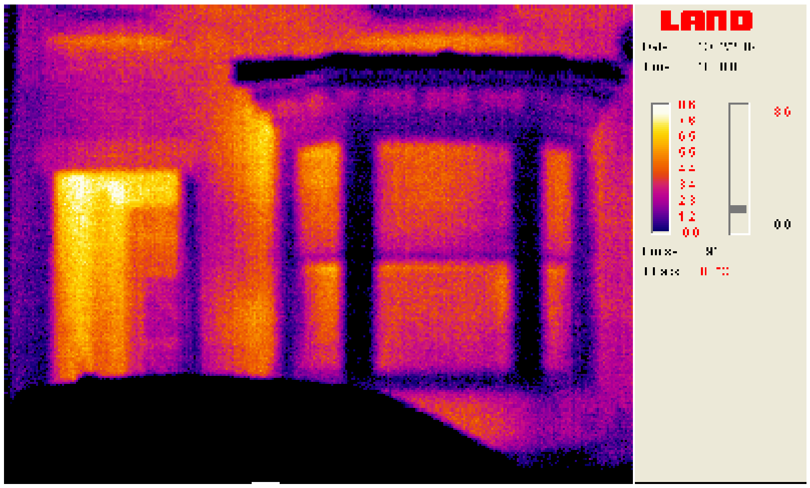

Report on Demonstration Action for Fitting of Doors to Terrace Walk-Throughs

3 June 2010

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Contents

Executive Summary

This work is the result of a Demonstration Action commissioned by SSE plc under the Carbon Emissions Reduction Target (CERT) scheme to determine by practical and calculation means the energy savings, payback and related consideration for *Fitting of Doors to Terrace Walk-Throughs*. This low carbon and energy efficiency measure was proposed by Sheffield businessman and Rotarian John Dunkley who determined, making certain basic reasonable assumptions, a potential CO_2 reduction of up to 1t per annum per walk-through.

An experiment was designed and implemented by E9 Limited with calculations sub-contracted to Buildings Research Establishment (BRE) to test the practicability of the measure and obtain a more accurate carbon saving. This methodology was approved by OFGEM prior to commissioning.

The work produced high quality measured data, based on 8 installations, with data recorded before and after the fitting of the doors. A positive effect on recorded temperature and comfort levels in the walk-throughs was immediately observed in the experimental work.

The elevated temperatures recorded in the walk-throughs over the trial period translate into **carbon savings of 672kg CO_2 per passageway** after deduction of a "15% comfort allowance" and thus this figure is secure and conservative. This corresponds to savings of c. £150 per annum per passageway. We consider the **payback to be no more than 7 years** based on a high end door installation with an average **life expectancy of 35 years** (and up to 100 years[1]).

We discuss in the report how these figures can be refined and improved based on energy efficiency alone or to reduce costs thereby optimising the payback. Utilising softwood doors, for example, can considerably reduce the cost without affecting the energy performance. Thus the payback may be cut at the expense of reduced average life expectancy and an increased requirement for annual maintenance. GRP doors might reduce the payback to c. 4 years and softwood to less.

Consumer decisions in our opinion and experience are likely to be the deciding factor on quality versus pure energy performance in an installation. We examined a range of issues arising from the implementation from the perspective of both our experience as main contractor and from reported and observed consumer preferences.

Considerations including aesthetics, security, maintenance, convenience, agreement between householders, noise, etc are issues observed to impact on consumers decision making. Thus, the payback in this measure, now it is established, is not likely to be the most important issue in deciding the optimum installation where a premium installation may well be selected to meet consumer preferences.

Practical roll out should therefore be sensitive to consumer choice and preferences for greatest penetration. We recommend implementation is based on a sound, solid yet thrifty basic option with a range of customer options presented for a premium.

[1] From "The Life Expectancy of Building Components", BCIS, 2006, ISBN: 978 1 904829 39 3

Introduction

This Demonstration Action was designed to prove the energy saving potential of fitting doors to walk-throughs between terraced houses. The energy saving opportunity was identified by John Dunkley when he noticed that a walk-through with doors fitted at either end was significantly warmer than those without doors.

Initial calculations showed that a saving of approximately 1 tonne CO_2 per annum could be made per walk-through. The total estimated annual potential saving was significant given an estimated 4 million pre-1930s terraced houses in Britain, many of which have walk-throughs.

It was decided to undertake a Demonstration Action to assess the savings and gain CERT approval for the technique.

SSE provided funding for a Demonstration Action which was conducted by E9 Limited on eight terrace walk-throughs in Sheffield. The data from the trial was analysed by Buildings Research Establishment (BRE) using BREDEM methodology to obtain a projected average saving from the fitting of walk-through doors.

This report describes the trial, summarises the findings from BRE and discusses potential energy saving improvements and cost savings.

Description of trial

The trial can be divided into four overlapping phases.

1) Finding properties and recruiting participants.
2) Monitoring of properties.
3) Door construction and fitting.
4) Data collation and analysis.

A brief description and methodology of each of these phases is given in this section. Images of the installed doors and monitoring equipment are included in Appendix 1.

Finding properties and recruiting participants

Initially housing associations were approached, including St Leger in Doncaster and Sheffield City Council, as it was thought that they would own suitable properties and simplify decision making. After investigating the housing stocks available and visiting several properties, however, we were unable to identify suitable properties through single source.

Reasons for unsuitability included:-

- Houses had cavity walls – some housing with walk-throughs was found to have cavity walls in the passageway. This trial was designed to only look at solid wall construction as this was where the biggest benefit would be seen.

- Non-standard construction – houses were constructed from concrete or timber frame and were considered unrepresentative of the general housing stock.

- Walk-through not used – to be representative of most walk-throughs we required that there was some traffic through the passage.

It should be noted that although these houses were not suitable for the trial and would have a different energy saving to the trial houses, they would still benefit and save energy by retrofitting doors to the passageways.

It was decided to change strategy and approach householders directly. This is considered to have been beneficial to the trial although it considerably changed the cost of the recruitment phase. The search was limited to Sheffield as this has a large number of suitable properties in many areas of the city. Recruitment was done through both cold calling on suitable properties and through recommendations.

Approximately 130 houses were visited across Sheffield. Of these 56 expressed an interest and were given full information about the trial. Of these 29 ended up taking part in the trial. 16 as full participants (those with houses either side of the walk-through) and 13 who had access through the walk-through.

From the 56 households that were spoken to about the trial a number of issues were identified as barriers to installing the doors.

These included:-

- Aesthetic objections
  Some People did not think they would like the look of a door on the walk-through. 39% of households raised this as a concern with 11 not proceeding because of it[#].

  [#] Initially the offering this was based on a budget white GRP door c. £400. A high proportion of people had concerns about this including those that accepted the trial. Later the decision was made to use a c. £600 hand built hardwood door. All trialists were pleased with this door as implemented and those that had accepted the trial with white GRP doors were pleasantly surprised when the specification was changed.

- Access for wheelie bins etc
  54% of households raised this as a concern with 4 not proceeding. Many people were concerned that the doors would make moving wheelie bins, prams or bicycles through the walk-through more difficult. To address this concern the doors were made to latch back and are wide enough for easy access.

- Passageway would be dark
  71% of households raised this as a concern with 5 not proceeding. This was a concern for many people even with skylights above the doors. In some passageways, motion controlled LED lighting was fitted to address this concern.

- Maintenance
  A small proportion (8%) of households were concerned about who would maintain the door. A concern was sometimes made that even though it was meant to be a shared responsibility they would end up paying for the upkeep. The maintenance of the doors would have the same responsibility as the upkeep of the passageway itself. One household decided not to proceed because of this issue.

- House for sale
  5% of households approached expected either themselves or their neighbours to be selling their house during the trial period. Concerns were raised about the additional complication the trial would place on the sale. 3 households could not proceed because of this.

- Access for pets
  5% of households raised concerns that access for their cats or dogs from the rear to the front of the terrace would be blocked or made more difficult. In other cases this was seen as a benefit. One household decided not to proceed because of this.

Some of the walk-throughs are the primary means of access for up to six houses. Agreement for the fitting of the doors was sought from all households which had access through the walk-through. There were several cases, where one household refused permission even when their neighbours were keen on participating.

Additionally some of the households approached were tenants and in these cases approval from the property owner was sought.

Recruitment of participants started in December 2009 and continued through January 2010. The last participants signed up at the start of February 2010.

Monitoring of properties

Once the participants had been recruited we were able to install monitoring equipment. This was installed in the participating houses during late January and early February.

IP68 rated IceSpy temperature data recorders and loggers were sourced from Silvertree Engineering Limited. Some of the loggers were modified for the requirements of this trial. To ensure minimum disruption to the participants the monitoring system utilised wireless temperature sensors accurate to 0.1C which reported back to a base station at each trial location. Data from the base station was downloaded remotely via GSM data modem. Data was collated using bespoke software.

After discussions with BRE it was decided to install seven temperature sensors at each trial site to record the following:-

- ambient temperature in the garden at each location on a shaded or north facing wall.
- internal temperature of the two ground floor rooms adjacent to the walk-through in each property.
- two points in the walk-through itself. One near the front and one towards the rear.

After fitting the door opening and closing times was collected via magnetically operated reed switches attached to the wireless data loggers.

Data for hourly wind speed, wind direction and solar radiation was obtained from a Sheffield weather station.

BRE required data from days where the average temperature was below 6C. The start of the year was extremely cold and the first day where the average temperature rose above 6C was not until 13th March 2010. This meant that we were able to collect a good amount of valid data at each location for the period both, with the doors off and, with the doors on.

Valid data was recorded from participant sites on the 28th January 2010 and all sites were being monitored by 9th February 2010. Data was recorded up to 28th March 2010 and supplied as part of the assessment. The equipment was left in place until the data was validated by BRE (in April).

In addition to temperature monitoring the dimensions of each walk-through and the room sizes of each participant house were measured.

Some use of both thermal imaging and portable temperature measurement was made to assess stratification in the corridors and variation to building fabric such as missing plaster and to spot evidence of conductive thermal losses.

Doors Selection

A budget of £600 was created by approaching a commercial door supplier in Coventry. Work was done on value engineering the door selection at the request of the housing associations who suggested some manufacturers of uPVC or GRP doors. These were selected, because they are hard wearing, require little maintenance and have optimum thermal properties per unit cost.

Initial discussions were very positive and a style of door with window above was agreed on. The GRP design was abandoned after surveying the trial sites. It was found that it was not viable to make uPVC/GRP doors to fit many of the sites. There were three main reasons that the properties were not suitable.

1. uPVC/GRP doors require a tie-bar across the bottom of the doorway to hold them square. This is an integral part of the construction. We had agreed on using a low profile bar to ease access. During the survey, many sites were found to have uneven floors. The tie bar would not sit flush to the floor because of the slope or dips in the passageway floor. This presented a significant trip hazard and a barrier to the movement of wheelie bins and prams etc through the doorway.

2. Slopes found on some passageways necessitates profiling of the bottom of the door to match the slope and reduce the gap. The manufacturers were only willing to produce standard, square built, uPVC/GRP doors.

3. Some walk-throughs had utility pipes running along the passageway. Any door had to accommodate these either by adjusting the frame height or fitting panels for them to pass through. Making adjustments to the frames and fitting panelling would have added significantly to the cost and production time of the doors.

The deployment of custom built hardwood doors provided a ready and timely solution to all of the above and was preferred by the triallists. During a rollout of this measure, solutions to these issues can be expected to be found at a cost, however, a swift decision to change was made to ensure the project deadline was not compromised.

Local, Sheffield joinery company (Helliwell Purpose Made Joinery) was selected to provide hardwood doors with windows above. The company was selected on the basis of flexibility, reputation for quality and the ability to construct and fit the doors on time and cost.

The cost of the doors was £1060 ex VAT per walk-through including door and frame manufacture, glazing and fitting. This represents a “premium compromise” solution, however, cheaper solutions may be as effective. See the section *Further savings and cost reduction* for a discussion of this.

The doors were fitted with a Suffolk latch, spring loaded door closer and hook to hold the door open when required. They were installed during the week commencing 22nd February.

Figure 1 – Custom built walk-through door fitted with single glazed toughened glass panel above

Collation and analysis of data and reporting

Data capture continued until the end of March though the average temperatures had risen above 6C by the middle of March.

The data was collated packaged to BRE for validation and processing along with reports describing the properties and the door construction at the end of March 2010.

The monitoring equipment was collected during April following validation from the participant households and exit interviews conducted with fifteen of the sixteen participants. An access payment was made to participating each household.

Findings

Observations

It was observed that the external temperature measurements were strongly correlated as expected and little evidence of micro climates observed in the test sites.

It was observed that many of the households had poor control of temperature and that there was a wide range of heating strategies in place arising from preference, age and lifestyles. There is significant opportunity in this for further work.

Annual saving calculated by BRE

BRE analysed the data to produce a modified U-value for the walls and ceiling of the walk-throughs using standard CERT methodology and the BREDEM model. An average annual saving was determined for a walk-through. The full BRE report is attached as Appendix 2.

The total annual carbon saving from fitting the doors was calculated as 672kg CO_2/yr for each walk-through.

In monetary terms (assuming gas central heating and a cost of 3.5p/kWh to 5p/kWh for gas) the annual saving would be £123.85 to £176.93 per walk-through or £61.93 to £88.46 per household.

Cost and life-time of doors

The premium quality hardwood doors and glazing fitted cost £1060 ex VAT per walkthrough.

The functional lifetime of the doors is far in excess of the manufacturers guarantee on workmanship (typically 2 years) and materials (up to 10 years).

The lifetime average of a hardwood door is 35 years (range 5-100 years)

The lifetime average of a softwood standard flush door is 25 years (range 5-85 years)

Source: "The Life Expectancy of Building Components", BCIS, 2006, ISBN: 978 1 904829 39 3

One of the authors lived in a terraced house where the original hardwood door is still in place approaching 85 years with no sign of decay and these were common to most houses on the street. Thus lifetimes over 100 years may be realistic.

Participant feedback

The monitoring participants[1] were interviewed to gain some feedback on their experience of the trial with the doors. An option to remove the doors was made to all participants. No-one wanted to exercise this option at the end of the survey and title and responsibility to the doors was transferred on completion.

Increased warmth

All participants noticed that the walk-through was much warmer after the doors were fitted. Respondents reported that walk-throughs before the doors were fitted often seem to funnel the wind and several participants noted that there was little draft through the passageway even on windy days.

The two participants who regularly accessed their house through a door in the walk-through said that it had cut down on heat loss each time the door was opened. One of the participants reported changed behaviour using the walk-through door, which opened to the relatively warm now private passageway rather than the rear door which opened directly to elements.

Two of the three participants with doors in the walk-through also said that it had noticeably cut down on the draft around the door.

The doors were not fitted in time for the worst of cold weather. Some difficulty in distinguishing the perceived effects of the doors against the effect of the less cold weather was reported. Two participants said that they thought the house warmed up more quickly in the morning and four participants thought the house was noticeably warmer once the doors were installed. Most participants did not report any change in house temperature.

The survey was not long enough for the participants to notice any change in gas demand. We would expect participants to notice some savings over the next heating season though the effect could be amplified by degree day factors if the coming winter is closer to the recent average.

Security

Twelve of the participants said that they liked the increased feeling of security from the doors. It provided a barrier to prevent people from wandering round to the back of the house.

Increased security was seen as a major attraction of the doors alongside any energy saving.

The doors were supplied with non-locking latches to allow post and other deliveries to be made. Participants at two of the walk-throughs were considering fitting locking catches to the rear door.

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[1] One of the participants was not available for interview at the end of the survey.

One participant expressed a concern about people entering the passageway and not being able to see them until the door was opened.

Aesthetics and usability

The participants were satisfied with the aesthetics of the doors and wanted to keep them without exception.

Seven participants said that handles on the inside of the doors would make them easier to use. The catch on the Suffolk latch was not easy to pull on against the spring closer.

Initially four of the spring-closers were causing the doors to close too quickly causing noise and vibration. Concern was also expressed that this may be a hazard for young children trapping their fingers. The spring-closers selected were adjustable and once set correctly gave a slow close speed with little noise or vibration. The risk of trapping fingers and the potential harm was reduced to the level of any other door.

The doors did not cause a problem when moving items around specifically: no problems were reported in moving wheelie bins out to the road and back, or for users of push-chairs and bicycles.

Lighting

Three of the walk-throughs had energy efficient, motion sensitive lighting installed prior to the trial and this was sufficient once the doors were installed.

The level of light within the passageway was a concern for all the participants who did not already have lights fitted. Of these, three walk-throughs have fitted some lighting in the passage and the other two are considering fitting lighting.

Further savings and cost reduction

In the following section, we discuss some of the methods which might improve the energy saving from fitting walk-through doors and look at ways of reducing the cost of the doors.

Improving energy saving

From the BRE calculations energy loss has been reduced from 735W average per walk-through to 305W. This means that energy loss is reduced by 58.5% already.

Draft proofing

The main heat loss from the walk-through is from convection to air. Heat loss from conduction to the ground and radiation of heat are small in comparison and are not affected by the fitting of the doors.

The main heat saving effect of fitting the doors is therefore to reduce the flow of air through the passageway. To accommodate the slopes and dips of the floor there was a significant gap at the bottom of some of the doors. It is estimated that by reducing this gap at one end of the walk-through the through draft would be further reduced and the saving increased by 3% to 10%. This estimate would have to be verified through further trials.

This could be achieved with civil works or retrofitting e.g. a brush. The methods of reducing this gap which were considered included a. levelling of the floors (which was discounted on the grounds of cost and practicality), and b. fitting brush strips to the bottom of the doors. The fitting of brush strips on the doors was not undertaken because of limitations within the trial and the experience of the door manufacturers as they would have complicated door construction and fitting and potentially caused problems with opening and closing of the doors. There was not enough time in the trial to assess and fix any such issues. Changes are expected to increased the cost of the doors by approximately £15 to £25 per door.

Door insulation

The current doors are constructed of solid hard wood panelling of approximately 25mm thickness and the glazing above is single glazing. It is calculated that of the 305W being lost after the doors are fitted 200W is conducted through the doors and glass. The rest is lost through drafts and when the doors are opened and closed.

There is potential, through additional measures e.g. double glazing and improving the door insulation, to reduce the heat loss further (by c. 50%) and an additional 180kg CO_2/yr saved.

Double glazing the glass panel was estimated to add £200 per walk-through to the cost. In addition to double glazing, improving the insulation of the doors was discussed with the joiner and two ideas investigated. A laminated glass may offer some improvements and a marginally increased cost.

1. The first potential solution was to simply add another layer of boarding to double the thickness of the door and nominally halve the heat loss. It was estimated that this would add £400 to the cost of each walk-through.

2. The second solution was to sandwich a layer of insulating foam between the current panel and a thin board backing. This was estimated to add £300 to the cost for each walk-through.

So for an extra £500-£600 per walk-through it is estimated that an additional 180kg CO_2/yr could be saved.

It should also be noted that different door constructions – uPVC/GRP, softwood, glazed panels etc will all have different savings from thermal conduction. These can be assessed through their U values. A softwood door would be expected to have similar or slightly better energy performance to hardwood (as it is less dense) and be less expensive. This comes with compromises on life expectancy and maintenance.

Reduction in door cost

The doors fitted for the trial were a premium quality hardwood door from a small joinery company, a bulk contract may well reduce the manufacturing and material costs. They were selected on grounds of quality, longevity and the ability of the company to deliver on a tight schedule. The cost of the doors was not the most important factor.

As the major saving is from reducing the air flow through the walk-through a proportion of the benefit could be achieved with plastic stretched over a frame, however inexpensive this solution might be it would not be expected to be popular despite having a rapid return on investment.

This means that almost any door construction that significantly reduces the air flow will make a significant saving. If a decision to fit the doors is purely on the basis of maximum energy saving per pound spent then it is estimated that doors could be fitted for approximately 50% of the cost.

The most important consideration for any householder appears to be the aesthetics of the door and they will mostly pay a premium for the door they want.

Other considerations will be the security of the door, lifetime of the door, maintenance requirements and energy saving potential. Different householders will prioritise these in a different order.

Conclusions

The experiment designed and implemented by E9 Limited with calculations using the BREDEM model undertaken by subcontractor BRE (report see Appendix 2) was successful in proving the efficacy of the measure for fitting doors to walkthroughs in solid wall period housing.

High quality measured data was gathered at 8 installations between 16 monitored properties. The data recorded include before and after to eliminate confounding variability based on e.g. occupancy and lifestyle.

A positive effect on recorded temperature and comfort levels in the passageways was immediately observed in the experimental work. These elevated temperatures recorded in the passageways over an extended trial period translate into **carbon savings of 672kg CO_2 per passageway** based on the CERT methodology.

This corresponds to average savings of £61.93 to £88.46 per annum per household (£123.85 to £176.93 per walk-through).

The payback to be 7 years based on a high end door installation (a cost of £1,060 per fitted door pair (ex VAT and custom built in hardwood) with an average life expectancy of 35 years (and up to 100 years).

These figures can be refined and improved based on energy efficiency alone and also to reduce costs and so optimising the payback.

Utilising softwood doors, for example, can considerably reduce the cost without affecting the energy performance. Thus the payback may be cut to c. 3-4 years. The average life expectancy of the doors would become c. 25 years with maintenance.

A wide range of consumer objections and concerns were observed based on door construction, noise, pet access, aesthetics, security, maintenance, convenience, maintenance, trust etc.

Consumer preference and decisions related to the above in our opinion and experience are expected the deciding factor on undertaking an installation. The absolute savings potential and also the payback to be achieved in an installation is strongly dependent on the quality of the doors. The "right choice" is involves a "complex optimisation" of many factors and considerations. Once a payback has been established the most important issues in deciding the quality of the final installation is a trade off of the factors. We consider the evidence points to aesthetics being the dominant factor.

Thus, to make this work effective a range of solutions will be required. The simplest offer is to present a "plain vanilla option" as the basic efficiency measure perhaps a softwood or plastic construction and allow this to be customised by the consumer for a premium top up cost e.g. Hardwood, Low U value, double glazed, chrome door furniture, cat flap etc.

Appendix 1 – Images of door installation

Images of typical door installation and monitoring.

<table>
<tr><td></td><td>SSE Door Project

External Installation showing the stained Hardwood Door hand built for the job

Penistone Road Sheffield</td></tr>
<tr><td></td><td>SSE Door Project

IceSpy wireless monitoring unit wired to a door sensor to detect opening times</td></tr>
<tr><td></td><td>SSE Door Project

Close up of the door sensor</td></tr>
</table>

<table>
<tr><td></td><td>SSE Door Project

Light installed in the passage with motion sensor

Passage above showing plaster damage with exposed laths.

This may change the heat transfer from above and can be examined with thermal imaging</td></tr>
<tr><td></td><td>SSE Door Project

Arched passageway.

This architectural feature was found on two of the monitored walk-throughs.

These reduced the walk-through roof area and increased the thermal mass of the passageway but had little noticeable affect on the results.</td></tr>
<tr><td></td><td>SSE Door Project

IceSpy door sensor prior to final installation</td></tr>
</table>

	**SSE Door Project** External sensor location
	**SSE Door Project** Close up of external sensor location. Locations picked as far as possible to be on north facing walls. Out of direct sunlight to avoid solar heating effects giving false air temperatures
	**SSE Door Project** Installation rear door. All doors open inwards.

	**SSE Door Project** The passage ways are not perfectly square some air ingress is to be expected.

Appendix 2 – BRE Report

BRE report.

bre

CERT Savings for Terrace 'Walkthroughs'

Prepared for: John Trainor
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2nd June 2010

Client report number 253627

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Executive Summary

A 'Walk-through', 'Ginnel', 'Snicket', or 'Entry' may refer to a passageway dividing two terraced houses on ground floor level, with the upper floor of one or both houses forming a roof over the passageway. These passageways are often completely open front and back, allowing heat from the houses on either side to flow directly to the external environment.

It has been proposed that doors be installed at both ends of these passageways, reducing the rate of heat loss from the walls and roof of the passageway. The aim of this report is to quantify savings that may be attributed in the CERT (Carbon Emissions Reduction Target) scheme. This may be done by using BREDEM (BRE Domestic Energy Model) with standard methodology for CERT as appropriate, together with monitored temperature and other information relating to a number of these passageways. The required data and information was specified in discussion with BRE and Ofgem, and monitoring was undertaken between January and March 2010. This has been provided to BRE in the form of commendably high quality reports and temperature data.

The reports indicate that the monitored houses are from a variety of locations (i.e. not all of the same design in a single row of terraces), and as far as can be judged, are representative of terraced housing built around the end of the 1800s and start of the 1900s. All the houses are in Sheffield, but seem representative of this type of terraced housing, found in many parts of the country. Various other data and information is examined in this report and found to be acceptably varied and, as far as can be judged, representative.

The savings calculated in this report apply only to passageways with 9" brick construction with no internal or external insulation. They apply to passageway doors which are similar (in terms of characteristics which prevent heat loss, including a self-closing mechanism) to those described in one of the reports provided. The savings relate to a heat loss area which is an average of the 8 passageways monitored. Use of the savings for a CERT scheme would imply that this heat loss area is representative of the passageways in the CERT scheme. Sensitivity testing shows that the saving is proportional to this heat loss area (as would be expected). The thermal properties of the 8 passageway roofs vary, some being insulated, but again use of the savings for a CERT scheme would imply that this variation is representative of the CERT scheme passageways. (The area of the roofs is about a fifth of that of the wall heat loss areas, and will have proportionately less effect on the saving).

After applying the CERT methodology of a weighting for different heating systems (with oil central heating excluded since it will be rare in terraced housing), and a reduction of 15% 'comfort factor', gives

- **a saving of 672 kgCO_2/yr for installing doors at each end of a passageway.**

Contents

1 Introduction

Some areas of terraced housing have 'walk-throughs', sometimes also known as a 'Ginnel', 'Snicket' or 'Entry'. This is a passageway between two houses by which the rear can be accessed, with the upper floor of one or both houses forming a roof to the passageway. Some 'walk-throughs' have doors in the passageway wall giving access to the house (these are referred to as 'house doors' in this report).

Such passageways are often completely open front and back, allowing heat from the passageway walls and roof to flow directly to the external environment. It has been proposed that doors be installed at both ends (referred to as 'passageway doors' in this report), thus reducing the rate of heat loss from the walls and roof of the passageway.

The aim of this report is to quantify savings that may be attributed to the installation of these doors, suitable for use in the CERT (Carbon Emissions Reduction Target) scheme. This may be done by using BREDEM (BRE Domestic Energy Model) with standard methodology for CERT as appropriate, together with monitored temperature and other information.

Following discussions with BRE and Ofgem about the method of evaluation and data required, the following data was specified, and collected between January and March 2010.

- Dimensions of passageway: height, depth, width
- Construction of walls (e.g. brick), thickness of wall, and confirm no cavity
- Construction of roof to the passageway and floor of the room above, and particularly the presence of any underfloor insulation
- Rooms bounding the passageway in the house each side (e.g. living room, kitchen, hallway/stairs), and over the top (e.g. bedroom or bathroom).
- Heating system and fuel in the house each side.
- Any positioning of heaters/radiators in rooms/halls next to walls of passageway
- Description of houses, approximate year built, photographs
- Number of houses and number of passageways in the row of terraces

Temperature logging for each passageway:

- Hourly for a minimum of one week
- External temperature must be less than 6^{o}C for at least part of the week; preferably the average temperature over the week should be less than 6^{o}C, but there should be with at least two days with the 24hr averages less than 6^{o}C.
- (a) inside the houses on both sides, (b) in the passageway, (c) external air temperature, ensuring sensors are not directly influenced by heaters inside or the sun outside.
- Data collection for at least 8 passageways (i.e. 16 houses) from different rows of terraces (a) without passageway doors (preferably before installation), and (b) with passageway doors.

Additional information from the two houses on each side that would be useful but not essential:

- Usual heating hours (times on and off) on weekdays, and on weekends
- Number of adults, children, approximate ages

In addition there should be a clear description of the passageway doors, indicating their airtightness by describing their construction, and relevant details e.g. sealing around the edges, rising hinges or other methods to ensure the walk-through door closes.

This information was provided to BRE in the documents and spreadsheet listed in Table 1. It is of a commendably high quality with excellent detail, clarity, and useful photographs.

CERT Trial Location Summary – Passageway 1	pdf document
CERT Trial Location Summary – Passageway 2	pdf document
CERT Trial Location Summary – Passageway 3	pdf document
CERT Trial Location Summary – Passageway 4	pdf document
CERT Trial Location Summary – Passageway 5	pdf document
CERT Trial Location Summary – Passageway 6	pdf document
CERT Trial Location Summary – Passageway 7	pdf document
CERT Trial Location Summary – Passageway 8	pdf document
CERT Trial – Passageway Door Construction	pdf document
CERT Trial – Notes on Data	pdf document
BRE_Master_1hr_Data.xlsx	excel spreadsheet

Table 1. List of documented information

2 Description of the project

In CERT it is recognised that it is not practical to calculate the savings for each individual energy saving measure and dwelling. Because of this, savings are calculated using 'typical' dwellings and parameters; for example, a set of standard dwelling types and sizes is used to represent the range of dwellings in the stock for insulation measures. A wide variety of other parameters are also standardised (e.g. typical heating system efficiencies, typical heating on/off pattern, demand and external temperatures). These are described in detail in the CERT Technical Manual (1). In reality the energy consumption and savings in an actual dwelling will in some cases be greater than that calculated, and in other cases smaller than that calculated. The CERT savings calculated represent a 'typical' value for the measure between these extremes, and provide a standardised basis on which to compare the reduction in CO_2 emissions resulting from each of the measures.

In discussion with Ofgem it was proposed that the savings from installing passageway doors could be calculated in a way which was consistent with this CERT methodology as follows. The savings are calculated using BREDEM with the standard mid-terrace dwelling, which of course has a heat loss wall area to the front and back of the dwelling. The presence of the passageway is accounted for by adding:

(a) an additional heat loss area to represent one of the passageway's walls,

(b) a heat loss area to represent half of the passageway roof (above which is part of the upper floor).

The effective U-values for these areas are derived from the monitored temperature data. The energy savings are calculated for a single house, then doubled to give the total savings – this accounts for the installed passageway doors affecting two dwellings, one on each side of the passageway.

In this way, the savings will be correctly related to the heat loss area and improved thermal performance resulting from installation of the doors, using CERT 'typical' parameters (such as typical heating system efficiencies, typical heating on/off pattern, demand and external temperatures).

The house is modelled as a solid (no cavity) masonry wall dwelling (U-value 2.1 W/m^2K), while the roof remains at the 'typical' U-value used in CERT calculations. The use of the standard CERT mid-terrace dwelling gives a similar match to the dwellings being considered for this measure. The calculated saving will be largely independent of the size or shape of the dwelling (other than the size of the passageway heat loss areas) so it is unnecessary for it to be an exact match.

2.1 Additional heat loss wall area

The relevant heat loss wall area is that which is common to

- the heated rooms in the house
- the passageway wall.

Parts of the wall which are below the dwelling internal floor level, or which are above the level of the passageway roof, are therefore not included. This heat loss wall area is calculated from the following information which is taken from the 'Passageway 1 to 8' reports listed in Table 1.

- 'Layout Ground Floor' table with the height of the rooms on each side of the passageway
- 'Passageway dimensions' figure (sometimes with key information in the caption) and table with height and length of the passageway.
- Photographs also give useful information, particularly as to whether the dwellings on each side of the passageway are on a similar, or significantly differing, level.

The length of the heat loss area is the same as the passageway length, while the height of the heat loss area is interpreted from the above information. Table 2 gives the resulting passageway wall heat loss areas.

	A	B	C	A x B	A x C
Passageway no.	**Passageway length (m)**	**H1 Internal height (m)**	**H2 Internal height (m)**	**H1 wall heat loss area (m^2)**	**H2 wall heat loss area (m^2)**
1	8.84	2.85	2.85	25.2	25.2
2	9.00	2.4	2.4	21.6	21.6
3	8.74	2.425	1.8	21.2	15.7
4	8.86	2.54	2.54	22.5	22.5
5	8.85	2.7	2.7	23.9	23.9
6	9.16	2.7	2.7	24.7	24.7
7	8.85	2.54	1.85	21.2	16.4
8	7.50	2.54	2.54	19.1	19.1

Table 2. Passageway wall heat loss areas. H1 and H2 refer to the houses on each side.

(H1&H2) Average: 21.8 m^2 *Maximum 25.2 m^2 (+16%) Minimum 15.7 m^2 (-28%)*

2.2 Additional heat loss roof area

To correctly account for the passageway roof, half of the roof area is used for the CERT calculations. The effect of this is to associate with each terraced house an additional heat loss area which is the passageway wall area (a) and half the passageway roof area (b).

	A	D	A x D / 2
Passageway no.	**Passageway length (m)**	**Passageway width (m)**	**Roof heat loss area (m^2)**
1	8.84	1.05	4.64
2	9.00	1.02	4.59
3	8.74	1.06	4.63
4	8.86	1.05	4.65
5	8.85	1.10	4.87
6	9.16	1.08	4.95
7	8.85	1.03	4.56
8	7.50	1.06	3.98

Table 3. Passageway roof heat loss area. ***Average (of half of roof area): 4.61 m^2***

2.3 Heating systems and BREDEM zones

During the development of BREDEM in the 1980s, the optimum number of temperature zones for calculating space heating energy consumption was found to be two. Zone 1 is the living area and is attributed a higher demand temperature than zone 2, which is the rest of the dwelling. During development of the CERT methodology in 2007 the temperatures, and proportion of the dwelling, attributed to each of the two zones were derived, such that the average internal temperature was consistent with estimates of that in the stock.

In CERT methodology, four central heating and three non central (or room) heating systems are modelled (Table 11). The zoning, and the implications for the passageway heat loss areas, is as follows.

For central heating systems, zone 1 is 50% of a terraced house. The living area, zone 1, is the ground floor, while the upper floor is zone 2. It follows that the passageway wall area (a) should be attributed to zone 1.

For non-central (i.e. room) heating, zone 1 is 25% of a terraced house, and is half of the ground floor. The other half of the ground floor together with the upper floor forms zone 2. . It follows that for these heating systems, half of the passageway wall area (a) should be attributed to zone 1, and half to zone 2. (In reality this will vary in individual houses, but this attribution will give an average or representative result).

For all heating systems, it follows that the passageway roof area (b) is zone 2.

3 Findings

All the monitored passageways are in Sheffield, and from the photographs and descriptions would appear to be typical of UK terraced housing. Their approximate construction dates range from 1885 to 1911. They are from different rows of terraces, and oriented in a variety of directions (Table 4). Only two are in the same road, and these are on opposite sides of the road. It can also be seen from the photographs that they are from a variety of different rows of terraces, as required in the specification.

All except one of the houses has gas central heating, as would be expected for a representative sample of dwellings (see weighting in Table 11). In addition most of the houses' occupants use an intermittent morning/evening heating pattern; this is consistent with other data for the whole housing stock data and is again representative.

		(NNW is equivalent to SSE etc.)			
Passageway no.		**Orientation front of house**	**Orientation nearest North**	**Heating pattern H1**	**Heating pattern H2**
1	Haughton Rd	SSE	NNW	am/pm	all day
2	Providence Rd	NNW	NNW	am/pm	am/pm
3	Hawksworth Rd	NW	NW	am/pm	all day
4	Upper Valley Rd	N	N	am/pm	am/pm
5	Upper Valley Rd	SSE	NNW	am/pm	as required
6	Penistone Rd N.	ENE	ENE	am/pm	as required
7	Lister Rd	WNW	WNW	am/pm	am/pm
8	Woodview Rd	SSW	NNE	am/pm	all day

Table 4. House locations, orientations, heating patterns

3.1 Passageway wall construction

All the passageways are of 9" brick construction. In passageway 2, one wall is rendered with 25mm concrete; this will have a minimal effect on the thermal transmittance. The savings calculated in this report apply only to passageways of 9" brick construction with no internal or external insulation (or a construction with similar thermal transmittance).

Passageway 2 has a house door on both sides, one occasionally used, the other not used. Passageway 7 has a house door on one side, which is used as the main access to the house. The presence of a house door in the passageway will in general give the passageway wall a poorer thermal performance overall. It may therefore result in a small increase in the savings from installing a passageway door. However, data from two passageways is insufficient as a basis for any separate results.

3.2 Passageway roof construction

Passageway no.	Passageway roof construction	Passageway roof insulation	Passageway roof condition
1	hardboard	100mm fibreglass	good condition throughout.
2	plasterboard	not thought to be	moderate condition throughout.
3	plaster over wooden lathes	no insulation	approx. 5% of plaster missing exposing lathes, joists, floorboards.
4	12mm ply	150mm fibreglass	good condition throughout.
5	plasterboard nailed to joists	no insulation	moderate condition.
6	plaster over wooden lathes	no insulation	approx. 50% of plaster missing exposing lathes, joists, floorboards.
7	plasterboard nailed to joists	no insulation	good condition.
8	plaster over wooden lathes	no insulation	good condition.

Table 5. Passageway roof construction, insulation, and condition

It can be seen from Table 5 that the thermal performance of the passageway roofs will be variable. Passageways 1 and 4 have roofs insulated with fibreglass. Passageways 3 and 6 have roofs with areas of plaster missing, exposing the floorboards above, and these will have poorer thermal performance, though this will be offset slightly by the presence of two brick arches supporting the roof. (It can be seen from photographs that the arches only affect a small area of wall, and will have little effect on wall heat loss). The other four passageways have roofs that are in good condition and which are not insulated.

3.3 U-values and heat loss

The U-values of interest are:

- wall between house 1 and passageway
- wall between house 2 and passageway
- passageway roof to dwelling(s) above

The wall construction between the houses and the passageway is 9" solid brick, which has a U-value of 2.1 W/m²K.

The roof constructions are mostly uninsulated, although insulated in two of the passageways. The U-values shown in Table 6 were used for the analysis.

Passageway no.	Roof insulation	U-value W/m²K	Comment
2, 5, 7, 8	None	1.47	
3, 6	None	2.0	estimate with missing plaster
1	100 mm	0.42	
7	150 mm	0.30	

Table 6. Passageway roof U-values

The analysis of the effect of the passageway doors was based on the temperature readings (within the houses, within the passageways and external in the back gardens). The readings were recorded hourly, for a period of about four weeks without passageway doors and for about eight weeks with passageway doors. Average values of the temperature sensors were obtained for each sensor, before and after installation of the passageway doors. There were a few missing readings but they are small in number and the averages were obtained omitting any missing data.

The average temperatures measured at the front and back of the houses were averaged to represent the temperatures within the houses. Similarly the average temperatures measured at the front and rear of the passageways were averaged to represent the temperatures within the passageways. These averages are shown in Table 7.

	Without doors				With doors			
Passageway no.	**H1 °C**	**H2 °C**	**passage-way °C**	**external °C**	**H1 °C**	**H2 °C**	**passage-way °C**	**external °C**
1	17.3	17.1	3.7	1.8	18.1	18.4	13.5	6.0
2	19.3	15.8	5.7	1.9	20.3	17.5	14.5	6.0
3	18.2	22.2	7.3	2.2	17.8	22.4	13.7	5.8
4	14.0	12.9	3.7	2.0	16.1	13.4	10.5	5.6
5	20.2	13.9	4.0	2.1	19.9	15.9	12.8	5.5
6	16.0	17.9	4.4	2.0	17.5	18.5	12.4	5.7
7	16.3	20.5	4.6	2.1	18.3	21.1	13.7	5.8
8	14.3	20.8	4.1	2.1	16.2	21.2	13.9	5.9
average	16.9	17.7	4.7	2.0	18.0	18.6	13.1	5.8

Table 7. Average temperatures. H1 and H2 refer to the houses on each side.

The temperature in the passageways is higher than the external temperature because of the sheltering effect of the passageway. The sheltering effect is greatly enhanced when the passageway doors are in place, as indicated by the average passageway temperature relative to external temperature. To provide a means of taking account of this in calculations of energy use, the data in Table 7 were used to obtain effective U-values for the building elements between the houses and the passageways. This effective U-value is the heat loss rate (per unit area and unit temperature difference) from the house to the external environment inclusive of the sheltering effect of the passageway.

The heat loss rate from the dwellings to the passageway is

$$Q = A_{w1}U_{w1}(T_1 - T_p) + A_{w2}U_{w2}(T_2 - T_p) + A_{r1}U_{r1}(T_1 - T_p) + A_{r2}U_{r2}(T_2 - T_p) \qquad (1)$$

where A is area, U is U-value and T is temperature. The suffices are w for wall, r for roof, 1 for house 1, 2 for house 2 and p for passageway.

All quantities on the right-hand side of equation (1) are known, allowing Q to be calculated for each passageway.

The heat loss rate from the houses can alternatively be expressed as

$$Q'' = A_{w1}U''_{w1}(T_1 - T_e) + A_{w2}U''_{w2}(T_2 - T_e) + A_{r1}U''_{r1}(T_1 - T_e) + A_{r2}U''_{r2}(T_2 - T_e) \qquad (2)$$

in which T_p has been replaced by T_e (external temperature) and U" represents an effective U-value for the element concerned between the house and the external environment, i.e. taking account of the sheltering effect of the passage. U" is taken as being of the form

$$U'' = 1/(1/U + R_p)$$

where R_p is an effective thermal resistance introduced by the passageway, assumed to be the same for each element.

The data were analysed for each passageway, without and with doors, by obtaining the value of R_p such that Q" = Q.

The results are shown in Table 8.

	Without passageway doors			With passageway doors		
Passageway no.	**R_p**	**U" for walls**	**U" for roof**	**Rp**	**U" for walls**	**U" for roof**
1	0.068	1.84	0.41	0.771	0.80	0.32
2	0.157	1.58	1.19	0.953	0.70	0.61
3	0.199	1.48	1.43	0.652	0.89	0.87
4	0.084	1.79	0.29	0.565	0.96	0.26
5	0.072	1.82	1.33	0.705	0.85	0.72
6	0.093	1.76	1.69	0.566	0.96	0.94
7	0.090	1.77	1.30	0.683	0.86	0.73
8	0.076	1.81	1.32	0.821	0.77	0.67
averages	**0.105**	**1.73**	**1.12**	**0.714**	**0.85**	**0.64**

Table 8. Effective U-values

The results for each passageway are reasonably consistent, and the average U-values shown in the last row of Table 8 are appropriate for energy analysis.

The number of minutes that the passageway doors were open was recorded for each hour of the test period. Average values ranged for 1.4 minutes to 4.4 minutes for the eight passageways. There is no reason to suppose that this is not representative of passageways with self-closing doors.

The effect of the passageways on heat loss is expected to depend on wind conditions, as air movement through the passageway will tend to make the passageway temperature closer to external. The passageway temperature is not well correlated with wind recorded at a local weather station (see Appendix A) probably because of the influence of local topography on the wind conditions in the immediate vicinity of the passageway. However the average wind speeds during the two test periods, 6.3 m/s without doors and 6.2 m/s with doors, are very similar (Table 9). It is therefore reasonable to assume that the collected data are representative of long-term average conditions.

	Without doors			With doors		
Passageway	**minimum**	**average**	**maximum**	**minimum**	**average**	**maximum**
1	0.0	6.0	18.5	0.0	6.2	27.4
2	0.0	6.3	21.3	0.0	6.2	27.4
3	0.0	6.9	26.6	0.0	6.1	27.4
4	0.0	5.5	18.5	0.0	6.3	27.4
5	0.0	5.8	18.5	0.0	6.3	27.4
6	0.0	6.8	26.6	0.0	6.2	27.4
7	0.0	6.9	26.6	0.0	6.1	27.4
8	0.0	6.2	21.3	0.0	6.2	27.4
Average	0.0	6.3	22.2	0.0	6.2	27.4

Table 9. Wind speeds (m/s) during the test periods

It is also important that the data cover a suitable range of external temperature conditions as would be encountered in normal winter conditions. Both test periods (without and with doors) cover such a range, as summarised in Table 10. The average temperature during the period with the doors fitted is significantly higher than that for the period without doors, but that does not affect the validity of the results since the analysis was based on the actual temperatures recorded in each test period.

	Without doors			With doors		
Passageway	**minimum**	**average**	**maximum**	**minimum**	**average**	**maximum**
1	-2.5	1.8	7.4	-3.9	6.0	18.6
2	-2.5	1.9	6.6	-4.1	6.0	15.1
3	-3.7	2.2	11.1	-6.0	5.8	15.2
4	-3.6	2.0	7.4	-6.3	5.6	14.5
5	-3.5	2.1	7.9	-6.0	5.5	15.0
6	-3.2	2.0	10.2	-4.5	5.7	14.6
7	-2.8	2.1	7.6	-4.8	5.8	15.4
8	-2.8	2.1	7.3	-4.8	5.9	15.4
Average	-3.0	2.0	8.2	-5.1	5.8	15.5

Table 10. External temperature (°C) during the test periods

4 Conclusion

Savings are calculated as described in the previous sections using:

- a standard CERT mid-terrace dwelling with BREDEM
- additional heat loss areas representing the passageway wall and roof heat loss areas
- U-values for these heat loss areas to represent 'before' and 'after' installation of the passageway doors
- other standard CERT parameters representing 'typical' values (e.g., typical heating system efficiencies, typical heating on/off pattern, demand and external temperatures)

In CERT methodology, each of the seven heating systems in Table 11 is modelled. In principle, it would be possible to identify the heating systems appropriate for each pair of dwellings associated with the installation of a passageway door and to apply specific saving. However, in practice a weighted average of the seven calculated savings may be used in CERT using a 'weighting' for the heating systems as given in Table 11. We suggest that it would be more practical to use a single weighted average saving.

One issue that should be considered is that the installation of these passageway doors is only relevant to terraced dwellings, and not the whole housing stock. The seven heating systems in Table 11 are likely to be found in similar proportions in terraced dwellings, except for oil central heating. This normally requires outside space for a storage tank, and is more commonly associated with larger houses in rural areas. The effect of removing this from the weighted average is considered in the calculations. Table 11 also gives the standard fuel coefficients which are used in CERT for converting delivered energy to CO_2 savings.

Heating system	Weighting	Weighting no oil	CO_2 coeff. $kgCO_2/kWh$
Gas central heating	84.24%	90.59%	0.1899
Electric storage heating	5.48%	5.89%	0.4308
Oil central heating	7.01%	-	0.2493
Coal central heating	0.72%	0.77%	0.2996
Gas non-central heating	1.34%	1.44%	0.1899
Electric non-central heating	1.07%	1.16%	0.4308
Coal non-central heating	0.14%	0.15%	0.2996
	(total 100.0%)	(total 100.0%)	

Table 11. CERT heating systems, weighting and CO_2 coefficients

Of the various energy end uses in a house (space heating, water heating, lights, appliances) the installation of passageway doors only requires consideration of space heating energy consumption. Table 12 shows the space heating energy values and resulting CO_2 saving. Following a review of a number of research papers in 2007, savings in CERT that related to improved thermal performance of fabric are normally reduced by a 'comfort factor' of 15%. This is to account for the way in which some of the saving may be taken by occupants as an improved heating standard, rather than as a reduction in energy use.

Heating type	Space heating consumption kWh/yr before	after	saving (x2)	CO_2 saving kgCO_2/yr	less 15% kgCO_2/yr
Gas CH	15533	13626	3814	724	616
Electric Storage	15348	13494	3708	1597	1358
Oil CH	15046	13214	3662	913	776
Coal CH	26730	23518	6423	1924	1636
Gas nCH	15285	13331	3907	742	631
Electric nCH	9148	7981	2333	1005	854
Coal nCH	26106	23007	6198	1857	1578

Table 12. Energy and CO_2 savings ('before' and 'after are per individual house, savings are x2 to account for the passageway doors affecting two houses)

Applying the weighting for the seven heating systems, gives an overall value of 679 kgCO_2/yr. However, as discussed above, it would seem appropriate to remove oil central heating from the mix since it is thought this will be rare in these terrace houses.

This gives a saving of 672 kgCO_2/yr.

The savings apply only to passageways of 9" uninsulated brick construction, where installed passageway doors are similar (in terms of preventing heat loss, including a self-closing mechanism) to those described in one of the reports provided. In addition, use of the savings for a CERT scheme would imply that the passageway heat loss area used in these calculations is representative of those in the CERT scheme.

The sensitivity of this result may be tested in relation to the passageway heat loss area. Table 2 indicates variability in the passageway wall heat loss area around the average of +16% to -28%. Table 3 indicates that the variability of the passageway roof area is much less. (The much higher variability of the former is due to the variation in the wall heat loss height, which is not the height of the passageway, as discussed).

Heat loss area	CO_2 saving kgCO2 /yr	+ %
+25%	841	25.3%
0%	672	
-25%	501	-25.5%

Table 13. Sensitivity to passageway heat loss area

The values in Table 13 suggest that the CO_2 saving is nearly proportional (at least for the small range of values calculated) to the passageway heat loss area, as might be anticipated. Thus for the CO_2 savings to be within e.g. 25% of the value calculated above, in a CERT scheme the average of the passageway heat loss areas will need to be within 25% of the heat loss area used in this calculation (which is of course derived from the eight passageways which have been monitored).

References

(1) Carbon Emissions Reduction Target (CERT) 2008-2011 Technical Guidance Manual. June 2008. www.ofgem.gov.uk/Sustainability/Environment/EnergyEff/InfProjMngrs/Pages/InfProMngrs.aspx

Appendix A – Dependence on wind speed

It would be expected that the sheltering effect of the passageway would be affected by wind speed. This is examined by considering the passageway temperature relative to the house and external temperatures, i.e.

$$(T_{passage} - T_{external}) / (T_{house} - T_{external})$$

Figure A1 shows the relative temperature of passageway 8 without doors plotted against wind speed measured each hour at a local weather station. There is a slight downwards trend (the expected behaviour) but the correlation is poor.

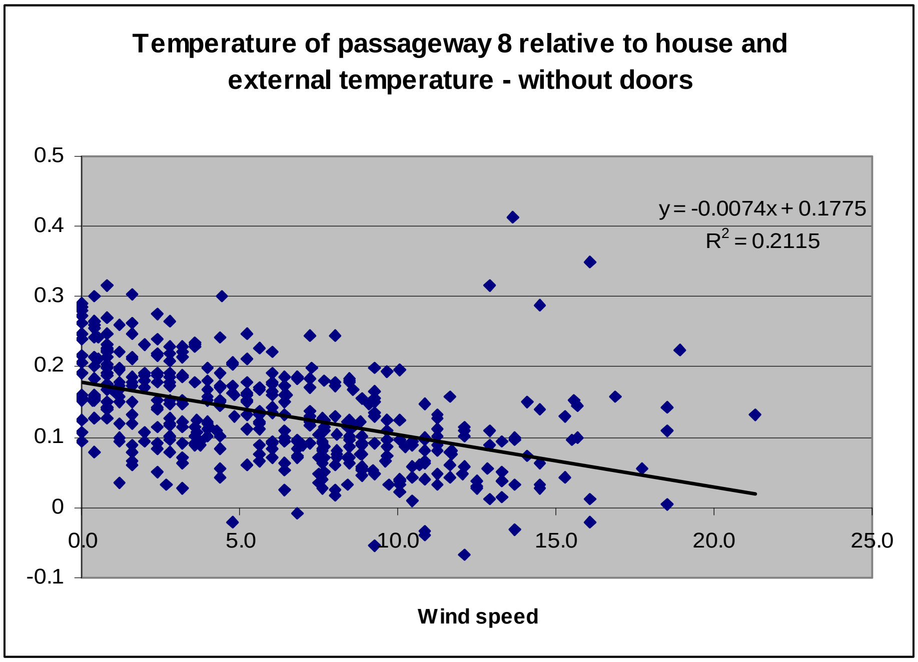

Figure A1.

Plotting the relative passageway temperature against the component of wind speed in the direction along the passageway is similar, Figure A2, although the correlation is actually slightly worse (as indicated by R^2 on the chart).

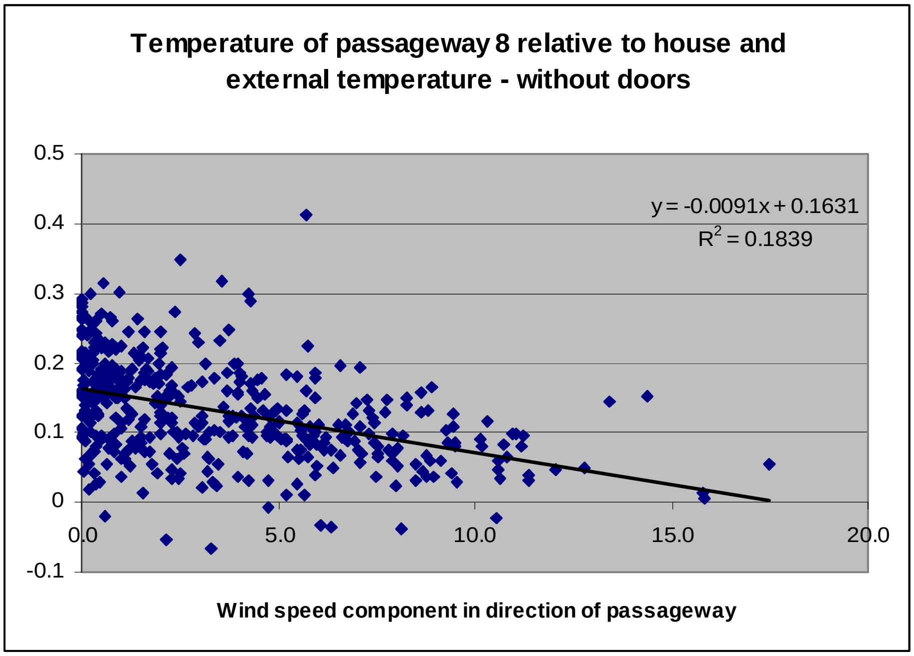

Figure A2.

The reasons for the poor correlation are likely to be:

- the local wind speed in the immediate vicinity of the passageway being poorly correlated with the wind speed measured at the weather station (in terms of both magnitude and direction) because of local topography;
- thermal inertia effects such that changes in the passageway temperature lag behind changes in house temperature of external temperature.

The position is similar for the passageway with the doors fitted: Figures A3 and A4.

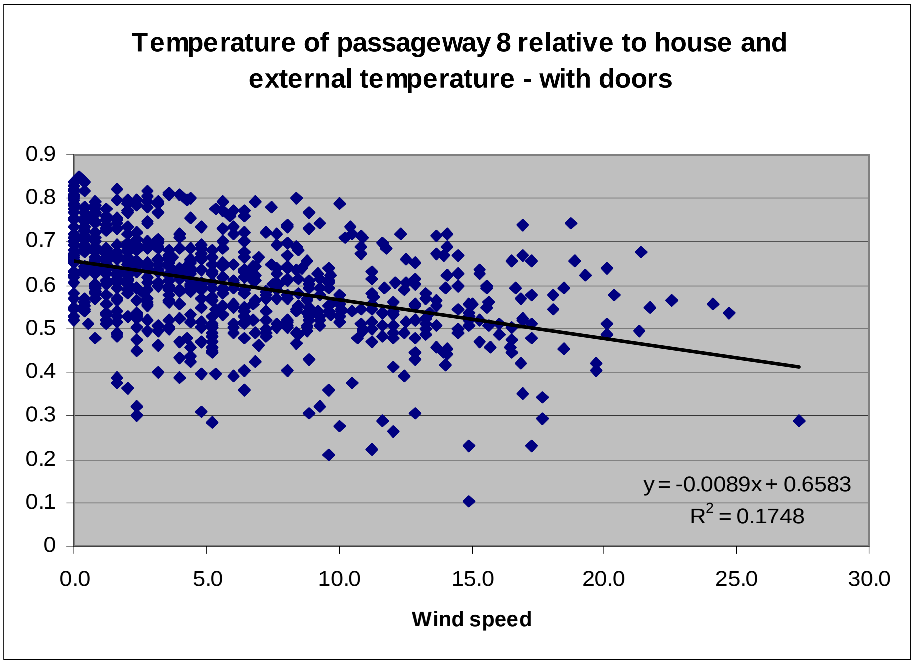

Figure A3.

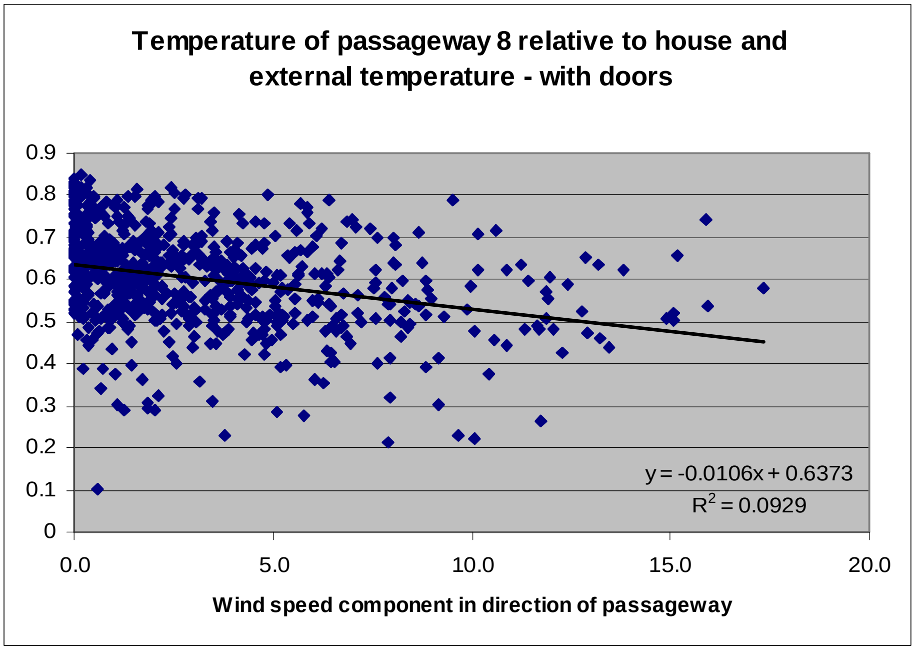

Figure A4.