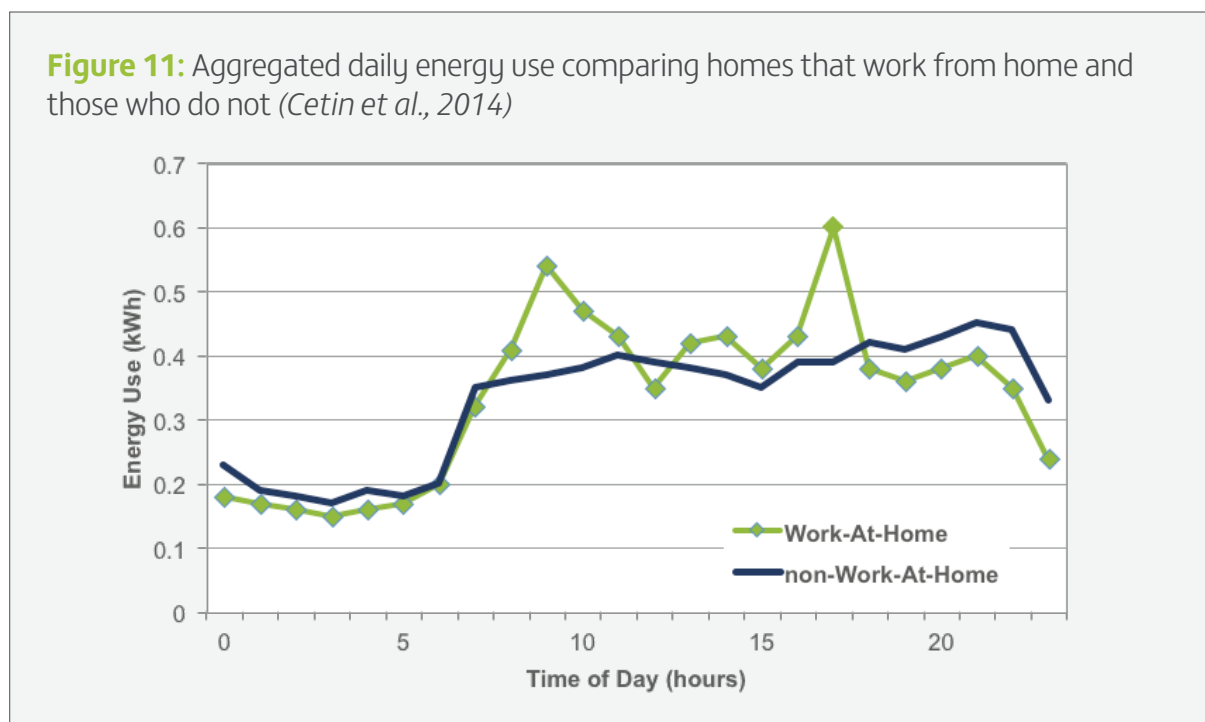
^b Based on Department Of Energy and Climate Change (DECC) energy & emissions projections central scenario for residential gas prices and discount rate of 5%.

Households where at least one person works at home are also likely to require a different bundle of whole house solutions from those who do not, since their patterns of energy use are likely to be significantly different. Figure 10 compares the energy use patterns in one household where a resident worked at home on one day (*Mallaband et al., 2014*).

Figure 10: The difference in household energy consumption when a resident works from home



Furthermore, as shown on Figure 11, people who work from home are much more likely to consume energy during peak times, and are therefore likely to be more vulnerable to the high costs associated with peak-time tariffs.



Basic differences in lifestyle and routine such as these largely account for the fact that households in the same street and with very similar appliances can differ in their energy consumption by as much as 300% (Kelly et al., 2015).

As a consequence of these very different usage patterns, the payback time from energy efficiency retrofits can be almost twice as long for households who spend most of their week and weekend at home, such as retired households, households with young children, households where someone is living with a disability or long-term illness, and households running a business from home, or working from home (a large proportion of all households, in other words). Whole house solutions will mainly generate greater savings and shorter payback periods for households other than these, but such constellations of household are neither difficult to identify nor to target.

When barriers persist – designing ways around them

Solid wall insulation is costly, labour-intensive, and disruptive for households. Choosing between insulating walls outside, or insulating them inside each room, is often a difficult choice because the former is more expensive, while the latter leaves rooms smaller. However, it is becoming more feasible to couple internal wall insulation with space-creating measures during deep retrofits. For example, in the living room and main bedroom, bay window modules can be added as part of the internal wall insulation programme, and in the roof, a new roof with built-in space pod can deliver extra living space (as much as 26 square meters in a standard mid-terrace).

Figures 12 and 13 illustrate these designs which could fully offset their concerns about a small reduction in room size incurred through internal wall insulation. These modules are manufactured offsite, limiting the length and extent of disruption for households, and do not always require decanting of residents (Crilly et al., 2012).

Figure 12: Bay window module and roof pod



These modern methods of construction are no longer simply pilot projects. The Scottish Government's Greener Homes Prospectus (2012) noted as its primary objective:

“To invest in greener technologies, modern methods of construction and modern materials by applying them to new-build homes and retrofitting them to existing homes in Scotland.” (p. 2)

MMC options have already been favourably evaluated in terms of their suitability for Victorian terraced housing in Belfast (Oliver et al., 2015), with a view to offering residents more than one set of modular options from which to choose, again permitting flexibility around lifestyles, household composition and people's need for a sense of choice and control.

Figure 13: Illustration of the size of space created in lofts after roof pod installation



Whilst not an option likely to suit all households (or all building types), it illustrates the extent to which thinking outside of the traditional constraints of current deep retrofit solutions can contribute to the portfolio of options which households can be offered. For many families with older children continuing to live at home after finishing school, roof pods may be very attractive, as they might also be for households setting up their own business at home (both of which are growing lifestyle adaptations).

Innovations of this sort are challenging, even in the most ideal circumstances. As Crilly and colleagues noted:

“Altogether, what seemed to be largely a technical and financial exercise, as is the case with simple insulation measures, turned out to be much more complicated. It lacked an adequate framework by which different technologies could be properly assessed. The scope for innovation in retrofitting houses for energy efficiency, therefore, lies as much in the complete process as in the particular technologies adopted. Some properties, for example, had a traditional ‘floating’ floor of timber joists and boards next to a solid concrete floor in the rear extension. These required considered approaches to edging details, the joining of elements and the impact of thermal bridging. Project experience suggests the use of a single strategy to dealing with hybrid elements, with the choice being made as much around lowering cost and disturbance to householders as around improvements in insulation. It was found that, faced with mixed construction elements, the scalability of a technique was less of a concern than simply finding a technique that worked.”

As the authors go on to note, the persistence, fine-tuning, and hand-crafting that the earliest prototypes needed for this project were the main reasons why successful implementation relied on a *local* building enterprise.

Conclusions

Whole house solutions are an ideal solution for proofing households in Northern Ireland against rising energy prices and fuel poverty. They maximise gains to thermal comfort and customer satisfaction, offer best value for money, and give local businesses new opportunities for delivering seamless high-quality installations. New and practical energy-saving innovations are coming onto the market at an unprecedented pace, and independent trials in real homes are enabling technologists to design out flaws (human and technical) which had initially created energy performance gaps. Early flaws and failures have been abundantly documented, but perhaps should not have been a particular surprise. As Janda and von Meier (2005) note, there are simply “more ways for things to go wrong than for things accidentally to go better than planned” (p. 37).

Rising energy prices currently leave us at a cusp, in which combinations of innovative and traditional technologies yield a steadily narrowing margin between costs and benefits. As a consequence, whole house solutions are set to accelerate exponentially in the next decade.

The challenges that remain are no longer predominantly technical; they are social, economic and political. As this report has illustrated, whole house solutions require multi-level stakeholder engagement, in which:

- the nexus of implementation resides at the level of “local”
- supported from above by key institutions, energy policies, and capital investment
- delivered as tailor-made whole house packages
- ideally through a single, trusted agency
- offering households a fully-supported concierge service stretching from initial customer contact through to a full aftercare service programme.

Customer support may need to de-emphasise achieving specific performance outcomes since this can lead to tunnel vision, where customers (and those who support their efforts) focus on reaching the goals rather than on acquiring the skills needed to reach them (Janda et al., 2015). As a type of intervention, whole house solutions usually involve making significant changes to the built environment, which can be categorized as both new and complex. The burden of change that is asked of householders should not be underestimated:

“In most countries, the building performance regulatory regime depends more on building physics than on the skill of their operators or ‘drivers’, and messages about operations and social responsibility are more muted. What if people were required to take lessons and pass tests about how they would drive a building in the same way that they must demonstrate their ability to drive a car? This kind of a shift would recognize that the built environment (like transportation) is a socio-technical system, rather than a just a technical one. It might also help close the gap between policy predictions and outcomes by initiating a policy regime that establishes stronger messages about ‘right’ and ‘wrong’ ways of running a building.” (Janda et al., 2015).

What is clear from this report is that, in the next three years, there is scope to take to scale a whole house solutions strategy which could reach more than 130,000 homes in Northern Ireland, offering all of these an element of future-proofing against fuel poverty that is pragmatic (i.e. within our means) but nevertheless transformative.

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