GREEN DEAL CORE CITIES LEEDS

The good, the bad, and the risky

Dr David Glew, Reader in Energy Efficiency and Policy, Leeds Sustainability Institute Leeds Beckett University



Overview

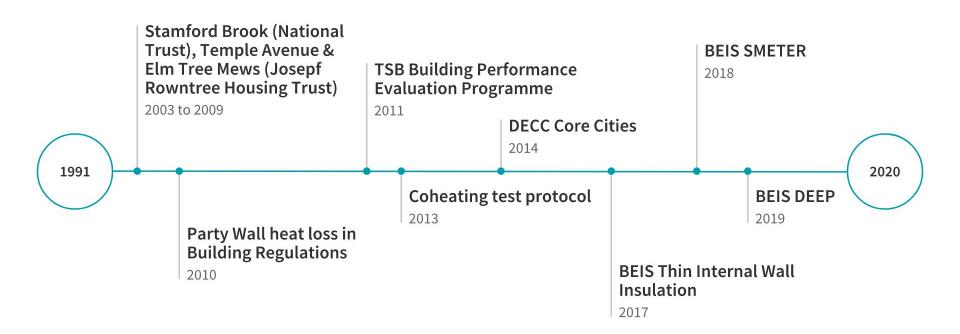
- 1 About the LSI
- 2 About the Core Cities Report
- (3) The Good

- (4) The Bad
- 5 The Risky
- **6** Up coming projects

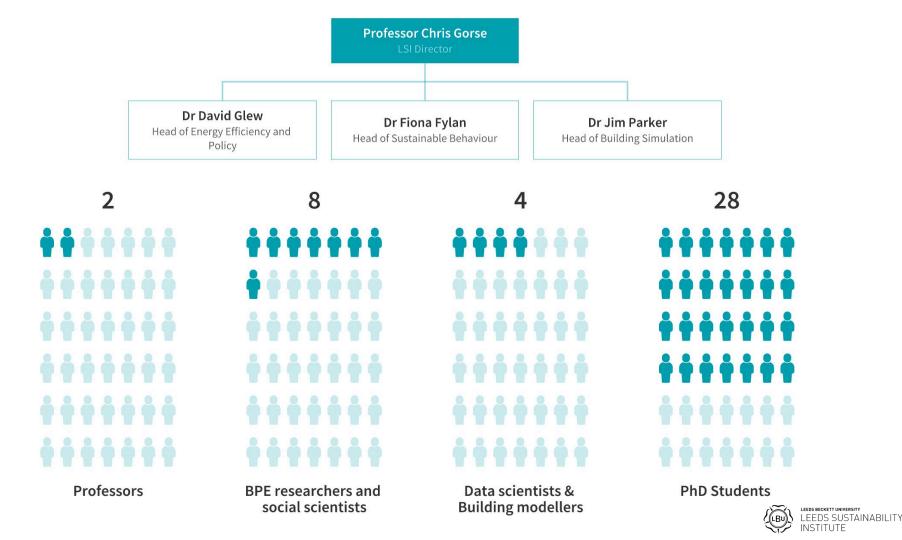
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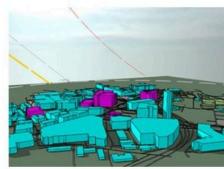
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Our Areas of Research Expertise



Data Analysis, Modelling & >
Simulation



Behaviour Change & Post Occupancy Evaluation



Retrofit Performance Evaluation >



New Build Performance Evaluation



Product Developments & Patents >



Regulations & Standards

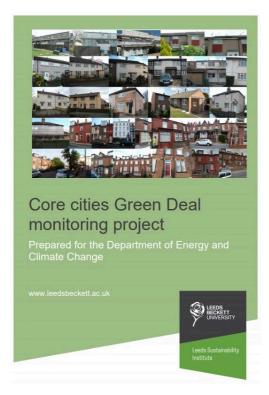


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Leeds Core Cities Project



Leeds Core Cities project



- Department of Energy and Climate Change now Business Energy and Industrial Strategy (BEIS)
- 2014 to 2017
- Leeds & Manchester designated a Green Deal Core City

Retrofits were funded (not via Green Deal)

- Aims
 - Performance gap
 Unintended consequences
- 3 main contractors on framework



Publications based on the Leeds Core Cities project

The current issue and full text arctive of this journal is available on Emerald Insight at

Assessing the quality of retrofits quality of in solid wall dwellings

David Glew Faculty of Arts, Emironment and Technology, Leeds Beckett University, Leeds, UK Melanie B. Smith

Leeds Sustainability Institute, Faculty of Arts, Environment and Technology, Leeds Beckett University, Leeds, UK Dominic Miles-Shenton Faculty of Arts, Emironment and Technology, Leeds Beckett University, Lends, UK, and

Christopher Gorse School of the Built Environment and Engineering, Leeds Beckett University, Leeds, UK

Abstracts: The purpose of this pages is to provide a detailed appeared of the quality of desentic constant.

Purpose: The purpose of this pages is no provide as detailed appeared of the quality of desentic constant and the foliation of severys and 3 to reside the constant and the foliation of severys and 3 to reside the constant and the constan

Practical implications - Recommendations to reduce the failure rates may include making changes to the

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Keywords Survey, Policy, Unintended consequences, Retrofit, Donnotic energy efficiency, Moisture Paper type Emerch never

Dwellings account for 29 per cent of UK primary energy use (BEIS, 2016a), domestic thermal efficiency has been the focus of government policy for the past 20 years munifesting currently as a commitment to insulate one million homes between 2015 and 2020 (BUES, 2016t). Table I describes the scale and success of province domestic energy efficiency S per cent of all households in Great Britain (DECC, 2016).

The methodologies used to calculate savings shown in Table I were not consistent across schemes; thus, comparisons should be made cautiously, although the relative success of the policies is apparent. These savings are only modelled estimates, i.g. using 8dSAF, 80G; 2012) which, in mulity are rarely achieved, a phenomenon known as the performance gap



petrofits

501

Energy Research & Social Science

Original research article

Reflections on retrofits: Overcoming barriers to energy efficiency among the fuel poor in the United Kingdom

Fiona Fylan*, David Glew, Melanie Smith, David Johnston, Matthew Brooke-Peat. Dominic Miles-Shenton, Martin Fletcher, Patricia Aloise-Young, Christopher Gorse Level formattely institute Area decirel Descripty, Level 213 308; 18

ARTICLE INFO

The set of again, and all previous country of shours and other removes contributions and all the set of the teams and the set of the

While new lumes in the UK most meet enemy efficiency stripents, a combination of low pew build rates and low demo-trates means around 80-85% of homes occupied in 2000 are

likely to be those currently standing today (2.28); Consequently

there is a seed to focus on inspection the energy efficiency, of

existing bosses [46], In the UK there is a range of energy effi-

Schetze [12]: Funding schetzes also operate at Europe and in the

cavity wall annulation. Some homes, termed "land-to-treat", cannot

accommodule communica al cost effective filtery energy efficiency

accuminator commission con-risority family energy entering measures [16,4,10], primarily because of the nature their constitu-tion, for example they have solid walls, they have no loft, or they are

high-rise flats [4]. There have been various programmes to improve

the energy efficiency of hard-to-treat bosses, primarily becoming on attenuable external multimodation, floth local authorities and social huming associations provide such schemes, usually learing the

majority of the cost, as their tenants are generally on low incomes

and are often so fort powerty [41]. Using these schemes to reduce first powerty has been crassions, however, became of the atherest

There are several key drawers to belying bouseholds reduce the energy they commer, aroung from both the need to reduce fact coverty and to endow curban emissions. Loone in a worm bone privery and to receive castom remissions, living as a waster money out only one as that occupants can have money but it can also lead to improvements in physical and mental health [11.5]. There was a legal commitment toon the UK Government that, in far as jie actual, by 2016 there alressed he no boundwicks hong in her poverty [45]. Progress towards this goal has been sline, however, with around 10% of households in fact poverty and no decrease in this figure over recent years [14]. More recently, in the UK there is a far-USA, e.g. the US Department of Energy Weatherstation Assistance Program [15]. Schemes Typically include conventional anyone-ments such as appraising twilers and initialing loft condution and get that all bosseleids should have an energy efficiency rating of at local C for 2000 (10). As swell in naval discours business need to as bean C by 2010 [190]. As were as social direct, beans need to become more energy efficient as order to meet cathon ensours. tageris, The UK, alongsafe other European countries, is required to reduce carbon emissions by BUS before 2050 [7]. A substantial amount of this saying will need to come from the domestic setting

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Validating solid wall insulation retrofits with in-use data

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Crown Copyright © 2018 Published by Eleveiry R.V. All rights reserved. evit suggested that an order to meet the 5th UK Carbon Budget

Imprining the everyy efficiency of the UK beasing such is important both to easi's unline resistant action to tappe and in rather had purely first thin immediately imprint an interest had purely first thin immediately imprint an impairing simulation of the entire of t

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Energy & Buildings

the domestic sector is expected to cut emissions by a further 225 between 2015 and 2020 [10].

There are several options available when remissions a dwelling that can been on the fabric or the services in the bone. Of the 2 million measures installed via ECO, 18% were carry wall mode. tion (CW), 203 loft insolution and 213 bodies opposite [13], Go entiment statutics on annualised gas data from a large number hopes show that these measures trust in a savor of E-G. 215. and 8.15 respectably on anyone bookshold flort fight (125. As a re-

salt, their there measures are often devened to have the store sal-bon savings.

The benefits of mild walt mentation (SWI) are less well midded. with this lack of information ther, in least in part, to the retaining low installation stars of SWI. This is a significant oversight since SEL of the UK housing stock is estimated to have solid walls, SEL of which remain unmodated [15]. A summary of Steramer on the posterial savings from SWI has been published by the BEE [15]. and individual care insides often reveal than SWI can result in higher savings than CWI - spwards of SRE [14] or even fifth when part of a deep transacion [15] However, assessment methods used to validate the effectiveness of transfer on small numbers of dwellings, as in the case of SWI, inherently have line scannical power and high uncertainty. Conversely, savings for conventional incusarry are demand from samples of trees of shousands of honors.

SWI may be applied as average wall arrelation (WK) or ex-Wil may be appert at norther wall contained [190] or co-ternal wall confusion (EWI), with struktures approach typically dependent on local factors such as building geometry and local

Configurating action.

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In 2015, the domestic sector accounted for 2015 of UK total etregy consumption [1] and of this percentage, space beating car at sum for around 60% [2]. The large amount of energy expended on domestic beautier means that reduction opposes, are visal if

the UK government is so much it carpot of coming government governmenters by 80% by the year 20%0 (3). Two of the samplers ways to reduce resolution from document bursting are to resoure that bosons are braned efficiency and no consist they much that bear

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the 1995 relation of the 1901 LK Balding Repulsions being the first this required use changes in storagy efficiency requirements of new looms [4]. However, the English Housing Survey reports

that over 80% of homes were built grow to this brigitation comme

ann fore and these leaves are therefore expected in have gen-erally poster thermal performance [5]. This means that large scale renodleting is crucial for accreasing the efficiency of former, [6], and

is has also been demonstrated that water soon-economic locable

section retriest enterin exclusion; are Larbest introvision sections of Euger (CRES), Secondate Felicia fincienties (ERS), Community Heregy Soving Programme (CRES) and the Energy Gompanion Obligations (ICEO) have been relainely effective, as reflected in the East that dwellings with AC Energy Performance Certificate (TRC) taking these results than per SSU in 2005 to 28°th at 2015 [ES]. This should be a compared to the CRES of the CRES

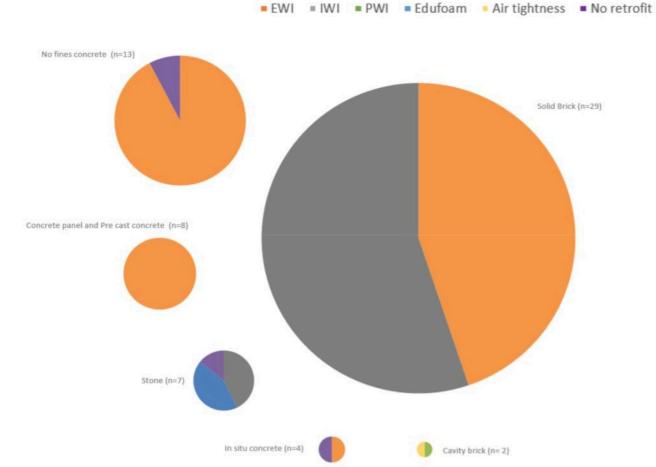
community wide benefits can be artiseved via certodic policy

Recess recroits efform including the Carbon Entirenes Reduction



Houses & retrofits

- Mostly solid wall
- Mostly Brick
- Mostly EWI
- Some IWI
- Mostly Leeds





C-1 C-2 Solid Brick IVVI Boiler Boiler Solid Brick IWI C-3 Cavity Brick PWI LI 1-01 Solid Brick IWI 1-02 LI Retrofits in detail Solid Brick IWI Windows Floor 1-03 Solid Brick IWI 1-04 Solid Brick IWI Boiler Windows 1-05 Solid Brick IWI 1-06 Solid Brick IWI 1-07 Solid Brick IWI 1-08 Solid Brick EWI IWI 1-09 Stone Edufoam 1-10 Stone Edufoam Mostly single 1-11 Stone Edufoam 1-12 Solid Brick 1-13 Solid Brick 1-14 Solid Brick IWI 1-15 Stone IWI L Windows Floor E-1 measures No-fines concrete **EWI** E-2 EWI No-fines concrete E-3 No-fines concrete **EWI** E-4 IWI Solid Brick Boiler LI Windows Controls E-5 Solid Brick Controls IWI Boiler LI Windows No whole house E-6 Solid Brick IWI Boiler LI Windows Controls E-7 No-fines concrete **EWI** Boiler Windows E-8 No-fines concrete EWI Boiler Windows E-9 In-Situ Concrete EWI In-Situ Concrete None E-11 In-Situ Concrete None approach Precast Concrete **EWI** E-13 In-situ Concrete **EWI** Concrete **EWI** Concrete **EWI** Concrete **EWI** PAS 2030:2014 E-17 Stone IWI LI Windows Solid Brick EWI IWI IWI Solid Brick **EWI** E-20 IWI Solid Brick EWI E-21 Solid Brick **EWI** E-22 Solid Brick **EWI** Pre Each E-23 Solid Brick EWI E-24 IWI Stone E-25 No-fines concrete **EWI** E-26 No-fines concrete No retrofit E-27 Solid Brick **Homes Counts** E-28 Solid Brick E-29 Solid Brick EWI E-30 Solid Brick EWI E-31 Solid Brick **EWI** E-32 EWI Concrete panel Pre PAS2035 **EWI** No-fines concrete No-fines concrete **EWI** E-35 No-fines concrete EWI **EWI** No-fines concrete No-fines concrete EWI No-fines concrete EWI E-39 Solid Brick **EWI** E-40 Solid Brick **EWI** E-41 Solid Brick EWI E-42 Brick cavity **EWI** Stone Windows Solar HW E-44 Concrete EWI Concrete **EWI** EWI Concrete

Dwelling ID

Wall type

Stone

No retrofil

Measure

Measure 2

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The tests



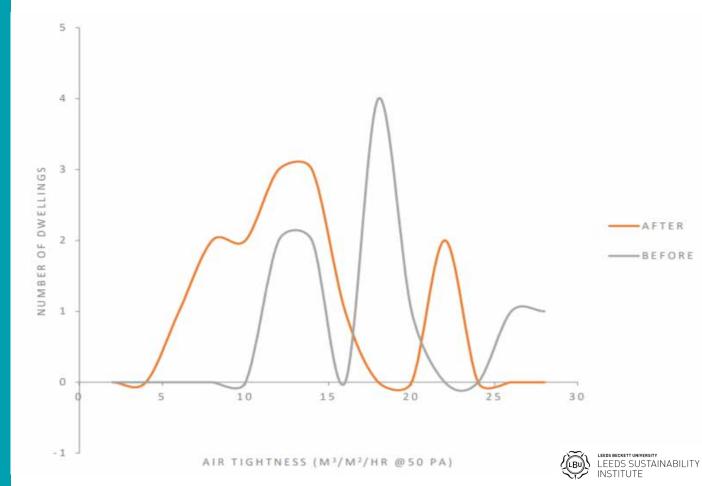


The Good



 The retrofits improved airtightness in the dwellings by, on average 25%

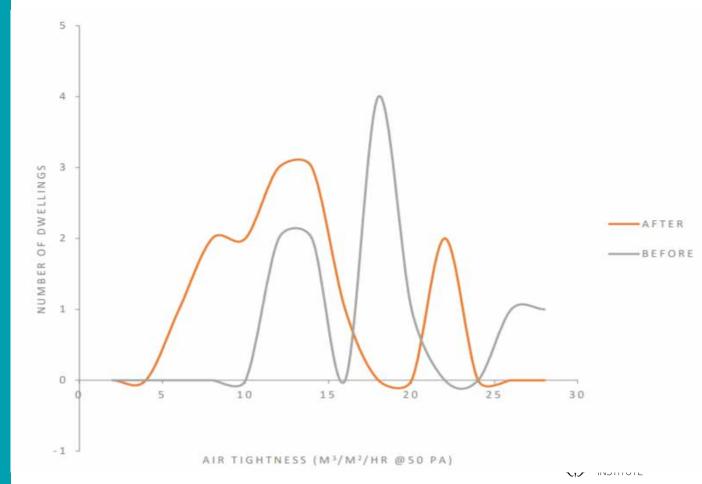
Air tightness improvements from 15 IWI retrofits



The greatest improvements in airtightness were achieved where a whole house approach was taken and specific designs for the air barrier were made.

This resulted in an infiltration rate reduction of 61%.

Air tightness improvements from 15 IWI retrofits



3 Case study homes undergoing Coheating testing

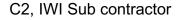
2 x IWI

- Mid terrace
- 9 inch solid brick
- Sub contractor vs. Housing Charity

PWI

- 1957 Brick cavity wall
- Manufacturer's own installation
- Separate loft replacement

C1, IWI Housing Charity













Heat Transfer Coefficient

- All the retrofits reduced heat loss
- There was
 variation in
 performance due
 to specification and
 quality

- The housing charity IWI retrofits achieved reductions 56%
- The sub contractor retrofit achieved reductions of 25%
- Party wall cavity fill achieved reductions of 8%

Dwelling	HLC before intervention (W/K)	HLC after intervention (W/K)	Improvement in HLC (%)
C-01	138.2 (± 2.8)	60.9 (± 1.2)	56%
C-02	135.3 (± 2.5)	101.6 (± 3.8)	25%
C-03	180.2 (± 9.2)	166.4 (± 4.8)	8%



Ventilation vs. Fabric heat loss

IWI retrofits reductions:

- Fabric = 70-80%
- Ventilation = 20-30%

Ventilation heat loss reductions from C1 were similar to fabric heat loss reductions from C2

Table 4-3 Ventilation heat loss improvement

Dwelling	Before ventilation rate (ACH @ 50 Pa)	After ventilation rate (ACH @ 50 Pa)	Before heat loss (W/K)	After heat loss (W/K)	Improvement (W/K)	Percentage Improvement
C-01	20.85	7.99	38.9	14.9	24.0	62%
C-02	30.19	26.36	56	48.9	7.1	13%
C-03	17.81	16.11	40.2	36.3	3.9	10%

Table 4-4 Fabric heat loss improvement

Dwelling	Before U- value (W/m²K)	After calculated U-value (W/m²K)	After measured U-value (W/m²K)	U-value performance gap (%)	Before heat loss (W/K)	After heat loss (W/K)	Improvement (W/K)	Percentage Improvement
C-1	2.08	0.14	0.17	21%	99.3	45.0	53.3	54%
C-2	1.57	0.29	0.31	7%	79.3	52.7	26.6	34%
C-3	0.3	n/a	-0.02	n/a	140.0	130.1	9.9	7%



Party wall retrofit savings were similar to loft replacement

More tests would be need to have certainty on PWI benefit

Table 4-3 Ventilation heat loss improvement

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Table 4-4 Fabric heat loss improvement

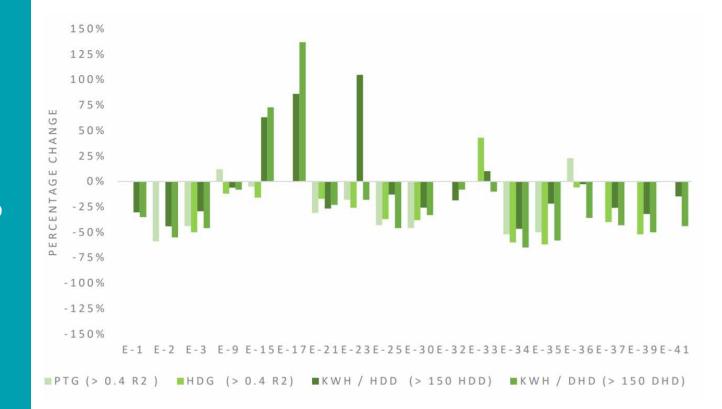
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Heating demand reductions

- Variation in savings was very large
- Mean savings
 were estimated to
 be between 4%
 and 29%
 depending on the
 assessment
 method chosen

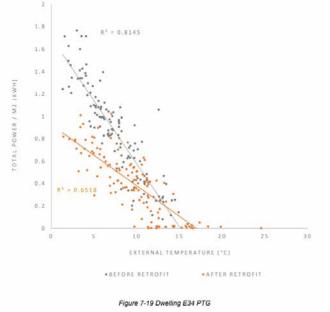
In use monitoring from 47 homes EWI & IWI

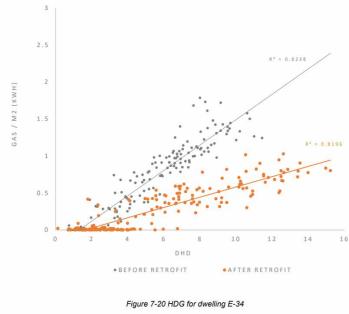




- All analysis methods showed a reduction in heat demand on average
- Power
 Temperature
 Gradient (PTG)
 was less certain
- Accounting for internal temperatures improved accuracy

In use monitoring from 47 homes EWI & IWI







CIBSE Adaptive Comfort analysis

- Most homes became warmer after the retrofit
- 15 homes were considered "cold"
- 5 out of 8 "cold" homes, with reliable data, became "acceptable"

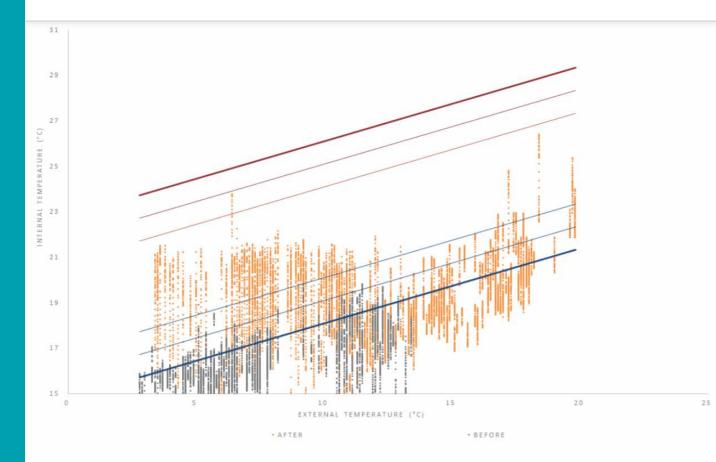
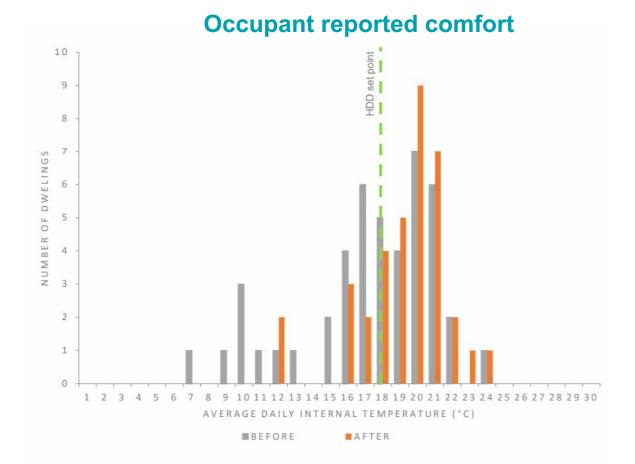
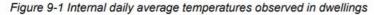


Figure 7-15 Dwelling E-34 thermal comfort assessment



- Most participants reported having good control over their thermal comfort after the retrofit
- This increase was not statistically significant
- There was no change in their ratings of their home becoming too warm







Wider benefits

- Occupants were generally pleased that they had the retrofits
- Some confusion over benefits
- Some concerns over risks

"Nearly all of the occupants had positive experiences of the retrofit they received (although they had usually not paid for the installation) and described their homes as being warmer, easier and cheaper to heat as they retained heat for longer and in some cases were less draughty"

"one of the major occupant centred benefits of the retrofits was the indirect improvements to the streetscape, making the appearance of the homes and neighbourhood more pleasant and enjoyable to live in"



The Bad



Generally poor levels of air tightness across the sample

There were some dwellings with unacceptable air leakage after retrofits

10 of 18 houses tested after retrofit had air tightness levels worse than the minimum allowable for new builds

Air tightness is often not addressed in retrofits



Figure 3-7 Dwelling C-02 under depressurisation following refurbishment.



Insulation did not always achieve its designed U values:

- Performance gap for Housing Charity IWI was 7%
- Performance gap for the subcontractor IWI was 21%

Performance gaps were observed

Installers who have a whole house approach to the retrofit and who give attention to detail to air barriers, achieve better outcomes than retrofits performed by sub-contractors.

Performance gaps could not be calculated since the retrofits did not require before and after heat loss calculations to access funding and so it was not possible to compare the predicted with the observed savings.



Surveyor observations of poor quality

- Surveyor visited each retrofit site before and after where possible
- Most sites had more than one issue
- Not simple to quantify the impact on performance

Gaps in insulation (e.g. around wall mounted objects)
Penetrations and fittings not being adequately sealed
Thermal bridging at element interfaces
Ventilation pathways blocked up
Missing insulation around jambs, sills and lintels
Lack of access to install insulation (no IWI behind

kitchens, EWI stopping before party wall etc.)



Multiple examples of "work arounds" causing unsightly installs and thermal bridges

- Services
- Utility meters
- Complex geometry
- Obstructions



Figure 2-6 Thermal breaks at insulation cut-outs at external pipes, services, walls, doors, gates etc: these are typical for pre-1919 terraces where these services are not being amended in the EWI works



Some examples of poor workmanship:

- Seals
- Drainage
- Existing damp



Figure 2-5 Effects of water ingress through an imperfect seal at the top of EWI









Field work data collection problems

- In use monitoring often failed
- Only 18 of 47 homes could be analysed
- Householders did not always cooperate
- Installer companies did not fully engage

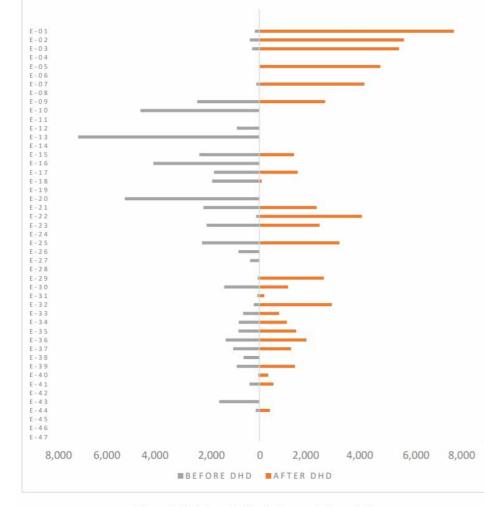


Figure 7-11 Data collection before and after retrofit



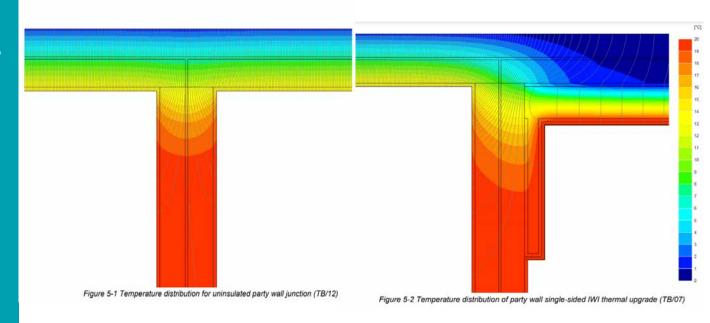
The Risky



Risks to the neighbour from IWI

IWI returns can increase thermal bridging at party walls by more than 60%

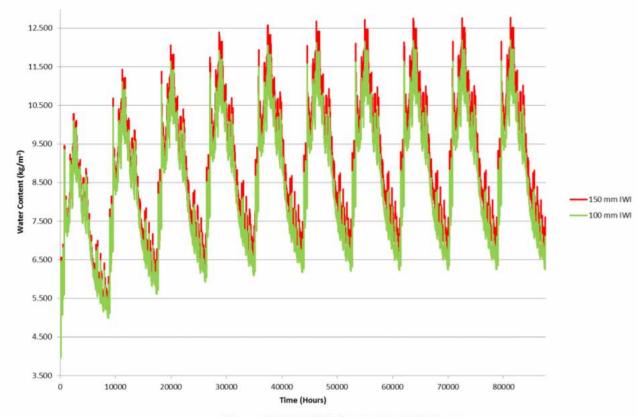
Returning IWI on the party wall could reducing neighbours' internal wall surface temperature to a level that may promote condensation





- WUFI models undertaken to predict risk of moisture accumulation
- Moisture balance occurs after a longer period

Moisture build up following IWI







IWI leads to reduced heat input into the wall acts as a moisture barrier causing a risk of rot to embedded timbers.

IWI requires further longitudinal monitoring to explore the impact and the ability to mitigate and control long-term moisture risks.

Moisture build up following IWI

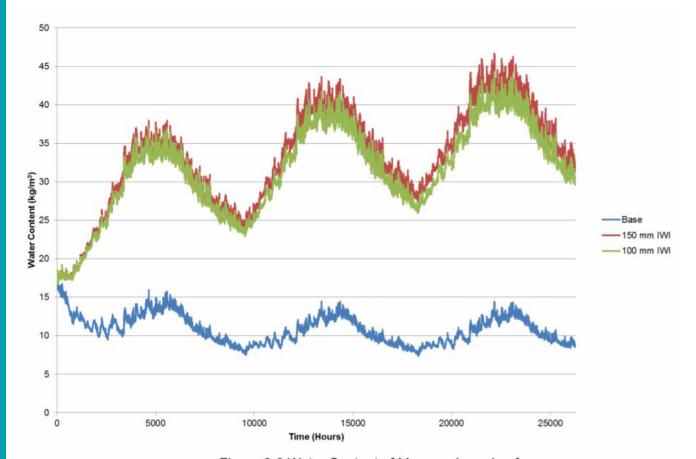


Figure 6-6 Water Content of Masonry Inner Leaf



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Common architectural features can create thermal bridges

Thermal bridging reduces surface temperatures in homes

Roof wall junctions were particularly problematic



Figure 2-1 Thermal breaks introduced to top floor wall/ceiling junctions: pre-1919 terraces and back-to-backs

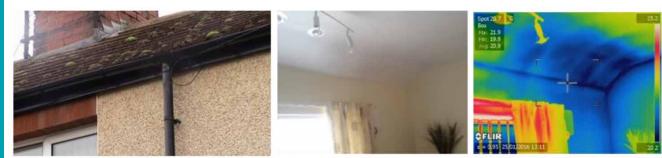


Figure 2-2 Thermal breaks introduced to top floor wall/ceiling junctions: the above three pictures are of the same property and show a typical 1919-1940s solid brick semis and terraces where the top floor is partially in the roof void with a sloping ceiling against the rafters



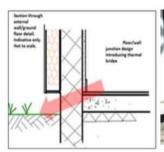
Figure 2-4 Thermal imaging for thermal break at top floor wall/ceiling junction for a 1970s no-fines end terrace



Thresholds, party walls and floor wall junctions were common areas of thermal bridging.

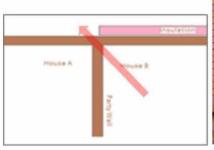
EWI rarely extends below damp proof course

Intermediate floors appeared to not always be insulated







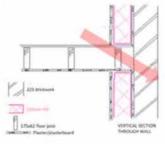


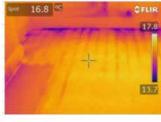














Upcoming projects



TIWI: Thin Internal Wall Insulation (BEIS)

To be published in winter 2020



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Thin Internal Wall Insulation













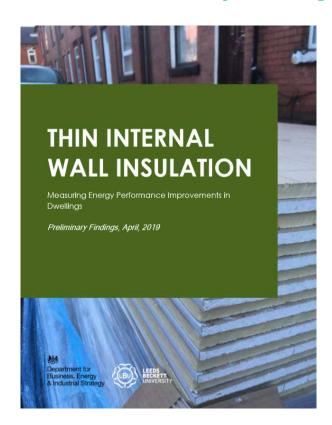


TIWI can reduce risks of condensation

Doubling the insulation thickness between the IWI and TIWI no. 1, only resulted in an additional 13% reduction in U-value and 3% better HTC reductions.

90% of homes require remedial work

TIWI Preliminary Findings



https://www.leedsbeckett.ac.uk/TIWIReport



WHY DO WE NEED THIN INTERNAL WALL INSULATION (TIWI)?

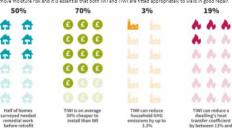
Thin Internal Wall Insulation (TWI) can provide significant energy savings for almost 8 million uninsulated sold wall homes in the U.T. The current solid wall insulation (SWI) market, including retrofits undertaken via ECO, has been focused on installing thicker internal wall insulation (WII) to achieve U values of 0.3 W/m²K. However, this has resulted in low market penetration with only around 7% of ECO restrofits including SWI, meaning fWI accounts for less than 1.8% of ECO measures. In addition, conventional IWI has been found, in some instances, to be disruptive to householders and increases the nix of moisture problems manifesting in homes. TWI may provide a solution to this. If it is asset to insulic heaper, lower fish and still reduce feel bill life solid wall homes.

EVALUATING THE PERFORMANCE OF TIWI

This report presents the preliminary findings from before and after building performance evaluation (BPE) field trials understants to measure the impact of 5 FIIVI and 1 Conventional IVI retroffets. Their impact on thermal bridging and hygrothermal models identified how they affected moisture risk. Dynamic immulsion models predicted the energy demand reductions to evaluate potential carbon and false IVIII saimlings. Cohesting test measured the reduction in the heat transfer coefficient (HTC) measured in W/X, which describes the holistic impact on the home's heating demand. In addition, blower door tests and heat flux measurements quantified the difference that the retroffs had on infiltration (uncontrolled as irestage) and father heat ones, it, wall I value measured in W/mK, respectively. Appraisal of the installation scots and how the TIVI products could overcome installation betriev as understants, supported by surveys in 100 homes to identify inclusion and dwelling characteristics that affected costs or risks, such as requirements to replace plumbing, bollers & radiators, apply decoration or repair damp walls.

FINDINGS

TIWI provides substantial benefits for uninsulated solid wall dwellings at lower cost and reduced risk of condensation, although thicker insulation will provide further energy savings. However, TIWI cannot completely remove moisture risk and it is essential that both IWI and TIWI are fitted appropriately to wall in good repair.





Other projects in the LSI

BEIS, Smart Meter Enabled Thermal Efficiency Ratings (SMETER) **Innovation Programme** 2018 to 2021

EPSRC, Smart Energy Research Lab. 2020 to 2022

NIC, H21: Public perceptions of converting the gas network to hydrogen Social Sciences Study 2018 to 2020

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Demonstration of Energy Efficiency Potential (DEEP) 2019 to 2022

- BEIS funding (£2.7 million)
- Alternative solutions to SWI
- Impact of missing PAS out of whole house retrofit
- Mimic national retrofit journey
- Evaluate deterioration in insulation over time











84 Coheating or QUB tests across 30 dwellings



266 Blower Door & PULSE tests



150 Building Surveys



50 Cavity Inspections



150 Loft Inspections



5 Floor voids monitored



Monitoring indoor air quality in 11 dwellings







