Demonstrating the 'Passivhaus' standard for the Scottish volume housing market.

DEVECI, G. and MITCHELL, G.

2020

Demonstrating the 'Passivhaus' standard for the Scottish volume housing market

Can 'Passivhaus' standard houses be rolled out to the Volume Housing Market? This is the outcome for the [Construction Scotland Innovation Centre](#) (CSIC) funded research proposal, titled "Demonstrating the 'Passivhaus' Standard for the Scottish Volume Housing Market", which is being undertaken in partnership with Dandara Limited (DA) and Robert Gordon University (RGU). A deeper understanding of the performance of the Passivhaus Homes in Scotland is required if the 'Passivhaus' Standards are to find widespread application in the mass market volume housing sector. This will enable Scotland to meet its CO2 reduction targets and address the performance gap. This applied research project will test the hypothesis that the 'Passivhaus' standards (PH) can be applied to provide high-quality housing at a competitive cost level, utilising the local Scottish supply chain and taken to mass market. The two dwellings were successfully built to the certified 'Passivhaus' standards by Dandara Homes. Both of these builds utilised a timber frame designed and manufactured in Scotland, erected by a locally based specialist timber fame installer. This project demonstrates that the design and construction skills are thus evidently available in Scotland, implying that this research can act as a viable template for other volume housebuilders. The project sets out the process of evaluation and improvement of a standard volume-market product. It highlights what is required to achieve the Passivhaus standard and ultimately to promote the embrace of the standard by volume housebuilders. The research also makes a significant contribution to the national target to have all newly built homes carbon-neutral, as now mandated by Scottish Government. With the potential to be adopted in future volume housing developments across the UK, this will create wide ranging and long-term benefits for the UK economy, the environment and its occupiers.

Material in this portfolio is taken from three sources:

1. An executive summary (pages 4-10):
    - DEVECI, G., MITCHELL, G., BURNS, D. and BUCHANAN, S. 2021. *Demonstrating 'Passivehaus' standard for the Scottish volume housing market: executive summary.*

2. research report (pages 11-54):
    - DEVECI, G. and MITCHELL, G. 2020. *Demonstrating 'Passivehaus' standard for the Scottish volume housing market: final report*.

3. Presentation slides (pages 55-84):

    - DEVECI, G. *Demonstrating 'Passivehaus' standard for the Scottish volume housing market*. Presented at the CSIC Building better homes workshop, 19 February 2019, Glasgow, UK.

4. A brochure produced by Dandara Homes (pages 85-93):

    - DANDARA. 2021. *The Rowan Passivhaus: Oakfields, Hazelwood*. [Brochure]

DEMONSTRATING 'PASSIVHAUS' STANDARD FOR THE SCOTTISH VOLUME HOUSING MARKET

Executive Summary **January 2021**

Professor Gokay Deveci RGU.
Grigor Mitchel, RGU, Darren Burns, Dandara Ltd, and Sarah Buchanan CSIC

Dandara Rowan PassivHaus. Hazelwood, Aberdeen

Project Details

Design Team	Professor Gokay Deveci RIBA FRIAS. RGU Grigor Mitchell, Research Assistant, RGU
Title	Demonstrating ''Passivhaus'' Standards For The Scottish Volume Housing Market
Output type	Practice-based Research Design Output
Function	Low-Energy Housing Design
Location	Hazelwood, Aberdeen, Scotland
Client	Dandara Ltd.
Completion	December 2020 - 18 Months
Funder	Construction Scotland Innovation Centre (CSIC)
Consultants	Scotframe ltd, Ingo Theboold (PH Certification) Fairhurst Consulting Engineers

Executive Summary

Can 'Passivhaus' standard houses be rolled out to the Volume Housing Market?

This is the outcome for the Construction Scotland Innovation Centre (CSIC) funded research proposal, titled 'Demonstrating the 'Passivhaus' Standard for the Scottish Volume Housing Market', which is being undertaken in partnership with Dandara Limited (DA) and the Robert Gordon University (RGU).

A deeper understanding of the performance of the Passivhaus Homes in Scotland is required if the 'Passivhaus' Standards are to find widespread application in the mass market Volume housing sector. This will enable the Scotland to meet its CO2 reduction targets, and address the performance Gap.

This project will test the hypothesis that the 'Passivhaus' standards (PH) can be applied, to provide high-quality housing at a competitive cost level, utilising the local Scottish supply chain and can be taken to mass market. The two dwellings were successfully built to the Passivhaus Standard by Dandara Homes. Both of these utilised a timber frame designed and manufactured in Scotland, and erected by a locally based specialist timber frame installer. It will demonstrate that the design and construction skills are thus evidently available in Scotland, and that this project can act as a viable template for other volume housebuilders. .

This project sets out the process of evaluation and improvement of a standard volume-market product. Highlighting what is required to achieve the Passivhaus standard, and ultimately promote the embrace of the Standard by volume housebuilders.

This project enabled a deeper understanding of PH design and the market adoption of the 'affordable Passivhaus' in the Scottish context. It looked to maximise the employment of local companies along the supply chain and to help them gain Passivhaus certification for their products.This project sets out the process of evaluation and improvement of a standard volume-market product. Highlighting what is required to achieve the Passivhaus standard, and ultimately promote the embrace of the Standard by volume housebuilders. It's a great showcase for the low-carbon technologies being developed in Scotland. With the potential to be adopted in future housing developments across the UK, this will create wide ranging long-term benefits for the Scottish economy, the environment and occupiers.

It's hoped that jobs at Scottish based Dandara will be created, including those within the supply chain, if new products that bear the 'Passivhaus' seal can be developed and approved. This project could also make a significant contribution to the national target to have all newly built homes carbon-neutral, as now mandated by Scottish Government.

Research Process

Can 'Passivhaus' standards can be applied to provide high-quality housing at a competitive cost level, utilising the local Scottish supply chain and taken to mass market?

In 2015, when this project began, the Scottish Government had set targets of reducing carbon emissions by 42% by 2020, which was having a significant impact on how the construction industry was thinking about and approaching current and uture works. In the UK's domestic housebuilding sector, for example, volume-build housing accounted at the time for around 90 per cent of new dwellings built. Properties were being produced to low-carbon standards, but not to the coordinated design and quality assurance standard of the Passivhaus or equivalent standards.

In January 2016 housebuilder Dandara was awarded a CSIC grant to fund applied research project Into whether volume housebuilders could design and build to the 'Passivhaus' standards using Scottish supply chain. Working alongside Robert Gordon University (RGU) in Aberdeen, Dandara aimed to develop a new product: the Scottish Passivhaus model.

Scottish companies has been slow in comparison to equivalents to pursue the benefits offered by developing components and systems for the low- energy sector. The Dandara/RGU project aimed to create a deeper understanding and market adoption of an 'affordable Passivhaus' standard based on establishing, as far as possible, a Scottish-based supply chain. Two homes would be built as part of the project: one to approved and Certified Passivhaus standards and one that would replicate the process using locally-sourced components and materials wherever they were available.

As well as assessing effectiveness and affordability, the project would seek to maximise employment of local companies along the supply chain and help them gain Passivhaus certification for their products. It would also examine the benefits of the Passivhaus build for occupants, not only in terms of reduced energy bills but also as they relate to comfort, health and well-being. The project would focus on Dandara's Hazelwood development in Aberdeen. The 'Rowan' home type was selected for adaptation as a representative of a standard home in terms of specification, buildability, build cost, energy efficiency, running cost and open market value.

One would be built to to Passivhaus standard, using certified Passivhaus products and processes, and one created to the 'Scottish Passivhaus' standard. As well as establishing whether a Scottish supply chain could be created, this would identify technical and project management modifications needed to achieve compliance, and allow Dandara effectively to cost future builds created to emerging regulatory standards. Dandara's Scottish base at the time the project took place was in Aberdeen, which meant they were excellently placed for working with RGU and local suppliers, a key element in reducing embodied carbon during the build as well as meeting the overall objective. Both the Dandara and RGU teams were involved in generating the design of the home to be created under the project.

Scottish timber frame specialists Scotframe, with a base in Aberdeenshire, had previous experience of Passivhaus builds and the knowledge required to meet the performance standards of the design. They were engaged in the early stages of the process to provide the closed panel timber frame walls and roofs with insulation on the inside face. A specialist local labour team was also appointed early on to carry out the build.

Low-energy home builder Cairnrowan Homes were brought on board by Scotframe to erect the timber frame up to the airtight stage, and then to ensure air and wind tightness after service installation. That created a single point of contact for airtightness works and testing from a local firm with experience in building to Passivhaus standards, with air and wind tightness membranes and tapes provided by Perthshire firm Proctor Group.

At the time the project was carried out, there were some gaps in the supply chain — windows were sourced from Ireland, for example, partly to ensure the design of both experimental homes was identical and partly because at the time there were no Scottish-made products in windows and insulation barriers that could fulfil the project's needs.
Similarly, there were no Scottish suppliers at that time for internal rigid wall and floor insulation of MVHR heating systems, and these had to be sourced outside of Scotland.

Dandara had trained their own staff in Passivhaus building methods, and some additional training relating to the installation of taping and insulation barriers was delivered on site. By the end of the project Dandara had a full in-house team with specialist knowledge and understanding of low-carbon technologies, on-site logistics and sequencing and financial implications of the Passivhaus model.

Research questions

1. What additional roles, services and time are required for a Passivhaus compared to a conventional volume house builder's product
2. The impact of 'Passivhaus' standards to an existing mass house design.
3. The role of structural engineer in reduction of Cold-bridges in timber kit frames
4. Utilisation of BIM for the 'Passivhaus' projects
5. The impact site specific data (orientation altitude and location) in Scotland. Is compliance using Heating Load is more suited to Scottish Climate
6. Issues with MVHR unit and duct layout.
7. Comparison of 'Passivhaus' QS process and that of and volume-house build.
8. What is the economic impact at the level of local employment.

Project Challenges

Technical

- Maximising Air Tightness – Junction treatment – Workmanship and appropriate detailing to limit air infiltration
- Increasing Fabric Insulation and Glazing – Insulation Type (Injected insulation in lieu of glass fibre quilt)
- Minimising Linear Bridging – Lining the inner studs and around openings with PI (closed cell) insulation.
- Understanding MVHR (Mechanical Ventilation and Heat Recovery) and it's contribution to balancing the environmental conditions of the supply and extracted air within the building
- Minimal Heating– Underfloor heating on the ground floor and reduced radiators to upper floors
- Airtightness - Checks in intervals

Impact on processes

- Instigated changes to supply, and reached consensus to alter the building components
- Introduced additional quality assurance checks post conclusion of works, impact of which increased those checks from 50 to 54.
- There was an uplift on both capital costs and impact on the business. Dandara undertook several discussions with valuation surveyors and funders, to re-evaluate the end product and agree the market price for sale
- Dandara changed processes and assessed quality assurance standards, which incurred additional checks at the conclusion of the project.
- Lessons and challenges involved, in particular how the company will utilise the gained experience and potentially enable the repeat of the project

Lessons Learned

Early appointment of Passivhaus Consultant / Certifier

- Stage 2 (Concept Design) is important for insulating and erecting the timber frame should be established during
- Availability of thermal bridge calculation software is critical for the early assessment of thermal bridges and saving cost
- The timber frame would ultimately have the biggest impact on the successful delivery of the 'Passivhaus' through specification, detailing and construction: timber fraction, thermal bridging and installation.
- Use of specialist kit erectors, and airtightness experts for the first attempt

Enhanced role of Structural Engineer in reduction of timber in kit.

- Optimise timber frame designs in terms of reducing the timber fraction and minimising waste.
- Number of structural timbers at triple studs etc. Utilising non-full depth' structural timbers at posts and window apertures.
- Future trade opportunity OR does it complicate the build process and make it more expensive.

Site specific data Influence – Orientation, altitude and location

- Initial assessments indicate that 'orientation' does not influence compliance by the Heating Load. However, the location has a considerable effect with possible sites in southern regions complying by Space Heating Demand.
- Combining semi-PH and assessing as a single entity improves compliance results due to more compact form

The Passive House criteria allow buildings to meet either criterion

- The Heat demand (15 kWh/m^2yr) OR the Heating Load ($10W/m^2$)
  Compliance using the Heating Load is more achievable in Scotland due to lack of solar gain. It will be worthwhile to investigate whether compliance by Heating Load could be embraced by Scotland as the basis for future 'local' Passivhaus standards.

- The ability to heat with the ventilation air. A certain amount of heat can be distributed with very little effort via the supply air coming from a Passive House building's ventilation system. The ventilation system thus serves a dual function (fresh air and heating) and reduces th investment required for heat distribution to a minimum. (Further research needed).

Issues with MVHR unit and duct layout.

- Should be co-ordinated earlier in concept design stages (WP2)
- Utility and store spaces should be 'larger and taller' enough to allow for access for installation and maintenance.
- Posi-joist or equivalent rather than solid joist allowed for flexible approach for ducting

Client's statement

Both the homes selected for the study were successfully built to 'Passivhaus' standard. Both utilised a timber frame designed and manufactured in Scotland and erected by a locally based timber kit frame installer. That showed that both design and construction skills were available in Scotland and created a viable template for other volume housebuilders to follow.

It also identified some key opportunities for development, like the manufacture and installation of 'Passivhaus' standard window systems, and internal insulation products, as well as low-carbon heating and ventilation systems like MVHR.

It addressed issues and concerns like costs and skills shortages by demonstrating that volume house builders could meet and overcome those challenges without significantly negative impact on business and profitability. And the final report documented the entire process of achieving 'Passivhaus' standards, giving other volume builders a clear set of guidelines to follow.

"Throughout this project, we continued our mission to design and build innovative homes while actively pursuing solutions which contribute to the global movement tackling climate and environmental challenges."

"Its achievements will continue to inform how we build homes across the UK, with learnings finding their way into future developments as we seek to deliver the very best in new home design and construction. Passivhaus now forms part of our future business strategy." Darren Burns, technical Director Dandara.

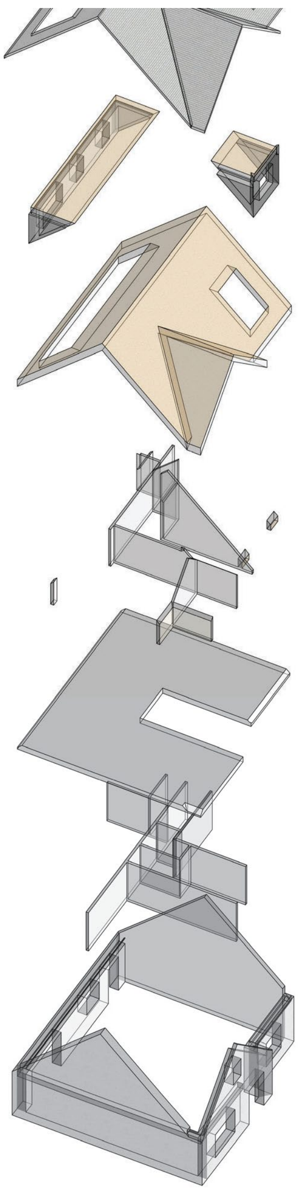
Impact

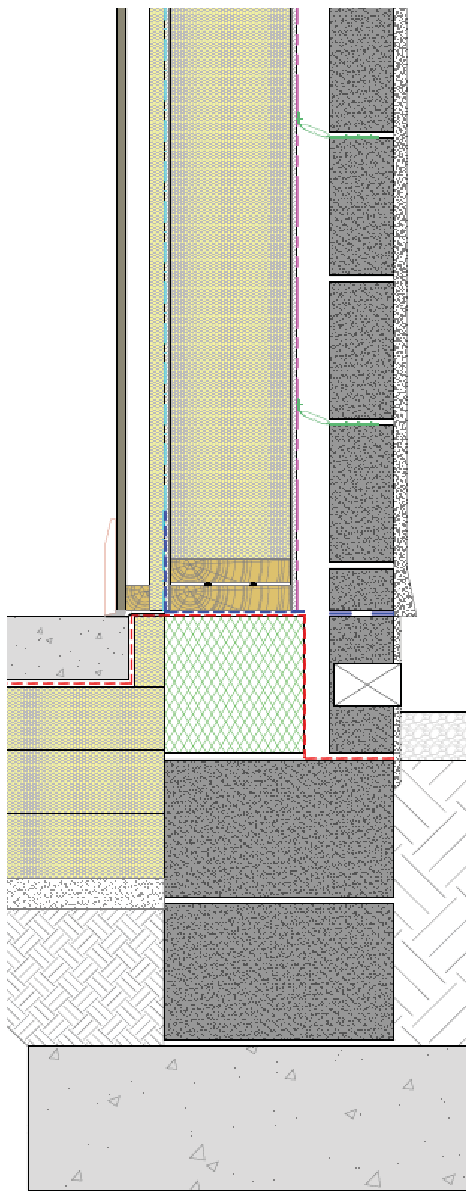
This project enabled a deeper understanding of PH design and the market adoption of the 'affordable Passivhaus' in the Scottish context. It looked to maximise the employment of local companies along the supply chain and to help them gain 'Passivhaus' Certification for their products.

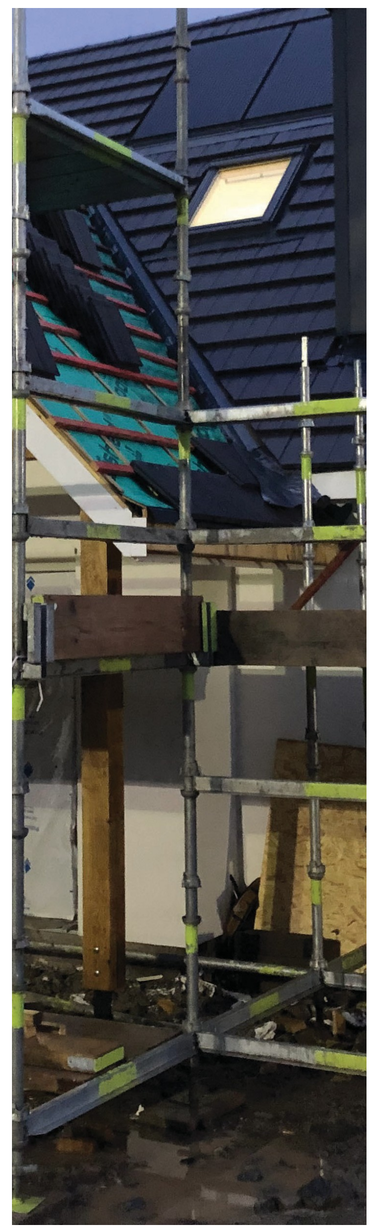
DEMONSTRATING 'PASSIVHAUS' STANDARD FOR THE SCOTTISH VOLUME HOUSING MARKET

Final Report. January 2020

Professor Gokay Deveci *RIBA FRIAS. RGU.* ***Grigor Mitchell,*** *RGU*







CONTENT

Appendixes

1.0 ABSTRACT

- ***Can 'Passivhaus' standard houses be rolled out to the Volume Housing Market?***

This is the outcome for the Construction Scotland Innovation Centre (CSIC) funded research proposal, titled 'Demonstrating the 'Passivhaus' Standard for the Scottish Volume Housing Market', which is being undertaken in partnership with Dandara Limited (DA) and the Robert Gordon University (RGU).

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This project will test the hypothesis that the 'Passivhaus' standards (PH) can be applied, to provide high-quality housing at a competitive cost level, utilising the local Scottish supply chain and can be taken to mass market. The two dwellings were successfully built to the Passivhaus Standard by Dandara Homes. Both of these utilised a timber frame designed and manufactured in Scotland, and erected by a locally based specialist timber frame installer. It will demonstrate that the design and construction skills are thus evidently available in Scotland, and that this project can act as a viable template for other volume housebuilders. .

This project sets out the process of evaluation and improvement of a standard volume-market product. Highlighting what is required to achieve the Passivhaus standard, and ultimately promote the embrace of the Standard by volume housebuilders.

It's hoped that jobs at Scottish based Dandara will be created, including those within the supply chain, if new products that bear the 'Passivhaus' seal can be developed and approved. This project could also make a significant contribution to the national target to have all newly built homes carbon-neutral, as now mandated by Scottish Government.

It's a great showcase for the low-carbon technologies being developed in Scotland. With the potential to be adopted in future housing developments across the UK, this will create wide ranging long-term benefits for the Scottish economy, the environment and occupiers.

2.0 INTRODUCTION

Aims and objectives of the project

The Scottish government's aims to cut carbon emissions by 42%, more than a third of 1990 levels, by 2020. One key means of achieving this would be to ensure that new homes, and in particular mass housing, are more energy efficient. This can be achieved by moving towards the Passivhaus standard, which would align with other countries in Northern Europe.

The PH standard is well established throughout Europe and will now be adopted as a standard for European Building Regulations by 2020. This necessitates a requirement for a deeper understanding, and market adoption of the 'affordable Passivhaus' in the Scottish context. This will additionally maximise the employment of local supply chain companies.
This evaluation and improvement of a standard volume-market product, should highlight what is involved in achieving the Passivhaus standard, and ultimately promote the early embrace of the Standard by volume housebuilders.

The project should also lead to the development a new product, namely the Scottish Passivhaus. In parallel there will be new (business) processes developed, including marketing strategies, enhancement of local industries supplying low energy components, and a valuation process taking into account the capital and whole life cycle costs of the building.

Another core aim of the project is to demonstrate that the Passivhaus standard can provide an affordable method of delivering ultra-low energy market housing; whilst addressing occupant wellbeing, fuel poverty and energy security. The optimised design can be conceive both as a demonstration of a high-performance product, and also as a demonstration process for achieving best practice. The design responds to both best practice and research at European level, in addition to the specific Scottish cultural context of dwelling form within the mass housing market. In its form, systems, and materials it also focuses on replicability and flexibility.

2.1 Approach

With a standard specification house relating to detailing, specification, build-ability, build cost, energy efficiency, running cost, and open market value, two houses have been built and tested. One house to Passivhaus (Classic) standard, using standard certified 'Passivhaus' products; and one replica house (Scottish Passivhaus) using locally sourced Scottish supply chain building components and materials, wherever possible. The chosen house type has used one of Dandara's standard house type designs to allow Dandara to define the build cost. This will allow effective costing of their future range to emerging regulatory standards. Moreover this will aid the identification of which product modifications (both technical and project management) are required to achieve compliance.
Consideration of site placement, orientation, form, floor area and area/ orientation of glazing is a prerequisite of a typical 'best practice' Passivhaus design process. In the case of this project however, these factors are effectively pre-determined, and thus the principal design focus of energy efficiency improvements relative to the standard house type, is the external envelope of the dwelling. This will ensure the relevance of the study to the wider housing sector where currently overall form, external aesthetic, and site layout fall within established parameters.

2.2 Legislative context

The UK and the Scottish government have an ambitious target to reach 'net zero' emissions by 2045. A challenging interim target of achieving a 75% reduction in emissions by 2030 has also been set. The 'Passivhaus' standard, recognised worldwide as the leading energy performance standard with a proven track record, is thus an effective basis for the effective implementation of such an ambitious reduction. In the domestic sector in the UK, volume-build housing accounts for a high proportion of the new dwellings built (90%). Although properties are produced that comply with the rigorous technical standard, they have not yet embraced the coordinated design and quality assurance approach of the Passivhaus or equivalent standards. Meanwhile Scottish companies have also been slow, in comparison to their equivalents in Ireland for example, to pursue the benefits offered in developing components and systems suitable for the low energy sector. There is therefore a need for a deeper understanding and the market adoption of the 'affordable Passivhaus' in the Scottish context thereby maximising the employment of local companies along the supply chain.

2.0 Environmental and social context

Achieving the adoption of a rigorous low energy standard such as Passivhaus, will result in a two-fold benefit. This will be a reduction in carbon emissions, and also assuring that the end user benefits from, lower running costs and improved thermal comfort. On the social level it aims to address key user concerns, such as very high levels of fuel poverty, by reducing fossil fuel dependence, and improving energy security and occupant well-being.

2.1 Demonstrator

This project aims to demonstrate that the 'Passivhaus' standards can be applied to provide good quality housing at a competitive cost level, using the local Scottish supply chain and can be taken to mass market, thus overcoming the barriers to its larger scale adoption.
It is also expected that the life cycle cost analysis will show the long-term benefits of the PH standards, both financially as well as environmentally. This will provide Dandara with demonstrable evidence that the PH Standard is capable of creating beneficial impetus to the house building industry. The impact on the wider Scottish construction industry will be manifold. The project demonstrates that the Passivhaus Standard is not only a very environmentally friendly way to build houses, but also financially viable for volume housing, Ultimately a successful outcome will generate valuable data and lessons, which could be exploited by Housing designers, providers and developers. This will make a significant contribution to the national target to have all newly built homes towards the carbon-neutral and mitigate fuel poverty. Through CSIC and HEI partners knowledge will be shared;

- To provide a template/model for others to follow
- Attendance at national and international low-energy conferences and workshops
- Feedback into teaching at postgraduate levels
- Press release and presentations at relevant workshops and CPD events

2.3 Cost

The project will promote an ethos to the industry house builders and valuation surveyors that any additional cost will and should have a positive and direct effect on value through the life cycle cost benefit to the end user. Any increased construction cost should therefore not necessarily affect the competitiveness within the industry. This will offer a wider choice and house value advantage for the PH compliant house, over non-passive standard houses to the ever increasing, energy cost conscious public. Dandara will use this information to inform future projects, with the aim of ensuring that Scotland remains at the heart of the development towards the zero-carbon housing.

2.4 Local supply chain

The project aims to help provide a visual demonstration to the public and the Scottish construction industry for the low carbon technologies being developed in Scotland. This will showcase the potential to be adopted in future housing developments across the UK, thus creating wide-ranging long-term benefits for the Scottish economy, the environment and occupiers.
The project partners are ready to develop and deliver systems and components that are capable of meeting the Passivhaus standard requirements.

2.5 Economic/ Commercial

At the end of the project Dandara will have a Scottish Passivhaus design standard, meaningful comparison data and lessons learned, which provide the platform for the commercialisation. The company will have the confidence and knowledge required to roll out the modified product through their existing business infrastructure with the assistance from their Sales & Marketing Strategy, which will include an evaluation of "Green Premium" on sales values.
It is anticipated to increase the number of Dandara's Passivhaus sales. It is anticipated that other house builders will follow this proposed Passivhaus model and the overall number of Passivhauses build in Scotland by 2020 could be in excess of 100 units.

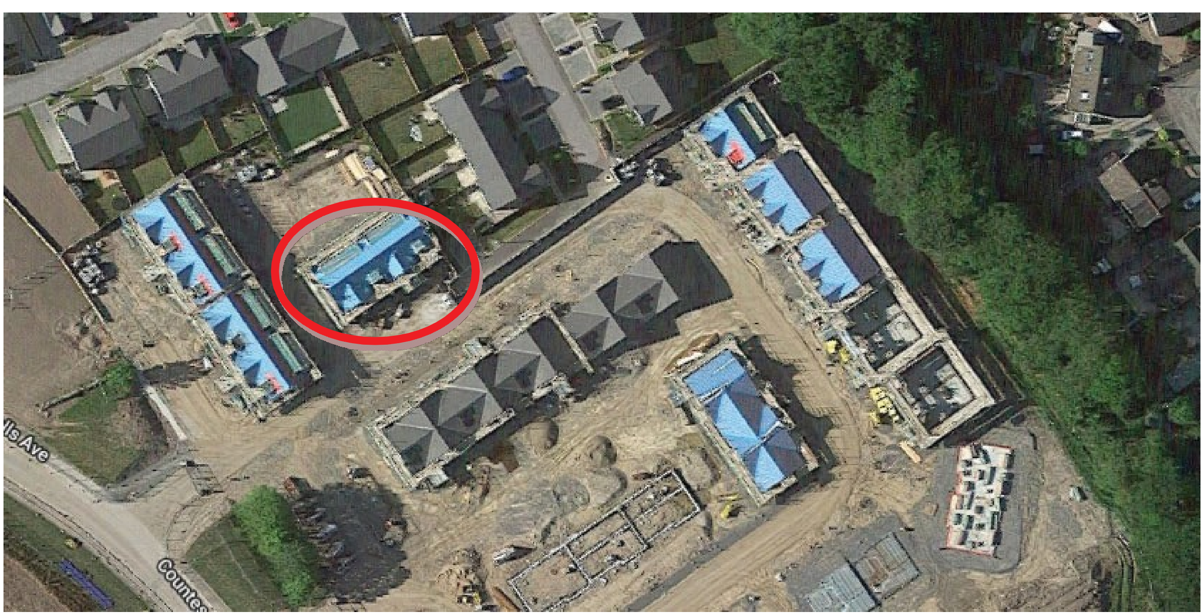


Figure 02: Dwellings an context under construction. Plots are circled in red. Google Earth

3.0 PROJECT WORK PROGRAMME

- The report has been structured to correspond to the work programme (WP) or work stages and milestones defined in the Project Agreement (PA,) and as such is organised as a chronological description of the process.
- The milestones have also been addressed in the sequence defined in the Project Agreement. In practice however, there was greater overlap of the activities and milestones WP1 and WP2, due to the further optimisation of the specification and details during coordination with the Passivhaus Certifier.
- The actual methodology to deliver the aims of the project have encompassed three key facets:
    1. **Process:** Liaison and coordination with Project Partners, encompassing progress and technical meetings, site workshops and other discussions with suppliers etc.;
    2. **Assessment:** Assessment of options using Passivhaus Planning Package software (PHPP) and further development by the Passivhaus Certifier;
    3. **Technical:** Optimisation of specification and details, to ensure delivery of the Passivhaus's.
- Assessment data and specification notes are highlighted in blue.

Figure 03: Site location in context of Aberdeen. Google Earth

WORK STAGE 1 - DESIGN AND SPECIFY

- *Robert Gordon University will provide the following services:*
    - *Develop and propose the technical design/specification of the Scottish Passivhaus*
    - *Review build costs (at design stage) and whole life cycle costs*
    - *Contribute and support overall review to determine that project is reasonably practical to continue (taking account of buildability/deliverability and cost).*
- *Dandara will provide the following services:*
    - *Provide supporting information re design, specification and cost.*
    - *Review designs and specification, and sanction.*
    - *Lead and manage overall review to determine that project is reasonably practical to continue (taking account of buildability/deliverability and cost) Sanction or otherwise progression to next stage.*
- ***Milestone 1: The Scottish Passivhaus has been proposed to Dandara.***
- ***Milestone 2: The specifications for the Scottish Passivhaus have been signed off by Dandara.***

- A main focus of the work during the WP 1 was to undertake and document an energy assessment of the house types selected from DH standard range, utilising incrementally increasing levels of insulation to provide a range of options for possible compliance with the 'Passivhaus' standard., with dimensional and volumetric data derived from 3D models prepared using BIM (Revit 2017).
- Following on from this, with a specific option agreed with DH, the process of developing key details and the specification could be progressed in conjunction with the project partners.
- The following methodology was undertaken to achieve the defined milestones:

    - Project Team progress and technical meetings *(See Appendix 01 for full record)*;
    - Dimensional and volumetric data derived from 3D models prepared using BIM (Revit 2017);
    - Assessment using Passivhaus Planning Package (PHPP) software as the main methodology for calculating the space heating demand and heating load of each variant.
    - Options comparison and optimisation.

Figure 04: *Site layout plan. Dandara Homes Limited*

Plot selection and house type initial feedback

- The two Passivhaus’ are constructed as a semi-detached block in the Dandara Hazelwood Development in Aberdeen 4 miles West of City Centre as show on figures 01, 02 and 03.
- Prior to commencement of the project Dandara issued the site plan of Zone F at Pinewood and various house types to RGU for their feedback on nomination of most suitable options.
- RGU noted that plots 5 & 6 presented the most favourable location in terms of the Passivhaus requirement of maximizing solar gain due to orientation, as well being a ‘stand-alone’ and prominent site.
- RGU provided feedback on current house type designs by RGU, in the context of general Passivhaus criteria of form, floor area, airtightness and thermal bridging.
- Although all of the house types were considered suitable it was proposed by RGU that the internal garages to the Hazel, Baldwin and Maple would pose issues for achieving airtightness and elimination of thermal bridges.
- The Rowan was noted by RGU as a preferred option due to the larger internal floor area, compact form and marginally increased amount of south glazing, although there are concerns regarding the detailing and thermal performance of the front and rear dormers. Market requirements also defined the selection of this house type.
- The Rowan is a 3-bedroom detached or semi-detached home house-type. See figure 05. The ground floor features a separate lounge and kitchen-dining room, utility room, W.C. and bedroom/study with an en-suite shower room. On the first floor the large master bedroom features a walk-in dressing room and en-suite. There is a further double bedroom a family bathroom.
- The Rowan house type will present challenges for achieving airtightness and eliminating thermal bridging in construction to the level required by Passivhaus. It was agreed therefore that an alternative house type should be assessed in parallel with the Rowan. The Maple house type was proposed by DA as the preferred option. This approach was undertaken to provide DA with the flexibility in choosing between the two different house types for latter stages.

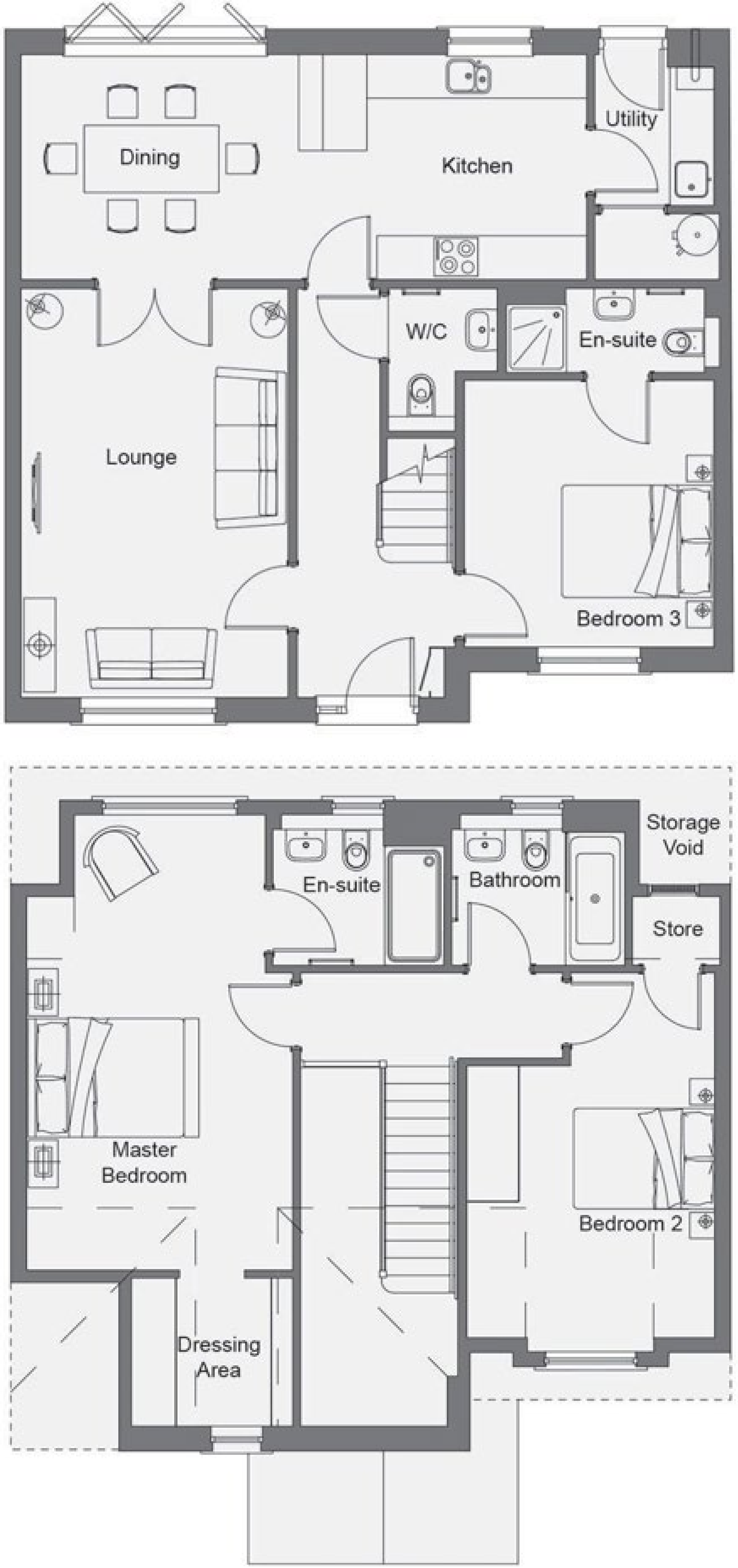


Figure 05: Rowan House-type Floor Plans. Dandara Homes Website

4.1 Project Team progress and technical meetings

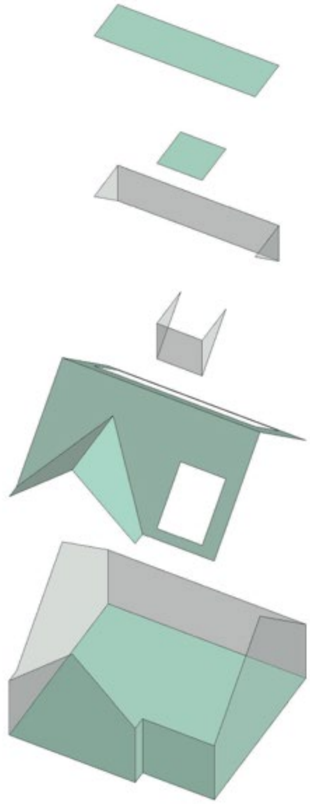
Initial meetings were conducted to set design parameters to achieve Passivhaus Certification Standard. Specifically, to discuss the impact on the Passivhaus Standard on the structural design, detailing, manufacturing and erection of the timber frame; and review how concerns over thermal bridging, airtightness and sequencing can be addressed.
Target U values of envelope, air tightness target, linear bridging targets set by RGU.
Further information was provided by Dandara on their typical and proposed specification for the external envelope as well as their preferred supply chain for windows and mechanical services.
Following this, with the design effectively fixed and an initial Passivhaus assessment undertaken, meetings allowed for the review of draft key interface details prepared by RGU and Scotframe's Structural Engineer, in the context of Passivhaus requirements and the manufacturing and erection of the timber frame. The timber frame supplier: Scotframe (SF) and their associated Structural Engineers were integral to discussions throughout regarding insulation thickness/ types, means of airtightness, thermal bridging, a reduced timber fraction, sequencing and delivery methods.

The timber frame would ultimately have the biggest impact on the successful delivery of the Passivhaus through specification, detailing and construction: timber fraction, thermal bridging and installation.

BIM modelling

Milestone 1. Following receipt of the current construction drawings and specifications from Dandara for the Rowan and Maple house-types, RGU were able to commence the preparation of a 3D BIM model of the 'base' house-types using Autodesk Revit.

- The 'base' house-type is used as the 'option 1' from which variables for optimising performance will be derived by RGU.
- The BIM model is used to calculate the usable internal floor area; the dimensions of the window and door apertures; the building volume and external surface areas for each option (taken to the outside face of the insulation layer to the walls, roofs and floor in each case); and the length of linear thermal bridges derived from 3D massing model of the house type variants. It also provided a graphic depiction and record of the PHPP inputs.
- The use of BIM software allows for the scheduling of the wall surfaces and apertures, thus assisting in the process of incorporating data on the different options into the PHPP software *(see figures 06, 07, 08 and 09 as well as Appendix 02).*
- 'Schedules' data from a Revit file can be extracted in Excel format, thus a live link could in the future ultimately be formed between the BIM and PHPP software.



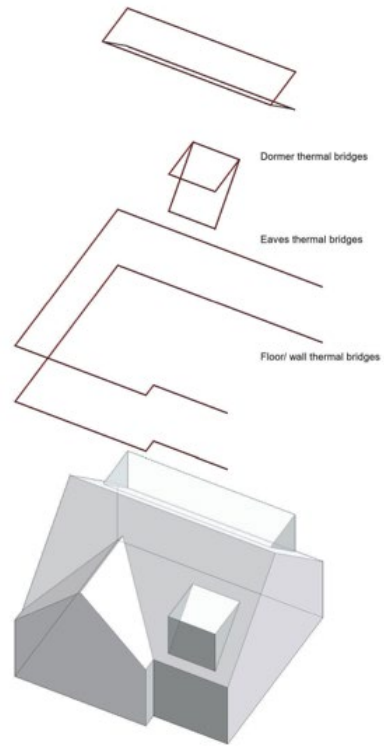


Figure 06: Surface area analysis from BIM model. RGU

Figure 07: Volumetric analysis from BIM model. RGU

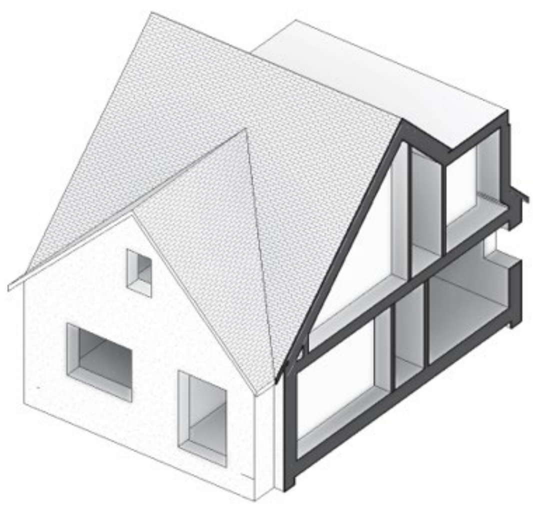


Figure 08: Base BIM model of Rowan house-type. RGU

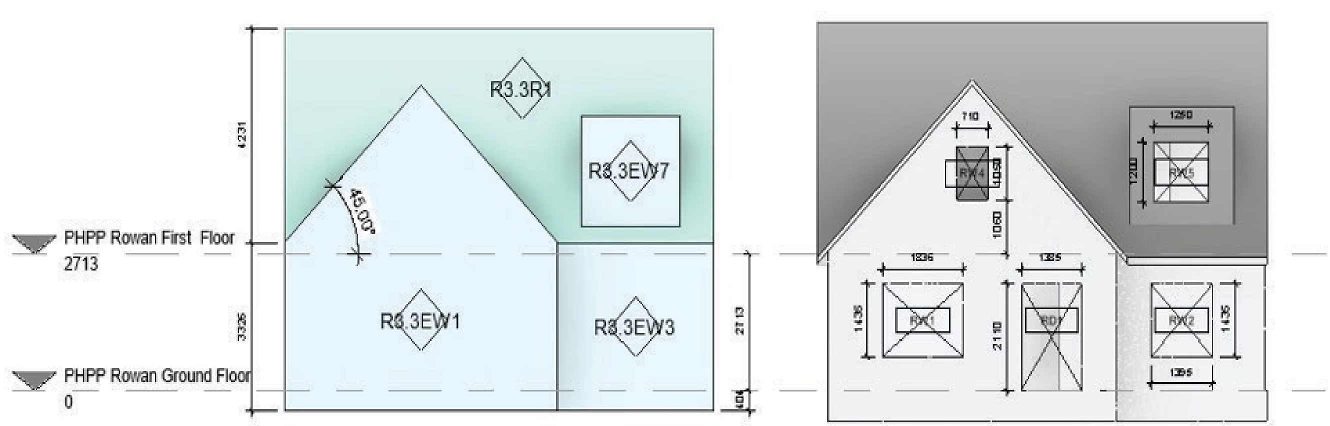


Figure 09: Assessment of surface areas and aperture sizes from BIM model. RGU

4.4 PHPP assessment

An initial PHPP 'base model' assessment was commenced by inputting the above BIM dimensional and area information into the PHPP spreadsheet to calculate the following main Passivhaus criteria:

- Annual heating demand - kWh/m2.annum;
- Heating load – W/m2;
- Overheating potential – defined as % of the year over 25 deg. C;
- (All using an airtightness value of 0.6 unless otherwise specified);
- Annual energy balance showing gains and losses though different elements such as windows, roof, walls, thermal bridges etc.;
- Monthly heating demand showing how space heating requirements and internal and solar gains make up the overall need. kWh/m2.month.

- The initial PHPP assessment calculates the main criteria for a Passivhaus, which involves completion of the 'Verification', 'U-values', 'Areas', 'Components' 'Windows', 'Shading', 'Ventilation', and 'Ground' worksheets. All other values are set to default values. The scope of work which described provides a good indication of compliance, and will form the basis of the full assessment that would be required by a Certifier.
- As well as a compliance tool, the PHPP model is used to assist in optimising value and performance to allow for the evaluation of the most practical way in order to achieve the Passivhaus standard.
- The above sea level of the dwellings is included so that the climate data set can be completed.
- At this stage the two Passivhaus options (one using standard certified products and the second using locally sourced materials and components) are not differentiated, with information on window and ventilation components drawn from available technical information.
- For example, thermal and dimensional information for Munster Joinery's Passivhaus Certified window range is used for the initial assessment. Dandara use Munster joinery products as part of their supply chain. It is also currently proposed that for the purposes of ensuring that both detached properties have a similar appearance, that the same window types are used on both properties.
- The key possible variables in the current assessment relate to the thermal bridge heat loss values (psi values) and MVHR system. Elimination of thermal bridges and an improved efficiency of the MVHR unit will result in an improved space heating demand. Conversely increased thermal bridging and a lower efficiency MVHR unit could jeopardise to potential of complying with Passivhaus criteria.
- The U-Values stated by Scotframe in their literature cannot be input directly into the PHPP spreadsheet, as the software calculates U-Values using its own algorithms. The PHPP results are generally higher than Scotframe's published figures.
- The thermal conductivity of 0.035 W/mK provided by Scotframe for their insulation is used in the PHPP assessment, although this performance needs to be declared to 'Lambda 90/90' for the purposes of Certification.
- Data for foil faced/ reflective breather or vapour control membranes, which propose to alter the surface emissivity of the wall panel, cannot be input into the PHPP U-Value calculator.
- As part of the U-Value calculations within the PHPP software, the timber fraction can have a large influence on the resultant U-Value. Typically a timber fraction of 15% might be applied, although without evidence a Certifier might use up to 25%. Clear graphic evidence

for the specific house type will therefore be required from the timber frame supplier to improve the accuracy of the PHPP assessment and ultimately to satisfy the Certifier.

- Thermal Bridge values are not calculated as part of the initial assessment, although the lengths of the linear thermal bridges at floor/ wall; mid floor; eaves; internal corner; windows; dormers etc., have been established using the BIM models and a with a nominal psi value of 0.01 W/mK included in the PHPP model. These have a large bearing on the optimisation of the thermal envelope and thus final PHPP result, which is why it is important to have a reasonable 'buffer' in the compliance calculation for the initial assessment. The Psi value of each junction will be calculated as the details are developed. The Certifier will calculate the Psi values of key junctions as part of their scope, although only they can decide which junctions should be assessed.

- Quotes were sought from 2 Passivhaus Certifiers proposed by RGU with DA to select their preferred during the next stage of the project.

4.5 Options and Optimising Performance

The Rowan house type was confirmed as the preferred option for the next stage of the project and the Maple house type eliminated from the process.

- The initial results of the 'Option 1' assessment suggest that the space heating requirement and/ or heating load (both means of achieving compliance) is above that required to comply with Passivhaus criteria. An incremental approach or options appraisal is therefore undertaken to establish which key variables can be optimised to further increase the performance (*see figure 10 and Appendix 03*). There are generally numerous variables to review in the model, although due to the fixed nature of the design the key ones are:
    - U values of wall/floor and roof;
    - Window performance and nominal installation details;
    - Linear thermal bridges.
- The incremental improvements in insulation relative to space heating/ heating load figures allow for compliance to be based on the optimal thickness of insulation. As such the key focus is to derive the most cost effective solution which meets the technical and certification requirements of the supplier.
- The PHPP results are structured to analyse each option in turn. Each is based on an incremental improvement in the insulation thickness/ U-value of the external wall from the 'Base' case up to 'Option 4' (25 mm – 100 mm). Standard thermal conductivities are used in each case for the assessment.
- The roof construction is based on 2 different thicknesses of Valutherm closed panel.
- The floor has either 200 or 300 mm of rigid board laid below the slab.
- The 'Base' option was derived from a standard house type specification for the thermal envelope and is not considered as a viable Passivhaus route, being a baseline performance to highlight the incremental optimisation of performance relative to a wider range of increased U-values. It should also not be considered representative of the space heating demand of a standard house, due to the inclusion of a heat recover ventilation system and low levels of air leakage required for the PHPP assessment, which would not be used as standard.
- Further optimisation of each option is provided by either standard or improved psi values for the window installation.

For Option 4, a further means of improvement is offered through the increased percentage of south glazing relative to face area. As this is not a preferred route of improving the PHPP result, it has not be applied in each case

The house form, layout, internal dimensions and orientation have been retained, although the increased thickness of insulation on each incremental improvement, marginally increases the surface areas and overall volume of each variant. The marginal increase does not have a large impact on the calculation although is important for the accuracy of the result.

The surface areas and volumes have also been used to calculate the A/V (External Surface Area/ Internal Volume) and Form Factor (External Surface Area/ Usable Floor Area) ratios. Although strictly not direct indicators for compliance the ratios can, when compared against optimal figures, indicate how efficient the house is in terms of heat loss relative to form. Generally the more compact the form, the less heat loss that a building exhibits. The A/V calculation leads to a more favourable result as the surface area and volume increase - i.e. the building is getting more compact. Meanwhile the surface area/ treated floor area result becomes less favourable, which is what you would expect, as the TFA is a constant.

Cells are highlighted in red where the inputs or results exceed the recommendations of the Passivhaus standard. Those in green highlight compliance. The usable floor area, highlighted in blue, is a fixed value.

As noted the initial assessment does not include the full range of thermal bridge values and thus a margin of error of 2-3 kWh/m2A or 1 Wm2 should be incorporated into the results.

A high efficiency HRV unit has also been used in the assessment and a lower efficiency unit will also impact on the result.

In addition, the timber fraction of the timber frame should be calculated, as this will impact on the U-value of the wall and roof. A figure of 15% has been allowed for in the walls and 10% in the roof, although without detailed information a Certifier will use a TF of 25%.

RGU would suggest that Option 0 (base) and Option 1 will not achieve compliance for either house type and should therefore not be considered.

Option 2 achieves compliance through heating load, although without any margin for error in the result it should be considered a risk to progress of this basis, unless the calculated thermal bridge and timber fraction results are available and do not raise the result.

Both Options 3 and 4 may achieve compliance for both space heating demand and heating load although Option 4 is not perceived as being a 'last resort' solution with the levels of insulation in the walls not being seen as economically viable for a future roll out.

Revised specifications have been incorporated into the PHPP assessment process, generating the following additional options:

- Option 1.1: 140 wall panel + 25 internal insulation/ 225 roof cassette + 50 internal insulation/ 300 mm under slab insulation;
- Option 3.1: 184 wall panel / 225 roof cassette + 50 internal insulation/ 300 mm under slab insulation;
- Option 3.2: 184 wall panel + 25 internal insulation/ 225 roof cassette + 50 internal insulation/ 300 mm under slab insulation.

- Results:
  - Option 1.1 does not comply with either the space heating demand nor heating load;
  - Option 3.1 complies marginally with the heating load as an optimised version;
  - Option 3.2 complies with the heating load as a standard and as an optimised version.

- The PHPP assessment of 2 units as a single block would generate more favourable results. In this case it is not utilised because of the difference in specification between the 2 units.

Housetype	Option	Insulation thickness / U-values					
		Walls		Roof		Floor	
Rowan	Base	140 mm PU	0.252 W/m2K	200 mm PU	0.142 W/m2K	200 mm PU	0.107 W/m2K
	Option 1	140 + 25 mm PU	0.179 W/m2K	220 mm PU	0.142 W/m2K	200 mm PU	0.107 W/m2K
	Option 2.1	140 + 25 mm PU	0.179 W/m2K	225 + 50 mm PU	0.103 W/m2K	300 mm PU	0.072 W/m2K
	Option 2	140 + 50 mm PU	0.146 W/m2K	245 mm PU	0.130 W/m2K	200 mm PU	0.107 W/m2K
	Option 3	140 +70 mm PU	0.129 W/m2K	300 mm PU	0.108 W/m2K	300 mm PU	0.072W/m2K
	Option 3.1	184 mm PU	0.166 W/m2K	225 + 50 mm PU	0.103 W/m2K	300 mm PU	0.072W/m2K
	Option 3.2	184 + 25 mm PU	0.136 W/m2K	225 + 50 mm PU	0.103 W/m2K	300 mm PU	0.072W/m2K
	Option 3.3	184 + 25 mm PU	0.136 W/m2K	225 + 50 mm PU	0.105 W/m2K	300 mm PU	0.072W/m2K
	Option 4	140 + 100 mm PU	0.109 W/m2K	300 mm PU	0.108 W/m2K	300 mm PU	0.072 W/m2K

Figure 10: Options appraisal matrix. RGU

- **Milestone 2:** As there were still a number of variables to be incorporated into the model and at that stage the project team did not have enough information on the level of thermal bridging or timber fraction in the kit, Option 3.2 was established as the basis on which further development of the detailing would proceed.

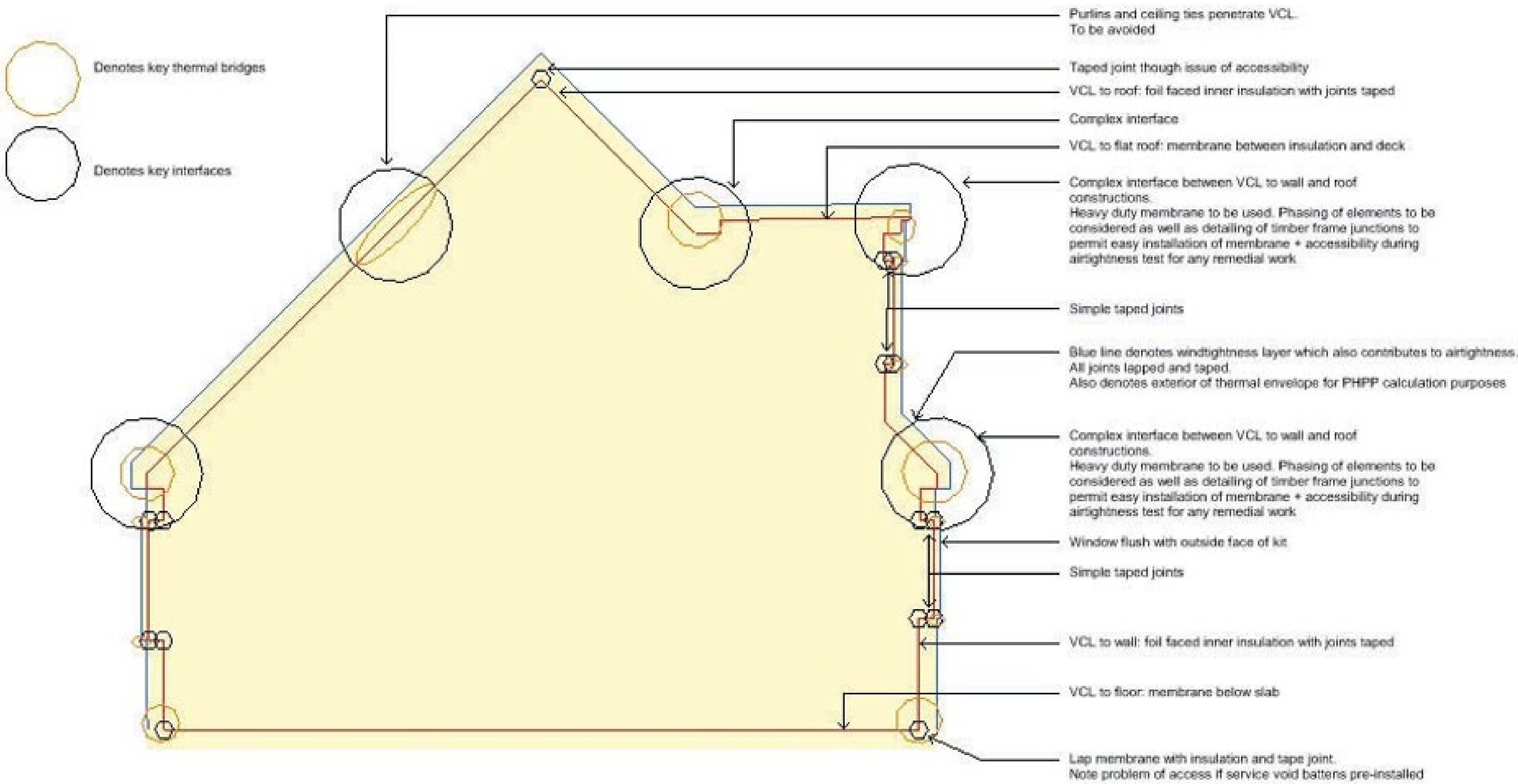


Figure 11: Assessment of wind and airtightness layer and key details. RGU

4.6 Outcomes from WP1 - Construction Specification: Timber Frame Thermal Design

- From the outset, the DA proposal was to use standard Scotframe 'Valutherm' closed panel timber frame wall and roof panels with additional internal insulation installed on the inside face. Various options for wall panel thickness are available however it was agreed that although a thicker wall panel such as a 184 mm or 235 mm would provide an improved thermal performance on paper, the added continuous internal insulation will mitigate thermal bridging at structural elements.
- SF noted that there is a BBA certification issue with using more than 25 mm rigid insulation on the inside face of the wall cassette panels. This issue is derived from the extended fixings required for thicker insulation and their impact on the structural integrity of the external wall in the event of fire. The reduced thickness of insulation, other than the reduced material cost can help reduce the cost of specialist fixings, additional installation time and difficulties in cutting and sealing the materials to the required standard for airtightness.
- It was understood that the reduced thickness of insulation would require further thermal analysis of the thermal bridges to be conducted as part of the Certification process.
- The Structural Engineer applied the principal of the reduction of timber such as cripple studs, in order to help reduce the timber fraction and thermal bridges at gable and window details. This principal will be applied to all critical interfaces.
- The Structural Engineer proposed that the ridge beam to support the roof cassettes should be formed in timber such as glulam rather than steel, which presents thermal bridging, settlement and coordination issues.
- The resultant strategic technical specification, developed during the Project Team technical meetings and tested using the PHPP based 'options assessment, was agreed by DA to progress on the following basis:

- Walls: 184 mm closed panel with 25 mm inner insulation. This constitutes the most cost-effective means of proceeding to suite the requirements of thermal performance, fabrication and BBA certification.
- Floor: 300 mm insulation below the Ground Floor slab. This is deemed a cost-effective means of offsetting other areas of heat loss in the timber frame.
- Roof: 225 mm deep joist with 50 mm internal insulation is proposed as the most optimal solution for the purposes of thermal performance, fabrication and installation. wall. SF advise that the roof cassette panels should be formed with solid timber rather than I-joists as they are easier to fabricate and create interfaces with reduced timber.
- Dormers: These are complex elements for achieving thermal bridge free and airtight interfaces as well as the increased timber fraction in the construction. Development should focus on the elimination of thermal bridges in their construction and as such the dormer wall construction includes 50 mm internal insulation.
- Intermediate floor: Open web joists such as Posi Joists, for ease of feeding through ductwork. These can also be manufactured in Scotland.
- Any projections on the building, e.g. eaves and canopy etc. should be thermally separate from the main thermal envelope to avoid thermal bridges and puncturing the airtightness layer.

4.7 Outcomes from WP1 –Air-tightness Strategy

- The airtightness membrane or vapour control layer (VCL) to each construction element should ideally be positioned on the inside face of the insulation layer to minimise possible interstitial condensation. In practice, if foil faced, the inner face of insulation to the walls and roofs should act as the VCL, with all simple junctions taped (board to board, wall to floor, window perimeter etc.). The VCL layer to the floor may be formed using a membrane below the concrete slab, which should lap and taped to the wall VCL.
- Complex junctions, in particular to eaves, ridge and dormers may involve the use of additional heavy-duty membranes. The sequencing of construction elements such as wall/ floor/ roof for instance should be investigated to ensure that the membranes are correctly fitted and form effective and accessible laps with adjacent construction elements. The successful installation of these membranes can be subject to joining methods between components, lifting methods and weather conditions.
- In order to gain maximum benefit from this, that all junctions should be accessible during erection (e.g. wall base detail where battens for the service void are placed to low relative to the floor).
- RGU have noted the key research potential of investigating how a high level of airtightness can be achieved through the wall and roof panels and how they join, rather than an over- reliance on tapes and membranes. Scotframe have a strong preference for this approach and they have previously achieved a good level of airtightness (though not to Passive standard) by sealing all junctions with gap filling foam. There preferred installer of this is Gregor Davidson of Cairnrowan Custom Homes.

Figure 12: General arrangement elevation of the Rowan. Dandara Homes Limited

Outcomes from WP1 - Window Installation Strategy

- The method of window installation and resultant installation psi value can have a sizable impact on the result of the PHPP assessment due to the length of the thermal bridges (2 x length and height for each opening). In order to reduce the thermal bridging, the window should be positioned at the face of the timber frame and not directly behind the outer leaf masonry as is conventionally considered best practice. In additional there should be reasonable coverage of the frame with rigid insulation, ether externally or internally, which will depend on whether windows are inward or outward opening.
- The placement of the windows will entail additional complexity and cost in detailing and constructing the window reveals and head due to the need to bridge the cavity between the masonry and the timber frame both in terms of fire stopping and providing a robust finished surface. In this situation a rendered cement fibred board can be used or alternatively a flashing which matches the frame finish and colour. For both cases and in addition to the deeper set-back of the windows, there will be an impact on the exterior aesthetic of the house which can be used positively if correctly detailed.
- Windows need not be pre-installed, although based on outward opening (fully reversible) windows; the apertures can be lined internally with insulation by Scotframe to improve the thermal performance of the interface.
- Windows are to be sourced from Muster Joinery, who supply a range of Certified Passivhaus windows that would match Passivhaus performance criteria as well as being typical suppliers for DH.

5.0 WORK STAGE 2 – REGULATORY APPROVAL

- Robert Gordon University will provide the following services:
  - Support the application process for NHBC and Local Authority.
  - Prepare, submit and liaise with the Passivhaus Institute in order to obtain approval and certification.
- Dandara will provide the following services:
  - Prepare, submit and liaise with NHBC and Local Authority in order to obtain approval.
  - Support the application process for Passivhaus certification.
- **Milestone 3: Applications are submitted to NHBC, Local Authority and Passivhaus Institute.**

- With the design effectively fixed and an initial Passivhaus assessment undertaken, the main focus of the work covered in this stage was for RGU to further develop, optimise and finalise the specification and detailing of the building fabric and components in conjunction with DA and SF, with the aim of establishing a set of preliminary construction layouts and details with the aim of bringing the Passivhaus' to site.
- The Passivhaus Certifier was also appointed to the project during this stage and was able to complete the 'Design Stage Certification of the two Passivhaus', having reviewed the PHPP assessment carried out a thermal analysis of thermal bridge junctions.
- On the basis of the thermal bridge calculations, the DA technical team were then able to refine the junction details to sign off on the technical designs and specifications in line with Certifier's advice.
- DA also developed the information for Building Warrant / Construction detailing stage.
- The following methodology was undertaken to achieve the defined milestones:

  - Project Team progress and technical meetings;
  - Conclusion of assessment using Passivhaus Planning Package (PHPP);
  - Review of design and assessment data by the Passivhaus Certifier and analysis of key thermal bridges.

5.1 Project Team progress and technical meetings

- The meetings were held with DH and SF and their associated Structural Engineer, to further develop and review draft key interface details prepared by DH, in the context of Passivhaus requirements for airtightness and mitigating thermal bridging as well as fabrication and erection criteria.
- It was reiterated by RGU that the reason for the requirement for increased insulation thickness to the thermal envelope is to overcome the complexity, large surface area and reduced solar gain of the Rowan house type. The mitigation of the thermal bridges as well as reduction of the timber fraction are also imperative to achieve compliance with the Passivhaus standard.
- The two proposals received from Passivhaus Certifiers: Ingo Theobold and Warm Associates, were also reviewed at the meeting in May, leading to the appointment of Ingo Theobold in July 2017.
- Following Ingo's initial assessment and stipulation of which thermal bridges should be calculated as part of his certification process, the project team investigated whether the thermal information could be obtained from alternative sources.
- The meetings also involved discussions regarding possible manufacturers and suppliers of, ventilation, heating, window and door systems.
- RGU provided feedback on the junctions to enable DA to work up the required kit depth and any other detailing modifications that RGU need to satisfy the PH analysis. DA's Housing Director could then finalise discussions with Scotframe to obtain a kit price based on a fully PH workable solution for the Valu-therm kit for the walls, roof and dormer as an entire package incorporating RGU's requirements within the general constraints of the baseline house design.

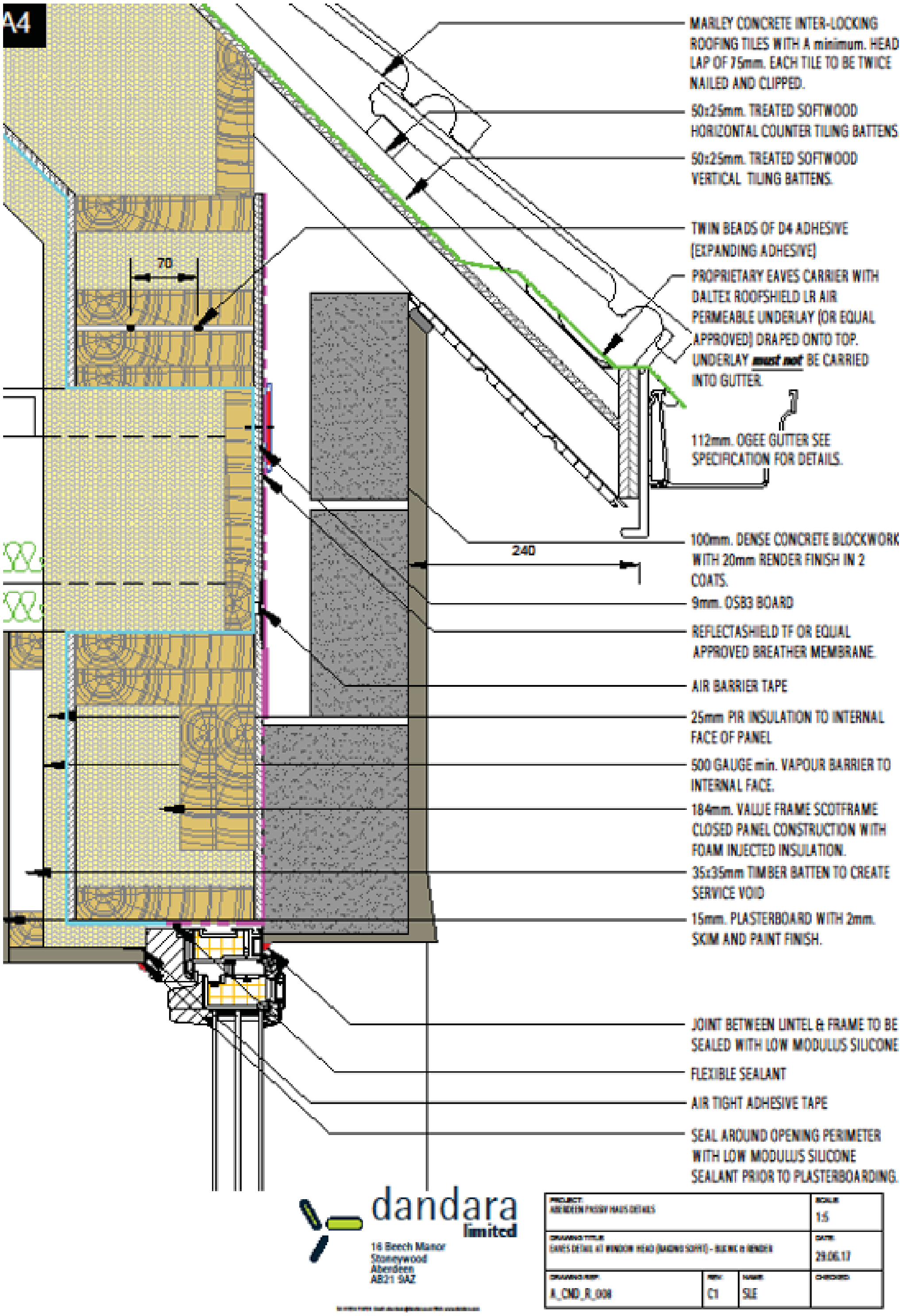


Figure 13: Construction details through window head, mid-floor and eaves. Dandara Homes Limited

5.2 Refinement of PHPP Assessment

- The initial PHPP assessment was further refined based on the technical optimization and resulted in a new Option: 3.3.
- Amendments included the detailing of the dormer construction with 50 mm internal insulation; an addition of roof window over dressing room; and an increased net internal air volume due to inclusion of attic space within thermal envelope.
- In tandem and associated surface areas and volumetric studies were further developed to suit the agreed option using BIM.
- The completed initial PHPP assessment and associated information were issued to the Passivhaus Certifier for verification of the proposals on behalf of the Passivhaus Institute.

5.3 Passivhaus Certification

- Ingo Theobolt (IT), a free-lance Passivhaus Certifier based in Sweden, was appointed by Dandara on 16.06.17. IT has been involved in a number of projects in Scotland and has extensive experience of the Scottish construction industry, climate and housing typology.
- As a summary of the initial assessment, Ingo made the following statement:

> *I have worked through the PHPP provided and it only needed some small changes. The building would be certifiable via the heating load just as it stands now, BUT there are quite a lot of details which need attention as regards to thermal bridging. Some values have already been added - but these need to be confirmed - and quite a lot of additional ones will have to be evaluated for the certification. We are trying to "salvage" as much as possible from existing calculations and values, but it is not clear as of yet how many will still have to be done. There is still room for some additional heat losses via additional thermal bridges which are not yet contained in the energy balance calculations, but there is a limit and as of now it is not sure that we remain on the good side of it. There is a good chance that the house clears as it is - but this will have to be verified for the certification.*

- Compliance via heating load. IT outlined the background to this from the perspective of the Passivhaus Institute and how initially, it wasn't proposed as a route to compliance, as projects had to comply with both Space Heating Demand and Heating Load. The change was made to give smaller properties common in the UK a more viable route to compliance.
- The reason that the house complies by Heating Load, is due to the smaller temperature gradient between inside and outside temperatures in Scotland. In Sweden for instance, a building would comply using Space Heating Demand, though fail badly by Heating Load.
- On the basis of his assessment, IT established the location and number of Psi value calculations that are required in order to complete the assessment and recorded as part of the certification process. IT has proposed to use the Dandara details as a basis for his thermal bridge analysis. Some of the thermal bridges required may have a positive outcome on the result of the PHPP assessment, by offsetting the negative Psi values.
- IT was calculated prior to the thermal bridge analysis, the house-type could afford additional thermal bridging of 4.0 W/K (e.g. 200m of 0.020 W/(m*K) with factor 1.0) and then reach 10.49 W/m² heating load (which is the maximum).
- On 25.01.18 IT was asked by DA to proceed with the thermal assessment of critical details to generate Psi values.

- IT confirmed on the basis of initial thermal assessment of critical details and the incorporation of the psi value results into the PHPP worksheet that if the house is being built according to the CND-details and further input, it will still fulfil the 10W/m² heating load criteria. He noted that some Psi-value-results turned out to be higher than expected, but others in turn were lower, which was helping to balance the overall result.
  (See Appendix 8 for email, PHPP Verification Sheet and Certifier Statement) (See appendix 9 for Thermal Bridging Report)
- During and following the process of carrying out the thermal bridge analysis, a further refinement of the PHPP assessment was undertaken by IT to incorporate the following requirements:
  - EPS (Jabfloor EPS 70) with a thermal conductivity of 0.032 W/(m*K), used instead of PIR/PUR insulation 0.022 W/(m*K) included in the initial PHPP assessment.
  - The use of outward-opening model of the Munster Joinery window.
  - Mid-level transom to the large sitting room window was included in the PHPP assessment. This reduced the area of glazing relative to the frame.
  - Ground bearing slab/ wall detail: 65mm Marmox was proposed in lieu of the 215mm Perinsul block. This increased the Psi-value of the detail by a factor of two.
  - DH requested that IT investigate two options for the positioning of the windows relative to the timber frame, with the first option showing the window pulled back in line with the timber kit and a deeper block at jambs and head bridging the cavity and the second option similar to DH standard detail with the face of the window pushed immediately behind the internal face of the blockwork, in line with the cavity barrier. Thermal analysis of the details proved that the second option is a thermally poor interface and not usually acceptable to fulfil PH criteria.
  - Munster's Ecoclad door does not come with any Passivhaus certification and an alternative solid Nordan product was put forward.
  - Changed roof detail with the steel beam altered to a glulam.
- These changes though generally increasing the heating load do not exceed the compliance criterion and both Passivhaus' comply according to heating load.
- The sole difference between the two Passivhaus' is the use of an alternative MVHR unit system in the 'Scottish' Passivhaus. IT is currently seeking confirmation of the testing data and certifying body for the unit from Vent-Axia. He assumes that the PHI-equivalent heat recovery rate of their device is at least 80% and with this the house will still pass via the heating load criteria.
- The Zehnder ComfoAir Q 350 HRV (90% HR) has been used in lieu of the Paul Novus unit as noted and although the efficiency is lower, compliance via the heating load criteria has not been affected.
- Both Passivhaus' are currently due to be certified based on current airtightness results.

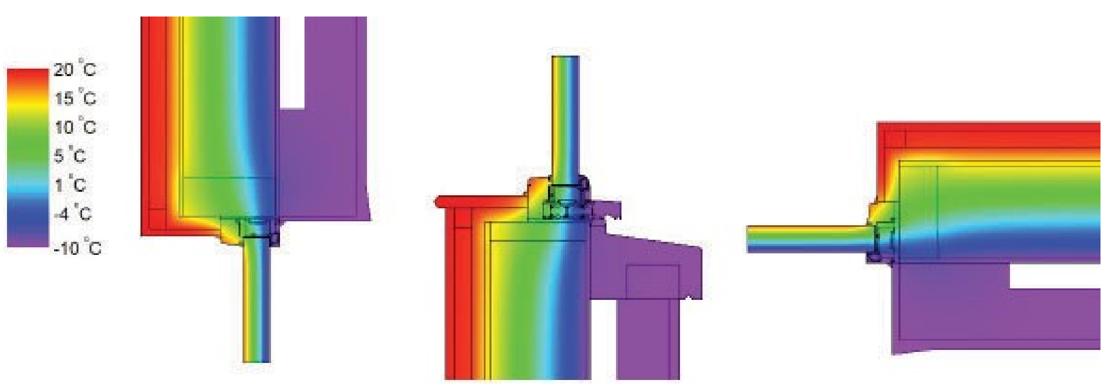


Figure 14: Thermal analysis of window details. Ingo Theobolt

5.4 Outcomes of WP2: Optimisation of Construction Specification

- The key principals of the specification and detailing of the thermal envelope were agreed at the conclusion of WP1.
- Further work to optimise the thermal performance and airtightness of the timber frame and detailing was conducted in conjunction with DA and SF during the process of developing the main interface details.
- Strategies for the erection of the building frame and practical application of airtightness also informed this development.
- Specific products were also researched and incorporated into the details.
- It was agreed that both Passivhaus variants (Standard and Scottish) utilise the same timber frame construction system, windows and membranes.

- Walls: Scotframe Valutherm 184 mm closed panel with 25 mm continuous inner insulation as agreed in WP1. The internal insulation mitigates the thermal bridging at key interfaces by providing continuity of the thermal envelope, although positive psi values will still be present and are be calculated as part of the Passivhaus Certification. The full depth timbers at the panel connections are unavoidable. SF propose however that the panels can be formed in long sections to reduce the frequency of the panel connection detail.
- Roof: For the roof a 225 mm deep joist with 50 mm internal insulation as agreed in WP1. The ridge beam is insulated below, within the ceiling void cavity to eliminate the thermal bridge. The airtightness layer should be taken above the finished ceiling, rather than over the top of the ridge beam, to simplify the ridge beam installation.
- Floor: A thickness of 300 mm XPS type insulation below the Ground Floor slab. The use of the Foamglas 'Perinsul HL' blocks in lieu of the upper course of the underbuilt blockwork, will help reduce structural thermal bridging at a key location and ensure continuity of the insulation zone around the thermal envelope. A Marmox block is also proposed by DA in lieu of the Perinsul.
- Separating wall: The void in the separating wall is also fully insulated to eliminate thermal bypass and ensure that the party wall can be considered a zero-heat loss element within the PHPP calculations.
- Windows: For the window installations, the window unit is pulled back to be within the insulation layer of the timber frame in order to enhance airtightness and mitigate the thermal bridging. In practice, this is at least flush with outside face of the kit. The blockwork and render then return to finish the external reveal. Lining the aperture internally with 25 mm insulation on all sides will improve the thermal performance of the window jamb, head and cill details.

- A preliminary set of construction details were prepared by DH on the basis of the above discussions and have been issued to the Passivhaus Certifier to use as a basis for the thermal bridging calculations.
- *(See appendix 5 for main GA's and appendix 3 for main details).*
- *(See appendix 4 for main interface details).*

5.5 Statutory consents

- The statutory consents process was carried out in parallel to the research project by DA and did not impact on the aims and timeframes of the research project.
- Stage 2 Warrant for Zone F has been approved with the Passivhaus plots submitted as standard Rowan house types initially and then to be included under an Amendment of Warrant to the Passivhaus standard.
- The site has been registered with the NHBC and relevant Site Investigation information passed to NHBC engineer in readiness for plot registration when works commence on site.

5.6 Costings

- Dandara carried out a review to determine that the project is reasonably practical to continue, taking account of buildability, deliverability and cost and sanctioned the progression to the next stage of the project.
- Refer to section 8.9 for an indication of the percentage uplift cost of the Passivhaus dwellings relative to a standard house type.

5.7 Air-tightness

- RGU noted the difficulty of achieving the maximum air change rate of 0.6 h-1 @ 50 Pa., which is roughly equivalent to having a hole in the envelope area of the building less than the size of a 5 pence piece for every 5 m2 of building envelope. In comparison a building that achieves the limiting figure for airtightness to comply with the Building Regulations Part L or Section 6 of the Building Standards, Scotland will have an equivalent hole the size of a 20 pence piece for every 1 m2 of envelope.)
- Passivhaus certification is awarded on the basis of 'as built' rather than 'as designed' performance. Pressure test results, commissioning certificates and a record of the build must be submitted before a certificate can be issued by the certifying body.
- The use of a specialized installer with their own quality control process is viewed by DH and SF as a benefit for the aim of achieving a very low level of airtightness. In order to gain maximum benefit from this, that all junctions should be accessible during erection (e.g. wall base detail where battens for the service void are placed to low relative to the floor).
- A correctly fitted and sealed external breather membrane will also contribute towards a high level of airtightness and reduce thermal bypass in the wall insulation.
- Further to the above the method of using Hilti or Ilbruck foam installed by a specialist sub-contractor, used in conjunction with the vapour control layer, was discussed as an alternative means of achieving the stringent level of airtightness required by the PH standard, rather than purely relying on the performance of the tapes and membranes. An airtightness result of 0.4 m3/m2h has previously been achieved in the past by Cairnrowan Custom Homes (Gregor Davidson) on a SF project.
- RGU were able to attend site to meet Gregor Davidson and witness foam airtightness works.
- Further investigation of the on-site airtightness strategy will be carried out in the next stage of the project and how this can be aligned with DH site management procedures.
- Sequencing and forward planning:
    - Ensure that correct sequencing of key stages is clearly understood at the outset and in particular how these relate to the timing of airtightness tests.

- Critical stages in the project sequencing including ordering of specialist components or preparatory requirements, such as fitting of airtightness membranes before the installation of mid floor cassettes, glulams or internal walls.
- Tool box talks and site briefings should be scheduled prior to critical stages in the build programme.
- The site manager and others responsible for airtightness should be present during all briefings.
- Detailed production drawings annotating any special sequencing and fixing procedures should be displayed on-site.
- Indoor air quality will be spoilt if ductwork, MVHR and control systems are not adequately protected during their storage and installation. Open ends of ductwork to be kept completely sealed until they are fully installed.

- On site Strategy:
  - Key junctions sealed with foam
  - Internal continuous vapour control layer, protected by service void using an internal membrane with taped joints. Ensure that substrates are clean and free of dust prior to installing tapes or sealants.
  - External wind-tightness layer using a breather membrane with taped joints
  - An 'airtightness champion' should be appointed. Ideally this person would be a site operative who will be present throughout the build; someone who thoroughly understands and can communicate the designer's air tight strategy. Risk of airtightness being lost at later stages of build and in particular when services are being installed.
  - Keep penetrations through the airtight envelope to a minimum. Ensure adequate space is left to seal around individual penetrations using proprietary seals (top hats and gaskets). Avoid services penetrations being located too close to a corner or a wall.
  - The objective is to achieve an airtight structure for the life of the building, not one which will be adequate for the air pressure test
- Airtightness tests:
  - Minimum of two pressure tests although three would be preferred.
  - Airtightness target is the number of air changes per hour in the building at a reference pressure differential of 50 Pascals. The n50 units are expressed as m3/m3.h which may be simplified to h-1 or ac/h. This is different to the standard air permeability using m3/(h.m2).
  - First conducted at the end of first fix when the glazing and doors have been installed, but the airtight barrier is still open to inspection.
  - Site manager and site operatives to be present to identify and remedy any defects in the air tightness layer.
  - Possible additional test once services have been installed through the airtightness membrane.
  - Final test at the completion of works to verify the airtightness after all of the building services have been installed and commissioned.
  - Once the n50 test has been passed the test certificate should be forwarded to the Passivhaus certifying body as evidence of compliance with the air pressure testing requirement.

5.8 Building Services

- *(See appendix 7 for services layouts)*
- IT has noted that if there is gas on-site that a small gas boiler is the most sensible thing to use for heat generation. With direct electric heating and DHW, the house will jump over the PE-limit and will therefore not be certifiable. Gas condensing boilers work well in scenarios with a low space heating output as the DHW demand is as per standard properties. A small, efficient boiler, which also can be run independent of room air is the option with least risk and property owners are familiar with the technology.
- The Vent Axia MVHR System Lo-Carbon Sentinel Kinetic Advance S has been used in the "Scottish Passivhaus" as a non-certified and conventionally used system.
- It was agreed to proceed with the Zehnder unit in lieu of the Paul unit, as recommended by the supplier, Paul heat recovery Scotland for use in this house type. Also this unit could be manufactured and delivered to site a lot sooner than the Paul unit.
- The MVHR ductwork layouts have been progressed by DH with their subcontractor and provided to SF, to ensure that the (assumed semi-rigid) ducts can be accommodated within the mid floor depth. The MVHR unit will also need to be positioned as well as the supply and extract terminal on the external wall. The manifold for the ducting is located in a dropped ceiling space in the utility room.
- Heating and DHW system: Combi boiler (Potterton or Baxi) 15kW with 210 l HWC.
- Reduced Sized Boiler – compared to the Building Regulation compliant house type.
- Underfloor heating at ground floor and rads at first floor.
- PV panels: commercial consideration by DH.

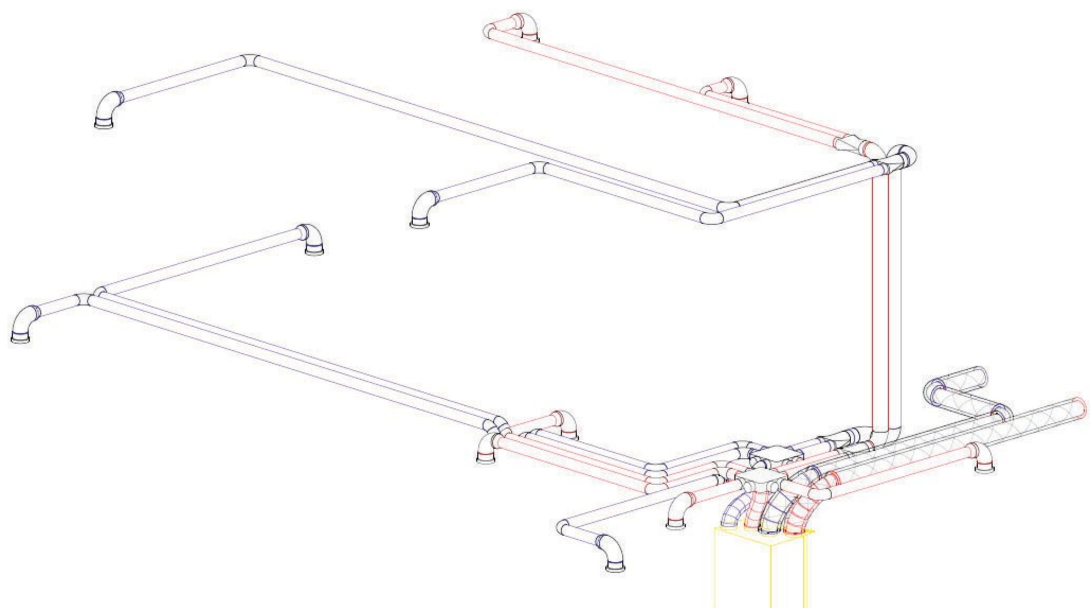


Figure 15: MVHR installation schematic. Paul Heat Recovery Scotland Ltd.

Figure 16: MVHR units. RGU.

5.9 Components

- List of key components and suppliers proposed by DA, relative to the Standard and Scottish Passivhaus types:
  - Timber frame
    - Standard PH – Scotframe, Valutherm.
    - Scottish PH– Scotframe, Valutherm.
  - Insulation:
    - Standard PH – Val-U-Therm *PLUS* insulation in frame. Ecotherm or Celotex internally
    - Scottish PH – No Scottish based manufacturers for rigid wall and floor insulation.
  - Windows:
    - Standard PH – Munster Joinery.
    - Scottish PH – As above due to concern regarding different possible aesthetics to the two variants. It was noted that there is not currently a Scottish based manufacturer of timber PH windows in Scotland, although companies could be approached to establish whether future opportunities exist (Allan Brothers). Data from other sources could also be used as part of a parallel PHPP assessment in lieu of actual installation.
  - MVHR:
    - Standard PH – Paul Novus. Supplier TBC.

    - Supplier and design for MVHR system to be progressed, as duct routes should be established within building fabric as part of detailed design. Posi-joists are proposed for the intermediate floor, which are suitable for feeding ducts through.
    - Scottish PH – Ventaxia (UK based company. Currently no MHRV manufacturers based in Scotland.
- Airtightness/ wind tightness membranes and tapes:
    - Standard PH – Proctor Group Limited. Hilti Foam
    - Scottish PH – Proctor Group Limited. Hilti Foam

6.0 WORK STAGE 3 - CONSTRUCTION PHASE

- Robert Gordon University will provide the following services:
  - Inspect and support the build process to ensure compliance with Passivhaus requirements
- Dandara will provide the following services:
  - Project manage and deliver all aspects of build to ensure compliance of NHBC and Local Authority.
- **Milestone 4: The Scottish and the Certified Passivhaus have been build.**

- The following methodology was undertaken to achieve the defined milestones:

  - Project management and delivery of the build by DA;
  - Site inspections by RGU and reporting;
  - Telephone interviews conducted by RGU with timber frame supplier and timber frame erector/ airtightness specialist.
  - Provision of relevant build information with Passivhaus Certifier

Figure 17: Dwellings under construction, October 2018. RGU.

6.2 Progress meetings and discussions:

- A 'tool box talk' type review meeting was held on site on 04.05.18 with Dandara site management, kit erectors and sub-contractors in attendance. The purpose was to describe the aims and objectives of the project and to stress in particular the need for a strict policing of the airtightness.
  (See appendix 6 for presentation material)
- Further site inspections were carried out by RGU to review and record progress.
- Additional telephone interviews were undertaken with main project partners.

6.3 Site and quality management:

- Onsite operations and material procurement has been undertaken by the contract and site manager using standard DA quality control procedures.
- An airtightness coordinator has been appointed to the project.
- *(See appendix 10 for record of site operations and other site photographs*)

6.4 Timber frame supply:

- Sequencing: SF have confirmed that the erection process is the same as that undertaken on a typical Valutherm timber frame.
- Discussion with Alan Brodie, Scotframe 20.11.18.
  - Standard Valutherm product and fabrication process, although vapour control layer, Reflectatherm Plus, has been applied as an additional measure. Typically, the foil face of the internal insulation would be taped for standard timber frames.
  - Service void battens are prefitted although due to the fixings through the VCL cause air leakage. A future measure would be to seal the battens in the factory.
  - SAP results. *(See appendix 11)*
  - The reduction in timber, investigated through the technical design process, is not usual as SF as a company are constantly trying to optimize their timber frame designs in terms of reducing the timber fraction and minimizing waste.

Figure 16: Dwellings under construction, June 2018. RGU.

6.5 Timber frame erection and airtightness works:

- Airtightness works have been carried out by a specialist sub-contractor.
- Discussion with Gregor Davidson of Cairnrowan 20.11.18.
    - Cairnrowan Homes (CR) deliver ow energy homes as a main contractor, principally in the Aberdeenshire area and specialize in low airtightness levels.
    - CR had not worked with Dandara homes previously. The route to project for CR was through Scotframe, with whom they have worked on a number of bespoke projects, with generally 12 – 15 projects per year.
    - CR have been appointed to the project to erect the timber frame up to airtightness, prior to first fix joinery and subsequently following installation of services to rectify any breaches. GD noted that this two-stage involvement means that there is a single point of contact for airtightness works during the timber frame erection and further 'policing' of the airtightness following internal joinery and services works. CR are also responsible for carrying out the first and second airtightness tests.
    - The timber frame as supplied has not presents any difficulties. Cairnrowan are familiar with the Valutherm type of panels with internal insulation.
    - The service void battens are pre-installed and sealed on site to prevent air leakage.
    - The details as prepared by Dandara have not pose any problems for the erection of the timber frame.
    - An Ilbruck FM 35 foam has been used to seal the joints during the timber frame erection, the advantages of this specific product relative to standard expanding foam is that the FM35 remains elastic whilst standard foams become brittle, thus degrading the airtightness.
    - Undulations in the foundation slab have posed issues for the airtightness works at the wall floor interface. The ground floor slab was ground down as a result and liquid applied DPM installed.
    - First airtightness results of 0.347 ach and 0.357 ach have been achieved.
      (See Appendix 12 for initial air tightness reports)
    - Remedial airtightness works to the MVHR ductwork penetrating the airtightness layer has been complicated by the blockwork which had been erected prior to CR's second stage works.
    - Second air test was carried out pre-plasterboard, w/c 19.11.18 and the results are; Plot 5 – 0.50 ac/h and Plot 6 – 0.48 ac/h. It is usual for the airtightness results to worsen due to the number of penetrations during the first fix stage.
    - GD has recommended an alternative detail for the mid floor would be to hang the posi joists off the kit, with a 40 mm projection into the frame depth of the top chord to the posi joist. This would minimize thermal bridging and air leakage.

6.6 Site visits:

- Site visits were carried out by RGU on 07.09.18 and 23.11.18.
- The associated discussions with the Dandara Site Manager and Airtightness Champion confirmed the following aspects:

- The same erection process has been carried out for both Passivhaus', utilizing DH quality management processes.
- The same sub-contractors have been used on the Passivhaus' as on the standard house units for non-kit erection and airtightness works.
- Differences in erection process:
  - Use of specialist kit erector who have glued rather than nailed panels and are responsible for the airtightness works and testing. The erector is appointed to return following second fix to ensure airtightness at any services penetrations.
  - Underfloor heating not standard for Rowan
  - Approach different. No battens typically with recessed electrics boxes.
  - Airtightness works are labour intensive
  - Layout changes to suit MVHR
  - The posi-joists and glulam are also non-standard items.
- The MVHR ductwork has been installed by the plumber.
- Problem details:
  - Wall/ floor detail was difficult to implement and caused air leakage issues.
  - Dormer roof complexity.
  - Patio doors air leakage.
  - Electrical cables penetrating building fabric most air loss.
- The installation of the MVHR has caused programming and sequencing issues due to limited space for the ductwork and MVHR unit and in particular to the 'Standard' Passivhaus.
- Site manager has found the process challenging though enjoyable.
- Relative to a standard build, delays (cumulatively1 month) were caused due to:
  - The coordination with an additional trade (kit erector).
  - Additional airtightness works (implementation + testing).
  - MVHR installation.
  - Differences with (electrical / heating and plumbing)

7.0 WORK STAGE 4 – TESTING AND CERTIFICATION APPROVAL

- Robert Gordon University will provide the following services:
  - Conduct airtightness and co-heat testing
  - Thermal imaging
- **Milestone 5: Approvals by NHBC, Local Authority and Passivhaus Institute have been given**

- Airtightness testing has been completed. See airtightness reports in Appendix 12...
- Thermal imaging will be carried out by RGU once work is completed on site.

7.1 Process of Certification:

- The Certification process was concluded by the Certifier on 15.11.2019 and the Certificates, plaques and leaflets issued to Dandara Homes.
- Certification provides a detailed review of the design and construction. This quality check is carried out to give confidence that the building will work as intended.
- The process itself is led by the Certifier with the involvement of RGU and required the compilation of a large amount of technical document, relevant to proving compliance with the Passivhaus Certification and Quality Assurance criteria.
- The documentation has been entered on the Certification Platform provided by the Passivhaus Institute by RGU. See below for main headings.

1. Passive House Planning Package (PHPP)
2. Planning documents for architecture
3. Standard and connection details
4. Windows/doors
5. Ventilation
6. Heating/ Cooling + Plumbing
7. Electricity
8. Renewable energy
9. Construction phase

- Although the vast majority of the documentation had already been provided by Dandara, the level of detail required for the Platform entailed a fairly lengthy process of coordination with the Certifier. Throughout the process the Certifier displayed a high level of flexibility and was readily available for queries.

8.0 WORK STAGE 5 – ANALYSIS AND REPORTING

- Robert Gordon University will provide the following services:
  - Collate, Analyze and present information.
- Dandara will provide the following services:
  - Input, support and challenge comparisons to ensure information generated is sufficiently robust.
- **Milestone 6: Final project report is produced.**

- The information below has been derived from emails from DA as well as the content of their presentation at a dissemination event at CSIC in Hamilton on 19th February 2019.

8.1 Principle Differences Between standard and Passivhaus Construction:

- Maximizing Air Tightness – Junction Treatment – Workmanship and appropriate detailing to limit air infiltration
- Increasing Fabric Insulation – Insulation Type (Injected insulation in lieu of glass fibre quilt)
- Minimizing Linear Bridging – Lining the inner studs and around openings with PI (closed cell) insulation.
- Understanding MVHR (Mechanical Ventilation and Heat Recovery) and its contribution to balancing the environmental conditions of the supply and extracted air within the building
- Minimal Heating levels required – underfloor heating on the ground floor and reduced radiators to upper floors
- Multiple air tightness checks

8.2 Final Costings:

- The uplift costs are computed into individual percentage uplifts on the standard house baseline figures. See figure below.

Pinewood, Zone F

Passivhaus Costs - Plots 5 & 6

Sub Op	Operation	Passivhaus Variance Comments	% Uplift of Plot 5 Passivhaus and Standard Rowan and Passivhaus	% Uplift of Plot 6 Passivhaus and Standard Rowan and Passivhaus
2F	Foundations	Reconfigure foundation to include Marmox Thermoblock to reduce thermal bridging	372.53%	372.53%
2G	Ground Slab	Increase thickness of insulation around and below floor slab	99.32%	99.32%
3C	Timber Frame	Scotframe val-u-therm preinsulated timber kit	78.17%	78.17%
3C	Timber Frame	Erection of kit including additional sealing and testing	251.41%	251.41%
3M	Windows And Doors	Upgraded windows and doors	104.29%	104.29%
3M	Windows And Doors	Upgraded Velux Window	183.29%	183.29%
5B	Electrical Installations	Removal of extractor fans and fan isolation switches as not required	-6.85%	-6.85%
5B	Electrical Installations	Reduce PV Panels (2nr Passiv, 8nr Standard)	-61.94%	-61.94%
5H	Plumbing Installations	Reduce boiler, hot water cylinder and radiators sizes	-4.98%	-4.98%
5J	Ventilation Systems	MVHR Systems (Paul Heat System in Passivhaus & Vent Axia System in Alternative Passiv)		
8H	Internal Fees	Additional Internal Dandara Staff Costs - Design & Site Management		
8J	External Fees	Design calculations, registration & certification		
		Total	76.40%	71.41%

Figure 17: Project uplift cost. Dandara Homes.

8.3 Making the commercial case for rolling out Passivhaus to the mass housing market:

- Construction costs should be streamlined.
- Flexibility from the Statutory Authorities – where current Building Regulations and supplementary planning guidance (SPGs) currently favour low and zero carbon technology over fabric first.
- For instance, Aberdeen City Council Supplementary Planning Guidance – currently requires that 20% of the carbon reductions are achieved using low and zero carbon (LZC) technology i.e. PV panels, air source heat pumps or other similar LZC technologies
- Building Regulation compliance and SAP 2012 is not favourable to fabric first approach to allow a pass without the use of some form of Low and Zero Carbon.
- Housebuilders can apply the principles as Building Regulations move "Towards Zero Carbon" targets. But Building Standards and Planning Authorities need to embrace the benefits of a fabric first (Passivhaus approach) and balance this with LZC technologies.

8.4 Convincing the house buying public and valuers:

- Marketing the benefits to the public in sales literature
- Promoting running costs over a standard Building Regulation compliant house
- Energy conservation benefits
- Valuation surveyors – recognition of increased value of Passivhaus v Standard Rowan House type
- Dandara can test the market to determine what increased value can be achieved for the 2 Passivhaus compliant versions of the Rowan house type compared to the standard Building Regulation compliant Rowan House Type.
- The outcome of the testing of the market and appetite for customers paying additional costs and valuers supporting an acceptable uplift will be determined as this phase of the Hazelwood Development in Aberdeen is released for sale.
- Available mortgage funds (First time buyer sized property v second homes and 3rd homes). Constraints at lower end of the market

9.0 CONCLUSION

The CSIC funded project is to test the hypothesis that the 'Passivhaus' standards (PH) can be applied to provide high-quality housing. These to be delivered at a competitive cost level, using the local Scottish supply chain, and can be taken to mass market. The two dwellings were successfully built to the Passivhaus standard by Dandara Homes (figure 18). Both units are obtained official 'certificated Passivhaus Classic' certification from the Passive house Institute, Darmstadt, Germany.

The certificated PH houses demonstrate that the design, components and construction skills are evidently available in Scotland, and we are hopeful that the PH process documented in this pilot scheme can act as a viable template to follow for other volume housebuilders. There are still barriers for the implementation of the PH standards in Scotland, ranging from up-lift costs to skills shortages. However, the pilot project evidenced that a volume house builder has the capacity and resource to overcome these challenges. The report documented the entire process of the achieving PH standards, which will aid the understanding of other volume house builders with regards to the process of achieving PH standards.

The next challenge for the project is testing the commercial case for rolling out Passivhaus to the mass-housing market, and convincing the house buying public and valuation surveyors. The houses are currently in the process of being valued, and will be going onto the market in spring, which will be a real test for the research question- 'Can Passivhaus standard houses be rolled out to the Volume Housing Market?

Figure 18: Completed Dandara Passivhaus

RECOMMONDATIONS (Lessons learned)

The following summary covers the barriers, benefit, critical learning points, and identifies the future research needed. It will also provide and a useful template with for others to follow, including identified improvements.

9.1 Barriers to the implementation of Passivhaus:

- Capital and LC Costs + Payback + Valuation
- Technology and User Briefing
- Life style and Cultural Acceptance
- Supply Chain Management
- Skills Shortage - Capacity to build
- Perceived Health and air quality concerns (MHVR)
- Too Much Change for Volume Builders?

9.2 Tools for the implementation of Passivhaus:

- Building confidence within the Volume house building industry by removal of the "fear factor" and developing a Practical, Commercial and Marketing understanding of low-energy housing ahead of changes in Building Regulations in 2020 and the new CO2 emission targets 2030 and beyond.
- To provide information to Volume House Builders which promotes the marketing potential.
- To identify quantifiable benefits to the public.
- Investigation into Surveyor's valuation practice!

9.3 Benefit:

- Understand and document the process of achieving PH standards, using both the PH Certified and the locally sourced components available, including critical learning points for the volume market
- To provide template for others to follow, and the implementing of identified improvements
- The cost benefits accrued over the life-span of the building based on identified financial scenarios.

9.4 Key lessons learned:

- The timber frame component would ultimately have the biggest impact on the successful delivery of the Passivhaus through specification, detailing and construction sequence, thermal bridging calcs and installation.
- Use of 'specialist kit erectors' and airtightness experts are critical.
- Enhanced role of the Structural Engineer in reduction of timber in kit:
- Optimise timber frame designs -reducing the timber fraction and minimising waste.

9.5 Site specific data Influence – Orientation, altitude and location:

- The assessments indicate that 'orientation' has a minimal influence with compliance by the

Heating Load. However, the location and altitude has a considerable effect complying for both Heating Load and Space Heating Demand.

- Combining semidetached PH, and assessing as a single entity, improves compliance results due to the more compact form

9.6 Issues with MVHR unit and duct layout:

- Should be coordinated earlier in concept design stages (WP2)
- Utility and store spaces should be more 'generous 'to allow for access for installation and maintenance

9.7 Further research outcomes/ observations:

- **Further Research Outcome 1**: What additional roles, services and time are required for a project involving Passivhaus, compared to a conventional volume housebuilder process to deliver standard house-types?
- Early appointment of Passivhaus consultants.
- Fabric first approach suggests that the strategy for insulating and erecting the timber frame should be established during Stage 2 of the project.
- Availability of software to allow early assessment of thermal bridges.
- Comparison of RIBA Plan of Work stages with activities undertaken during projects and milestones reached:

- **Further Research Outcome 2**: Description of how application of Passivhaus standard to an already established design is not efficient relative to cost and influence of change
- I.e. adoption earlier in the design process would have a bigger impact on the form, the product and help reduce cost of the build.
- A simplified house-type could be assessed to represent a hypothetical process of design optimisation at RIBA Stage 2 – Concept Design.
- It may be that with a 11/2 storey dwelling that there is no advantage by eliminating dormers for instance, due to the loss of usable floor area.

- **Further Research Outcome 3:** Enhanced role of Structural Engineer in reduction of timber in kit.
- The timber frame would ultimately have the biggest impact on the successful delivery of the Passivhaus through specification, detailing and construction: timber fraction, thermal bridging and installation. Working with engineers is critical for the following:
- Optimise timber frame designs in terms of reducing the timber fraction and minimising waste.
- Number of structural timber at triple studs etc.;
- Utilising non-'full depth' structural timbers at posts and window apertures;
- Investigation of improved details such as hanging mid-floor.

- **Further Research Outcome 4**: Utilisation of BIM for Passivhaus Projects.
- Allows for coordination of model with PHPP and the direct extraction of volumetric and surface area data.
- BIM can be used with timber frame suppliers, MVHR designers etc. Allows for clash avoidance in addition to understanding where the principal thermal bridges lie.
- Software has been developed to enable the synthesis of BIM and PHPP.

- **Further Research outcome 5:** What influence does site specific data have on the result of the preferred option and ultimately costs, in relation to micro factors such as orientation and altitude and macro factors such as location.
- Combining both PHs and assessing as a single entity improves compliance results due to more compact for,
- Initial tests indicate that orientation does not influence compliance by heating load. The location has a huge effect with possible sites in southern regions complying by Space Heating Demand.

- **Further Research outcome 6:** Analysis of why compliance using Heating Load is more possible in Scotland: e.g. lack of solar gain although reduced temperature gradient between inside and out. As an alternative to heating energy demand, the heating load can be used as an evaluation criterion.
- The Passive House criteria allow buildings to go by either criterion - the 15 kWh/(m²yr) heat demand OR the 10W/m² heating load (for residential buildings).
- The amount of heating required to keep a building at a specified temperature while the outdoor temperature is accordingly low (kW).
- The ability to heat with the ventilation air. The heating load is the decisive factor: a certain amount of heat can be distributed with very little effort via the supply air coming from a Passive House building's ventilation system. The ventilation system thus serves a dual function (fresh air and heating) and reduces the investment required for heat distribution to a minimum. However, the amount of heat that can be distributed via the fresh air system without any additional costs is limited.

- This is beyond this report, but in relation to Building Physics, although it would be interesting to investigate whether compliance by Heating Load could be embraced by Scotland as the basis for future 'local' Passivhaus standard.

- **Further Research outcome 7**: Issues with MVHR unit and duct layout.
- Should have been coordinated earlier in design.
- Posi-joist allowed for flexible approach.

- **Further Research outcome 8:** Explanation for the use of the same components on the two Passivhauses, with only the MVHR being different.
- Sales requirement for both houses to look the same. Commercial consideration transcending research aims.
- Note that the majority of the frame and membranes on both houses have been designed manufactured in Scotland,

- **Further Research outcome 9:** Utilisation of DA QA systems
- Comparison of Passivhaus QA process and that of DA.
- This would need to be investigated by Dandara.

- **Further Research outcome 10:** Use of specialist kit erectors and airtightness experts.
- Future trade opportunity OR does it complicate the build process and make it more expensive.
- Deviates from standard DA procurement although Scotframe prefer this approach.

Certificate

Certified Passive House Classic

Passivhusbyrån

Authorised by:

Passive House Institute

Passivhusbyrån Ingo Theoboldt Vasared 301, 523 94 Tvärred, Sweden

Dr. Wolfgang Feist
64283 Darmstadt
Germany

The Rowan, Plot 5, Hazelwood · 9 Pinewood Gardens, AB15 8JY Aberdeen, United Kingdom/ Britain

Certified
Passive House
Passive House Institute
classic | plus | premium

Client	Dandara Limited Isle of Man Business Park, Cooil Road IM2 2SA Braddan, Isle of Man
Architect	Dandara Limited Isle of Man Business Park, Cooil Road IM2 2SA Braddan, Isle of Man
Building Services	Pitkerro Plumbing & Heating Ltd. Ivory Place DD5 3RY Dundee, United Kingdom/ Britain
Energy Consultant	RGU Garthdee House, Garthdee Road AB10 7QB Aberdeen, United Kingdom/ Britain

Passive House buildings offer excellent thermal comfort and very good air quality all year round. Due to their high energy efficiency, energy costs as well as greenhouse gas emissions are extremely low.

The design of the above-mentioned building meets the criteria defined by the Passive House Institute for the 'Passive House Classic' standard:

Building quality			This building		Criteria	Alternative criteria
Heating						
	Heating demand	[kWh/(m²a)]	21	≤	15	-
	Heating load	[W/m²]	10	≤	-	10
Cooling						
	Frequency of overheating (> 25 °C)	[%]	0	≤	10	
Airtightness						
	Pressurization test result (n_{50})	[1/h]	0.5	≤	0.6	
Non-renewable primary energy (PE)						
	PE demand	[kWh/(m²a)]	92	≤	0	

The associated certification booklet contains more characteristic values for this building.

Tvärred, 15.11.2019

Certifier: Ingo Theoboldt, Passivhusbyrån Ingo Theoboldt

Passivhusbyrån

www.passivehouse.com 24847_Passivhusbyrån_PH_20191115_IT

Certificate

Certified Passive House Classic

Passivhusbyrån

Passivhusbyrån Ingo Theoboldt Vassred
301, 523 94 Tvärred, Sweden

Authorised by:

Passive House Institute

Dr. Wolfgang Feist
64283 Darmstadt
Germany

The Rowan, Plot 6, Hazelwood · 11 Pinewood Gardens, AB15 8JY Aberdeen, United Kingdom/ Britain

Certified
Passive House
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classic | plus | premium

Client	Dandara Limited Isle of Man Business Park, Cooil Road IM2 2SA Braddan, Isle of Man
Architect	Dandara Limited Isle of Man Business Park, Cooil Road IM2 2SA Braddan, Isle of Man
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Energy Consultant	RGU Garthdee House, Garthdee Road AB10 7QB Aberdeen, United Kingdom/ Britain

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Building quality			This building		Criteria	Alternative criteria
Heating						
	Heating demand	[kWh/(m²a)]	21	≤	15	-
	Heating load	[W/m²]	10	≤	-	10
Cooling						
	Frequency of overheating (> 25 °C)	[%]	0	≤	10	
Airtightness						
	Pressurization test result (n_{50})	[1/h]	0.5	≤	0.6	
Non-renewable primary energy (PE)						
	PE demand	[kWh/(m²a)]	92	≤	0	

The associated certification booklet contains more characteristic values for this building.

Tvärred, 15.11.2019

Certifier: Ingo Theoboldt, Passivhusbyrån Ingo Theoboldt

Passivhusbyrån

www.passivehouse.com 24848_Passivhusbyrån_PH_20191115_IT

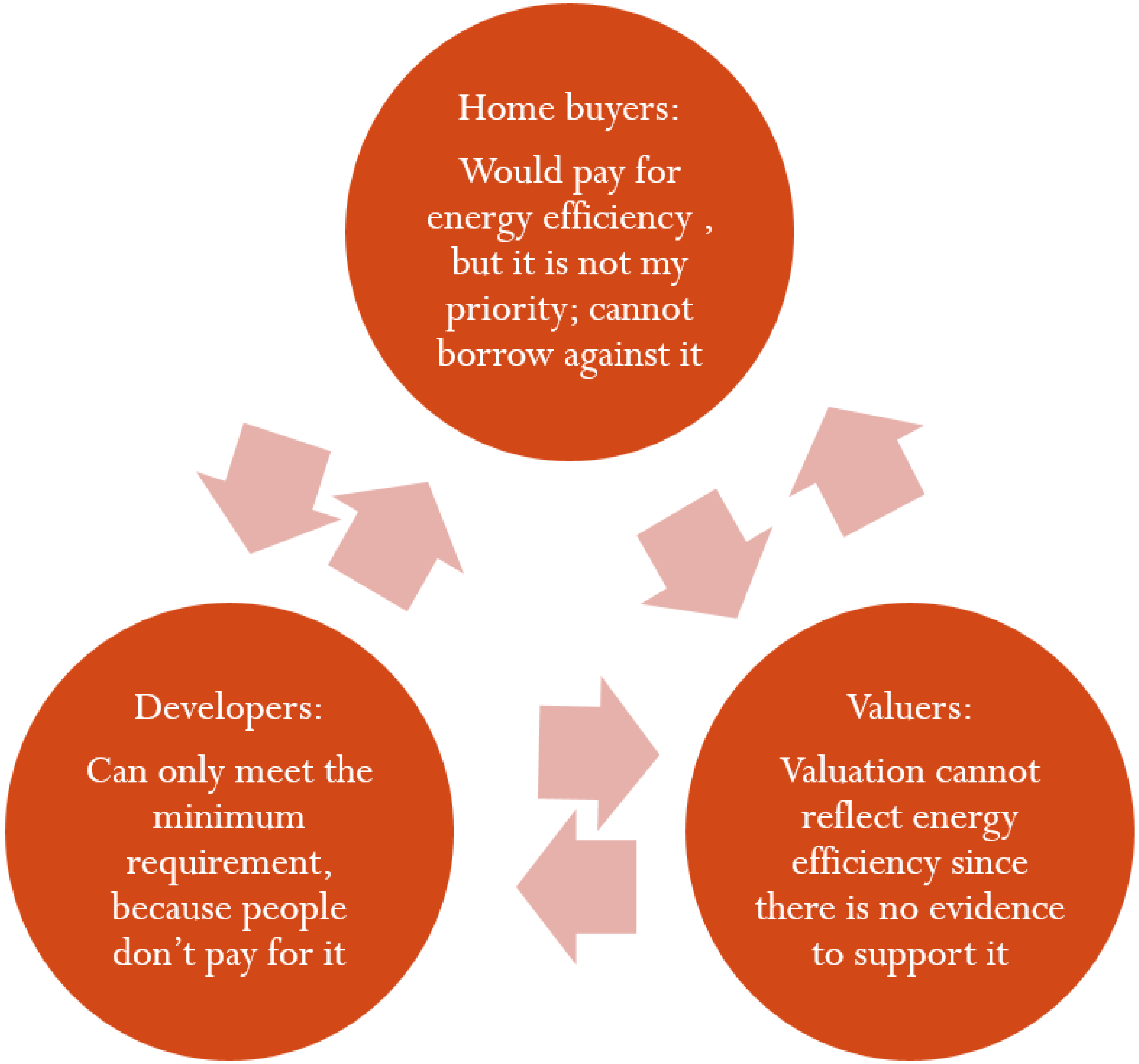
Prof G Deveci , ARB, RIBA FRIAS

DEMONSTRATING ‘PASSIVHAUS’ STANDARD FOR THE SCOTTISH VOLUME HOUSING MARKET

dandara
award winning property

CONSTRUCTION SCOTLAND INNOVATION CENTRE

RGU
ABERDEEN



Vicious circle of energy efficient homes Blame. (Cadman 2000)

INTRODUCTION

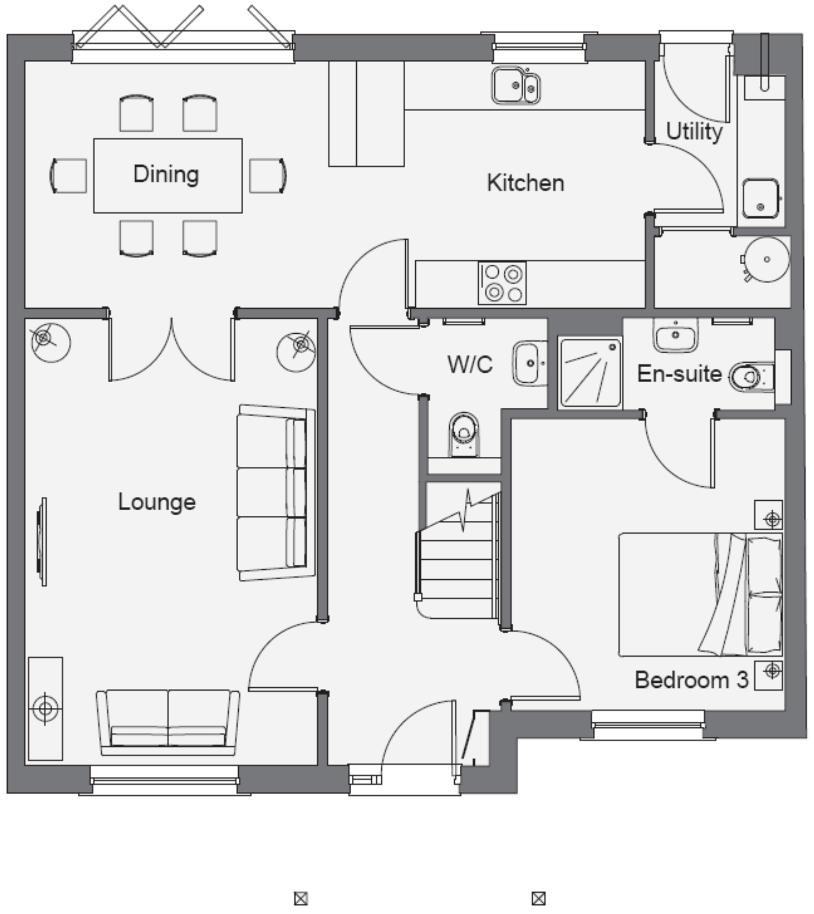
Dandara Ltd Partnership with Robert Gordon University to test the **hypothesis**:

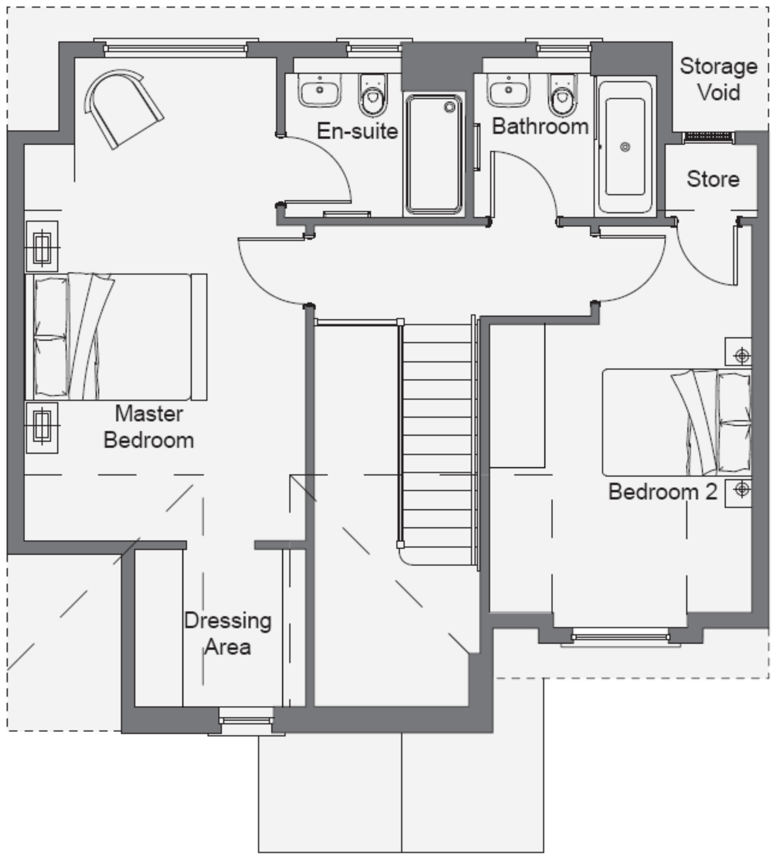
Can ‘Passivhaus’ standard houses be rolled out to the Volume Housing Market?

Project sets out to test if the ‘Passivhaus’ standards can be achieved by simply adapting a Dandara Standard house type into a Passivhaus Standard House

Dandara’s Standard “Rowan” House (most complicated) type chosen – to be constructed as a semi detached block in Dandara’s Hazelwood Development In Aberdeen.

18 months research project is funded by the Construction Scotland Innovation Centre.





Semi detached Houses

Methodolgy

One Constructed Using Locally Sourced Materials and the other

one using German Passivhaus Certified Materials

House designs were developed by Dandara.

Periodic Design Coordination Meetings with RGU's Passivhaus researchers working to set design parameters to achieve Passivhaus Certification Standards

Target 'U' values of envelope, air tightness target, linear bridging targets set by RGU research team,

Linear Bridging Junctions assessed by Passivhaus approved certifier

First ‘**Passivhaus’** Social Housing Project in the UK - Tigh-Na-Cladach, Dunoon. 2010.   G Deveci RIBA FRIAS A

RESEARCH QUESTIONS

What additional roles, services and time are required for a Passivhaus compared to a conventional volume house builder's product.

The impact of Passivhaus standards to an existing house design

The role of structural engineer in reduction of timber in kit.

Utilisation of BIM for the 'Passivhaus' projects

The impact site specific data (orientation altitude and location) in Scotland

Why compliance using Heating Load is more possible in Scotland:

Issues with MVHR unit and duct layout.

Comparison of Passivhaus QA process and that of an Volume House builder .

RATIONALE

Why Built very low-energy houses

- Action against climate change and reduce energy consumption
- Lower environmental impact
- Lower life Cycle Cost
- To fulfil Political agreements (2024 Regs and Zero-Carbon 2040)

Why Built Passive house buildings

The performance gap

iI is much more than energy performance standard, it is a quality assurance standards that closes the gap between the theoretical performance and reality (more robust)

If Scotland is to achieve an 80% reduction in carbon emissions by 2040 the quality of the buildings that it builds and refurbishes needs to be considerably improved.

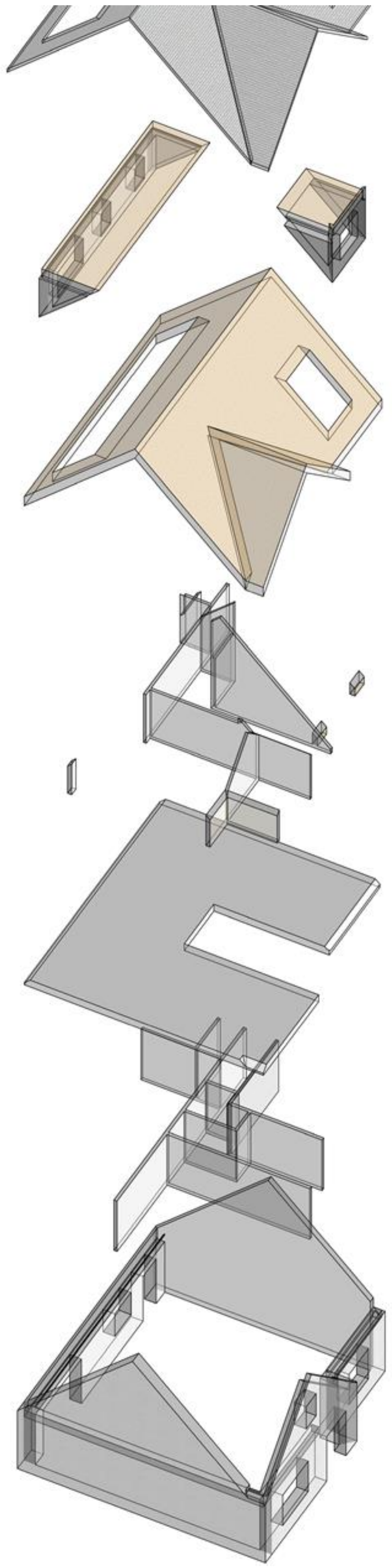
With the low carbon energy buildings this can only be done a through an appropriate quality insurance systems, like the ‘Passivhaus’ standards throughout the design and delivery.

Guaranteed performance’ to reduce energy **by design**, not offsetting carbon by add-ons

BARRIERS

- Capital and LC Costs + Payback
- Technology and User Briefing
- Life style and Cultural Acceptance
- Supply Chain Management
- Skills Shortage - Capacity to build
- Health and air quality (MHVR)
- **Too Much Change for Volume Builders?**

DESIGN METHODOLOGY and ASSESSMENT WORK PACKAGES (WP)



- **WP1**: RGU undertook and documented an energy assessment of the standard Rowan house type, incrementally increasing levels of insulation to provide a range of options to meet ‘Passivhaus’ standards

  Dimensional and volumetric data derived from 3D models prepared using BIM (Revit).

- **WP2**: After initial Passivhaus assessment, RGU optimise and finalise the specification and detailing of the building fabric and components in conjunction with Dandara Homes and the timber frame suppliers (Scotframe)

- The Passivhaus Certifier from Sweden was also appointed to the project during this stage (late!). He completed the ‘Design Stage Certification of the two Passivhaus’, after reviewing the PHPP assessments incl, analysis of thermal bridge junctions.

BIM MODELLING + PHPP

- The BIM model is used to calculate the usable internal floor area; the dimensions of the window and door apertures; the building volume and external surface areas for each option (taken to the outside face of the insulation layer to the walls, roofs and floor in each case); and the length of linear thermal bridges derived from 3D massing model of the house type variants. It also provided a graphic depiction and record of the PHPP inputs.

- The use of BIM software allows for the scheduling of the wall surfaces and apertures, thus assisting in the process of incorporating data on the different options into the PHPP software.

PHPP (must)

Passive House Verification

Building:	New dwelling (Rowan Housetype Option 3)
Street:	Dandara Development
Postcode/City:	
Province/Country:	Aberdeen / Scotland
Building type:	Private dwelling
Climate data set:	GB0017a-Aberdeen
Climate zone:	3: Cool-temperate — Altitude of location: 55 m
Home owner / Client:	Dandara Limited
Street:	Isle of Man Business Park, Cooil Road Bradden
Postcode/City:	IM2 2SA
Province/Country:	Isle of Man

Architecture:	Dandara Limited	**Mechanical system:**	
Street:	Isle of Man Business Park, Cooil Road Bradden	Street:	
Postcode/City:	IM2 2SA	Postcode/City:	
Province/Country:	Isle of Man	Province/Country:	
Energy consultancy:	RGU	**Certification:**	
Street:	Garthdee House, Garthdee Road	Street:	
Postcode/City:	AB10 7QB Aberdeen	Postcode/City:	
Province/Country:	UK	Province/Country:	

Year of construction:	2017	Interior temperature winter [°C]:	20.0	Interior temp. summer [°C]:	25.0
No. of dwelling units:	1	Internal heat gains (IHG) heating case [W/m^2]:	2.5	IHG cooling case [W/m^2]:	2.5
No. of occupants:	2.7	Specific capacity [Wh/K per m^2 TFA]:	60	Mechanical cooling:	

Specific building characteristics with reference to the treated floor area

				Criteria	Alternative criteria	Fulfilled?[2]
	Treated floor area m^2	125.3				
Space heating	Heating demand $kWh/(m^2a)$	20	≤	15	-	yes
	Heating load W/m^2	9.48	≤	-	10	
Space cooling	Cooling & dehum. demand $kWh/(m^2a)$	-	≤	-	-	-
	Cooling load W/m^2	-	≤	-	-	
	Frequency of overheating (> 25 °C) %	0	≤	10		yes
	Frequency excessively high humidity (> 12 g/kg) %	0	≤	20		yes
Airtightness	Pressurization test result n_{50} 1/h	0.5	≤	0.6		yes
Non-renewable Primary Energy (PE)	PE demand $kWh/(m^2a)$	81	≤	120		yes
Primary Energy Renewable (PER)	PER demand $kWh/(m^2a)$	72	≤	-	-	-
	Generation of renewable energy $kWh/(m^2a)$		≥	-	-	

[2] Empty field: Data missing; '-': No requirement

I confirm that the values given herein have been determined following the PHPP methodology and based on the characteristic values of the building. The PHPP calculations are attached to this verification.

Passive House Classic? yes

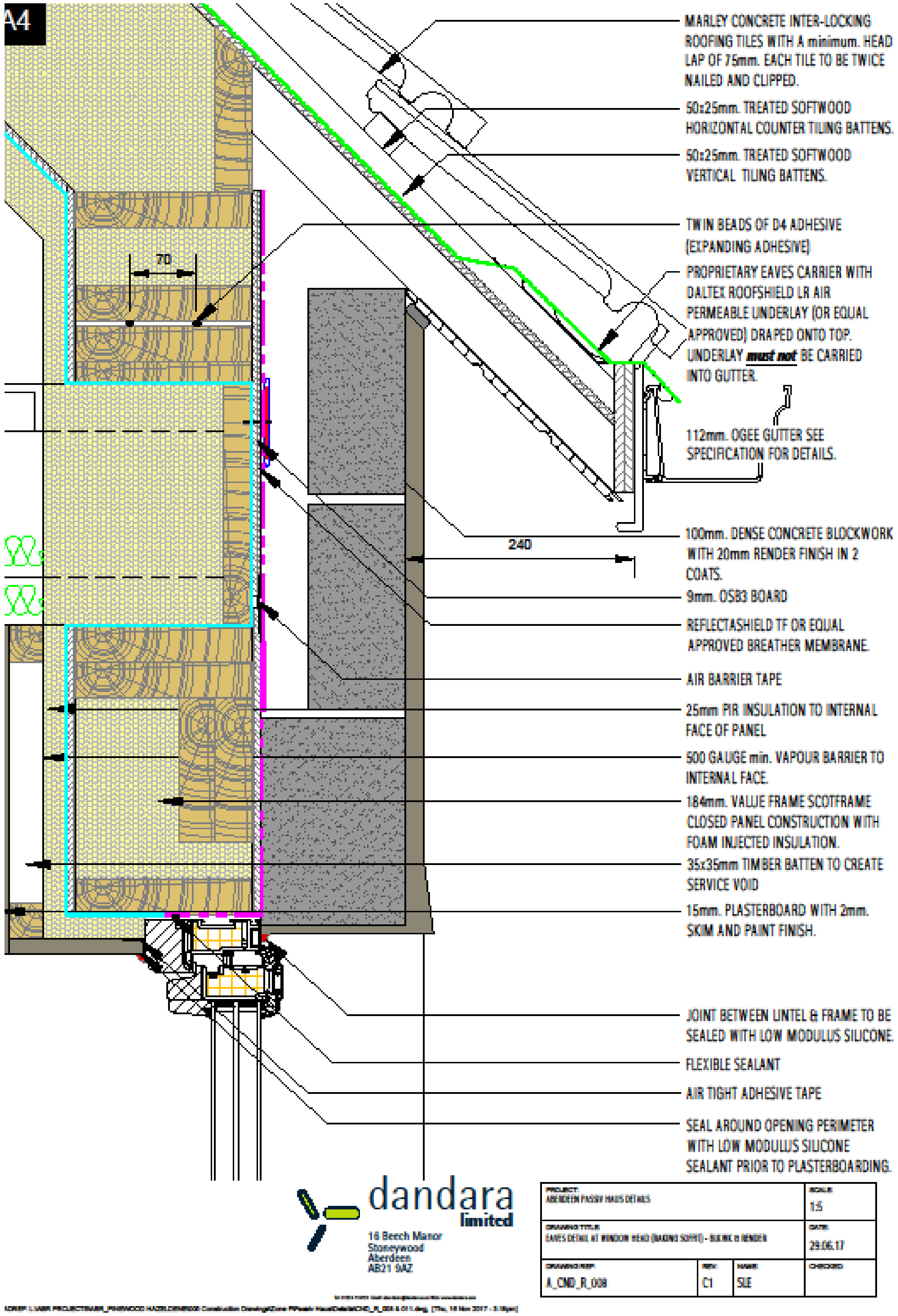
Task:	First name:	Surname:	Signature:
	Issued on:	City:	

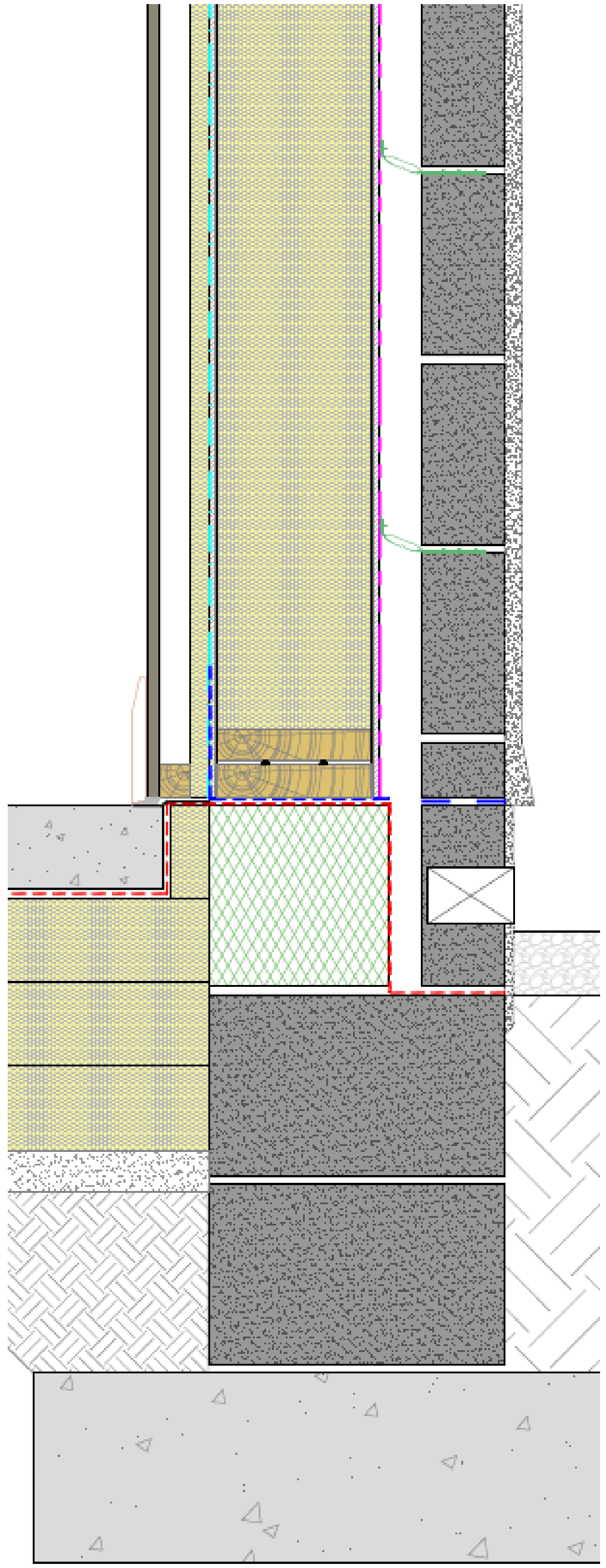
OPTIONS (incremental appraisal)

Housetype	Option	Insulation thickness / U-values						Passivhaus Compliance			
		Walls		Roof		Floor		Heating Demand (kWh/m2A)	Optimised	Heating Load (Wm2)	Optimised
Rowan	Base	140 mm PU	0.252 W/m2K	200 mm PU	0.142 W/m2K	200 mm PU	0.107 W/m2K	39	35	14	13
	Option 1	140 + 25 mm PU	0.179 W/m2K	220 mm PU	0.142 W/m2K	200 mm PU	0.107 W/m2K	30	27	12	11
	Option 2.1	140 + 25 mm PU	0.179 W/m2K	225 + 50 mm PU	0.103 W/m2K	300 mm PU	0.072 W/m2K	26	22	11	11
	Option 2	140 + 50 mm PU	0.146 W/m2K	245 mm PU	0.130 W/m2K	200 mm PU	0.107 W/m2K	27	24	11	10
	Option 3	140 +70 mm PU	0.129 W/m2K	300 mm PU	0.108 W/m2K	300 mm PU	0.072W/m2K	23	19	10	9
	Option 3.1	184 mm PU	0.166 W/m2K	225 + 50 mm PU	0.103 W/m2K	300 mm PU	0.072W/m2K	27	23	11	10
	Option 3.2	184 + 25 mm PU	0.136 W/m2K	225 + 50 mm PU	0.103 W/m2K	300 mm PU	0.072W/m2K	23	19	10	9
	Option 3.3	184 + 25 mm PU	0.136 W/m2K	225 + 50 mm PU	0.105 W/m2K	300 mm PU	0.072W/m2K	23	19	11	10
	Option 4	140 + 100 mm PU	0.109 W/m2K	300 mm PU	0.108 W/m2K	300 mm PU	0.072 W/m2K	21	17	10	9

- An incremental approach appraisal is undertaken to establish which key variables can be optimised to further increase the performance. The key variables key ones are:
  - 'U' values of wall/floor and roof;
  - Window performance and nominal installation details;
  - Linear thermal bridges.
- The incremental improvements in insulation relative to space heating/ heating load figures allow for compliance to be based on the optimal thickness of insulation. As such the key focus is to derive the most cost effective solution which meets the technical and certification requirements of the supplier.

DETAIL DESIGN WP3





PASSIVHAUS CERTIFICATION

PHC established the location and number of 24 Psi value calculations that are required in order to complete his assessment. A very high number of crtical interface details were thermally assessed and their Psi value results into the PHPP worksheet for final verification.

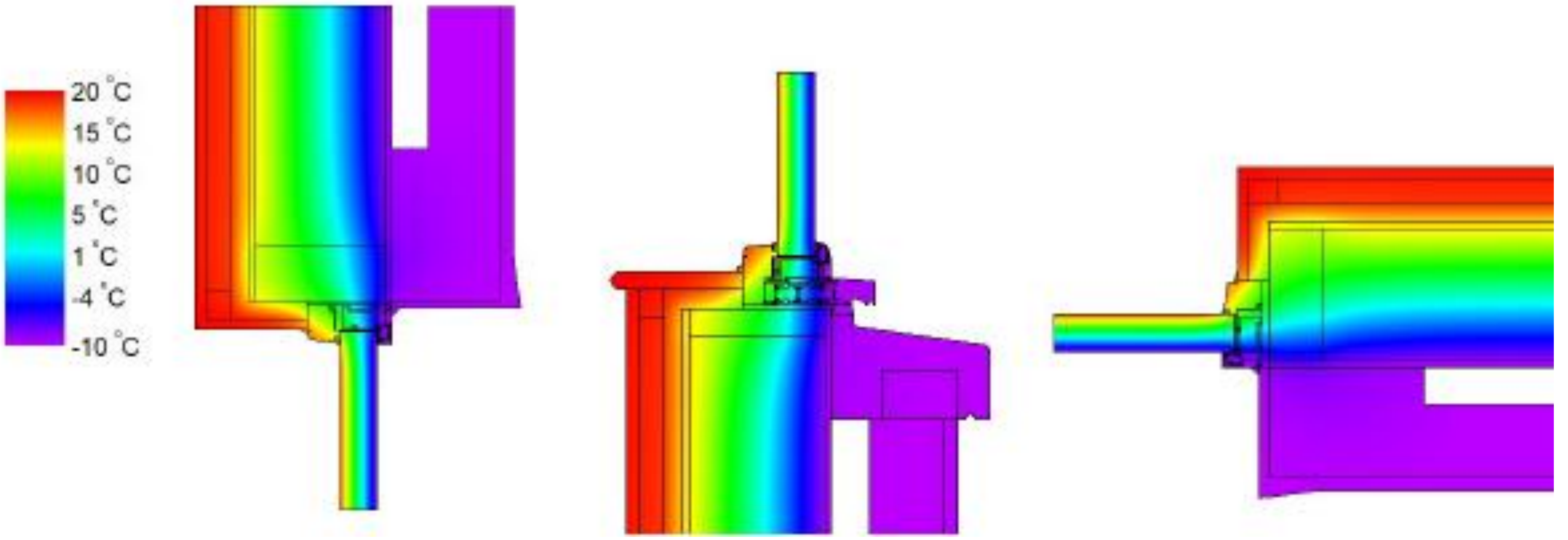
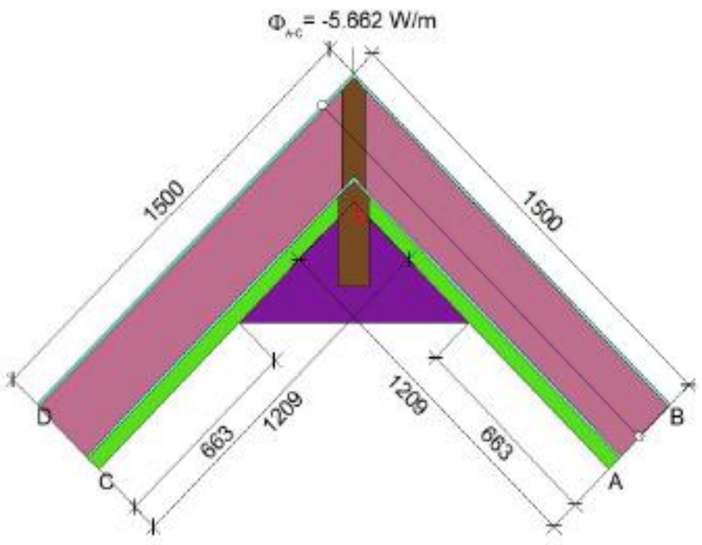
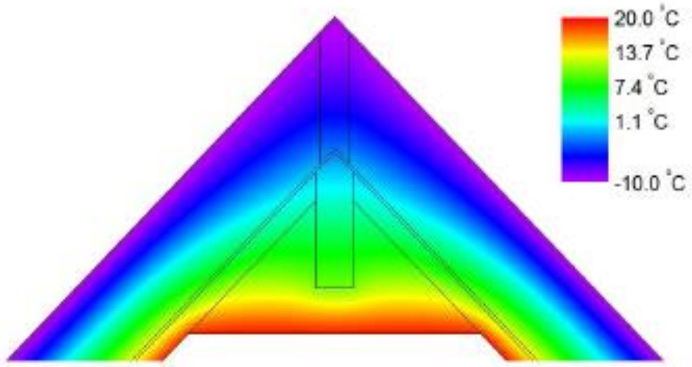


Figure xx: Thermal analysis of window details. Ingo Theobolt

3. Ridge

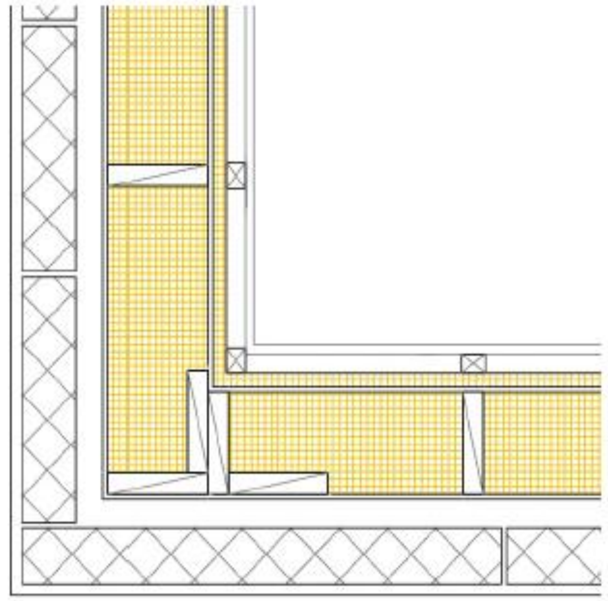


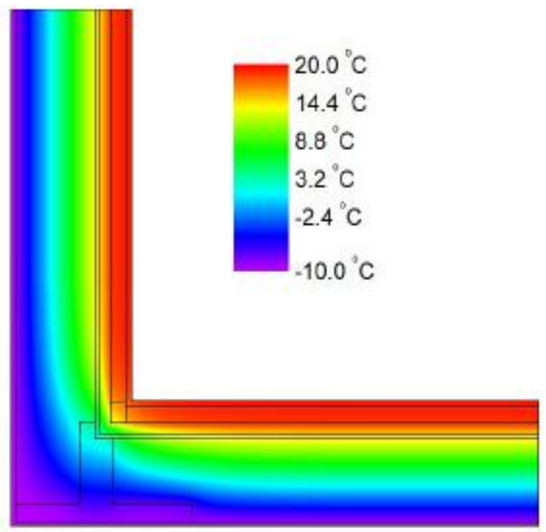


Ψ_{PHI} = -0.072 W/(m^2·K)

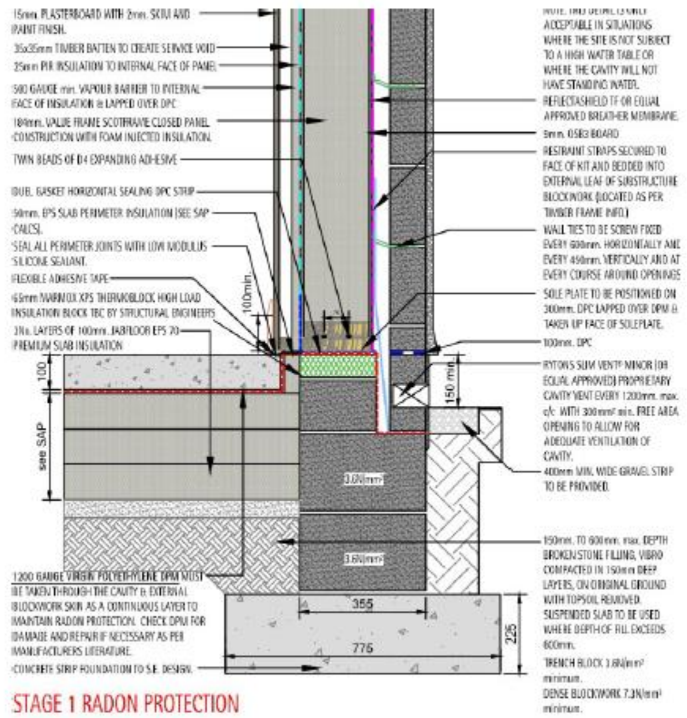
Ψ_{SAP} = 0.073 W/(m^2·K); -0.018 W/(m^2·K) *)

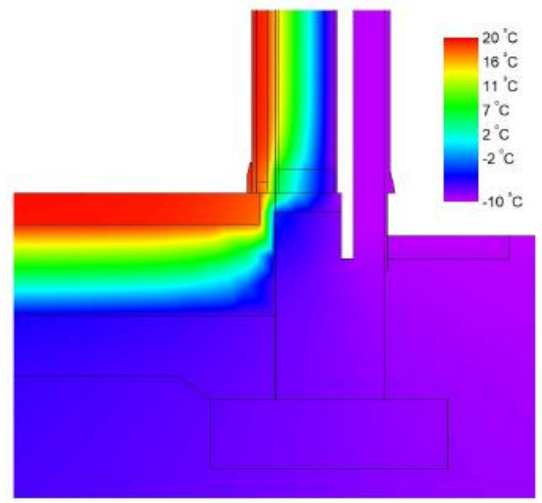
1. External Wall Junction





$\Psi_{PHI/SAP}$ = -0.030 W/(m^2·K) / 0.038 W/(m^2·K)





$\Psi_{PHI/SAP}$ = 0.038 W/(m^2·K) / 0.027 W/(m^2·K)

DELIVERY

Awareness

The requirements that will place on the project.
Run a pre-start workshop with all concerned on site prior to site start:

- What it means to produce a passive house

- The myths about buildability.

- Air tightness and thermal bridging

SITE CHALLENGES for Dandara

Maximising Air Tightness – Junction treatment – Workmanship and appropriate detailing to limit air infiltration

Increasing Fabric Insulation and Glazing – Insulation Type (Injected insulation in lieu of glass fibre quilt)

Minimising Linear Bridging – Lining the inner studs and around openings with PI (closed cell) insulation.

Understanding MVHR (Mechanical Ventilation and Heat Recovery) and it’s contribution to balancing the environmental conditions of the supply and extracted air within the building

Minimal Heating– Underfloor heating on the ground floor and reduced radiators to upper floors

Airtightness - Checks in intervals

Enhanced specification

Floor slab - 200mm Insulation increased to 300mm. Plus Marmox insulation block beneath the soleplate.

Walls – ‘U’ Values Reduced from 0.22 to 0.12W/m2K. 180mm PI Insulation in lieu of 140 Glass Fibre Quilt. Plus 25mm PI insulation lining.

Windows - UPVC double glazing U Value 1.2 / 1.4 down to Composite Aluminium / insulated/ timber triple glazed 0.5W/m2K

Air tightness – 4ach (air changes per hour) improved to **0.38 / 0.49** based on a Passivhaus target of **0.6 ach.**

Ventilation – Intermittent mechanical ventilation changed to MVHR (Mechanical Ventilation and Heat Recovery). Vent Axia and Passivhaus Certificated Paull system. Controlled balancing of supply and extracted air within the building.

Reduced sized boiler – Compared to the Building Regulation compliant house type

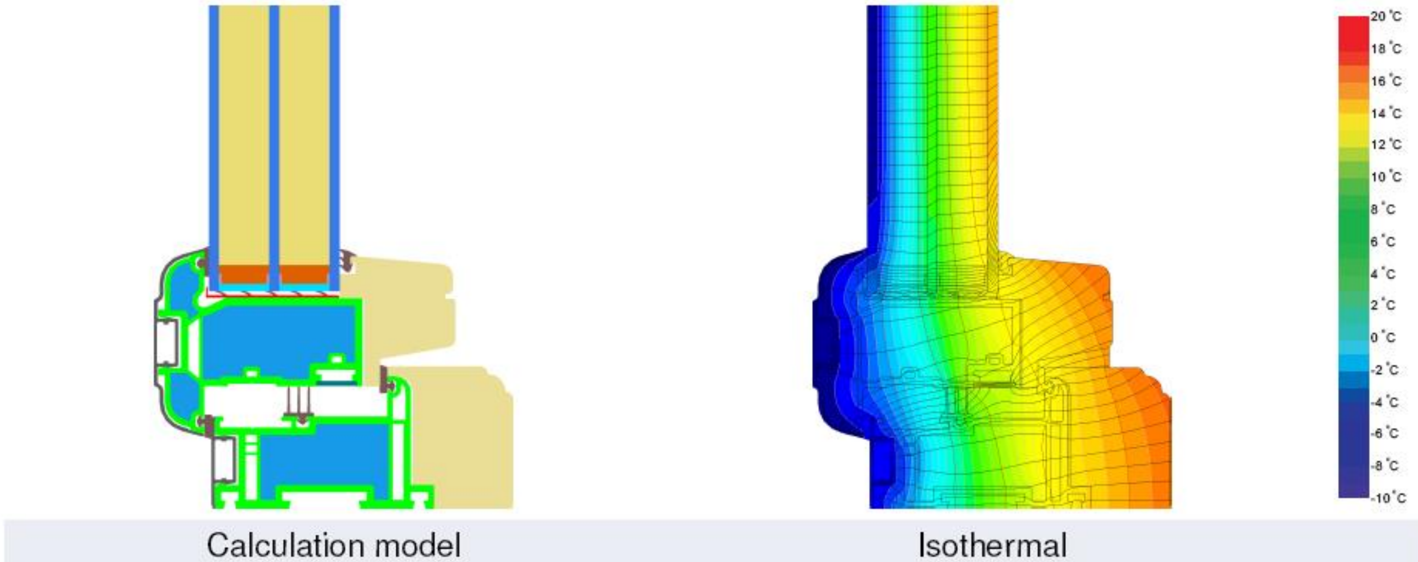
Floor slab

200mm Insulation increased to 300mm. Plus Marmox insulation block installed beneath the soleplate.

Walls; U Values Reduced from 0.22 to 0.12W/m2K. 180mm PI Insulation in lieu of 140 Glass Fibre Quilt. Plus 25mm PI insulation lining.

Windows : UPVC double glazing U Value 1.2 / 1.4 down to Composite Aluminium / timber triple glazed 0.78W/m2K

Air tightness : 4ach (air changes per hour) improved to **0.38 / 0.49** based on a Passivhaus target of **0.6 ach.**



Ventilation – Intermittent mechanical ventilation changed to MVHR (Mechanical Ventilation and Heat Recovery). Vent-Axia and Passivhaus Certificated ‘Paul’ system.

Controlled balancing of supply and extracted air within the building.

Regulatory Challenges

Flexibility from the Statutory Authorities –

current Building Regulations and supplementary planning guidance (SPGs) currently favour low and zero carbon technology over fabric first.

Aberdeen City Council Supplementary Planning Guidance –

currently requires that 20% of the carbon reductions are achieved using low and zero carbon (LZC) technology ie PV panels, air source heat pumps or other similar LZC technologies

Building Regulation compliance and SAP 2012 -

is not favourable to ‘fabric first’ approach to allow a pass without the use of some form of Low and Zero Carbon.

Building Standards and Planning Authorities need to embrace the benefits of a fabric first (Passivhaus approach) and balance this with LZC technologies.

Cost Challenges

Up-lift costs

Increased insulation values for the external envelope – walls / roof / floors and windows & doors

MVHR in lieu of conventional intermittent ventilation

Increased supervision of junctions / service penetration, sealing and air tightness around window and door openings.

Additional linings of the inner face of the kit with additional layer of barriers and insulation to deal with linear bridging.

Other costs

Learning Curve, supervision and management – standard Dandara’s QA checks up from 44 to 50!.

Marketing the benefits

Dandara will test the market to determine what increased value can be achieved for the 2 Passivhaus compliant versions of the Rowan house type compared to the standard Building Regs compliant Rowan House type

Energy conservation benefits- Promoting running costs over a standard Building Regulation compliant house

Valuation surveyors – recognition of increased value of Passivhaus V Standard Rowan House type

The outcome of the testing of the market and appetite for customers paying additional costs, and valuers supporting an acceptable uplift will be determined as this phase of the Hazelwood Development in Aberdeen is released for sale.

Constrains - Available mortgage funds (First time buyer sized property v second homes and 3rd homes). Constraints at lower end of the market

LESSONS LEARNED

- Early appointment of Passivhaus Consultant / Certifier
- Stage 2 (Concept Design) is important for insulating and erecting the timber frame should be established during
- Availability of thermal bridge calculation software is critical for the early assessment of thermal bridges and saving cost

LESSONS LEARNED

- The timber frame would ultimately have the biggest impact on the successful delivery of the Passivhaus through specification, detailing and construction: timber fraction, thermal bridging and installation.

- Enhanced role of Structural Engineer in reduction of timber in kit.
    - Optimise timber frame designs in terms of reducing the timber fraction and minimising waste.
    - Number of structural timber at triple studs etc.
    - Utilising non-‘full depth’ structural timbers at posts and window apertures;
    - Future trade opportunity OR does it complicate the build process and make it more expensive.
    - Use of ‘specialist kit erectors’ and airtightness experts.

LESSONS LEARNED

Site specific data Influence – Orientation, altitude and location

- Initial assessments indicate that ‘orientation’ does not influence compliance by the Heating Load. However, the location has a considerable effect with possible sites in southern regions complying by Space Heating Demand

- Combining semi PH and assessing as a single entity improves compliance results due to more compact form

LESSONS LEARNED

- The Passive House criteria allow buildings to meet either criterion :
  The Heat demand (15 kWh/m²yr) OR the Heating Load (10W/m²)

- Compliance using the Heating Load is more achievable in Scotland due to lack of solar gain. It will be worthwhile to investigate whether compliance by Heating Load could be embraced by Scotland as the basis for future 'local' Passivhaus standards.

- The ability to heat with the ventilation air. A certain amount of heat can be distributed with very little effort via the supply air coming from a Passive House building's ventilation system. The ventilation system thus serves a dual function (fresh air and heating) and reduces the investment required for heat distribution to a minimum. – Further research needed.

LESSONS LEARNED

Issues with MVHR unit and duct layout.

- Should be co-ordinated earlier in concept design stages (WP2)
- Utility and store spaces should be ‘larger and taller’ enough to allow for access for installation and maintenance
- Posi-joist or equivalent rather than solid joist allowed for flexible approach for ducting

Questions?

Why PH houses are not valued at a higher price than other property. This is the biggest investment one will make yet while fuel efficiency is highly prized in vehicles other goods and reflected in its purchase price, it does not seem to be something that is taken into account when valuing a house!

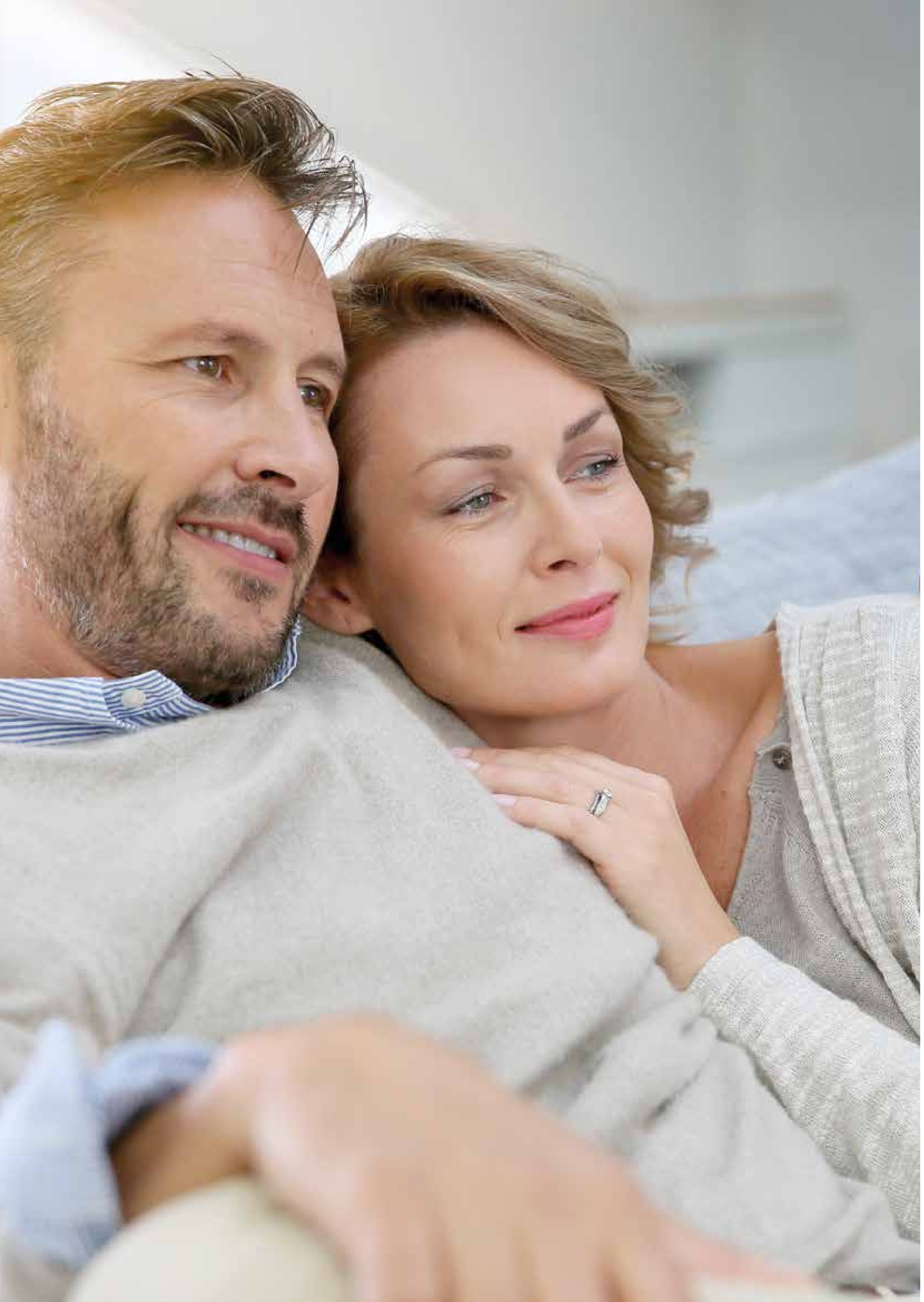
“An energy efficient home can save you thousands of pounds over the course of its lifetime and that needs to be recognised by both Funders, Providers, Valuation surveyors and house buyers.”

THE ROWAN

PASSIVHAUS

OAKFIELDS | HAZELWOOD

dandara



WHAT IS A PASSIVHAUS?

An ultra-low energy residential property.

The Passivhaus Institute was established in Germany in 1996, with an ambitious target: to develop a standard for the design and construction of a building which required 90% less space-heating than a standard, new-build home at the time.

Now world-renowned, the Passivhaus Institute offers the only truly global performance-based energy standard for the construction industry.

It evaluates the design and construction of new properties with a focus on three core principles: the creation of a highly insulated envelope; assurance of maximum air-tightness; and the elimination of cold bridging.

These principles were established through research by Lund University and Wolfgang Feist of the Institute for Housing and Environment in Darmstadt, Germany, who perfected their aspirations.

The standard which emerged from their research is internationally recognised as the pinnacle in sustainable housing development, and has three core targets:

1. a peak heat load of $10W/m^2$;
2. primary energy requirement of $60kWh/m^2$ per year for all energy (heating, hot water and electricity); and
3. an air leakage rate no greater than 0.6 times the volume of the building per hour.

Every Passivhaus Institute Certified building must achieve these targets.

Only through rigorous scrutiny and assessment of every aspect of the design, construction and commissioning of each home as it is created, can the accolade of the Passivhaus Institute certification be gained.

THE ROWAN PASSIVHAUS

Located in the peaceful, sought-after West End of Aberdeen, Oakfields at Hazelwood offers homebuyers a unique opportunity to acquire Dandara's first Passivhaus Institute-approved home: the Rowan Passivhaus.

Dandara is proud to have achieved this impressive standard, working in conjunction with a joint research partnership between RGU and experienced Passivhaus certifier, Ingo Theoboldt. The Construction Scotland Innovation Centre provided funding to support the academic research element.

Through this project, we have successfully continued our mission to design and build innovative homes while actively pursuing solutions which contribute to the global movement tackling the climate and environmental challenges that face us all.

Its achievements will continue to inform how we build homes across the UK, with learnings from the creation of these homes finding their way into future developments as we seek to deliver the very best in new home design and construction.

AN INTERNATIONAL STANDARD, ACHIEVED WITH LOCAL EXPERTISE

As part of this ambitious project, we undertook an additional challenge – to craft two Rowan Passivhaus properties at Oakfields with very different origins.

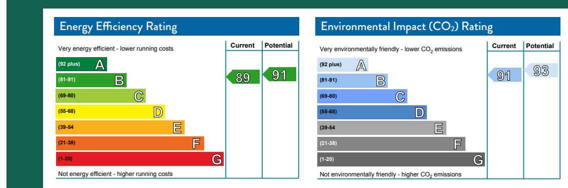
The first uses technologies already certified by the Passivhaus Institute, originating and sourced in Germany.

The second uses technologies from within the UK, many from the Aberdeen City and Shire region, which have achieved the Passivhaus standard – supporting the local economy and encouraging innovation in Scotland's housebuilding industry.

By achieving the Passivhaus standard in both properties, we have shown that further carbon reduction can be secured by reducing the logistics and shipping required to order components from international locations.

Both of our Rowan Passivhaus properties have the same standard of superior air-tightness, insulation, ventilation and heat recovery systems, which work together to minimise heat loss while generating energy by harvesting atmospheric heat. Both of the certified Rowan properties has a 'B' band EPC rating.

Predictive Energy Assessment



Energy performance has been assessed using the SAP 2012 methodology and is rated in terms of the energy use per square metre of floor area, energy efficiency based on fuel costs and environmental impact based on carbon dioxide (co_2) emissions.

Diagram shown is indicative only.

THE ROWAN PASSIVHAUS

This Rowan is a new three bedroom semi-detached home with on-drive parking. The ground floor features a separate lounge and spacious kitchen-dining room with French Doors to access the rear garden. There is also a utility room, WC and bedroom/study with an en-suite shower room.

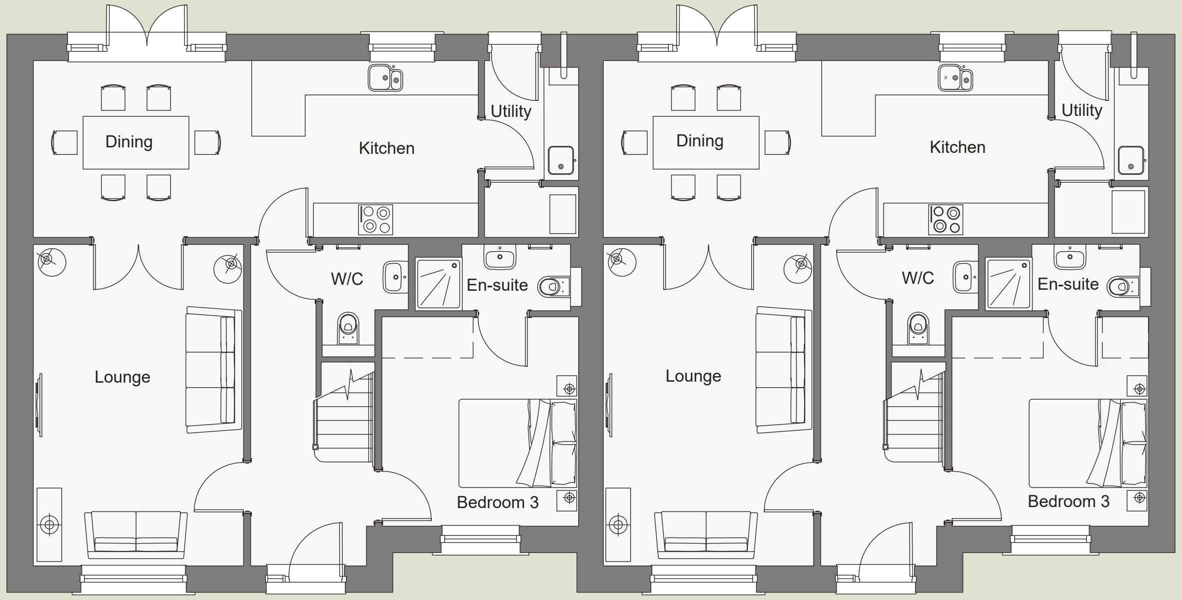
On the first floor the large master bedroom features a walk-in dressing room and en-suite. There is a further double bedroom and a stylish family bathroom.

GROUND FLOOR

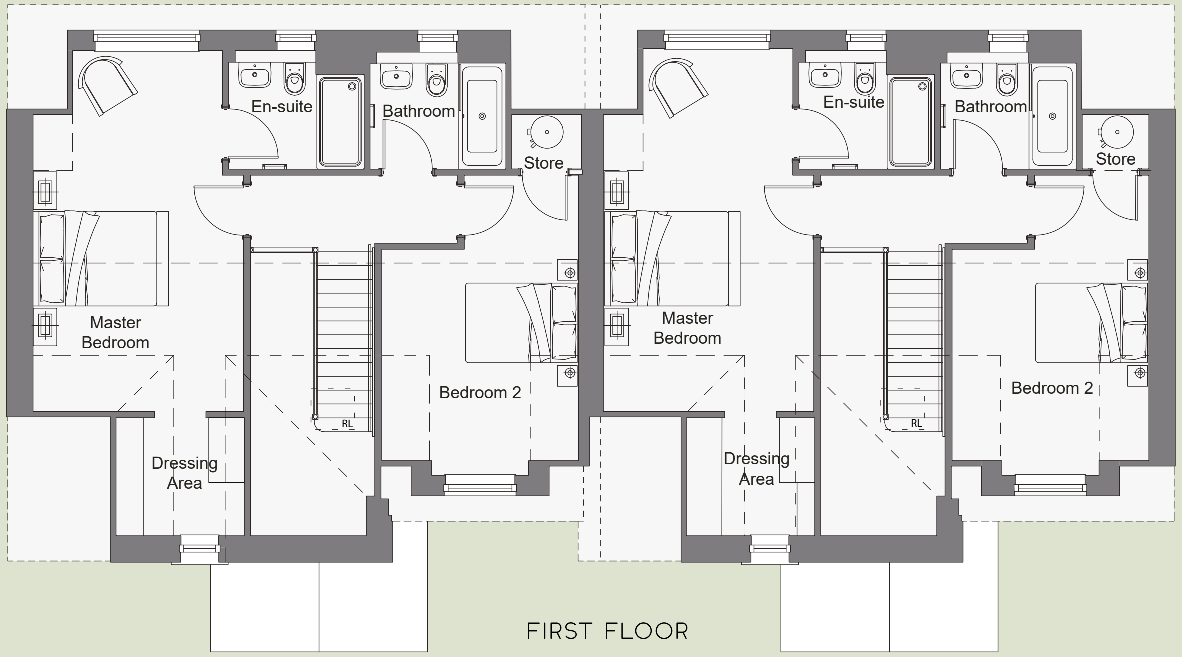
Kitchen/Dining	7.56m x 3.00m	24'10" x 9'10"	
Lounge	3.57m x 5.46m	11'8" x 17'11"	
Utility	1.59m x 2.04m	5'2" x 6'8"	max
Bedroom 3	3.33m x 3.55m	10'11" x 11'8"	
En-suite	2.66m x 1.12m	8'9" x 3'8"	max

FIRST FLOOR

Master bedroom	3.58m x 6.12m	11'9" x 20'1"	max
En-suite	2.30m x 2.03m	7'6" x 6'8"	max
Bedroom 2	3.33m x 5.09m	10'11" x 16'9"	max
Bathroom	2.30m x 2.00m	7'7" x 6'7"	max



GROUND FLOOR



FIRST FLOOR

THE DANDARA DIFFERENCE

Ensuring that the build quality and interior finish of your new home exceeds your expectations is the very foundation of what we do.

We have achieved the Passivhaus standard without compromise to the aesthetic touches which make the Rowan such a sought-after property.

The following specification provides you with an outline of the internal and external features we include as standard in your new home at Oakfields.

AWARD WINNING SPECIFICATION

We pay great attention to detail to ensure that the build quality and interior finish of your new home exceeds your expectations. The following specification provides you with an outline of the internal and external features we include as standard in your new home at Oakfields.

☑ ENERGY EFFICIENCY

The Passivhaus certified Rowan offers significant benefits – consuming less carbon resource and delivering significant energy cost-savings, it is an efficient, environmentally-friendly home of the highest specification.

Passivhaus Institute-accredited materials and techniques have been employed in all aspects of each home's construction, including custom-made timber frame, and multi-layer insulation featuring a skin which wraps each room in an energy-efficient shell.

Technology builds upon that core strength, ensuring that heating and circulating air work together to balance thermal conditions throughout the home. Underfloor systems on the ground floor provide superb, low-fuel consuming warmth and facilitate the use of smaller radiators throughout the upper floor without any loss of comfort.

Photovoltaic panels are also fitted to your new home, providing supplementary low-carbon-generated electricity, which can help reduce your energy bills even further.

☑ WINDOWS

All windows are triple-glazed units which receive and retain heat, while keeping out the cold. Internal panes remain at room-temperature, reducing cold air volumes and eliminating condensation. All Velux rooflights are computer controlled to ensure a secure seal to maintain the home's energy efficiency.

☑ EXTERNAL DOORS

External doors, custom made for the Rowan Passivhaus, offer a higher level of insulation, sealing the building's envelope reliably. Patio doors are triple-glazed to the same standard as all windows, achieving room-temperature inner panes and eliminating condensation. External doors feature polished chrome door furniture, dead lock and lever latches.

☑ KITCHENS

Our contemporary, German kitchens are designed with both functionality and practicality in mind. Featuring high quality laminate worktops and flush unit doors in natural tones they come fully equipped with all appliances including double oven, gas hob, extractor hood and fully integrated microwave, dishwasher and fridge freezer. Stainless steel 1½ bowl sink with chrome mixer tap in the kitchen plus an additional stainless steel single bowl sink with chrome mixer tap in the utility room.

☑ BATHROOMS

Our elegantly designed bathrooms feature a stylish, contemporary white porcelain suite comprising bath with thermostatically controlled shower, wall-mounted basins, concealed cistern WC, chrome towel rail and fully integrated storage concealed behind mirrored vanity units.

Bathroom floors are fully-tiled. Wall tiles to wet-areas.

☑ EN-SUITES

The stylish en-suites feature high quality contemporary white wall-mounted basin and concealed cistern WC, thermostatically controlled shower units, polished chrome taps and towel rails. Floors are fully-tiled. Wall tiles to wet-areas.

☑ WC

Cloakrooms also get the 5-star treatment and feature the same high quality white porcelain sanitary-ware as our bathrooms, which include wall-mounted basin, concealed cistern WC and polished chrome taps. Floors are fully-tiled.

☑ JOINERY

All internal doors are finished in white and fitted with attractive contemporary chrome door handles.

☑ WARDROBES

Fitted wardrobes included in master bedroom.

☑ ELECTRICAL

We include plenty of sockets throughout your new home, which are finished in chrome in the hall, lounge, kitchen and dining area. There are telephone sockets in the lounge, master bedroom and one in bedroom two. We provide a Sky master point in the lounge along with a Sky Multiroom point in the master bedroom. All other bedrooms benefit from TV points.

☑ LIGHTING

We fit recessed down lighting in the hall, kitchen, bathrooms and all en-suites and provide pendant light fittings in the lounge, dining room and bedrooms, so that you may install fittings of your own choice.

☑ DECORATION AND INTERNAL FINISH

Walls and ceilings are decorated in neutral tones with internal woodwork finished in a mix of natural and white gloss, giving you the perfect canvas to personalise as you wish.

☑ FIRE SAFETY

A mains smoke detector system with battery back-up pack is fitted as standard for additional peace of mind.

☑ GARDEN AND LANDSCAPING

All pathways are paved with slabs, front gardens are landscaped and turfed, and we seed the rear garden so that you may plan your own landscaping.

PASSIVE HOUSE CERTIFIER
Passivhaus Institut accredited

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CONSUMER CODE FOR HOME BUILDERS
www.consumercode.co.uk

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