PassivTEN: Upgrading Glasgow’s Tenements to Passivhaus Standard

For Milnbank Housing Association, published 5 February 2013
1. Contents

Introduction .................................................................................................................. 1
Project Participants ...................................................................................................... 2
The Tenement ................................................................................................................ 3
Testing and Analysis ................................................................................................... 3
Review of Methods and Projects ............................................................................... 7
Strategies .................................................................................................................... 8
Drawings and proposals ............................................................................................... 10
Specification ............................................................................................................... 11
Energy and Fuel Cost Results ...................................................................................... 13
Cost Analysis .............................................................................................................. 15
Conclusions ................................................................................................................. 16
Appendix 1 – Airtightness Report .............................................................................. 17
Appendix 2 – WUFI Analysis of Front Wall Proposals .............................................. 18
Appendix 3 – Cost Breakdown .................................................................................... 19
Appendix 4 – Photovoltaic Array Information .............................................................. 20
Appendix 5 – Detail Drawings .................................................................................... 21

This research was funded by Milnbank Housing Association and CIC Start Online.
This work is licensed by John Gilbert Architects Ltd, The Mackintosh Environmental
Architecture Research Unit and Towler and Hyslop under the Creative Commons
Attribution-NonCommercial-ShareAlike 2.5 UK: Scotland License.
Version 4 issued 7 February 2013
While we have made every effort to ensure that the information within this guide is
correct, we take no responsibility for errors or omissions contained within it. You
should take professional advice specifically for your project.
2. Introduction

John Gilbert Architects, The Mackintosh Environmental Architecture Research Unit and Towler and Hyslop Ltd (Quantity Surveyors) were appointed by Milnbank Housing Association and CIC Start Online to explore the feasibility of upgrading tenements to reduce energy use, reduce energy bills and explore the possibility of meeting the internationally recognised Passivhaus standard.

Traditional sandstone tenements make up over 35% of Milnbank Housing Association's stock. They are not listed and do not fall into a conservation area. Whilst they have no historic designation, they are fundamentally sound, beautiful buildings that could have a number of adaptations made to ensure that residents can continue to live long lives in these homes without suffering fuel poverty.

Based on a walk around the Milnbank area and discussion about energy use in the tenement properties of Haghill area, we propose the following methodology for a study on reducing the cost of tenants' fuel bills. We have examined the existing situation for three standard flat types and consider strategies to meet:

- **BRONZE** – 30% reduction in energy
- **SILVER** – 50% reduction in energy
- **GOLD – Passivhaus (EnerPHIT) standard refurbishment**

These strategies will consider physical refurbishment such as insulation, heating systems, window replacement and draught proofing.

Our process consisted of:

- surveys of sample flats
- intrusive testing
- thermal imaging survey
- airtightness testing
- review of current knowledge and projects within the UK
- energy evaluation using Passivhaus Planning Package (PHPP) software
- considering range of options
- preparing schedule of options for each flat
- preparing costs associated for each flat
- drawing proposals together in a final report.
3. Project Participants
The following team worked together on this project.

3.1. Milbank Housing Association - Client
Milbank Housing Association was founded in 1975 and is a Community Based Housing Association operating in the East End of Glasgow. The Association is a non-profit making organisation registered as a Friendly Society and also registered with the Scottish Housing Regulator, who has a supervising and monitoring role in the Associations activities. In June 2008 the Association became a registered charity.

As a registered Housing Association Milbank Housing Association’s main function is the provision and management of affordable rented housing for people in need. The Association manages a stock of over 2200 units. As we have been established for almost 35 years our original modernisation programme has been completed we have moved into a more management and maintenance function, although we continue to actively pursue future development opportunities for new build within the area.

3.2. John Gilbert Architects - Architects
John Gilbert Architects is a small design studio, based in Glasgow, passionate about designing places for people and the planet. Experts in ecological, low carbon development designed with the community, we undertake design work from a strategic level to detailed architecture with creativity, enthusiasm and knowledge. We have been at the forefront of the social and community sector for over 19 years delivering award winning designs for places across Scotland. The majority of our work is for Housing Associations, public bodies and community organisations. We have worked with over 30 housing associations, development agencies and local authorities, developing a keen understanding of their requirements and constraints for all sizes of project. This year, our projects will deliver over 100 new homes and we have over 200 retrofitted houses due for completion next year.

3.3. Mackintosh Environmental Research Unit - Research
The Mackintosh Environmental Architecture Research Unit (MEARU) is built on an established track record in two main environmental domains within the Mackintosh School of Architecture: passive solar energy design and participatory design. MEARU now undertakes strategic and applied research into a wide range of aspects of sustainable environmental design, responding to a growing commitment to user-centred, low energy, eco-sensitive architecture in the context of increasing global concerns.

MEARU has undertaken a wide range of research, published extensively and is represented on several national and international committees. This activity contributes greatly to the learning and teaching culture of The Glasgow School of Art and has also established the Centre as a significant global research player in scientific and architectural circles.

3.4. Towler and Hyslop - Quantity Surveyors
Established in 1979, Towler & Hyslop carry out a broad range of new build and refurbishment contracts for both public and private clients. Services include quantity surveying, building surveying and employers agent’s duties.

Towler and Hyslop is currently employed on projects ranging in value from £25,000 up to £12,000,000 with developments including social and private housing, community buildings, doctors’ surgeries, licensed premises, offices, workspaces, retail units, external landscaping and streetscaping.

3.5. Assistance
We were assisted by Elite Energy for the airtightness testing and reporting, and by Bruce Newlands at Kraft Architecture in undertaking WUFI calculations for the internal insulation.
4. The Tenement

For this study, we chose an unlisted, stone tenement in generally good condition on Ballindallock Street. The front facade is good quality sandstone with decorative features, as with many Glasgow tenements, and it is desirable to retain these features. The back walls are lower quality stone blocks and these need not be retained as the facing materials.

The tenement has received regular investment from Milnbank Housing Association and represents a good level of repair compared to other blocks in this area. Windows, bathrooms, kitchens and gas boilers were replaced in 2002.

We chose three flats for the study – one mid-terrace at the ground floor, one mid-terrace on the first floor and a third which is mid-terrace on the upper floor. This was due to current voids within the building and accessibility. We will use these flats to interpolate results for end-terrace situations.

5. Testing and Analysis

As part of the investigation process, we undertook the following investigations.

5.1. Visual Survey and Measurements

We surveyed the following flats:

- **Flat Type A** – Flat 0/2 at 28 Ballindallock Drive
  - 63m² with two bedrooms
  - This ground floor flat has an existing gas central heating using radiators, double glazed windows and the ventilation is through extract fans in the bathroom and kitchen.

- **Flat Type B** – 2/2 at 40 Ballindallock Drive
  - 47m² with one bedroom
  - This flat has an existing gas central heating using radiators, double glazed windows and the ventilation is through extract fans in the bathroom and kitchen. We used this flat as a top floor flat and assumed there was already 250mm of insulation in the loft.

- **Flat Type C** – 1/1 at 40 Ballindallock Drive
  - 83m² with three bedrooms
  - This mid-floor flat has an existing gas central heating using radiators, double glazed windows and the ventilation is through extract fans in the bathroom and kitchen.

5.2. Intrusive Survey

An intrusive survey was undertaken in a vacant flat at Flat 2/2, 40 Ballindallock Drive Flat on 18 April 2012.

A hole approximately 50mm square was cut out of the wall lining to investigate the wall build up at Location 1 to the rear of the property (north facing) as indicated in plan below.

A less disruptive method of investigation was employed for the front of the property and an electrical socket was removed at Location 2 to assess the wall build up to the front south facing elevation.

Both front and rear walls have an identical build up as follows:
- 680mm stonework
• 25mm softwood battens
• 15mm phenolic foam insulation
• 12.5mm plasterboard.

5.3. Thermal Imaging
An infrared survey was undertaken during the early hours of 2 May 2012, between the hours of 3:00am and 5:00am. Weather conditions were damp but there had been no rain during the survey period. The ambient temperature was around 5°C.

The bar on the right hand side of each image shows a temperature scale (in degrees Celsius) with the recorded maximum and minimum temperatures shown at the top and bottom respectively. The colours relate to the temperature of each element along this scale.

Glass reflects the IR camera so the window panes generally show up as cold elements even though they may actually be warmer.

The key points we are looking for are particularly warm or cold spots, or reoccurring features which show heat loss.

28 Ballindalloch Drive – frontage (south facing)
This image was taken from the side street and allows a full over view of the street elevation. The majority of the heat loss would appear to be via the stonework. As this elevation is south facing, this could be partially due to the radiant heat. It is however evident that the upvc windows also show an inherent weakness possibly due to the lack of seals or insulation between the window frame and the surrounding stone.

The unheated floor space between flats also indicates a greater heat loss in these areas.

40 Ballindalloch Drive – front elevation (south facing)
From the images take of the frontage at 40 Ballindalloch Drive there are two areas that show areas of high heat readings.

It would appear that there is a heat loss in the unheated space between the ceiling and floor of the flats. This appears indicative throughout the building.

There also appears to be a large heat loss at the eaves of the roof and around the bay windows. It should be noted the horizontal banding between the first and second floor is the decorative stone banding to the front elevation.
28 Ballindalloch Drive – rear elevation (north facing)

Due to the narrowness of the back court it was difficult to get a full image of the rear elevation. What appears evident is the heat loss of ground floor flat.

Window surrounds once again appear to be an area of weakness.

The close also indicates a further area of heat loss the unheated space combined with the large single glazed windows.

The use of curtains has an noticeable effect in reducing the heat loss through the windows.

There does not appear to be significant heat loss between floors.

40 Ballindalloch Drive – rear elevation (north facing)

As with the rear elevation at 28 Ballindalloch Drive, it would appear that the ground floor flat is subject to the greatest heat loss. There is a variation in this, however as the greatest heat loss does not appear at ground level and is instead concentrated around the junction of the ground and first floor.

Conclusions

From the images taken, it would appear the greatest weakness in the front elevation could be summarised in three key areas:

- at the windows junctions
- in the void space between floors
- at the eaves.

The rear elevation unaffected by direct sunlight gives some slightly different findings:

- there is a greater heat loss at the ground floor level
- windows junctions appear to be an area of heat loss, but not as significant as the front elevation
- the communal close and the large single glazed windows are areas of significant heat loss.

5.4 Airtightness Testing

Elite Energy was commissioned to undertake an airtightness test on Flat Type C. Their report is in Appendix 1. John Gilbert Architects was present for the testing and had the opportunity to use the thermal imaging camera to examine the areas causing the most leakage.

The airtightness test was undertaken throughout the morning of 29 May 2012 at Flat 1/1, 40 Ballindalloch Drive. The flat is slightly unusual in its layout in comparison to the other flats in the block as it has been amalgamated with the single aspect flat on the landing.

This amalgamation has must have been undertaken some time ago as there is no trace of the original entrance to the amalgamated flat on the landing (Image 1). The flat is privately owned and has been altered in a number of ways compared to the standard flat layout.
The most obvious of these alterations are an increased build up to the floor and the inclusion of a glazed sliding doors into the kitchen (Image 2). Because of the height of the ceilings, storage cupboards have been located at high level within the kitchen and accessed via bedroom 1 and located above the bathroom.

Prior to the testing, a single fan was fitted to the entrance door and all window vents, flues and extracts were sealed with adhesive plastic sheeting.

It was while this sealing work was being undertaken that the location of the water stopcock for the flat came to light, as it is located in the service duct behind the bathroom suite. Currently this access hatch is not hermetically sealed (Image 3).

Following measurement of the external air pressure within the close, the de-pressuring of the flat and airtightness testing were commenced.

From the infrared survey undertaken on 2 May 2012, there were a number of areas within the outer fabric of the property that we wanted to check. The IR survey had indicated heat loss around the upvc window frames and also the stonework between floor levels and at the bay windows.

These areas along with other internal areas such as the light sockets, electrical cupboard, skirting boards, electrical wall sockets, storage cupboards and kitchen units were checked internally with the aid of an IR camera and a smoke stick.

While the windows showed relatively little effect with the smoke test, cold patches were detected using the IR camera (Image 4). While the light sockets in the ceiling, the electrical cupboard in the hall and the frame around the flat entrance door showed a marked effect on the smoke stick (Image 5).
6. Review of Methods and Projects

We undertook a review of projects and literature across the UK on the subject of improving traditional buildings to Passivhaus standard. The following outlines key findings.

6.1 The Tenement Handbook

Written by John Gilbert and Annie Flint. This was used as the basis for this study, in terms of tenement construction and typical details.

6.2 Solid Wall Insulation in Scotland

This report was prepared by Changeworks and followed a whole day conference in Edinburgh on the subject. The main findings from this report are as follows:

- solid walls perform thermally better than current energy modelling assumes
- there are numerous techniques and systems for insulating solid walls
- although external wall insulation (EWI) is more expensive than internal wall insulation (IWI), it is generally considered the technically easier solution as it creates fewer cold bridges and fewer potential problems with moisture build up within the walls.
- IWI can lead to moisture build up in external walls (interstitial condensation), as exterior walls stop receiving heating and become more likely to attract and retain moisture.
- the moisture modelling method adopted by many solid wall insulation (SWI) manufacturers may not be appropriate when applied to solid masonry walls, as it was developed for use on timber-framed buildings.

The findings of this report were incorporated into the development of the strategies for each house.

6.3 Passivhaus EnerPHit Standard

It is not always possible to achieve the Passivhaus standard (new build) for refurbishments of old buildings, even with adequate funds. For this reason, the Passivhaus Institute has developed the “EnerPHit – Quality-Approved Energy Retrofit with Passive House Components” certificate.

Significant energy savings of between 75% and 90% can be achieved even in existing buildings, for which the following measures have proved to be particularly effective:

- the improved thermal insulation
- the reduction of thermal bridges
- considerably improved airtightness
- the use of very good quality windows
- ventilation with highly efficient heat recovery

- efficient heat generation
- the use of renewable energy sources

These are exactly the same measures that have proved to be successful in new build work. A number of examples demonstrating the application of high-efficiency technology in existing buildings have become available in the meantime. The Passivhaus Institute has advised on the implementation of several projects and carries out measurements in modernised buildings.

Certification for Passivhaus standard can be achieved and is regulated by the Passivhaus Institute in Germany. This requires an external certifier to be appointed early in the process to advise on the development and assess the design and construction.

6.4 Meeting with Wolfgang Feist

Dr Wolfgang Feist developed the Passivhaus principles at Darmstadt University. He ran a series of workshops across the UK in summer 2012 and Matt Bridgestock took the opportunity to discuss some of the technical aspects of this project with him. In particular:

- communal ventilation significantly increases energy efficiency but the need for fire separation and baffles increases costs
- communal heating is much easier than ventilation as spread of fire is not such a significant issue. The lower heat demand of Passivhaus level projects means that a small communal heating system is more efficient that a number of individual systems sized larger than normally required. Communal heating is not unusual in Germany.
- the junction with floor joists and external walls is tricky where insulation needs to be installed. There is an issue of condensation / moisture build up here.

The outcomes of this meeting were used to inform the emerging strategies developed in this report.

6.5 Retrofit for the Future Projects

We have reviewed information from similar projects available on the Retrofit for the Future website http://www.retrofitforthefuture.org/ It is clear that refurbishment up to EnerPHit standard is possible for traditional buildings but requires significant work. It is also clear that the airtightness issue is significantly larger than increasing insulation. This thinking has been translated into our strategies and proposals.

6.6 Historic Scotland Technical Guidance

Historic Scotland has published technical guidance on a number of important issues related to tenements including:

- u-values of traditional walls
- air quality issues in refurbishment
- keeping warm in a cooler house
- energy modelling of traditional houses

We have reviewed this guidance and in particular, used the u-values of traditional walls information as a starting point for our study.
6.7. Improving Energy Efficiency in Traditional Uist Houses – Locate Architects

This report and experiment on Uist looks at different strategies for dealing with traditional solid wall houses, particularly in relation to improving airtightness over additional insulation. It is clear that there is a significant benefit in reducing the air leakage rate of traditional buildings and working with natural, hydroscopic materials.

We have incorporated and developed these approaches in our study.

6.8. Solid Wall Insulation Conference

We have reviewed the presentations from this conference which took place in Edinburgh on 20 April 2012. This conference covered a range of techniques including internal and external insulation of traditional buildings together with different heating mechanisms and achieving excellent airtightness. We have incorporated and developed these approaches in our study.

6.9. CICStart Online Conference on Green Deal and ECO Funding

CICStartOnline held a one day conference in Glasgow in October 2012 to review and discuss issues around Green Deal and ECO funding mechanism implementation in Scotland. The key issues for this study were:

- There is a mechanism for loan funding through the Green Deal for private home owners that should help implement ‘block by block’ approaches to upgrade works rather than a ‘flat by flat’ approach;
- ECO funding is available for housing associations to complete retrofit projects. This can cross postcode boundaries and be used with the Green Deal to supplement private home owners where projects depend on a large scale approach;
- Further research and case studies.

6.10. The Passivhaus Handbook – Janet Cotterall and Adam Dadeby

Amongst a number of issues covered in The Passivhaus Handbook it includes advice and diagrams showing approaches to creating airtightness around intermediate floor junctions.

6.11. Conclusion

It is clear from the research that there are significant issues with internal wall insulation in the tenement situation. It is also clear that there are a range of alternative strategies focusing on minimising air leakage and controlled ventilation. Based on this research and the actions undertaken to these properties to date by Milnbank Housing Association, we propose to look at a route that optimises airtightness followed by installation of appropriate levels of insulation.

7. Strategies

We developed these strategies by examining the results of the analysis and looking for likely solutions in the literature review. Through experimentation with PHPP software, we determined where the biggest initial gains were likely to be. The improvements by Milnbank Housing Association to date, including insulation and double glazing, meant that our starting point focused on the current airtightness of the tenement.

Based on the research and analysis, the following diagram outlines how the original construction and changes in heating system have led to high energy use and how airtightness is a key aspect of reducing the energy use.

Tenements were originally designed to be heated by radiant heat, that is by a fire or similar source. Air circulated freely which maintained air quality with the open fire.

Central heating systems rely on warming the air within a room, coupled with significant air leakage this means that tenements are relatively expensive to heat.

By increasing insulation and cutting down the air leakage the heating required would be significantly reduced but we need to introduce mechanical ventilation to ensure good air quality is retained.

We have considered addressing the airtightness issue for every level of the study as it makes a significant impact on the energy use of the properties.

Insulation of the front elevation is a key aspect of the study. We have taken an approach favoured by many of the studies in the literature review which is to minimise the level of insulation for this facade, to install the insulation on the interior of the wall and to use natural hydroscopic materials to ensure the moisture in the wall does not get trapped and cause mould or rot.

Insulating the rear walls and gables with external insulation and a render finish is a tried and tested method of insulation. It protects the existing wall from moisture and allows a significant level of insulation to be used.

Ensuring ventilation is sufficient to offer a healthy indoor environment is important for residents and for the fabric of the building. We propose to use an efficient mechanical ventilation heat recovery (MVHR) system for each flat, this would recover 90% of the heat lost from the house. The hallway ceiling would need to be lowered to enable suitable ducting to be installed. A communal system would also work but there is an issue in these flats as to where the bulky ducts would be located. Individual systems would offer easier installation and easier use for residents.

In the silver and gold levels we have illustrated a communal heating and hot water system. The heating demand of the whole block will be significantly reduced and a communal system linked to solar panels on the south facing roof would be a significant increase in efficiency. Further design work for this would be essential to ensure its viability.
7.1. **Decant of Residents**

In order to reduce the air leakage of the house the walls, floors and ceiling will need to be stripped, airtightness barriers installed and decoration replaced. This will be required at some stage in order to reach the Passivhaus EnerPHit standard. We have chosen to bring all of this disruptive work into all of the standards as our analysis suggests this will offer the single biggest improvement to the flats individually.
8. Drawings and proposals
Type A - Ground Floor
65m² with 2 bedrooms

Type B - Top Floor
47m² with 1 bedroom

Type C - Mid floor
83m² with 3 bedrooms
15mm bead insulation behind plasterboard

Double glazed UPVC windows with some cold bridge and air leakage issues

Gas central heating with combi boiler

Uninsulated door and fan light

15mm bead insulation behind plasterboard

Significant air leakage detected around bathroom fittings

Airtightness 17 ach (assumed based on Type C testing)

Key areas for air leakage:
- light fittings / sockets
- floor junction and skirting boards
- service penetrations through walls
- Behind cupboards and kitchen units

Base of bays showing cold spots and high air leakage

Few internal decorative features, no decorative cornicing

Client: Milnbank HA
Project: PassivTEN Research
Title: Type A Existing
Scale of A3: 1:200, 1:500
Drawing No: [EP]03
John Gilbert Architects
15mm bead insulation behind plasterboard

Double glazed UPVC windows with some cold bridge and air leakage issues

Gas central heating with combi boiler

Few internal decorative features, no decorative cornice

Airtightness 17 ach (assumed based on Type C testing)
Key areas for air leakage:
- light fittings / sockets
- floor junction and skirting boards
- service penetrations through walls
  Behind cupboards and kitchen units

Base of bays showing cold spots and high air leakage

Uninsulated door and fan light

Significant air leakage detected around bathroom fittings
Doubled glazed UPVC windows with some cold bridge and air leakage issues

Few internal decorative features, no decorative cornices

Gas central heating with combi boiler

Uninsulated door and fan light

Significant air leakage detected around bathroom fittings

Uninsulated door and fan light

Significant air leakage from skirting area according to airtightness testing

Base of bays show cold spots and high air leakage according to testing

15mm bead insulation behind plasterboard

Significant air leakage from skirting area according to airtightness testing

Plumbing fixtures in kitchen show high air leakage

15mm bead insulation behind plasterboard

Airtightness 17 ach (as tested)

Key areas for air leakage:
- light fittings / sockets
- floor junction and skirting boards
- service penetrations through walls
Behind cupboards and kitchen units

Uninsulated door and fan light

TC-EXIST Type C Cutaway

1:200

Client: Milnbank HA
Project: PassivTEN Research
Title: Type C Existing
Scale: 1:200, 1:500
Drawing No: [EP]07

John Gilbert Architects
Front wall detail
U-value - 0.30

- Build up:
  - Existing stone wall
  - Plaster finish
  - Masonry insulation
  - Wood fibre board
  - Insulation carefully installed round joint ends

- Build up:
  - Existing stone wall
  - Masonry insulation
  - Wood fibre board
  - Insulation carefully installed round joint ends

- Joists carefully sealed with airtightness tape and lapped into plaster single sheet

- Joists carefully sealed with airtightness tape and lapped into plaster single sheet

- Deadening reinstalled as floor is relaid
- Plasterboard ceiling

Rear wall detail
U-value - 0.80

- Lift floor finishes on ground floor. Install 50mm mineral wool on net between joists. Lay airtightness membrane, lap into internal walls and external plaster. Lay 8mm OSB and relay floor finishes. U-value 0.6

- Lead flashing along top of string course to avoid excessive moisture build up

- Plaster carefully installed round joist ends
- Deadening reinstalled as floor is relaid
- Plasterboard ceiling

Roof
Existing insulation lifted, airtightness membrane installed and lapped in to head of wall. 350mm warm cell insulation relaid.
U-value - 0.12

- Maintain ventilation of roof space

Refer to individual sheets for internal works.
Wall stripped back to stonework, plaster parge coat applied, 100mm wood fibre board fitted with mechanical fixings, finished internally with 50mm insulated plaster and organic paint

Insulation and plaster airtight barrier continued through floor zone.

50mm mineral wool insulation laid on net laid between joists. Airtight membrane laid over top, 18mm OSB laid over top, floor coverings reinstated.

Airtightness of 3ach

MVHR unit (Brookvent air cycle) fitted in ceiling of kitchen, new suspended ceiling in kitchen and hall. Rigid galvanised ducts to each room.

Airtightness tape between windows and new plaster

Kitchen and bathrooms
Units, appliances and fittings to be removed whilst floor is lifted and reinstated thereafter.

TA-BRONZE
Type A Bronze Standard
1:200
Wall stripped back to stonework, plaster parged coat applied, 100mm wood fibre board fitted with mechanical fixings, finished internally with 50mm insulated plaster and organic paint.

350mm cellulose insulation in loft - ceiling stripped, airtight layer installed, lapped into plastered walls. Ceiling reinstated.

MVHR unit (Brookvent air cycle) fitted in ceiling of kitchen, new suspended ceiling in kitchen and hall. Rigid galvanised ducts to each room. Airtightness tape between windows and new plaster.

Wall stripped back to stonework, 20mm insulating plaster applied

Plaster continued through floor zone

Airtightness target of 3ach

TB-BRONZE
Type B Bronze Standard 1:200
Wall stripped back to stonework, plastered, 100mm wood fibre board fitted with mechanical fixings, finished internally with 10mm insulated plaster and organic paint.

New lowered ceiling in hallway

Nailed insulation and plaster airtight barrier continued through floor zone.

MVHR unit fitted in ceiling of kitchen, new suspended ceiling in kitchen and hall. Ducts to each room.

Airtightness tape between windows and new plaster

MVHR intake and extract on rear wall

Wall stripped back to stonework, 20mm insulating plaster applied

Plaster continued through floor zone

Further investigation of solar thermal panels on roof required

Airtightness target of 3ach

<table>
<thead>
<tr>
<th>Client</th>
<th>Project</th>
<th>Title</th>
<th>Scale of As</th>
<th>Drawing No</th>
<th>JOHN GILBERT ARCHITECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milbank HA</td>
<td>PassivTEN Research</td>
<td>Type C Bronze Strategy</td>
<td>1:200, 1:500</td>
<td>[PP]04</td>
<td></td>
</tr>
</tbody>
</table>
New communal boiler in roof space, supplying hot water and heating to each flat via duct in close. Fire proof utility cupboard formed from timber frame and superlux.

Solar thermal panels mounted on south facing roof

**Roof**
- Existing insulation lifted, airtightness membrane installed and lapped in to head of wall.
- 35mm cellulose insulation laid.
- U-value - 0.12

**Front wall detail**
- Existing stone wall
- Plaster parge coat
- 100mm Wood fibreboard
- 50mm insulated plaster finish
- U-value - 0.30

Lead flashing along top of string course to avoid excessive moisture build up

**Rear wall detail**
- Existing stone wall
- Plaster parge coat
- 40mm Wood fibreboard
- 50mm insulated plaster finish
- U-value - 0.13

Refer to individual sheets for internal works.

Lift floor finishes on ground floor, install 200mm polystyrene between joists. Lay airtightness membrane, lap into internal walls and external plaster. Lay 78mm OSB and relay floor finishes.

U-value 0.14

Roof may need extending at eaves

Insulation to run past ground floor into ground to protect joist ends.
Wall stripped back to stonework, plaster parged coat applied, 100mm wood fibre board fitted with mechanical fixings, finished internally with 10mm insulated plaster and organic paint.

Insulation and plaster airtight barrier continued through floor zone.

200mm polystyrene insulation laid under and between joists. Airtight membrane laid over top, 60mm OSB laid over top, floor coverings reinstated.

Strip dry lining (where present) at party walls, seal any gaps and replaster. Plaster to be tied into walls in flats above and below along with being sealed to new plaster work at external walls.

Communal heating system with solar thermal panels on roof. Airtightness target of 1 acht.

MVHR unit (Brookvent air cycle) fitted in ceiling of kitchen, new suspended ceiling in kitchen and hall. Rigid galvanised ducts to each room.

Airtightness tape between windows and new plaster.

250mm polystyrene and render applied externally.

Wall stripped back to stonework, 20mm insulating plaster applied.

Plaster continued through floor zone.

Kitchen and bathrooms
Units, appliances and fittings to be removed whilst floor is lifted and reinstated thereafter.

TA-SILVER
Type A Silver Standard
Wall stripped back to stonework, plaster parget coat applied, 100mm wood fibre board fitted with mechanical fixings, finished internally with 10mm insulated plaster and organic paint.

350mm cellulose insulation in loft - ceiling stripped, airtight layer installed, lapped into plastered walls. Ceiling reinstated.

New lowered ceiling in hallway

Lift floor

Insulation and plaster airtight barrier continued through floor zone.

Wall stripped back to stonework, 20mm insulating plaster applied

250mm polystyrene and render applied externally.

MVHR unit (Brookvent air cycle) fitted in ceiling of kitchen, new suspended ceiling in kitchen and hall. Rigid galvanised ducts to each room.

Airtightness tape between windows and new plaster

Strip dry lining (where present) at party walls, seal any gaps and replaster. Plaster to be tied into walls in flats above and below along with being sealed to new plaster work at external walls.

Lift floor

Communal heating system with solar thermal panels on roof

Airtightness target of 1 ach

Type B Silver Standard
Wall stripped back to stonework, plaster parget coat applied, 50mm wood fibre board fitted with mechanical fixings, finished internally with 10mm insulated plaster and organic paint.

New lowered ceiling in hallway

MVHR unit (Brookvent air cycle) fitted in ceiling of kitchen, new suspended ceiling in kitchen and hall. Rigid galvanised ducts to each room.

Airtightness tape between windows and new plaster

MVHR intake and extract on rear wall

Lift floor

Insulation and plaster airtight barrier continued through floor zone.

Communal heating system with solar thermal panels on roof

Airtightness target of 0.1 a-ch

Strip dry lining (where present) at party walls, seal any gaps and replaster. Plaster to be tied into walls in flats above and below along with being sealed to new plaster work at external walls.

25mm polystyrene and render applied externally.

Wall stripped back to stonework, 20mm insulating plaster applied

Plaster continued through floor zone

Lift floor

Type C Cutaway

TC-SILVER
New communal boiler in roof space, supplying hot water and heating to each flat via duct in close. Fire proof utility cupboard formed from timber frame and supalux.

Solar thermal panels mounted on south facing roof

Roof
Existing insulation lifted, airtightness membrane installed and lapped in to head of wall. 350mm cellulose insulation laid.

U-value - 0.12

Front wall detail
U-value - 0.30
- Existing stone wall
- Plaster parget coat
- 100mm Woodfibreboard
- 10mm insulated plaster finish

Lead flashing along top of string course to avoid excessive moisture build up

Lift floor finishes on ground floor. Install 200mm polystyrene between joists. Lay airtightness membrane, lap into internal walls and external plaster. Lay 18mm OSB and relay floor finishes.

U-value 0.14

Refer to individual sheets for internal works.

New windows and doors in close, replaced with triple glazed, passivhaus certified units. Spacetherm to be used to form insulated Jambs and sills, to be sealed into airtight barrier. Installed uvalue to be 0.8

Windows all replaced with triple glazed, passivhaus certified units. Spacetherm to be used to form insulated Jambs and sills, to be sealed into an airtight barrier. Installed uvalue to be 0.8

Roof may need extending at eaves

Rear wall detail
U-value - 0.13

Insulation to run past ground floor into ground to protect joist ends.

U-value 0.14

Rear wall detail
U-value - 0.13

Roof may need extending at eaves

Rear wall detail
U-value - 0.13

Roof may need extending at eaves
Wall stripped back to stonework, plaster, parget coat applied, 100mm wood fibre board fitted with mechanical fixings, finished internally with 10mm insulated plaster and organic paint. Window reveals to be lined with Spacetherm to eliminate thermal bridging.

Airtightness tape between windows and new plaster

Airtightness target of 1 ach

Passivhaus certified triple glazed windows installed and taped into airtight barrier

Lift floor

Insulation and plaster airtight barrier continued through floor zone.

200mm polystyrene insulation laid under and between joists. Airtight membrane laid over top, 88mm OSB laid over top, floor coverings reinstated.

MVHR unit (Paul Focus 200) fitted in ceiling of kitchen, new suspended ceiling in kitchen and hall. Rigid galvanised ducts to each room.

Strip dry lining (where present) at party walls, seal any gaps and replaster. Plaster to be tied into walls in flats above and below along with being sealed to new plaster work at external walls.

Kitchen and bathrooms
Units, appliances and fittings to be removed whilst floor is lifted and reinstated thereafter.

Communal heating system with solar thermal panels on roof

TA-GOLD
Type A Gold Standard
Wall stripped back to stonework, plaster parged coat applied, 50mm wood fibre board fitted with mechanical fixings, finished internally with 50mm insulated plaster and organic paint.

350mm cellulose insulation in loft - ceiling stripped, airtight layer installed, lapped into plastered walls. Ceiling reinstated.

MVHR unit (Paul Focus 200) fitted in ceiling of kitchen, new suspended ceiling in kitchen and hall. Rigid galvanised ducts to each room.

Airtightness tape between windows and new plaster

Passivhaus certified triple glazed windows installed and taped into airtight barrier

250mm polystyrene and render applied externally.

Wall stripped back to stonework, 20mm insulating plaster applied

Plaster continued through floor zone

Strip dry lining (where present) at party walls, seal any gaps and replaster. Plaster to be tied into walls in flats above and below along with being sealed to new plaster work at external walls.

Communal heating system with solar thermal panels on roof 
Airtightness target of 1 ach
Wall stripped back to stonework, plaster parget coat applied, 100mm wood fibre board fitted with mechanical fixings, finished internally with 10mm insulated plaster and organic paint. Window reveals to be lined with Spacetherm to eliminate thermal bridging.

Insulation and plaster airtight barrier continued through floor zone.

Strip dry lining (where present) at party walls, seal any gaps and replaster. Plaster to be tied into walls in flats above and below along with being sealed to new plasterwork at external walls.

New lowered ceiling in hallway

MVHR unit (Paul Focus 200) fitted in ceiling of kitchen, new suspended ceiling in kitchen and hall. Rigid galvanised ducts to each room.

Airtightness tape between windows and new plaster

Passivhaus certified triple glazed windows installed and taped into airtight barrier

MVHR intake and extract on rear wall

Passivhaus certified triple glazed windows installed and taped into airtight barrier

250mm polystyrene and render applied externally.

Lift floor

Plaster continued through floor zone

Communal heating system with solar thermal panels on roof

Airtightness target of 1 ach
9. Specification

We aim to work with the natural materials that the tenement was originally constructed with, supplemented by high performance synthetic insulants for the overcladding elements and under floors. High quality timber windows and doors are used throughout.

9.1. Insulation of Front Walls

The front wall is decorative sandstone, therefore it requires to be insulated internally. We have based our specification on achieving a U-value of less than 0.35 (as required by EnerPHit standard) and have undertaken WUFI moisture analysis to determine if there is any dangerous build up of moisture.

Based on this analysis and previous work with tenements, we propose the following build up:
- existing stone wall, with additional lead flashings on string courses to remove water traps
- plaster parge coat
- 100mm woodfibre board, butt jointed (NBT Pavadento system)
- 10mm insulated plaster (Newton Diathonite insulation plaster)
- decoration with Auro natural paint

This build up must continue between each of the flats to prevent cold spots and ensure airtightness so the floor must be lifted adjacent to the walls to allow this to be continued through.

We envisage that relative humidity sensors would be embedded in the wall of a sample of the properties to allow regular checks of the moisture levels. This will improve knowledge for future phases and allow assessment of the success of the project in the future. The sensors will be placed on the internal face of the stonework and possibly a thermostor at the ends of the timbers.

An allowance of £3,000 should be made for sensing equipment for a small number of pilot flat renovations.

9.2. Front Wall External Works

Externally the stone walls need to be examined for water traps, these include the top of the string course (lead flashing to be placed) and damaged pointing (repair with lime mortar). Ensuring stone work stays dry is vital to the long term durability of the south facing wall.

9.3. Insulation of Rear Walls

Internally the north wall should be stripped and sealed with a plaster parge coat followed by 20mm build up of Newton Diathonite insulation plaster. This should be decorated with Auro natural paints.

The insulation of the rear walls and any party walls should be a high quality polystyrene based insulated render system. Render to be acrylic type to residents choice of colour. System to extend below ground floor joist ends by 200mm to protect them from moisture and interstitial condensation.

9.4. Replastering Party Walls

In order to achieve the airtightness targets set in the silver and gold standard, any lining on the party wall should be stripped and replastered. All gaps and holes should be sealed with airtight sealant prior to replastering. This includes chimneys and old extract vents.

9.5. Joist Ends

It is important that the joist ends remain dry for long term durability. Further intrusive testing may be required here however it is envisaged that injecting preservative treatment would be undertaken on all joist ends on the front (exposed sandstone) wall.

Each joist end should be carefully wrapped in airtight membrane and this should be sealed into the plaster layer to minimise air leakage through these areas. The insulation should be cut tight around the joists and sealed to minimise the thermal bridging effect.

9.6. Airtightness

The airtight layer for these proposals is generally formed by a lime based plaster parge coat on the internal face of the sandstone walls. Penetrations through this layer need to be sealed with airtightness tape or suitable grommets. SIGA / Proclima both make suitable products. We have assumed that each flat requires 4x large grommets for waste pipes and air intakes with a further 6x grommets for electrical and communications cables. The ground floor and top floor require an airtightness membrane to be installed, ProClima DB+ is suitable for this purpose.

Mechanical Ventilation Heat Recovery (MVHR)

This study is based on the assumption that the airtightness of the flats can be improved up to EnerPHit levels, for each level there is a need to fit effective ventilation system to ensure an healthy indoor environment.

We have proposed a Passivhaus certified system in each case and have modelled the flats using the following specific models:

<table>
<thead>
<tr>
<th></th>
<th>Bronze</th>
<th>Brookvent Air cycle 1.2</th>
<th>Not PHI certified</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Silver</td>
<td>Paul Focus 200</td>
<td>PHI certified</td>
</tr>
</tbody>
</table>

Any alternative MVHR model should meet the following performance criteria:
- frost protection on incoming duct (electric)
- F7 filter on incoming air
- insulation / vapour barrier between external duct and heat exchanger (50mm min)
- air to air heat exchanger at least 75% efficiency
- DC motors
- thermal insulation on MVHR unit
- condensate drain
- 25dB max noise rating
- operations – 70% / 100% / 130% boost / summer bypass
- mechanical decoupler
- openings for maintenance

In addition the ventilation system should be designed with these characteristics:
• supply inlet over door with jet nozzle
• ductwork in corridors as short as possible
• extract in bathrooms / kitchens
• transfer grills in the doors (2cm gap under door)

In each case the ventilation system must be designed, installed and tested to ensure ventilation rates exceeding the following:

• 30m³/h ventilation per person
• minimum airchange rate = 0.5/h
• airflow velocity kept below 0.1m/s

A small ventilation unit for the close should be fitted in the plant room in the attic. The charge for this energy would be part of the residents' communal fee.

9.7. Communal Heating

For the silver and gold standard, the heating demand of the block would drop to a level suitable for communal heating. We propose a gas-fired communal heating system is installed in the roof space, this could be linked to solar panels to preheat the water.

Our calculations illustrate a standard 30kW boiler should provide the heating output required for the improved flats. Therefore, for the purposes of costing, we propose two 30kW boilers mounted in tandem, connected to 10m² of solar thermal panel.

A plant room will need to be formed from fire resistant plasterboard (Supalux) in the loft space. Ventilation and flue will need to be formed in the roof surface (rear elevation) with a ladder access hatch into the close. The access hatch will require to be airtight and insulated to a u-value of 0.15 W/m²K (see Dolle Profi Plus airtight attic hatch from Ecological Building Systems).

We have assumed a flat rate charging mechanism for heating and hot water, this minimises administration for Milnbank Housing Association and reduces the capital cost of the installation.

A full communal heating design would be required from a qualified mechanical engineer prior to developing this proposal further.

9.8. Passivhaus Windows

The current double glazed windows appear to be in generally good condition. As they were installed within the last decade, there is no urgent need to replace them for bronze and silver level but Passivhaus compliant triple glazed units are required for EnerPHit certification.

For the gold standard, we propose the use of Ambiente Timber / Aluminium clad window (HF 300) supplied by Callum Walker Energy Source in Fife. This range of windows has a whole window u-value of 0.69 W/m²K. Warm edge spacers and wood fibre frame insulant are used to minimise thermal bridging through the windows and doors.

The windows must have an airtightness membrane fitted to them and this should be lapped into the plasterwork surrounding the windows.

9.9. Photo Voltaic Panels

We have made enquiries with Solar Century regarding the use of the roof for Photovoltaic cells. They advised the an 88m² array with a 10kWp rating would offer the best return.

The capital cost for the system would equate to £13,058 which with the current feed in tariff of 14p/kWh would give a payback period of 9 years and a total profit over 20 years of £19,283.

Appendix 4 has the complete breakdown from Solar Century. The cost of photovoltaic cells has not been included in the cost analysis below.
10. Energy and Fuel Cost Results

Based on our PHPP energy model and the proposals above, the graphs below outline the improvement in heating demand, energy requirement and energy cost.

It is clear that Milnbank Housing Association has invested in the modernisation of these properties with insulation behind the plasterboard and installation of the double glazing. We have shown a theoretical 'unimproved' standard which has single glazing and no internal insulation to illustrate the effect these upgrade proposals would have on other unimproved stock in the Dennistoun area, this potentially includes owner occupied housing.

10.1. Heating Demand

The graph below shows the output of the proposals based on the relative heating demand required for each flat type. This demonstrates how well the flat is insulated and how much heat is required to keep the home at a constant temperature throughout the year. This is all shown in kWh/m².

[Graph showing heating demand for different flat types and insulation levels.]

It can be seen that Flat type A is the poorest performer consistently throughout the study, this is due to its ground floor location and being relatively small compared to the area of exposed walls. Flat C is the best performer as it is mid terrace with a heated flat above and below.

The graph demonstrates the dramatic reduction in the heating demand of the various flat types. Achieving less than 25kWh/m² as an average across the flats is a requirement for the EnerPHit standard.

10.2. Total Energy Requirement

Based on our modelled energy requirement, the following shows the total energy requirement for each flat type illustrated in kWh/m². This total energy requirement is essentially the 'meter figure' for each flat type and in all cases is split between gas and electricity use. It includes heating, hot water and appliances. This can be directly related to reductions in tenants' fuel bills.

[Graph showing total energy requirement for different flat types and insulation levels.]

This graph shows that as heating energy is reduced, appliances and other uses within the home take on a significant percentage of the total energy requirement. This is particularly sensitive to high intensity uses such as tumble driers etc.
10.3. Annual Cost

Using current standard tariffs we have made an assumption about the energy costs for each flat type with the retrofit measures in place. The graph below shows the total cost for each flat, the size of the flat makes a significant difference to the total energy cost. We have not allowed for any increase in fuel prices and over a 25 year period, price increases have been significant in the last ten years and are likely to be significant.

![Graph showing total cost for each flat type](image)

Assumptions

We have used the following typical energy prices for our analysis:
- electricity – 14p/kWh
- gas – 4p/kWh

Where we have calculated a net present value we have assumed an interest rate of 5%. We have retained the standard residential use patterns with PHPP software. Different use patterns may effect the energy costs and efficiencies.

None of these calculations take into account any income or energy from photovoltaic cells on the roof.
11. Cost Analysis

11.1. Bronze

Based on the drawings and specification throughout this report, the costs for the bronze specification are as follows.

<table>
<thead>
<tr>
<th>BRONZE</th>
<th>Flat Type A</th>
<th>Flat Type B</th>
<th>Flat Type C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Works Cost inc Prelims and 5% contingency</td>
<td>£22,073.00</td>
<td>£13,518.48</td>
<td>£19,548.95</td>
</tr>
<tr>
<td>VAT and Fees</td>
<td>£8,471.07</td>
<td>£5,220.35</td>
<td>£7,511.93</td>
</tr>
<tr>
<td><strong>Total Budget</strong></td>
<td><strong>£30,544.07</strong></td>
<td><strong>£18,738.83</strong></td>
<td><strong>£27,060.88</strong></td>
</tr>
<tr>
<td>Cost per m²</td>
<td>£484.83</td>
<td>£398.70</td>
<td>£326.03</td>
</tr>
</tbody>
</table>

We have taken the common works, including works to the close, under the ground floor level and works in the loft, an divided them between each of the 8 flats in the close. This budget per flat is included in the costs above. The overall budget for the common works for the bronze strategy is £10,500.01.

11.2. Silver

Based on the drawings and specification throughout this report, the costs for the silver specification are as follows.

<table>
<thead>
<tr>
<th>SILVER</th>
<th>Flat Type A</th>
<th>Flat Type B</th>
<th>Flat Type C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Works Cost inc Prelims and 5% contingency</td>
<td>£39,101.05</td>
<td>£30,575.66</td>
<td>£35,080.12</td>
</tr>
<tr>
<td>VAT and Fees</td>
<td>£14,941.73</td>
<td>£11,702.08</td>
<td>£13,413.77</td>
</tr>
<tr>
<td><strong>Total Budget</strong></td>
<td><strong>£54,042.78</strong></td>
<td><strong>£42,277.74</strong></td>
<td><strong>£48,493.89</strong></td>
</tr>
<tr>
<td>Total budget per m²</td>
<td>£857.82</td>
<td>£899.53</td>
<td>£584.26</td>
</tr>
</tbody>
</table>

We have taken the common works, including works to the close, under the ground floor level and works in the loft, an divided them between each of the 8 flats in the close. This budget per flat is included in the costs above. The overall budget for the common works for the silver strategy is £118,600.01.

11.3. Gold

Based on the drawings and specification throughout this report, the costs for the gold (EnerPHit) specification are as follows.

<table>
<thead>
<tr>
<th>GOLD (EnerPHit)</th>
<th>Flat Type A</th>
<th>Flat Type B</th>
<th>Flat Type C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Works Cost inc Prelims and 5% contingency</td>
<td>£57,616.51</td>
<td>£47,359.00</td>
<td>£59,534.75</td>
</tr>
<tr>
<td>VAT and Fees</td>
<td>£21,977.61</td>
<td>£18,079.75</td>
<td>£22,706.53</td>
</tr>
<tr>
<td><strong>Total Budget</strong></td>
<td><strong>£79,594.12</strong></td>
<td><strong>£65,438.75</strong></td>
<td><strong>£82,241.29</strong></td>
</tr>
<tr>
<td>Total budget per m²</td>
<td>£1,263.40</td>
<td>£1,392.31</td>
<td>£990.86</td>
</tr>
</tbody>
</table>

We have taken the common works, including works to the close, under the ground floor level and works in the loft, an divided them between each of the 8 flats in the close. This budget per flat is included in the costs above. The overall budget for the common works for the gold (EnerPHit) strategy is £131,262.65.

11.4. Summary

The following diagram shows the cost per square meter for each of the options:

![Cost per Square Meter Diagram]

It is clear that the position of each flat greatly affects the cost of the work required with top and bottom flats being more expensive than middle flats.
11.5 Assumptions

Exclusions
The foregoing costs excludes the following:
- Increased costs beyond base date of January 2013
- Humidity sensors to monitor moisture level in walls
- Decant costs and other costs for existing tenants
- Additional requirements of Planning
- Additional requirements from Building Control
- New floor finishes
- Photo Voltaic Panels

Assumptions
The foregoing costs assume the following:
- No Planning fees expected
- Building Warrant assumed for heating system
- Vat has been allowed at current rate of 20%. However some energy saving items may attract the lower rate of 5% but we have not applied the lower rate on any of the specified items in this study.
- No draught proofing tape at junction of close external walls and close party walls
- Existing plaster on close external walls not stripped
- For communal costs it is assumed that there are 8 flats per tenement block

Basis of Costs
- Architects preliminary drawings
- Architects outline specification
- No Services Engineer’s information available for study
- No Services Engineer’s information to date
- Decoration works only allowed where new works and repairs are carried out
- The Ambience HF300 prices were provided by Callum Walker Energy Source
- Cruden Building and Renewals Ltd assisted with prices for insulation items

Construction Design & Management Regulations
- No Designers hazard and risk assessments available

12. Conclusions

This study has outlined the implications of three standards for tenements, investigated the technical constraints, proposed solutions and prepared budget costs.

The key outcomes are as follows:
- Testing of a tenement shows the key areas of weakness and suggests bespoke refurbishment work for that particular building
- Retrofitting of tenements is better undertaken on a close-by-close basis than a flat-by-flat basis
- There is a wealth of information and strategies on how to improve tenement flats and traditional buildings but there are few examples of retrofitting to a very high standard of energy efficiency in Scotland
- A strategy of improving airtightness, whilst ensuring sufficient ventilation, has a more significant affect on energy use than insulation alone
- Communal heating has an effect on the cost of heating for tenants rather than necessarily an impact on reducing energy usage. There are additional management and charging issues to be addressed when using communal heating
- It is theoretically possible to meet the EnerPHit standards with a tenement close offering significant reductions on energy bills and increased comfort for residents
- Photovoltaic cells can be added to the roof of the properties and have a simple payback period of 9 years meaning a significant surplus over 20 year life of the systems.
- The position of the flat has a significant impact on the capital cost of the refurbishment works
- Given the predicted raise in energy prices over the next decade, the silver and gold standard offer comfortable indoor temperatures with energy usage that significantly reduce the risk of fuel poverty
- The costs of any of these upgrades are significant, Milbank Housing Association have already addressed the ‘quick wins’ measures for these tenements. Ensuring that most benefit can be obtained by residents for this refurbishment is essential.