

Resource efficient house case study

A demonstration construction project



Growth that doesn't cost the earth

October 2014

A programme from



EUROPE & SCOTLAND
European Regional Development Fund
Investing in a Smart, Sustainable and Inclusive Future

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Executive Summary

1 Background and development

The Resource Efficient House is an innovative project managed by Zero Waste Scotland as part of Resource Efficient Scotland, the Scottish Government funded programme that helps businesses, the public and third sectors save money by using resources more efficiently.

[tp://www.resourceefficientscotland.com/](http://www.resourceefficientscotland.com/)

2 Introduction

The Resource Efficient House is a ground breaking exemplar project that aims to promote and encourage the construction of sustainable and affordable family homes across the country.

The house, which opened in June 2013 is a key feature and visitor attraction at the BRE Innovation Park at Ravenscraig, the national hub for construction industry innovation located within one of Scotland's largest regeneration zones.



Developed by Zero Waste Scotland under the Resource Efficient Scotland programme and in partnership with Tigh Grian Limited, the Resource Efficient House is a contemporary, three-

bedroom home which aims to demonstrate the route to a more sustainable house building industry in terms of its quality, repeatable, and affordable design.

Constructed off-site by means of structural insulated panels (SIPs) the modular and flexible Resource Efficient House is an airtight, highly insulated building designed to reduce home energy costs and achieve net zero carbon emissions. A range of green technologies have also been incorporated and in terms of energy efficiency the house is set to meet enhanced 2016 Scottish Building Standards Gold performance requirements.

The whole lifetime of the House has been considered to ensure minimal construction waste and support the effective reuse or recycling of construction materials at the point of property deconstruction. The Resource Efficient House aims to inform and support positive change in the future of house building in Scotland.

2.1 Zero Waste Scotland

The Resource Efficient House is a project that has been developed under the auspices of Zero Waste Scotland, which emerged out of Scotland's Zero Waste Plan. Launched in June 2010, the Plan sets out the Scottish Government's vision for a zero waste society. Central to this Plan is a vision for Scotland where resource use and production of waste is minimised and, when waste is produced, is treated as a resource that can benefit Scotland in line with the Government's economic strategy. The Zero Waste Plan sets out some ambitious new measures and identifies key priorities for Scotland.

Achieving this vision of a zero waste society requires collective action by business, the public sector, communities and individuals. The Scottish Government, Zero Waste Scotland, SEPA, enterprise agencies, local authorities and other delivery partners are working together in an integrated and coordinated way and will support this collective action.

2.2 Resource Efficient Scotland

Through the Resource Efficient Scotland Programme, Zero Waste Scotland is committed to supporting the construction industry to increase resource efficiency and reduce waste. Pushing existing boundaries and supporting new innovations is one of the ways that ZWS aims to help the sector make a difference:

The Resource Efficient Scotland Programme aims to engage with construction sector businesses including clients, contractors and designers around the requirements of the Waste (Scotland) Regulations and to promote the benefits of resource efficiency. Local Authorities, Housing Associations and other public bodies are also engaged in order to promote the benefits of resource efficient construction and the availability of appropriate construction techniques and materials.

A key role of Resource Efficient Scotland is to demonstrate the availability of improved construction techniques and the benefits of enhanced building standards to consumers with a view to generating greater awareness and demand for more resource efficient homes in Scotland. Emerging from this particular strand of the Resource Efficient Scotland Programme is the Resource Efficient House at the BRE Innovation Park at Ravenscraig.

3 BRE Ravenscraig

3.1 Origins of the BRE Innovation Park



Site in the context of the current context



Site in the context of the Ravenscraig development masterplan

The BRE Innovation Park at Ravenscraig is the first of its kind in Scotland. The origins of the Innovation Park can be traced back to 2003 when the Building Research Establishment (BRE) set out to create a full size demonstration of housing construction technology within the car park of their Garston research facility, in the environs of Watford. The houses built showcased new ideas in the development of offsite construction technology, and in 2005 the event was repeated with a challenge set to offer affordable solutions.

In 2007, shortly after the launch of the Code for Sustainable Homes, the first Zero Carbon Code Level 6 home was built using Modern Methods of Construction (MMC). In the same year the landscape around the buildings was designed to provide a more integrated response to sustainability by incorporating features such as biofiltration, attenuation, rainwater harvesting, native planting and recycled and renewable materials. In 2009 the park designed by Macfarlane Wilder was extended to provide examples of home zones and play in order to create a sense of place.

3.2 The Ravenscraig Development

The BRE Innovation Park at Ravenscraig (BRE Ravenscraig) is a purpose built facility in the UK that demonstrates housing construction best practice on one of Europe's largest brownfield sites - the former Ravenscraig Steelworks near Motherwell, North Lanarkshire. The Park is seen as an opportunity to demonstrate innovation and excellence in construction and to provide a platform for industry to research, develop and test solutions for energy efficient, sustainable and affordable buildings. The Ravenscraig model is also designed to be a live resource that provides the means for designers and manufacturers to build and monitor sustainable construction techniques. It is an opportunity to learn and disseminate the knowledge and expertise gained from the design, procurement and post-construction phases of development.

3.2.1 Project description - David Kelly, Associate Director, BRE Ravenscraig



"The BRE Park at Watford evolved over time. It began as an exhibition in 2002 when modern methods of construction and off site manufacturing was a new thing within the construction industry. At Watford there was an exhibition showcasing bits of new technology exhibited around the car park and this grew to a full size house being built. Then a few years later there were three houses, then seven houses, it really just snowballed. But effectively it was constructed on the BRE car park with some retrospective landscape work carried out around it.

When we started the process in Scotland we were presented with a site at Ravenscraig that had nothing on it at all. The former steel works had occupied over 1120 acres, and a huge amount of work was carried out after the demolition to remediate the contaminated land back to a state - effectively engineered platforms - where it could be used for construction. This whole remediation took a number of years and £30-40 million, so it's quite an investment for the Scottish Government. There are big plans for Ravenscraig as a whole, with plans for a new town centre and three and a half thousand new homes.

The BRE Innovation Park is located on one of those engineered platforms, which in this case is a capping layer of two metre thick clay. Initially, when we took over the site in 2009 there were certain issues with the site –for example there was no road, no access, no provision of facilities, so we were immediately faced with a challenge of servicing the site. However, we looked at these challenges as an opportunity to create in Scotland the idea of a 'ground up' development.

We looked at road access, provision of utilities, the layout of the park and also issues such as the surface water strategy; and the orientation of the buildings. We were concerned with exploring the demonstration products, technology and innovation going into the ground in the first instance. We didn't want it to be a case of creating a dull, boring platform and simply putting buildings on it. We had this vision of presenting a picture of what future developments could look like and all the features associated with this.

We're not trying to tell people that this is the only way to do it. We're demonstrating a range of different approaches that people can consider for new development in the future. It's very much about creating a sustainable platform for the provision of services and how you deliver an infrastructure package that can support the performance of the building and development of the community.

We wanted to try and have a more ground up and considered approach to the infrastructure works package and this will help the buildings to perform to their maximum potential – that is the thinking behind BRE Ravenscraig.”



3.3 The masterplan

Creating a sense of place is at the core of the BRE masterplan along with a cohesive framework that brings together alternative construction methods.

Designed by Macfarlane Wilder, four themes underpin the park’s design: energy, sustainability, affordability and community. It aims to showcase the future of sustainable housing design in Scotland, integrating landscape, community focus and zero carbon buildings to create a low carbon, inclusive development.

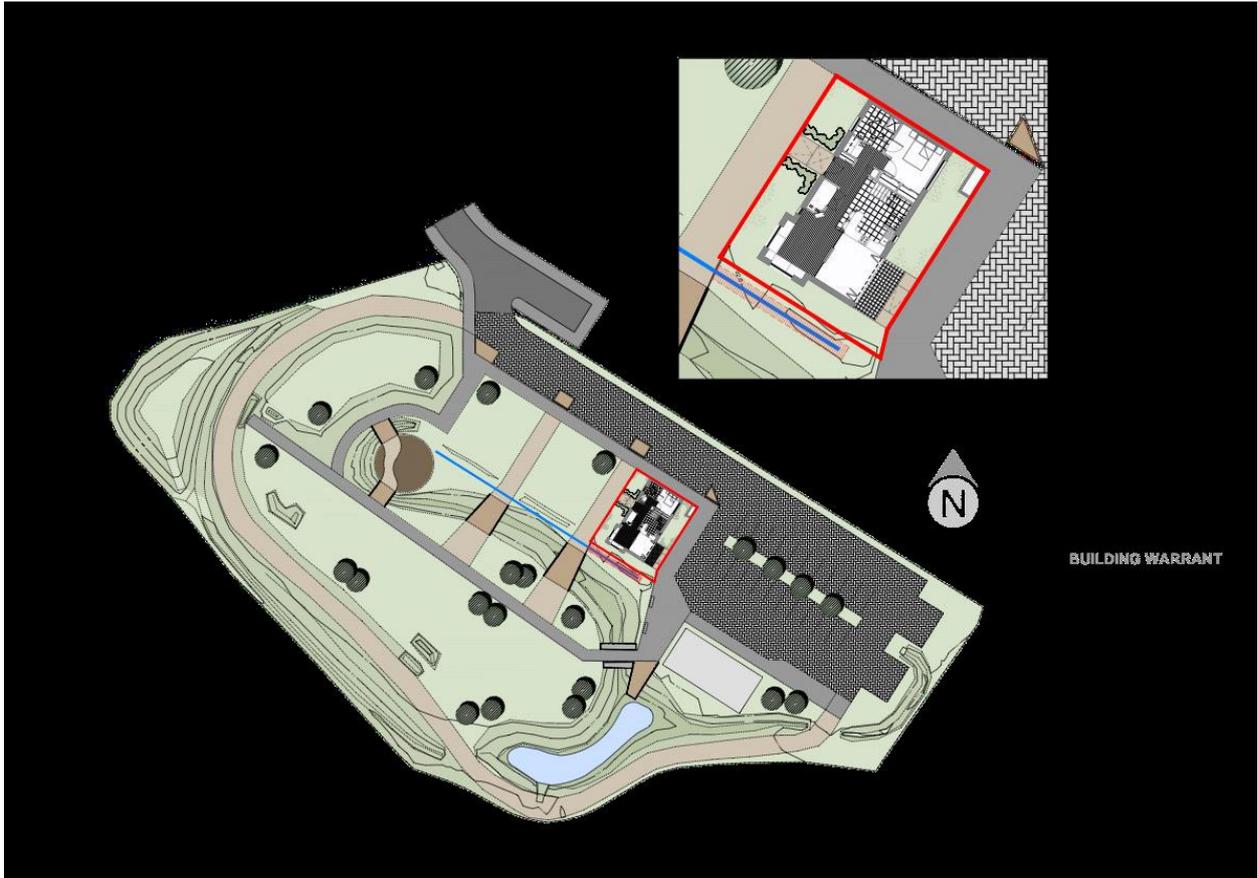
The East-West orientation of the scheme ensures each plot has optimum sun positioning for solar energy as well as space to demonstrate sustainable water management. Meanwhile, the layout has been structured around a central community space with play facilities, seating and gathering spaces, which help to make the park scheme feel like a real neighbourhood.

The BRE Visitor Centre is the information hub for the research activities undertaken at the Park as well as operating as a community facility to engage with local groups. Originally nine development plots were planned, but this has changed over time. Each plot was to be themed to encourage developers to demonstrate different solutions to achieving zero carbon, affordable housing.

3.4 2016 Building Standards

Each demonstration house, including the Resource Efficient House, will showcase products and technologies which enable the property to meet the 2016 Scottish Building Standards Gold Performance Requirements. Additionally, every house should be affordable and repeatable on a wider scale.

The Resource Efficient House is a showhome and exhibit on Plot 5 at the BRE Innovation Park at Ravenscraig and is the result of a partnership project between Zero Waste Scotland and Tigh Grian Ltd.



4 Design brief

The overall Brief for the Resource Efficient House, as envisaged by Zero Waste Scotland, was for a standard family sized detached home with a minimum number of 3 bedrooms. The design and resultant built form was to demonstrate an aspirational level of resource efficiency in terms of: Design; Construction; Occupational Living; and Deconstruction.

Furthermore, it was required that the end product should be realistic in terms of its ability to be replicated throughout Scotland. As a result the design should sit well in both rural and urban locations and be constructed affordably both in terms of the developer and also the house buyer. The Brief also called for the design to demonstrate the benefits of reducing waste, developing sustainable products and using resources in an efficient way.

4.1 The genesis and development of the house project

"Zero Waste Scotland saw this project as a challenge. We were keen to invest in the idea so we seized the opportunity to take on this plot when it came up. We've never done anything like this before, and in terms of our commitment we have a three year lease at the Park, which gives us the opportunity to bring in all the messages of Zero Waste Scotland.

In terms of exploring resource efficiency we were not only keen to promote design and look at the effect this has on the way we live but we also wanted to explore the aspect that the house-building industry doesn't generally consider – its de-construction. This is normally viewed as someone else's problem, but we felt that we had a unique opportunity to address this at the Park.

Volume house building is often about marketing a product, whereas we're trying to market an ethos. How do you build a resource efficient house? How do you live in it? And how do you de-construct it at the end? We are aiming to look at the whole life cycle aspect of the building.

Our aim is to bring attention to the fact that there are alternative sustainable materials out there. Part of the difficulty is actually finding these new materials, but we've been proactive in this field. We created a matrix of credentials seeking out materials according to criteria such as cost, availability and environmental impact. We selected materials that ticked the environmental box, as we wanted each of the products to have a positive message behind it.

We are keen to promote the use of these materials, as we would like to attract the house building industry as a whole, which is why we have also set a cap on costs. We didn't want to build something that was uneconomical to reproduce.

With these factors in mind Zero Waste Scotland ran a competition and put the project out to tender (the Tender Document was issued in summer of 2012). We encouraged companies to put forward their test models and future standard models. In the event, the tender was won by consortium, Tigh Grian Ltd." Allan Sandilands, Manager, Resource Efficient Scotland.

4.2 Background to Tigh Grian Ltd.

Tigh Grian, which means House of Sun in Gaelic, is a consortium comprised of Tigh Grian Directors:

- Colin Machin of Machin Associates, Chartered Architects and CDM Coordinators;
- Alan Johnston of Nuhaus GMBH, a UK based company specialising in Super Energy Efficient Modular Housing;
- Robert Cowie of JR Partners Limited, responsible for promoting affordable housing with clean energy.

The project has been funded by Jacqueline Schindler, President of the Zeno Karl Schindler Foundation (ZKS Foundation), which was established in memory of her father – an eminent engineer in electronic engineering. The foundation supports research and development in environmental engineering and medieval studies.

Tigh Grian Partners include:

- Odin Consulting Engineers Limited, structural design engineers based in Glasgow and led by David Irvine.
- Bennett Robertson Design, an award winning M&E design consultancy based in Belfast with extensive experience in the design of M&E services utilising renewable

technologies. Gary Bennett has provided advice and support to the design team throughout the tender process.

- Alloa Community Enterprises Recycling Group

5 Tigh Grian's design response to the brief



The ambition of Tigh Grian was to design an exemplar dwelling which drives forward the principles of resource efficient construction and deliver a market leading housing model that can be adopted for future housing developments in Scotland and the United Kingdom. Five principles are inherent to the design approach:

- Design for Reuse and Recovery
- Design for Off Site Construction
- Design for Material Optimisation
- Design for Waste Efficient Procurement
- Design for Deconstruction and Flexibility

The aim is also to exceed the Gold Standard of the 2016 Technical Standards, demonstrating to the Scottish and UK construction industry that the demanding requirements of the 2016 technical standards can be achieved within acceptable cost limits by using modern methods of construction. This involves an innovative construction process showcasing an "unprecedented" level of thermal insulation, air-tightness and energy-use derived from renewable sources, all within a budget which aims to prove that this form of construction can be adopted at a mass market level. In other words the proposed design and construction techniques have been devised to be affordable, flexible and repeatable by the volume house building industry in Scotland.

5.1 Deconstruction

The requirement for deconstruction as defined within the brief proved to be an early driver behind the design of the proposal. This factor provided confirmation of Tigh Grian's belief that the off-site manufacture of building elements would be the most effective approach to the project as a whole. The company quickly moved towards the progression of a modular design that would be manufactured in a controlled factory environment and assembled on-site. In order to facilitate deconstruction at the end of a three-year period, the process could simply be reversed and the building re-used on another site.

5.1.1 Detailed design response by Tigh Grian

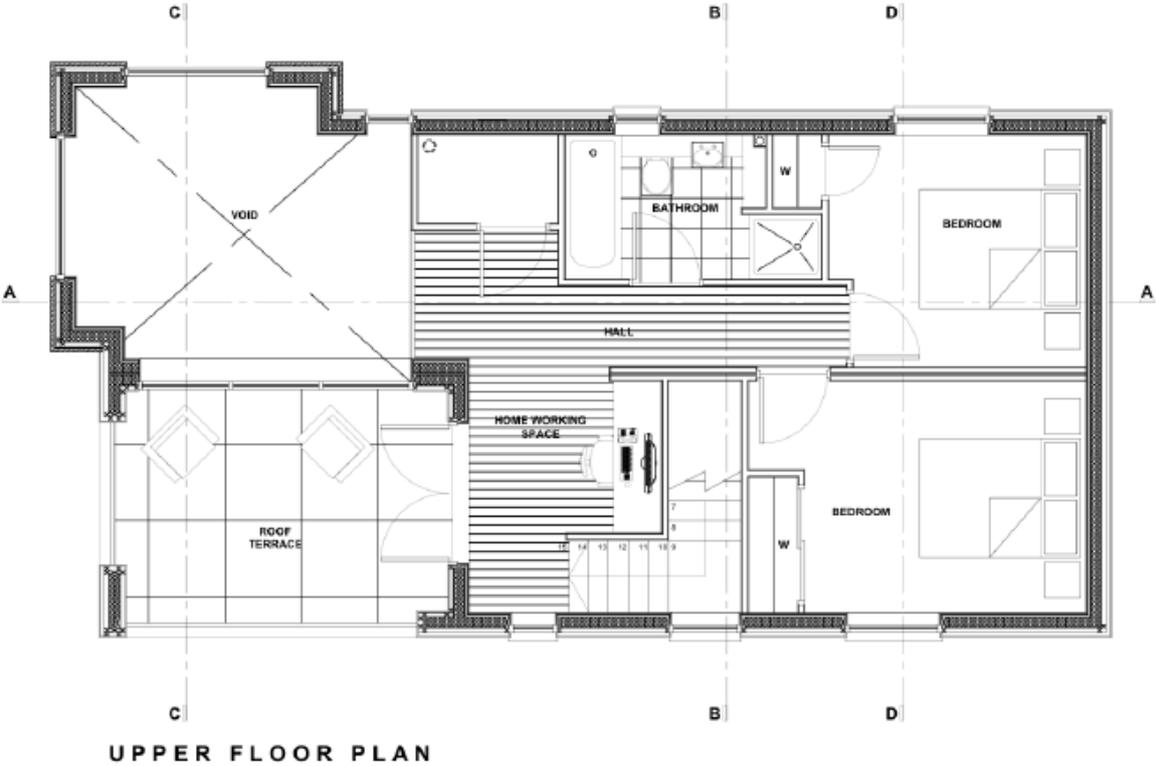
Tigh Grian's overall proposal is designed around a 600mm x 600mm grid. This allows a modular construction system to be achieved whereby standard building products are used without the need for adaptation. A standard sheet of plasterboard is 1200mm (w) x 2400mm (h) and all fenestration is coherent with this sizing so that no surplus plasterboard or off-cuts are generated throughout the manufacturing process. This grid provided a

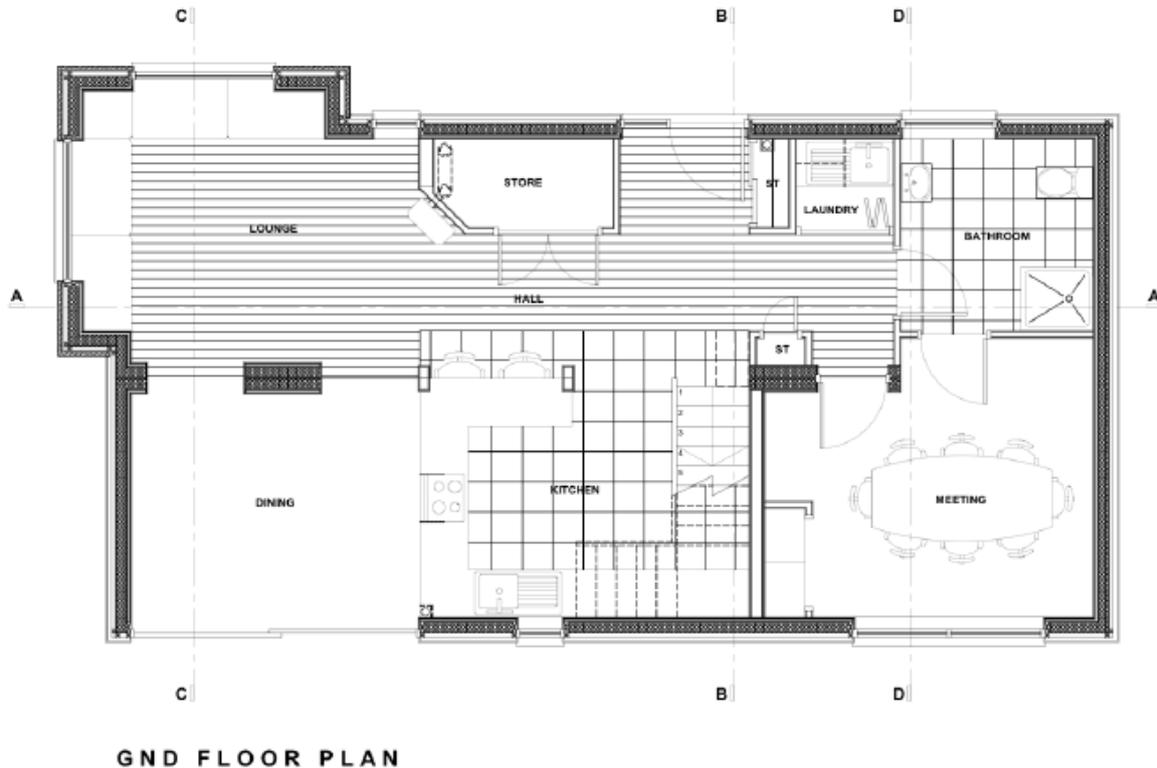
framework in which all rooms and spaces are formed and generated obvious lines for pods to be formed.

The general zoning of the floor plan is synonymous with traditional Scottish housing where there is a definitive separation between sleeping accommodation and general living spaces. Essentially all bedroom spaces are grouped to one end of the building; general living to the other and central to the plan is the heart of the house - the kitchen and circulation. The kitchen, dining and living area are kept open plan as a social hub and the double height lounge offers a visible link to the upper circulation space essentially allowing an element of interaction to all public spaces within the dwelling.

In addition to the schedule of accommodation required by a standard family dwelling, an external terraced area features on the upper level and includes a secluded external space that meets the Gold Standard contained within Section 7 of the current Technical Guidance. This space offers an element of adaptability as it may be "in-filled" to offer a fourth bedroom or enhanced office space.

Overall, the Tigh Grian design solution offers a level of adaptability that increases the ability for the house to be replicated throughout Scotland. By rotating the plan through 90 degrees and altering the position of some of the openings, the design can be amended to a semi-detached option which heightens its appeal as a mass market solution to developers and Housing Associations.





5.1.2 Orientation

The orientation of the dwelling within the site has been carefully considered with openings to the North being kept to a minimum to prevent excessive heat loss. Solar gain from the south has been maximised within the central areas of the dwelling as a means of “feeding” the entire dwelling. Photovoltaic panels feature to the South West elevation as opposed to the roof plane as it extends the electricity production into the Autumn/Winter period. These panels are installed in the factory thereby reducing the need for site installation and any unnecessary waste generated as a result.

5.1.3 Materiality

The exterior of the dwelling is clad in stone and locally sourced larch in order to “celebrate” the sustainable materials available in Scotland. The material is encouraged to weather over the lifespan of the dwelling allowing the built form to evolve through time. The modular approach to the project allows the pods to be pre-finished in the factory, negating any on-site installation and the waste generated by such works. The pods are also rendered within the factory as opposed to site applied render.

5.1.4 Energy Efficiency

The Resource Efficient House achieves a building fabric with U-Values as low as 0.1 W/m²/degC in the roof and an airtightness value of under 1m³/hour/m² @50Pa.

This means that, depending on occupant lifestyles, the amount of energy required to heat the building should be extremely low. With the inclusion of a wood pellet stove and an air source heat pump domestic hot water (DHW) cylinder to provide the energy for the primary space heating, the Resource Efficient House could be a net zero carbon, completely self-sustaining house.

Other U-Values achieved throughout the House include:

Walls 0.15 W/m²/degC

Floor 0.14 W/m²/degC

Roof 0.10 W/m²/degC

Windows 0.9 W/m²/degC

5.1.5 Waste management

The construction of an average three-bedroom home akin to the Resource Efficient House can produce up to 13 tonnes of construction waste. If demolition and excavation waste is included, the overall total could actually be as much as 20 tonnes per house.

If all 17,112 new homes built in Scotland last year had generated zero waste to landfill, an estimated 85,560 tonnes of construction waste would have been avoided. This would have saved the industry over £4 million in dealing with that waste. Often materials are wasted as a result of over-ordering or inefficient working methods.

Tigh Grian's choice of off-site modular construction enabled a more resource efficient construction resulting in greater control over costs, waste generated and ensured appropriate supply chain accreditation. With careful design, the Resource Efficient House produces less than four tonnes of waste. This excludes excavation waste which was re-used by a company who make hydraulically bound mixtures for road reinstatements, an approach which is an innovative waste management solution for a different part of the construction sector.

5.1.6 Accessibility of design features to visitors

A requirement of the brief was to consider how the proposed design can include creative ways to illustrate to visitors the resource efficiency innovations used both within the dwelling and in the construction / deconstruction process. In response the open plan/double height lounge within the model has a feature pop-out bay window which in turn forms an area of fixed seating offering a small theatre space in which video footage can be showcased which demonstrates the construction process within the factory and time-lapse footage of the modular system being assembled on-site. In addition to this, small cut away sections throughout the dwelling offers a real glimpse into the physical make-up of the construction with adjacent signage explaining each component and the importance of choosing resource efficient products.

The idea of celebrating the construction joints between pods as opposed to disguising them behind cladding has been explored. This offers an insight into how the house is assembled while also offering an educational look at innovative construction techniques. Visitors will be able to view a short film explaining the way in which pods are assembled and then appreciate the joint detail upon their exit from the dwelling. The construction detailing of these areas also offers an insight into the deconstruction process and conveys a message into the importance of considering re-use of materials/products when developing buildings.

5.1.7 Sustainability – Gold Standard

The design not only meets the requirements of the Gold standard but also exceeds that of Platinum Aspect 1 as a zero carbon house. The remaining elements of the Platinum standard remain undefined by Scottish Building Regulations at present.

6 Key dates and timeline



Resource Efficient House Animation by Low Carbon Building Technologies Gateway, Edinburgh Napier University

21 August 2012: Resource Efficient House (REH) Tender invitation issued by Zero Waste Scotland in conjunction with BRE Ravenscraig as technical advisors and A+DS SUST as design advisors

8 October 2012: REH Design Tender Deadline

23 November 2012: Partnership between ZWS and Tigh Grian Ltd. is formally announced

21 January 2013: Margaret Burgess, Minister for Housing, breaks ground on the site of the REH at BRE Ravenscraig

6 February – 19th April 2013: Construction to Practical Completion

6 – 19 February: Contractors start on site with building warrant and site cabins arrive

7 February – 6 March: Pods Manufactured in factory in 20 days

6 March: Foundation Excavation

7 March: Concrete Mud Mat / Blinding

8 March: Concrete Foundations

11-12 March: Steel Beams

13 March: Blockwork

14 & 15 March: Fill Foundations

18 & 19 March: Underfloor Drainage

15 March – 17 April 2013: Superstructure construction

15 March: Pod Delivery on site

20 & 21 March: Place Pods

20 – 26 March: Internal Connections of Pod System

27 March – 3 April: Second Fix

4 – 9 April: Final Fix

10 April: Kitchen Installation

11-17 April: Testing and commissioning /Inspections

27 & 28 March: Roof Structure

29 March – 2 April: Roof Membrane

2 April: Crane on site lift roof on to Pods

27 March – 4 April 2013: External Finish

27 March – 2 April: External Render

3 & 4 April: Flashings

27 March – 2 April: External Stone Cladding

27 & 28 March: Timber Sheeting

3 & 4 April: Drop scaffold

5 – 16 April 2013: Landscaping

External Landscaping - hard & soft (6 days, Fri 05/04/13 - Fri 12/04/13)

Contractor Clear of Site (2 days Mon 15/04/13 - Tue 16/04/13)

16 & 17 April 2013: Snagging

22 - 23 April: Internal Fit Out

Furniture and Equipment

Internal Wall and Floor Finishes

Fixed Furniture Installation

Lose Furniture Installation

IT / AV Installation

Monitoring Equipment Install

Communications Items Install

24 April 2013: Practical Completion

10th May 2013: Resource Efficient House Exhibition Opens at The Lighthouse, Glasgow

16 July 2013: Exhibition Closes

7 Construction

7.1 Pod Construction (Off Site Construction in Northern Ireland)

The structural 'pods' are constructed off-site under factory conditions, and pre-finished to include kitchen, bathrooms, tiling and paintwork. This enables complete control of cost, waste, and supply chain accreditations as well as providing certainty of delivery, as the process is not dependent on the weather.

Additionally, once the process is complete, assembly on site can take as little as one day for a three-bedroom house. The Resource Efficient House was transported as four 'pods' and installed on the Zero Waste Scotland plot at Ravenscraig in one day. The House is designed to be an extremely energy efficient, functional, practical and environmentally friendly exemplar home.

SUPPLIER: nühaus GmbH / www.nuhaus.org



Sample 'Pod' component as featured in the Resource Efficient House Exhibition at The Lighthouse Glasgow, May – July 2013. Photo: Alan Dimmick



7.2 Walls and Structural Make Up

The Resource Efficient House is constructed in sections, consisting of four steel-beam modular units built from Structural Insulated Panels – SIPs. The SIPs are purchased to required dimensions and factory-assembled generating no construction waste.

High density polyurethane is used for the insulation core. While this material affords high thermal efficiency and a strong structural core, it is not an environmentally friendly product, however, at the deconstruction phase it can be recycled. This is supplemented by Knauf Earthwool to achieve a U-Value of 0.15 W/m²/degC in the floor and roof cassettes. Three different external finishes have been selected for the House in order to trial different options and to illustrate the availability of consumer choice: Scottish Larch; stone and; smooth lime render.

The Larch is factory applied from standard lengths and eliminates waste on site entirely. The stone cladding will make the building stand out on the site. The fixing system requires tiling rather than traditional wall building skills. The remaining sections are rendered on site using a smooth lime render for the purpose of demonstrating aesthetic flexibility of the system.

Lime render has lower environmental impact than cement-based renders. Re-absorbs the CO₂ used in its manufacture during carbonation.

SUPPLIER: SIPFIT / www.sipfit.co.uk

Knauf Earthwool / www.knaufinsulation.co.uk

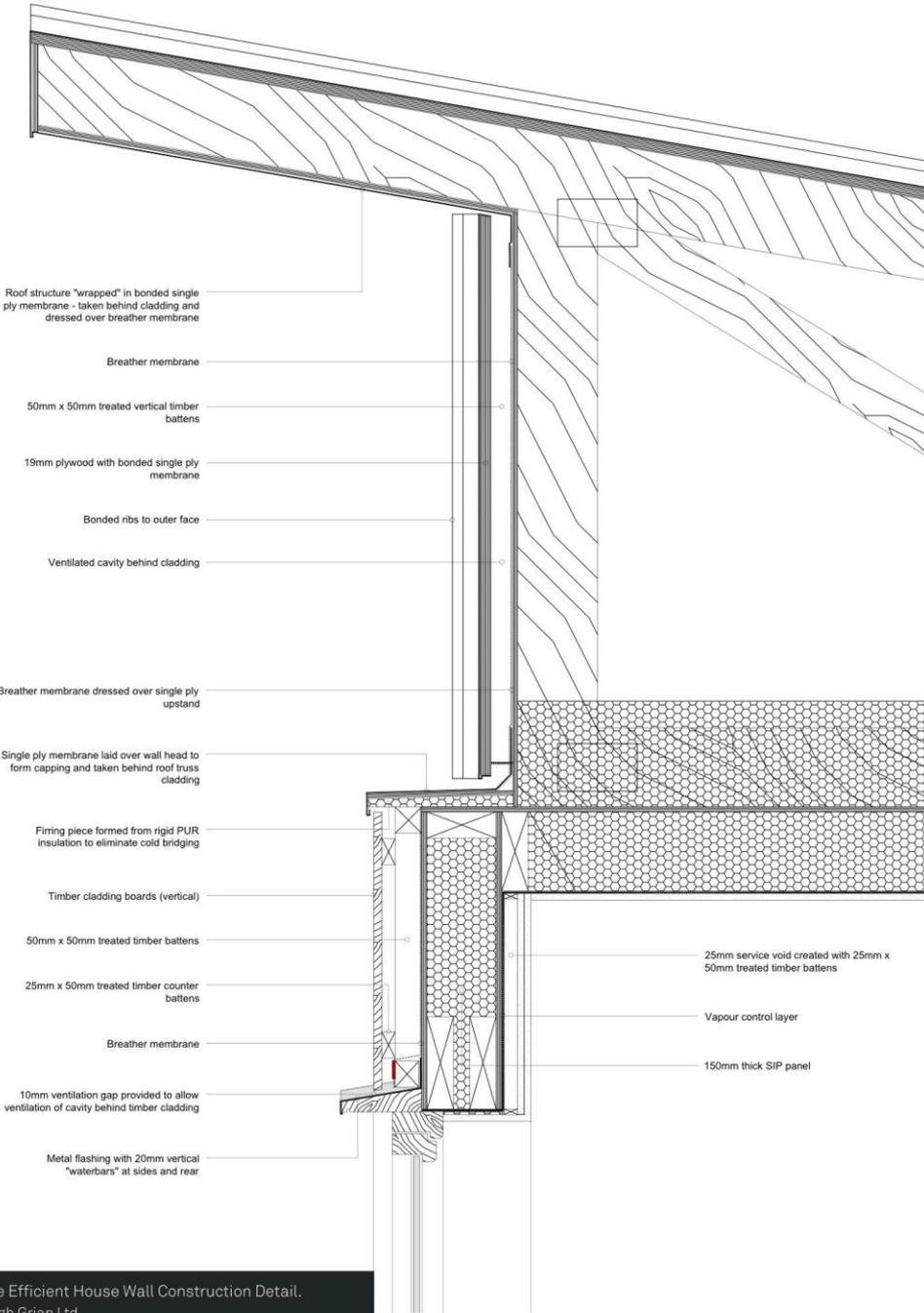


7.3 Internal dryline boards

The internal wall finish is plasterboard with 79% recycled content supplied by Knauf Drywall. This was selected over traditional plasterboard not only due to its high recycled

content, but also for whole life waste reduction in manufacture. In addition, the whole project was dimensioned based on the sheet sizes of plasterboard to reduce waste from offcuts.

SUPPLIER: Knauf Drywall / www.knaufdrywall.co.uk



Resource Efficient House Wall Construction Detail.
Credit: Tigh Grian Ltd

8 On Site Construction at BRE Ravenscraig

8.1 Foundations

The original proposal was to use a screw pile arrangement, with a beam and block base formed above to take the completed 'pods'. Further investigation revealed that the screw piles were not an option due to the shallow depth of the capping layer that was installed during decontamination works on the Ravenscraig site. It is critical that the capping layer is not breached by excavation or piling works and as such the design team concluded that this restriction would not facilitate the proposed arrangement.

With such restrictions, the team decided that the best approach would be to use concrete pads, formed in a grid like formation over the footprint of the dwelling. Each pad has a steel column bolted to the upper face, which supports a series of ring beams above to provide a structural base for the completed 'pods'. This option was the most effective solution in terms of re-use and recycling while providing a degree of ease during the deconstruction period. The steel sub-structure is bolted together which will allow for it to be taken apart and moved to a new location at the end of the demonstration period, at which point the concrete pads can be broken down and the rubble recycled. The steel can be fully reused/recycled. 100% recycled aggregate was used for the House foundations. This recycled aggregate used in the concrete was sourced from a Zero Waste Scotland Aggregates Directory approved supplier, Spotmix in Glasgow, who produced the concrete on site in a zero waste installation process.

Supplier: Spotmix / www.spotmixglasgow.co.uk

"The foundations worked very well. The solution produced no wastage. The pad foundations were cast in situ – a local firm brought in a cement mixer with the aggregate, mixed up the exact amount and there was no waste. It was another demonstration that there doesn't have to be waste. The house then took a day to be fixed onto the foundations." Gary Bennett of Bennett Robertson Design, M&E design consultancy.

8.2 Ground preparation works (in sequence)







The 'Pods' were transported via truck to BRE Ravenscraig





8.3 Pod Assembly

On delivery, the 'pods' are assembled with only interconnecting services between the ground and first floor 'pods' needed. There are a number of advantages to this method of construction, including:

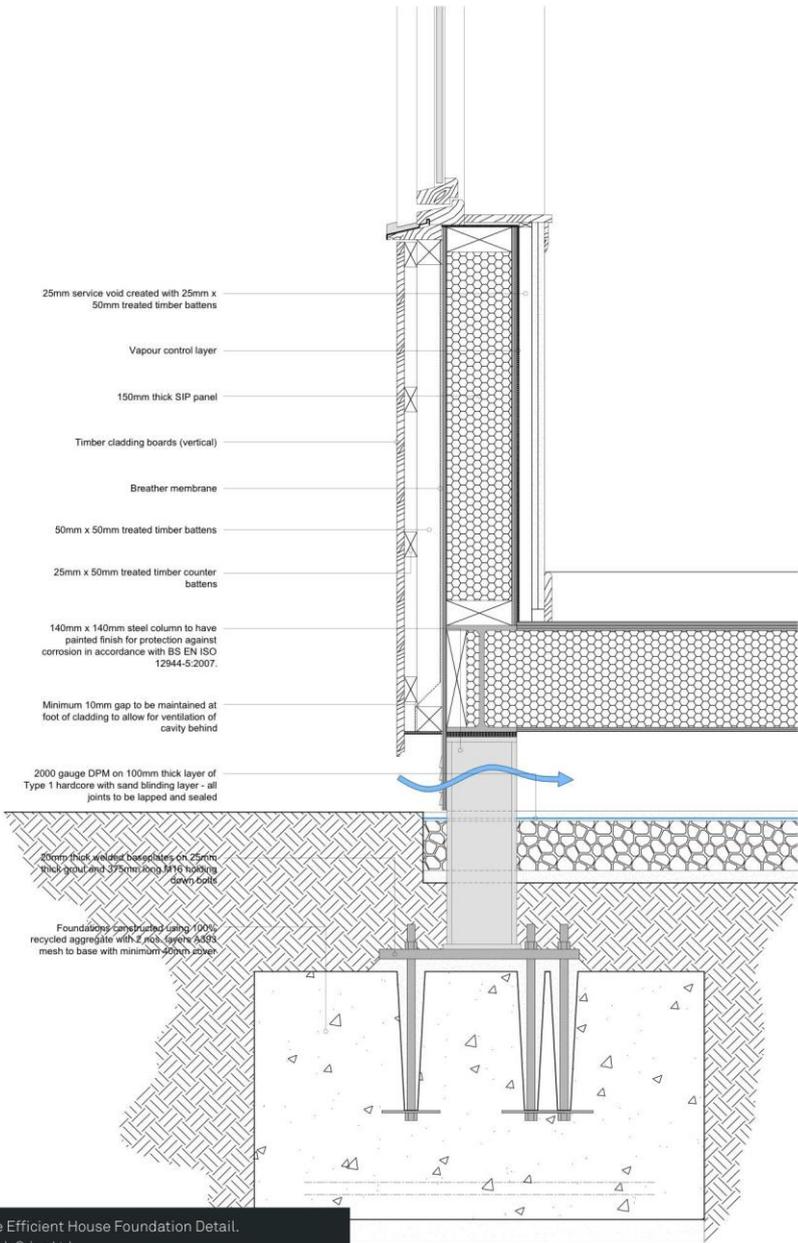
- dramatically reduced site build times compared with traditional build or timber frame;
- ideal for remote or difficult to reach sites; build is less weather dependent;
- the quality of the finished product is not reliant on site labour;
- high levels of airtightness can be guaranteed through factory testing;
- use of 'splined' joints means insulation is continuous, except at window and door openings and at structural joints between floors and roof structure.

This gives very low U-Values; reduced site wastage and very low factory waste levels of less than 3%.





"This is a modular house but it doesn't look like a modular house – that was part of the design ethos." Gary Bennett.



Resource Efficient House Foundation Detail.
Credit: Tigh Grian Ltd



“The stone cladding panels were applied on site – as they would have been too heavy to transport safely. The stone on the panels is recycled.” Gary Bennett.

8.4 Roof

Single ply membrane roofing material has been used. Sika Sarnafil roofing systems are not only manufactured in an ISO 14001:2000 accredited production facility, they also have a low embodied energy and long BBA Certified life expectancies. The company has proactively recycled factory production waste back into new roofing membrane since production began in 1960. In the roof, a combination of Knauf Earthwool, supplemented by Eco-Wool manufactured by YBS Insulation – achieves a U-Value of 0.10 W/m²/degC.

SUPPLIER: Sika Sarnafil www.gbr.sarnafil.sika.com

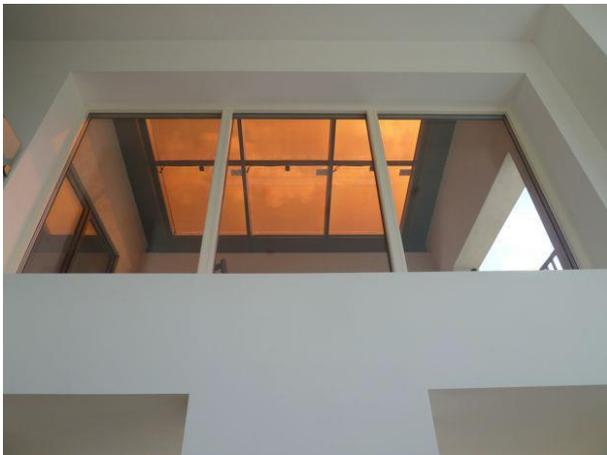
YBS Insulation www.eco-wool.co.uk

Knauf Earthwool / www.knaufinsulation.co.uk





8.5 The roof canopy glazing



The roof canopy is glazed with Polysolar BIPV (Photovoltaic panels) provided by Solmatix, supplied and fitted by Linn Tech Scotland Ltd.

These are embedded within the glass which is orange tinted to filter sunlight and provide a degree of shading, without affecting the growth of plants. The system was originally designed for greenhouses and comprises 9 x thin film integrated panels generation up to 0.81 kWp.

SUPPLIER: Linn Tech Scotland Ltd / www.linntech.co.uk

Solmatix Renewables / www.solmatix.com

8.6 First floor roof terrace



The roof terrace is furnished with: Recycled plastic decking supplied by Ecoplastic, selected to help reduce waste to landfill; a reclaimed steel balustrade; a Photovoltaic glazed roof to provide power and shading; a retractable washing line; and a reclaimed whisky barrel for growing your own vegetables, fruit or herbs.

SUPPLIER: Ecoplastic / www.ecoplastic.net

8.7 Windows

Timber from sustainable, well-managed and certified forests is the only truly renewable, standard construction material and, unlike many alternative materials, is 100% recyclable.

Timber is also highly durable if well maintained. Timber windows constructed with triple glazing will provide the most environmentally friendly and energy efficient glazing solution for the House. The windows were supplied by Russell Timber Technology, and achieve a U-Value of 0.9 W/m²/degC.

WINDOWS SUPPLIER Russell Timber Technology / www.russelltimbertech.co.uk

"The windows are great, very high performance, and we were so pleased that we managed to find a local supplier in Glasgow based Russell Timber Technology. They were delivered to the factory on time. This was critical to us, as they were pre-installed in the 'pods off site."
Gary Bennett



8.8 Exteriors

Bike and Bin Store

The bike and bin store was constructed using Scottish Larch to match the House wall cladding. One section of this outdoor facility offers secure bike storage and the other provides storage for recycling and general waste bins. For ease of use, the stores are accessible from both the roadside and the garden. The bikes in the bike store have been supplied by The Bike Station based in Glasgow.

SUPPLIER: The Bike Station / www.thebikestation.org.uk

Electrical

The electric meter is located remotely from the House in the bin store to allow ease of access for meter reading. This also avoids compromising the insulated structure of the House for a recessed meter.

An electric car charging point, controlled from inside the House, can be used as a dedicated charging point for the occupants. The charging point is powered during the day by the Photovoltaic panels. Electrical services are conventional except that XLPE (Cross-Linked Polyethylene) cable was used rather than PVC resulting in less end-of-life issues.

All electrical components were supplied by Click from their 'Define' range.

SUPPLIER: Click / www.click4electrics.co.uk



Garden

The garden was designed by DWA Landscape Architects and landscaped by GP Plantscape. Similarly to the first floor terrace, recycled plastic decking by Ecoplastic has been used to create a patio.

GARDEN SUPPLIER: DWA Landscape dwalandscapearchitects.co.uk

GP Plantscape www.gplantscape.com

Ecoplastic / www.ecoplastic.net

Water Butt

A water butt has been installed to collect, store and recycle rainwater for garden use only. A galvanised steel chain has been installed to help direct the rainwater from the roof gutter (in place of a downpipe) to the butt. The water butt is made from a reclaimed whisky barrel.

SUPPLIER: GP Plantscape / www.gplantscape.com



All Factory and On-Site images are stills from RE Launch Video by MR Media

Photographs: Caroline Ednie for SUST

All Quotations by Gary Bennett of Bennett Robertson Design, M&E design consultancy

9 Energy Efficient House

Technical Specification (Interiors)

9.1 Heating

The wood burner that provides the primary heating system is a Kaika Oyster by MCZ. The model selected is designed to Passive House standards and can be controlled remotely by smartphone. This unit is up to 94% efficient. It makes use of a waste by-product from the Scottish timber industry (sawdust compressed into wood pellets) which is close to carbon neutral if sourced from sustainably managed forests.

The secondary heating system comprises Fondital Blitz digitally controlled electric radiators, used in the bedrooms, and Kudox electric towel rails in the bathrooms. These are 100% efficient at point of use, and as a result less radiators are required. The stove and electric heaters have been supplied by Solmatix Renewables.

SUPPLIER: MCZ / www.mcz.it

Fondital / www.fonditalgroup.com

Kudox / www.kudox.com

Solmatix Renewables / www.solmatix.com

"The stove's fuel is wood pellet. As the house is mostly open plan and the living area is the biggest volume the concept was to heat it using a waste product. The stove's air supply comes from outside, through the floors which means that it doesn't draw air from inside the building, air that would then have to be replaced (see right hand image below)." Gary Bennett



9.2 Airtightness and ventilation

The Resource Efficient House has been designed to achieve a high degree of airtightness: 1.0 m³/hr/ m²@50Pa. It is essential to have controlled mechanical ventilation with heat recovery at these levels. This House has a Prometeo Plus HR400, supplied by Vortice which has a fully automatic CO₂ and humidity control allowing it to respond to varying conditions in the House thus optimising running costs

SUPPLIER: Vortice / www.vortice.ltd.uk

9.3 Grey Water Recovery

The House has been fitted with a Water Evolution reAqua+ grey water recovery system (see image below), which collects the waste water from the upstairs bath and shower. It then filters and treats the water and uses it for flushing the WCs. Heat is recovered from the warm grey water and used to pre-heat the domestic hot water cylinder. 30% of the total water use of the House and 30% of the heat DHW content can be recovered.

SUPPLIER: Water Evolution / www.waterevolution.co.uk



"The grey water recycling is a later addition. The normal practice would have been to dig a big hole for rainwater harvesting but due to the site and its history of contamination this wasn't possible. The grey water recovery was the best way to meet our tight water consumption requirements of 80 litres per person per day - this is the lowest target. The water tank removes heat from the water making it less microbiologically risky, as well as also treating the water, in a dosing process."
Gary Bennett.

9.4 Domestic hot water

The domestic hot water (DHW) for the Resource Efficient House is generated by an efficient Solmatix X3 Combi Plus Air Source Heat Pump Cylinder (see images above). This exhaust air heat recovery unit is ducted to the outside and removes heat from the air passing through it and heats water by using a small compressor to produce up to 2.3 kW of DHW heating. The unit is designed for passive/ airtight houses and has an intelligent air source input control system. The power supply for the DHW system is generated from the Photovoltaic array on the roof, which can generate sufficient power even on cloudy days to meet the system needs, thus providing solar generated hot water.

(DHW) SUPPLIER Solmatix Renewables / www.solmatix.com

"The heat recovery ventilation unit is controlled by remote control, and shows the inside and outside temperature. It monitors the relative humidity and carbon dioxide levels in the house, and ramps up the boost whenever it detects an imbalance. Whenever the house is unoccupied it goes down to a trickle and uses less energy. When the house is occupied the carbon dioxide and humidity goes up and the system kicks in."

"The cylinder has an air source heat pump which takes air from outside and extracts heat and pumps out very cold air. This is used to heat the water. For every one Kw you put in you get three Kw of heating out. The cross junction convertor box recovers heat and checks whether loft or outside air is warmer and whatever's warmer it will take. It's an intelligent controller. The loft is a solar collector and in winter it improves the efficiency of the house by 25%." Gary Bennett.



9.5 Laundry

There is no tumble dryer in the Resource Efficient House. The Bosch Exxcel A+++ rated washing machine has been selected not just for low energy use and water consumption, but also for water extraction efficiency on the spin cycle. Less water content in the clothes means less drying is required. There are two options for drying clothes in wet weather:

- The roof terrace provides cross ventilation with a sheltered roof canopy which gives outside drying capabilities with rain protection.
- The upstairs airing cupboard (pictured above) uses waste heat from the DHW cylinder to keep the space reasonably warm and there is a continuous through ventilation via the mechanical ventilation heat recovery exhaust. Any moisture in the air is extracted and the heat recovered is used to preheat the incoming fresh air.

SUPPLIER Bosch / www.bosch-home.co.uk

"There is a drying rack as this area is used as a drying cupboard. There's an extract vent which pumps in fresh air and pre heats the fresh air so 90% of the heat going out of the exhaust is recovered to go back in and has the effect of drying the atmosphere. The tiles also allow for wet clothes." Gary Bennett.

9.6 Water conservation

The House has been designed to achieve less than 80 litres per person per day, which is equivalent to Code for Sustainable Homes level 5/6. This has been achieved by using the lowest (4/2 litre dual) flush WCs available in Europe manufactured by Roca (Eco range), washbasins with 'Ecojoy' reduced water flow taps manufactured by Grohe and a low volume, 55% recycled steel enamel bath. In addition, the Grohe Grotherm showers use Ecojoy aeration and has Ecobutton technology to reduce water flow from the shower during lathering up. All other sink taps have flow restrictors and white goods (dishwasher and washing machine) were also selected to meet low water use targets. All sanitary ware and fittings were provided by Bassetts Ltd.

SUPPLIER: Roca / www.uk.roca.com

Grohe / www.grohe.com

Bassets Ltd / www.bassettsonline.com

"The wet room is pre-fabricated in the factory, in this case it's built out of chipboard by SIPFIT. The wet room arrived just as it is with all the light fittings and ventilation installed."

"This shower demonstrates that you can have a high end shower in a low water volume house – the whole in the middle of the shower head reducing the amount of water released."

"The toilet is a ROCA with the lowest flush volume on the market."

"We made life difficult in terms of our tight water consumption requirements by putting a bath in. However the bath is designed to hold the smallest water content. Also it's a steel bath that meets HA guidelines as well as having a 55% recycled content. It's a family home and that's how we approached the design and services." Gary Bennett.



9.7 Lighting

LED lighting is used throughout the House. LEDs have numerous environmental benefits over conventional lamps. They use 50-90% less energy, resulting in large carbon emission reductions, they do not contain mercury, and they last up to 20 times longer. Finally, LED lights are made from fully recyclable materials. The LED lighting was supplied by Ansell Lighting.

SUPPLIER: Ansell Lighting / www.anselluk.com

"The LED lights in the ceiling are guaranteed for 30,000 hours." Gary Bennett



9.8 Microgeneration

Two Photovoltaic (PV) arrays have been provided by Solmatix Renewables for the House to meet Platinum net Zero Carbon standards as defined in Section 7 of Scottish Building Standards:

- The main array is roof mounted and provides the power supply for the domestic hot water system. This comprises 9 x 250Wp REC Polycrystalline Panels to produce up to 2.25kWp.
- The secondary array comprises 9 x Polysolar 90Wp thin film integrated PV (0.81kWp total) set into the roof canopy over the terrace. These panels take the form of orange tinted glass and will provide an element of solar shading. Originally designed to provide power for greenhouses, the orange tint does not affect the growth of plants.

SUPPLIER Solmatix Renewables / www.solmatix.com

Polysolar / www.polysolar.co.uk

"The blue inverter control relates to the orange PV panels and converts the voltage into a meter reading. The orange panels are 80 Watts and the main panels are 250 Watts each. The red system is a 2KW inverter and tells you a lot more information. This larger size is normally only needed in a zero carbon house. It's an Ofgem approved system and it shows what the sun has been doing. We will be interested to see how effective both systems are

as they are both orientated in the same way. These are two different technologies side by side, and it will be very interesting to see how both perform."

"The three-year life cycle of the building will be monitored. It's currently operating as visitor centre but it will also be run as a home at quarterly intervals and readings will be taken in this capacity. Noise, humidity monitors and sensors in the house will allow a lot of climactic data to be captured." Gary Bennett.



9.9 Smart sensors, sub metering, performance appraisal

Smart sensors and sub metering have been installed throughout the House to allow monitoring of water, domestic hot water, heating energy, lighting energy and appliances. In addition, qualitative monitoring and recording of temperature, noise, airflow, light, movement and other sensory and performance information will be monitored, and analysed. This data will all be reported back to Zero Waste Scotland and the project development team. This will be critical in determining whether the House achieves the high standards of performance that are expected of this mode of design and construction.

SUPPLIER Energy Systems Research Unit, University of Strathclyde / <http://www.strath.ac.uk/esru/>

Joe Clark from the Energy Systems Research Unit at University of Strathclyde explains:

"We are the Research Partner of the BRE Innovation Park and it's our role to undertake monitoring and modelling evaluations of all the houses as they go up in the Park. Our monitoring intentions break down into two parts: monitoring the environmental conditions indoors – temperature, humidity and light levels: the second part is to look at the systems in terms of their energetic performance. Each house will have its own system or set of systems. So that's the bit that has to be designed for each deployment, whereas the monitoring of indoor environmental conditions is a standard package for each house. Innovation and new technology often doesn't come easy. Things might happen that aren't anticipated. Therefore our job as researchers is to look at how things work and then pass judgement in an impartial manner. But we do this in a sensitive manner. If we find a problem we don't focus on the negatives. We look at it to see how it can be overcome."

Where there is innovation you wouldn't expect to see everything to go well immediately. New issues will inevitably arise, particularly unexpected ones.

In terms of the Resource Efficient House arrangements will also have to be made to monitor the house in a period where there will be no visitors, and take results from that, to be more indicative of the house as it would be used as home.

Essentially, we are the research support team, which involves monitoring, modelling and expert visits. All the feedback then has to go back to those who are brave enough to put their ideas up for scrutiny...and this will hopefully be addressed in a constructive way that helps them move forward."

Photos: Caroline Ednie for SUST

9.10 Staircase

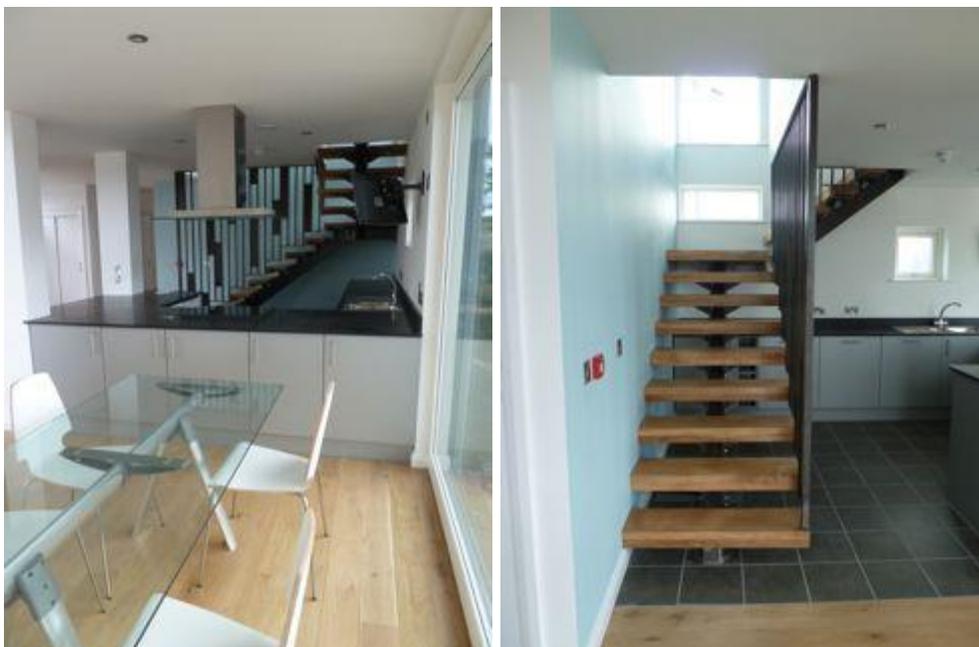
The staircase balustrade is made from reclaimed steel. This bespoke element is a key feature of the open plan interior and was designed and crafted by Jim Norval Architectural Ironmongery to match the external terrace balustrade. Reclaimed Oak has been used to create the stair treads, matching the look and feel of the ground floor finish.

The reclaimed timber was supplied by Falkirk Wood. The reclaimed timber was sourced from the University of Stirling following the redevelopment of part of the university campus which involved the felling of a number of Oak and Sycamore trees.

SUPPLIER: Jim Norval Architectural Ironmongery

Falkirk Wood / www.falkirkwood.co.uk

"The stairs are not a SIPFIT detail – in a standard house model the stair would be prefabricated into the 'Pod' off site in the factory." Gary Bennett.





9.11 Flooring

Various flooring materials were used throughout the House, each with either recycled content or fully reclaimed. Reclaimed Oak flooring supplied by Wilson's Yard is used throughout the hallway, living area and dining room. This was factory fitted prior to delivery to site. The kitchen and bathroom tiles have a high recycled content and were provided by Johnson Tiles. Reclaimed carpet tiles from Spruce Carpets are used in the downstairs bedroom. Carpet tiles with a high recycled content, supplied by Interface, were used in the upstairs bedrooms and hallway. Carpet tiles were selected for their durability, flexibility, and ease of maintenance.

SUPPLIERS Wilson's Yard / www.wilsonyard.com

Johnson Tiles / www.johnson-tiles.com

Spruce Carpets / www.sprucecarpets.org.uk

Interface / www.interfaceflor.co.uk

9.12 Fixed seating

The House is based on an open plan design, with a partial partition wall separating the lounge and dining room. A fixed seating arrangement is positioned in the bay window. This is upholstered with leather supplied by Andrew Muirhead & Son. The leather used is a by-product of beef and dairy farming and can be recycled when it has outlived its use. Andrew Muirhead & Son operate a closed loop energy and water recycling system, whereby waste to landfill is minimised. All heat energy used on site is supplied by a biomass plant and all process water is cleaned and reused.

SUPPLIER: Andrew Muirhead & Son / www.muirhead.co.uk



9.13 Furniture

A mixture of new, reclaimed and transformed furniture has been used within the Resource Efficient House. The bar stools are made from recycled wood reclaimed from whisky barrels. These were designed and donated by Scottish furniture maker, Stuart Clachan. A sideboard constructed from salvaged golf lockers (mostly Douglas Fir) was donated by John Johnston, a member of the Scottish Furniture Makers' Association. Revolve is Zero Waste Scotland's national re-use accreditation initiative, and some of the furniture was sourced via Revolve accredited stores.

SUPPLIERS

Revolve / www.revolvereuse.com

Clachan Wood / www.clachanwood.co.uk

John P Johnston-Furniture / www.johnpjohnston.com



9.14 Paint

The paint used in the House is 100% reprocessed water based paint. Brilliant white was used throughout and duck egg blue for the feature wall to accentuate the staircase. This was supplied by Castle RePaint who operate a paint recycling business in Glenrothes.

SUPPLIER: Castle RePaint / www.repaintscotland.com



9.15 Kitchen

The fitted kitchen units, including cabinets, doors, décor panels, cornice, pelmet and plinths, are all made from high recycled content chipboard at 70% or better. The kitchen was made in the UK, with much of the recycled content coming from post-consumer wood waste collected from waste sites around the country. The remaining 30% consists of FSC certified content. The cabinet handles are made from steel with up to 90% recycled content. The worktops are made from 'Charcoal-board', a black, granite effect material made entirely from recycled hard plastics, e.g. vending machine coffee cups and yoghurt pots. This material is well suited to large surfaces as there is no need for joining. The kitchen cabinets and worktops were supplied by Milestone Eco Design.

SUPPLIER: MilestoneEco Design www.milestone.uk.net

"The kitchen didn't get fitted in the factory, whereas normally in a standard pre-fabricated house model it would, so in terms of timing it took longer on site."

"In terms of interesting details, the cooker hood acts as a heat recovery system with a carbon filter. The oven and fridge & freezer are best performance they are highly insulated therefore most economical. They also display temperature on the outside. The Fridge is 'A Plus Plus Plus' with an 'A Plus Plus' Freezer. The cooker's induction hob is more economical in terms of energy usage as is the highly insulated 'A' rated fan oven." Gary Bennett



Photos: Caroline Ednie for SUST

10 Project Team. Points of view

10.1 Allan Sandilands Resource Efficient Scotland Manager.

"In terms of design and intention I think the Resource Efficient House is second to none."

One of the main areas of the Resource Efficient House that I am looking forward to is challenging traditionally held ideas, and also doing more with less given the current economic climate.

Resource Efficient House: Hopes and Aspirations

"One of the areas that we are keen to promote with the Resource Efficient House (REH) is off-site construction. In terms of Tigh Grian we have a Scottish architect and a Scottish developer and although this model is being manufactured in an Irish factory, the consortium is now looking to roll the product out in Scotland. This will involve investigating the prospect of creating a factory in Scotland to meet demand in this country.

We would like to create a demand for this type of housing. Currently sustainable housing isn't valued higher than traditional housing, however with the REH we are hoping to educate the public, particularly in the way that sustainable housing involves low running costs. And architecturally because it is modular with variations, we can show that there is a choice of materials and spatially, things can be flexible.

We are hoping that the REH concept will be adopted by volume house developers. That's our ultimate aim...to influence volume builders.

With this project we are aiming to show typical construction waste volumes can be dramatically reduced with offsite production. And show that a pre-fabricated modular house doesn't necessarily have to look like a modular house. It's possible to achieve the aesthetics that attract people to buy as well as offering high performance in a modular house.

Although the mass market isn't adopting this type of model at the moment, they are being slowly driven to it by the changes in Government building standards whereby builders are being rewarded for setting high standards of construction. We are approaching a tipping point where the efficiency of the house will become more important than just its overall capital cost. People will start to seek better performing houses and the Resource Efficient House is one such exemplar model."

Establishing supply chains

Another key area of the project is to look at establishing supply chains. A lot of products in the House have been sourced in Scotland, and we're making good use of social enterprises such as Revolve, which trains people to recondition and sell on high quality second hand furniture. <http://www.revolveuse.com/revolve-accredited-organisations>

We've sourced low energy electrical goods and we're also introducing the idea of renting electrical goods. It's not just about the products it's about the ideologies behind these products. By installing an energy management system we are showing people how their bills are performing. The more information that people have the more they are likely to change.

Overall, construction went very well. Our target is to hit gold standard in terms of building standards and I think we might be hitting platinum, however there were also lessons learned during the process:

Lessons Learned

- The pods were rushed out of the factory to meet the programme. The concept was to finish the house in the factory, however when the house arrived it wasn't the finished article. A better scenario might have seen the project spending more time in the factory and less on site. The consequence was that this created a chain of events that led to more work on site, which we were trying to avoid.
- Not having the roof pre-made was another lesson learned. A lot of efforts were put into the windows, scheduling them in and making sure they were installed in the pods, however the roof was overlooked. And the week chosen to install the Sarnofil roof was the one week of the year that specialist contractors were unavailable - they were employed to carry out roof maintenance on the country's schools. As a result the living room ceiling wasn't watertight. So the whole living area had to be de-humidified and re-painted. This caused a major delay.
- The third major lesson was the on-site management. The groundworks went exceptionally well. The company responsible for the groundworks was then given the role of on-site management, but they weren't properly briefed. The foreman was also taken off the job two weeks before the end of the job, so this affected the continuity. Everything was geared toward delivery of the pods and getting the pods in place and the on-site works were underestimated. This resulted in major delays. The lack of effective site management made the project more difficult than it needed to be.

Off-site modular construction is the way forward and speed of delivery is the way forward, but lessons have to be learned by the industry if they want to adopt this construction technology. However there is a certain amount of leeway that has to be given in terms of this product as it's a one-off and demonstration home rather than a standard housing model.

Conclusion

In terms of design and intention I think the Resource Efficient House is second to none. However I feel that the delivery of the end product hasn't matched the design and intention.

Some products within the House have excelled more than others. I can see some elements that could have worked better. There is a risk with brand new technologies where perhaps everything doesn't quite go to plan. It was difficult to find many products that ticked our resource efficiency boxes and many of the suppliers are small companies, so it's been a challenge. But I think parts of this project will challenge the industry, and we certainly produced less waste than traditional house construction.

As a first time client as part of an organization that hasn't done this type of thing before, I am very happy with the results. I can't wait to get the place open to the public, as so far I've been very encouraged by the comments of the young people that have visited the house..."

10.2 David Kelly Associate Director, BRE

"There are so many memorable elements in the house that visitors will remember and take away with them."

BRE Ravenscraig: Site Context

"We were keen to explore a number of themes at the Innovation Park at Ravenscraig. These were primarily: Energy efficiency; sustainability; community and affordability.

Affordability is a key consideration at Ravenscraig. This sets us apart from the Watford model, which features some iconic yet high cost buildings that will never make their way into the housing market. What we wanted to do was flip this on its head and create a scenario where the same levels of performance are attained but more affordably. It's important to promote models that can be taken forward to the mass market as real solutions that can meet future targets.

I would say at Ravenscraig we have a more focused and practical approach to demonstrating new buildings technologies, with a view to getting them out to the market in the short term.

In terms of the developers involved in the Park, we present them with a brief, which is a document that identifies what they need to provide us with before they can go ahead with construction. But how they achieve these objectives is up to them. This is the innovation part that comes forward with every development. It's up to each developer to come up with different ideas to meet the performance guidelines.

The Park runs with a lot of goodwill from the industry. Many large companies were keen to get involved as they could see the benefit of being associated with a development like this. People see their product in a unique setting, positioning them at the forefront of their industry.

The research, development and monitoring activity is core to our ethos at Ravenscraig. We want to develop the park to demonstrate the very latest in thinking in terms of construction techniques and performance and make sure that these messages are passed back into the industry so that they can learn from our activity. We won't be keeping information in house, we will be actively disseminating and promoting it.

We're hoping to take the industry along with us on this learning journey. Innovation Parks are springing up all over the world. We aim to share this across this platform. It's not just the UK that we're informing, we'll be informing the audience globally.

From a legacy point of view our aspiration is to become part of that global network. From a Scottish perspective we'd like to be seen as a hub of research activity into innovative building. It provides a great opportunity to share knowledge but is also great for the companies that are involved within the park to explore opportunities not only in the UK but overseas.

The building fits very well with BRE on a number of levels. From a performance point of view it's right up there. It's hitting gold level standards in terms of Section 7 Sustainability, and in some ways platinum.

Off-site manufacturing meant on site activity was reduced, minimising the use of resources on site, and leading to a quick turnaround. The project demonstrates high levels of operational performance and innovation in construction. Also running through the project is energy efficiency, so every component has been considered in this light. There is a 35% recycled content in relation to the House which chimes with our criteria.

Put simply

- *it meets the performance that we're looking for*

- *it's using a recognised modern method of construction in a recognised build form, cutting out-on site construction time and*
- *the resource efficient aspect adds another layer*

We're so pleased with the way it has developed and it is a real asset to the park. It looks great. There are so many memorable elements in the house that visitors will remember and take away with them."

10.3 Colin Machin Director of Tigh Grian Ltd. and Principal of Machin Associates Ltd. Chartered Architects and CDM Coordinators

"In terms of the completed house in Ravenscraig...I would want to live in that house, to be honest."

Tigh Grian: Background

"Tigh Grian is a consortium that Robert Cowie, Alan Johnstone and myself established in relation to the Resource Efficient House at BRE Ravenscraig.

About two years prior to coming together to form Tigh Grian I was introduced to Alan Johnstone of Nuhaus and at that time Alan was involved in promoting off-site modular construction in Northern Ireland, which I felt was ahead of its time. I discussed this new construction with some potential clients, such as Housing Associations, but they just didn't seem to be quite ready for it. Maybe the market conditions just weren't right at that time.

But it made a huge impact on me, this idea of modular construction. Although nothing came of this at the time, bringing things closer up to date, I heard about this tender opportunity from Zero Waste Scotland for the Resource Efficient House.

I then put the two things together and felt it was worth forming a project team. The consortium was named Tigh Grian (Gaelic for House of Sun) by Robert Cowie and Jacqueline Schindler. Jacqueline is the heiress to the Schindler Lift Company and is committed to the environment and medieval history – two areas that are funded by her charitable organization. She is hugely committed to this project and is its main funder, which was a key component of putting a bid together and delivering it. We came together just for this project – this is the first time we've worked together.

Across the continent they've been doing this type of offsite modular construction for a long time, however we as an industry have been slow to react to it. There is a momentum growing now, and it was exciting to seize this opportunity.

Resource Efficient House

One of the key things that we wanted to demonstrate at Ravenscraig is that a system of modular off site construction doesn't inhibit design. The house at Ravenscraig shows that resource efficiency and affordability doesn't sterilise design.

It's massively important to Machin Associates and Tigh Grian to be involved in the Innovation Park, and to have this as a platform. We're just beginning to realize how significant this is. Trust me it's monumental. When I see the work the ZWS and BRE have put in, it's really significant. It's been a pleasure to be involved in the whole process of working on this project.

Legacy

Just after completion of the Resource Efficient House the legacy for Tigh Grian is already palpable. Very soon after we got the commission at the site at Ravenscraig, the Scottish Government launched a fund for modular off-site construction and invited bids as part of a challenge bidding process. It was open to everyone: architects and developers all over the country. I had meetings with Clackmannanshire Council. Even though we were at the earliest stage at Ravenscraig we were able to demonstrate what we could achieve. And the long and short of it is that we have been successful with the housing development in Clackmannanshire for 48 units. The model is based entirely on the principles of the Resource Efficient House, but is much more conventional in its appearance. Without our involvement in the Resource Efficient House at BRE Ravenscraig this would never have happened. 100% it would never have happened.

Resource Efficient House challenges

The biggest challenge in terms of the Resource Efficient House was coming to terms with just how fast things happen.

One of the decisions we took was not to do the roof as a modular form, we could have done this in the factory but we decided that we would use trusses supplied to the site then direct them onto the top of the pods. Then the roof trusses had to be covered by Sarnofil, which is basically a product that has to be installed by licensed fitters. We were trying to get people to do this at the commencement of the Easter holidays, when we realised that many local authorities take this as an opportunity to overhaul their flat roofs. So we could not get anyone to install the membrane roof covering on site within the timeframe that we wanted. This should have been factored in at the beginning of the project, to make sure that licensed fitters were available and booked in on site. The lesson learned is that if we're going to proceed on this basis we will make sure that we will book in the specialists when we need them. Or we would change the programme.

That has been the biggest lesson learned during the whole process, but this emerged as a consequence of everything happening so quickly and so well. We thought it would be quicker to do the trusses on site but to do it again we would have produced the trusses in the factory and brought the roof on in four sections, then it would only have been three joints that would have been needed.

There was a period of time when the pods were exposed and vulnerable but we were largely blessed by dry weather. That is something we will take into account in the future. Had we had the benefit of previous experience we would have avoided this. But we will now be able to avoid this in future. It was a very valuable lesson learned.

Programming

The real art to a project like this is in the programming, where you have all the materials you need and all of the components. There are long lead times in areas such as windows and doors, which need to be ordered sufficiently early in order to avoid hiccups. Once the programme starts that's it!

The whole process forces discipline, which I see as a good thing. Once the off-site construction goes into production in the factory there is very little scope to change things. The house is being built from scratch. With traditional stick built timber frame construction, you are making the frame on site, and you can make changes as you go along. This is taken

away from you in this modular process. I don't see that as a negative. You have to think about everything at a very early stage and that removes any need to make decisions further down the line.

There are some elements of the construction industry that are lobbying to have the Scottish Government delay the implementation of the 2016 Scottish Building Standards. But we believe that we've adequately demonstrated that you can deliver high quality design and houses that people do want to live in, and they are affordable not only in terms of construction but also in terms of their running. The issue of affordability means different things to different people. I think it would be misleading to say that this is an affordable house in terms of an RSL (Registered Social Landlord) but I think it's affordable within the mainstream housing market that we're working within.

What's more it's simple to achieve. Firstly you get the fabric right – the fabric first approach. Then make the houses as airtight as you possibly can. And finally, introduce the mechanical and electrical systems to make that work for you. Once you understand this the rest of it is toffee. It's really straightforward.

We want as many people to come and see the REH as possible and talk about it and open up a debate about the principles on show.

Our long-term aim is to be talking to manufacturers about producing these Resource Efficient Houses in Scotland. It makes immense sense. There's ongoing discussions at the moment so it's hugely exciting times.

In terms of the completed house in Ravenscraig...I would want to live in that house, to be honest."

10.4 Janet Rennie Castle Re-Paint Technical and Development Advisor

"The Resource Efficient House is a fantastic project, I can't tell you how delighted we are to be involved in it."

Castle RePaint: History

We're part of the CastleRe furniture project in Cupar in Fife. The company were looking to expand their business that is primarily responsible for recycling and repairing domestic appliances - redirecting all the waste from landfill.

RePaint started up in 2008 in Glasgow but it didn't succeed. The original Glasgow operation established the process but it wasn't refined, there were still some quality issues. Our current process is based on a Canadian model, where the emphasis is on companies to have a responsibility for the materials they make. We're a bit slow to embrace this in the UK, but bigger paint companies are starting to latch on to the fact that if they don't do something the Government will have to legislate to meet sustainability targets.

Castle RePaint

I think the timing for this product is right. People are beginning to realise that there's limited resources.

Apparently there is £50 million litres of paint sitting in their garages. Everyone thinks they'll keep it to do some touching up and they rarely do. Paint has a limited lifespan, especially the modern paints with low Volatile Organic Compounds (VOC's). So we ask people to take the paint that they don't use to the recycling centre and we turn it into new paint.

We're a registered charity and we currently have agreements with Edinburgh City Council and Perth and Kinross, and we have a trial in Fife and North Berwick whereby household paint is collected for recycling. Discarding old paint is skirting on the edges of legality with SEPA directives, therefore this service is important from an environmental point of view.

The water-based paint that is unable to be recycled (such as watery or hardened paint) is bulked together and this can be used for composting. The bugs love it. They can digest it in that form.

The paint we manufacture is a premium product (the same product that features in the Resource Efficient House) and at a really competitive price, half the price of leading paint manufacturers. Price isn't a barrier.

Resource Efficient House

We find it harder to reach the masses, however Zero Waste Scotland is a larger organisation and as such we really value the opportunity to be involved with the Resource Efficient House - it is the right place to put our paint. It's a great fit with what the house is trying to achieve and what we are trying to achieve.

I think it will challenge people's perception of recycled paint as the quality of the finishes in REH are incredibly high. There is a common misconception that recycled paint is in some way a compromised product, but it's not. It's amazing quality. The market is full of paint, so people just don't want to take the risk. However we thought that this opportunity would really help us get the message out there, so to speak.

What we need to be a sustainable company is for a large organisation, such as a housebuilder, to come along and order a palette of magnolia, for example. A pallet a week would keep us buoyant as a company and the word of mouth we're hoping to generate via the REH is, we hope, what could do this for us.

We have the resources to achieve large orders. We create a 1000 litres batch of paint every week. There are also increasingly stringent environmental targets to meet and we could easily help organisations to achieve these targets. We're leading the way in recycled reprocessed paint in the UK, both for commercial purposes and for the benefit of the community.

Everyone loves the paint, and the ideal scenario for us would be a local council having the confidence to specify our paint. We are hoping to raise awareness at Ravenscraig that results in a deeper understanding and a commitment from someone big - that would be the outcome that we would love."

10.5 Julian Richards Milestone Eco Design

The UK's first producer of recycled kitchens.

"We're like Duracell Eco bunnies, we just keep going, chasing whatever we can find to complement what we do. I want to turn the whole world green, I'm an eco-maniac!"

Milestone Background

"Milestone Eco Design has been going from 1998 and we began our Eco range in 2005. Following this decision it then took me a year to source the eco materials for the recycled kitchen. I set myself a brief of five elements: Cabinets; Doors; Worktops; Tiles; Floor.

Everything had to be at least 50% recycled or it would be a waste of time.

Our first kitchen was the KORC, the UK's first kitchen to be made from genuinely recycled content materials, diverting kitchen household waste away from landfill to be recycled. We process the recycled plastics, which we buy in board form, and buy in the cabinets.

Our KORC kitchen features cabinets made from MSC board with the highest recycled material content. We found a plant in Liverpool that manufactured construction industry

board of up to 98% recycled material. The doors are made from 100% recycled mix of yoghurt pots and fridge liners. Our KORC kitchen is designed to look like an Eco kitchen however Resource Efficient House features a kitchen from our ECO Square range. This is a crisp, contemporary high-end kitchen. If you want a bigger audience for recycled products then you need to give a wider appeal, so that people like what they see initially and the bonus is that it's entirely eco.

The entire kitchen furniture i.e.: cabinets, doors, décor panels, cornice, pelmet & plinths is made from high recycled content chipboard at 70% or better. Made in the UK, the material comes from post-consumer wood waste collected from waste sites around the UK, the rest being FSC certified content. All the cabinets are 18mm dowelled & glued, rigid construction and all the drawers & doors in this range are soft close. The Resource Efficient House kitchen is a titanium colour finish.

The worktops are made from recycled vending machine coffee cups. There are only a few recycled plastics that can be used for worktops and the high impact polystyrene of coffee cups can be machined without melting it. The coffee cup board is very stable and behaves very similar to Corian. It can compete with Corian in terms of performance but this is a viable 100% recycled material alternative without any toxic by-products.

We've achieved everything that we can with the Eco Square kitchen within a reasonable budget. Everyone's perception of an eco-product is that it will be too expensive but in this case it simply isn't the case.

The Resource Efficient House is the first chance we've had to have a showcase for our products. I was blown away by the concept of the project at Ravenscraig, and we were so keen to be involved. It's very important for us for two reasons. One is that the kitchen looks stunning and it's totally made from recycled materials, it's very contemporary; and also it's joined by many other eco and sustainable materials in the house so it's great to see it within this context.

In terms of what we hope to achieve with the Resource Efficient House I would love a volume builder to be interested, one that's looking for affordable, sustainable and ecologically sound kitchens. Bring it on!"

Milestone Innovation

Since we installed our kitchen at BRE Ravenscraig we have also developed a new painted kitchen model that's been almost impossible to achieve until now. We just discovered a company in Lancashire - ECOS paints - that produces a paint that is completely solvent free, with no VOCs (Volatile Organic Compounds), no oil based petrochemical products at all and the pigment is organic based. This is what I've been looking for, for ages. We've painted a couple of doors and the finish is fabulous. It has a matt finish but any marks can be easily wiped off. So this will be perfect for people with allergies etc. as there's no offgassing. So suddenly we've cured our painted kitchen problem, and a massive eco bonus has opened up to us. So we're very excited about this.

10.6 Architecture + Design Scotland SUST

Architecture and Design Scotland (A+DS) undertook the role of design advisor and provision of project support through the various stages of the Resource Efficient House development. Sust. Programme Director **Lori McElroy** and Sust. Programme Manager **Kate Hendry**, in association with ZWS and BRE Ravenscraig, also organized an exhibition of the Resource Efficient House that considered both the materials and systems involved and also the implications on lifestyle of living in a resource efficient home. The exhibition took place at The Lighthouse 10 May – 16 Jul. Sust. Gallery - Level 2.

<http://www.thelighthouse.co.uk/visit/exhibition/resource-efficient-house>

According to A+DS Team members Lori McElroy and Kate Hendry:

"In terms of the Resource Efficient House we were primarily asked to provide design support. Throughout the tender process and subsequent development and construction we attended technical design team meetings, specifically to take on thoughts on design efficiency and also work out how to translate these thoughts into a repeatable exemplar model design.

Zero Waste Scotland were concentrating on resource efficiency and minimising waste to landfill and we were looking at these alternatives from a technical and design point of view. We helped ZWS weigh up the options at the tender phase and we also helped with the design aspects and assessment of the tender – organising the information into bite-sized chunks.

This tender didn't have any precedents as ZWS hadn't done a project like this before – it wasn't a case of picking a tender document out of the archive and re-working it, as it didn't exist. Therefore we helped flesh out a lot of the details. It's comparable to the work that we did at Scotland's Housing Expo in 2010 (<http://www.scotlandshousingexpo.com/>). Both competitions were set up in the same way in terms of looking for a designer and developer partnership that would be in a position of financially delivering it.

The intention was that 35% of the house would be recycled and we were on hand to help make the best decisions and recommend for example how to provide a concrete with a higher aggregate of recycled content and lower embodied energy recycled content to help gain percentage points. Not just chasing energy efficiency for the sake of it, but building it into the overall picture of the house.

Post tender, a few changes had to be made, such as the foundations and the deconstruction (in terms of inserting the steel). We were pleased to be able to help in an advisory capacity at this stage of the development.

From our point of view the Resource Efficient House is a step in the right direction. And there are undoubtedly many positives to take from the project. ZWS have achieved the targets and there are a lot of genuinely great things in there. It is a demonstration house, so there is a lot of experimentation. It's also a huge advert for great products such as the Milestone Kitchen and Castle Repaint. The Spruce carpet tiles downstairs are recycled and they look great. And we can't believe the timber floor is recycled. It's reclaimed, cleaned up and factory installed. The finishes are very high quality

The context to the resource efficient house is that 35% of the materials are reclaimed or recycled. Would you know that 35% of the house is reclaimed and recycled? Would you know that when you walked into the house? Not necessarily. And that is the interesting thing about the house. The message to come out of it is that we can do things more efficiently and it doesn't necessarily have a negative impact on the house. It doesn't have to look like an 'eco' house. You can create a house that looks like its reclaimed but if you want a house to look like a new and modern home it can also look like that with the resource efficiency built in.

Also a huge good news story to come out of the project is that a small architectural practice from Alloa (Machin Associates) has actually ended up expanding and getting commissioned to build new houses throughout Scotland, based on the Resource Efficient House design. And they are also currently in discussion to expand the manufacturing operation in Scotland. The positives should be celebrated."

Lessons Learned

Exhibition

Another key role that we had in the project was to help with documenting the project (in terms of this report) and also staging a related exhibition.

We had hoped that the exhibition would have been organised in parallel but as the focus was the house design and getting it on site, putting the exhibition together was not easy, as information wasn't coming through. In the event, the inflexible timetable set by the client for the build and the pressure that this subsequently created for the developer meant that the associated exhibition turned out to be more of a difficult task than it should have been. It wasn't until the house was nearly completed that we were able to get info to put the exhibition together, which meant that it was delayed.

We feel that it would have been worth building in a flexibility to the overall programme - not being so wedded to the specifics of the timetable, as this resulted in delays and rushed finishes that might have been avoided otherwise.

Materials

In terms of the materials I think there were a lot of compromises that could have been resolved if the programme had been more flexible. Doing something as innovative as this, perhaps some flexibility should have been allowed in the programme to give it a greater chance of succeeding.

The biggest issues were in relation to the project management of the overall project. A point of reference for everyone was lacking. A clerk of works that everyone could refer to would have been invaluable. While there was a very good clerk of works in charge of the build they were not linked into the design team meetings. Any big project that we've been involved in, the clerk of works is a key member of the team.

Creating a structure for delivery would be a recommendation that we would make in terms of any future projects. However we believe that this is a valuable lesson learned and we are also learning at the same time."

Materials library

Ultimately being involved with Zero Waste Scotland and the Resource Efficient House chimed with our aims at the Materials Library (Material Considerations: A Library of Sustainable Building Materials, The Lighthouse, Glasgow) as it gave us the opportunity to build up a number of new samples. We have done a lot of work with Historic Scotland and the Forestry Commission for the Materials Library and we were hoping to expand upon this into recycled materials. Our Materials Library isn't just about natural materials or Scottish materials, exploring resource and energy efficient materials are also important to the library, and this project has helped immensely in this respect.

It was an opportunity for us and as we grow and broaden the library, we understand what the linkages are and we will be able to point people in the right direction in terms of the advice we are able to give. We are now in a better position to direct people to Resource Efficient Scotland.
