SUSTAINABLE BUILDING DESIGN AND REFURBISHMENT IN SCOTLAND

DUNELAND BY JOHN GILBERT ARCHITECTS
LOW-ENERGY HOUSING DESIGN CONSIDERATIONS AND HIGHLIGHTS
OPTIONS APPRAISAL TOOL FOR ARCHITECTS
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Low-energy Housing Design Considerations and the Highlights
Dr Masa Noguchi, MEARU, The Glasgow School of Art, pp 23-30

Refurbishment of a granite building to reduce energy costs
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What is CIC Start Online?

- A three-year project of seven Scottish universities funded by European Regional Development Fund and Scottish Government’s SEEKIT programme, extended until 28th February 2013

- AIM: To embed sustainable building design and refurbishment into practice

- OBJECTIVE: To support academic/industry collaboration in developing and testing innovations, and to disseminate the outcomes in order to facilitate the application of innovations in practice

- WHY?
  - To reduce CO₂ emissions and other negative environmental impacts from buildings
  - To reduce fuel poverty and improve indoor climate
  - To create jobs and support competitiveness of Scottish construction industry through innovation
  - To remove the barriers to the application of innovation in practice

- HOW?
  - Through competitions for academic/industry feasibility studies and for 10-days free academic consultancy on sustainable building design and refurbishment
  - By testing innovations at the testing facilities of the project partners’ institutions
  - By publishing guidelines for the application of innovations in practice
  - By developing and publishing database of design solutions for sustainable refurbishment
  - By providing assistance and advice on sustainable building design and refurbishment to Scottish small to medium sized enterprises
  - By disseminating the project outcomes through the project website, seminars, interactive webinars, webcasts and three whole-day online events that will include an exhibition, a conference and networking facilities
  - By publishing information on products and services for sustainable building design and refurbishment offered by Scottish small to medium sized businesses registered with CIC Start Online.

BENEFITS OF FREE MEMBERSHIP

- Publish information on your company’s products or services for sustainable building design and refurbishment
- Receive a set of headphones with a microphone, monthly E-News and quarterly Innovation Review
- Ask for advice/assistance

Please click here to access the registration page at the project website

www.cicstart.org

PROJECT PARTNERS

FUNDED BY
Welcome to the penultimate issue of Innovation Review!

**CIC Start Online now has over 2,000 members in 47 countries.** Our autumn programme included three webinars whose video recordings are available on our website (pp 6-8) and a series of live conferences, focusing on topics that have recently been of interest to the construction sector in Scotland. Some conferences have been filmed and DVD packs produced (pp 9-13). Please see the programmes of the forthcoming conferences on pp. 14-17. Dissemination of the outcomes of feasibility studies and academic consultancies undertaken through our project continues through several webinars (pp. 18-22).

Two research articles, based on feasibility studies undertaken through CIC Start Online are available on pages 23-41. The last issue of Innovation Review published by CIC Start Online project will be online at the end of February 2013, just before the end of the project. We would like to invite researchers and practitioners to send in-depth articles on recent research or building projects (new or refurbishment) that contribute to the development of more sustainable built environment. Please send them to branka@cicistart.org by 15th February 2013.

We wish you a joyful festive season and a very successful 2013!

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**Your interactive webinars, video recordings and clips**

CIC Start Online team are offering the above services to businesses, universities and other organisations wishing to present products, services, research and information related to sustainable built environment.

As CIC Start Online currently has over 2,000 members across the United Kingdom and in 47 other countries, this is an excellent way of reaching a large audience.

Please see some ideas and suggestions for interactive webinars in which online viewers can ask questions by using chat facility. Video recording of the webinar can be made available on the CIC Start Online website for downloading.

- Presentation or demonstration of a product, process or service (20-30 minutes) followed by Q&A session with online viewers who can ask questions by using chat facility (30 minutes).
- Presentation of research outcomes (30 minutes) and Q&A session as another way of dissemination.
- Information on support available (e.g. advice, funding, etc.) at your organisation or business
- Short video clips about products or services that can be placed on the company/organization website.

Please contact Craig.Bishop@gcu.ac.uk, 0141 273 1401 to obtain more information and arrange the service.
Despite the growing interest in using BIM in construction, BIM technology has not been fully utilised in the current procurement strategies. Practical implementations of BIM are mostly during the design and construction stage. There is limited research that links knowledge gained from energy practices and BIM models to improve the overall operations and energy efficiency of buildings.

This feasibility study identified the key operational and carbon performance variables for Scottish public buildings needed for monitoring building performance, which are required to adopt BIM approach for better informing the stakeholders on the performance. This outcome will help in developing a smarter procurement strategy based on consistent information to be shared by all stakeholders.
This project addressed the need for a ‘quick start’ guide by the creation of a template for an occupant guide highlighting the benefits of energy efficiency through clear visual instructions for operating a new house. The Home Log Book Company (HLB) together with MEARU developed a bespoke ‘quick start’ guide for housing including the aspects addressed in the new building standards in Scotland. This project seeks to identifies a process of gathering this information and proposes a simple template which could be replicated by housing providers to meet the Section 7 criteria for new homes.

This ‘pilot’ guide was tested within a range of new house owners and tenants in both the public and private sectors. Feedback on the guide was obtained from residents by both a postal survey questionnaire and by a series of face to face interviews.
Communication Strategies to Reduce Water Consumption in Social Housing

Dr Mehreen S Gul, Heriot Watt University

Stuart Young, Home Log Book Company

This research aims to elicit and understand the attitudes and suggestions towards water conservation of tenants in social housing. These articulations and motivations will be used to develop a set of communication strategies to encourage tenants to participate in a programme of widespread water metering in social landlord dwellings. This is part of Scottish Water’s wider resource planning into demand scenarios for water supply and is managed by Home Log Book who commissioned this research to be carried out by Heriot-Watt University.

Through interaction with 12 tenants from two different housing associations it has been identified that there is a significant lack of awareness regarding water conservation amongst social housing tenants.

Please click on the image to access the video recording.
The conference explained how the Green Deal and ECO schemes will be funded, what the opportunities for clients and services providers are, and how to manage risks. The talks included case studies on planning, designing, delivering and monitoring energy efficiency improvements on hard-to-treat housing.

The conference theme relates to the Scottish Government’s consultation document “Developing Energy Efficiency Standard for Social Housing”.

The conference DVD pack is of interest to manufacturers of building products, building services engineers, property owners, Registered Social Landlords, Local Authorities, contractors and businesses who plan to engage with Green Deal and ECO.
Integration of Sustainable Infrastructure into the Existing Built Environment

This event explores how sustainable infrastructure can be integrated into the existing built environment. Policies and case studies on completed, on-going or planned projects for integration of services systems were presented, including green areas, energy generation from renewables, charging for electric vehicles, waste management, water saving and recycling, district heating and ICT management systems for infrastructure.

This conference DVD pack is of interest to the planners, architects, managers of public and private estates, services engineers, renewable energy professionals, building contractor and consultants, property owners and business offering products and services for more sustainable infrastructure for existing built environment.
Building Information Modelling (BIM) enables representation of building geometry, spatial relationships, light analysis, geographic information, quantities and properties of building components. Data integrated into BIM can be used to analyse and present the entire building life cycle. Quantities and properties of materials can be extracted and the scope of works can be easily defined. As these BIM features can facilitate the sustainability assessment of proposed designs and post-occupancy evaluation in relation to performance targets, the conference talks demonstrated how this can be achieved. Along with the use of BIM for new building designs, there is growing interest in its use for modelling existing buildings to facilitate renovation and refurbishment interventions. Populating a 3D model of an existing building with data that will assist decision making on renovation options is a challenge in further development of BIM. The conference indicated issues that need to be addressed to develop BIM for refurbishment.
Sustainable Refurbishment of Healthcare Estates

Along with the design for more sustainable new buildings for healthcare, sustainable refurbishment of existing buildings will play a significant role in reducing energy use and, ultimately, in making savings that will allow higher investment in care for patients. Interventions on existing healthcare buildings always present a bigger challenge than the interventions on other buildings as they should not disrupt or reduce the capacity and ability to provide a continuous level of service to the patients.

The conference explored how this can be achieved by informing on the context, research outcomes and case studies from Scotland and England. The conference DVD pack is of interest to the NHS Scotland Boards, managers of healthcare estates, architects, building services designers, manufacturers of building materials and components, and contractors.
Security of electricity supply, demand side management and Smart Grid strategy

This conference aims to address several issues related to the electricity supply such as the threats to the security and resilience of energy supply in the UK, the impacts of the electricity demand reduction, the demand side response to the energy requirements of electric vehicles and heat pumps, and the solutions to prevent fuel poverty in an all electric UK.

This conference is of interest to the electricity suppliers, energy regulators, services engineers, renewable energy professionals, construction industry professionals, property owners and organisation involved in the reduction of fuel poverty.

LOCATION

Seminar Room K505, Buchanan House, 58 Port Dundas Road, Glasgow G4 0HG

CONFERENCE FEES

The delegate pricing is as follows:

- CIC Start Online Member = £69 +VAT
- Non-member, per delegate = £89 +VAT

An invoice will be sent shortly after the conference.

EXHIBITORS

There is limited space to exhibit at this event, for more information please contact us on 0141 273 1411. Exhibition space will be allocated on a first come, first served basis. You can exhibit for only £100+VAT in addition to the delegate fee.
Conference Programme

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<th>Session</th>
<th>Speaker/Institution</th>
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<tr>
<td>09:30</td>
<td>Registration and light refreshments</td>
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<tr>
<td>10:00</td>
<td>Chair's Welcome</td>
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<td>10:10</td>
<td>What are the threats to the security and resilience of energy</td>
<td>Prof Joe Clarke, Director of BRE’s Centre for</td>
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<td>supply in the UK?</td>
<td>Energy Utilisation</td>
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<td>10:30</td>
<td>Will demand reduction result in a Jevens paradox or will it be the</td>
<td>John Counsell, Advanced Control Partnerships</td>
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<td>start of a revolution in energy utilisation?</td>
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<td>10:50</td>
<td>Can Electric Vehicles and Heat Pumps be economically sustained</td>
<td>Prof David Infield, University of Strathclyde</td>
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<td>without Demand Side Response?</td>
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<td>11:10</td>
<td>How do energy suppliers plan to ensure sufficient energy supplies?</td>
<td>Brian Galloway, Scottish Power</td>
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<td>11:30</td>
<td>In an all electric UK what will be the solutions to prevent</td>
<td>Scott Restrick, Energy Action Scotland</td>
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<td>unprecedented levels of fuel poverty?</td>
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<tr>
<td>11:50</td>
<td>Panel Discussion</td>
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Security of Electricity Supply, Demand Side Management & Smart Grid Strategy

A half-day conference by CIC Start Online

Thursday 13th December 2012
Seminar Room, K505, Buchanan House, Glasgow G4 0HG

Delegate fee of £69 (+VAT) for CIC Start members.
Delegate fee of £89 (+VAT) for non-members.
More information including online booking is available at www.cicstart.org
CONFERENCE DVDs

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More Conference DVDs coming soon!
While much emphasis has been placed on design tools to model energy usage, innovative materials to achieve greater energy efficiencies, specification and design development to provide low carbon houses, this is only the theoretical side of procurement. The practical delivery of low carbon homes is just as critical and dependent on good standards of workmanship on site as it is on the design aspirations of detailing, finishes and the materials in use. It simply takes under-performing systems, ill fitting materials, unsealed gaps, impossible detailing, poor construction standards and user mis-management to turn an energy efficient design into an energy wasteful building.

This scoping research project identified the potential for further targeted research in the following areas:

- Domestic and non-domestic buildings.
- Refurbishment and new build projects.
- Design, Building and Management factors.

A total of 12 distinct areas of co-ordinated research should assist a deeper understanding of achieving designed performance in the construction industry in the coming years.
Sustainability & energy efficiency of three new-build dwellings in Aberdour, Fife

Jon Stinson and Julio Bros-Williamson, Edinburgh Napier University
Stuart Hannah, Finex Joinery

Energy modelling for the three dwellings was undertaken to establish heating and power demand. These figures were used to compare against Scottish Building Standards Section 7 and Passive house design requirements. Each dwelling was virtually constructed using the plans, elevations and elemental build-up of the dwelling’s envelope as provided by the architect. Based on the space heating demand dwelling A achieved aspect 2 of the Gold standard and met the Passive house space heating criteria. Dwelling C achieved Gold standard and dwelling B obtained the Silver standard.

Assessment of the site ruled out a number of technologies pertaining to hydro and wind. In terms of electricity production, solar photovoltaic panels provide the most attractive solution available. The site allows for the placement of small solar farms adjacent to each house. The report comments on the foreseeable issues relating to living in home solely dependent upon on-site electricity generation. Living in within a dwelling committed to fully off-grid power generation comes with a host of lifestyle adaptations. The overarching goal is to provide on-site power generating solutions whilst ensuring a standard of electricity living that the prospective occupants can adapt to.

Complexities arise when considering the power demand during night time or times during low seasonal positioning of the sun. To achieve the off-grid aim the PV system requires additional equipment, batteries and solar regulator to enable storage of generated power to meet 24 hour demand. Snow fall presents a particular issue during the winter preventing the system to generate the simulated energy demand. It is important to be conscious that energy would be produced during the day but mainly used during the night and with a higher demand for lighting and other electronics during the darker winter period.
Thermal and humidity testing of a hard to treat wall

Julio Bros-Williamson, Edinburgh Napier University
Wilson Shaw, BCA Insulation

The study investigated and tested, in the context of buildings of solid wall construction, the condensation risk and heat loss associated with cold spots and areas that cannot be insulated such as:

- Decorative cornicing
- Window reveals
- Walls considered to impractical or not cost effective to insulate.
- Internal partitions and floors

This research is underpinned by BCA’s own prior research, experience and development in the area of solid wall insulation where the company has become a market leader in recent times having carried a major literature review ahead of writing its "Good Practice Guide" and years of case studies and trials both in its own training academy in Shotts and with clients such as Historic Scotland.

The study covered one dwelling from BCA's projects including houses being improved through the Scottish Governments’ Energy Assistance Package and local authority’s Universal Home Insulation Schemes, and included the following:

1. In-situ U-value measurement of a wall with two insulation solutions at pre and post intervention stages located in one site by measuring the performance of both an internal over-lining system as well as an injected solution, all in the same location and dwelling.
2. Interstitial condensation simulation of a selected wall element both pre and post intervention stages - test took place only on one wall.
The use of cross laminated timber in high density affordable housing

Peter Wilson, Edinburgh Napier University
Stuart Taylor, Artel Associates

This study has examined the benefits of cross laminated timber construction in high density affordable housing in three ways:

- Bespoke panel production related to specific project designs:
- The establishment of standardized panel sizes and repetitive construction parameters confirming to current housing standards;
- Offsite assembly of cross laminated timber elements into modular units that can be delivered fully fitted to site

The second part of the study explored the manufacturing technology, the local resource (forest and sawmill) demands and the potential for localized CLT production in the Dumfries and Galloway region. Each of these points have been examined within the wider context of the resources, economic viability, investment capacity and strategic disposition of future CLT manufacturing facilities in Scotland.
The project involves the application of a wireless sensor network (WSN) infrastructure to support monitoring of an energy-efficient built environment, specifically a mass-market affordable home design, created by Scottish company Applegreen Homes. The work includes the creation of a feature-set specification for a monitoring system, the development of hardware and software to provide the necessary functionality and an evaluation within a built environment.

The hardware and software components developed for the project are extensions to an existing WSN designed by the Mobile and Ubiquitous Computing research group (MUCom) at Glasgow Caledonian University (GCU). The system was due to be installed within an Applegreen demonstrator home on the BRE Innovation Park (Building Research Establishment Group) at Ravenscraig. Because of BRE’s delays in delivering the completion of the Innovation Park, the equipment has been field-tested in an eco-building at South Lanarkshire College and also within the Saltire Centre at GCU. The system is shown to be robust and flexible.

Future development of the system with Applegreen homes will be considered after the upcoming trial on completion of their building at the Innovation Park.
THE LAST SERIES OF RESEARCH OUTCOMES IN THE NEXT ISSUE

The last issue of the current series of Innovation Review will be published at the end of February 2013.

It will provide articles on the final group of completed feasibility studies and academic consultancies that were undertaken through CIC Start Online project.

This will be our largest issue, but as it will be online, you will be able to access the articles at any time following their publication.
Households who spend more than 10% of their total income may be experiencing fuel poverty. It has been reported that from 1996 to 2002, the fuel poverty population fell from 36% to 13%; however, it again rose to 15% in 2003. Since then, it has been on a constant growth with 33% in 2009. In 2010, the carbon emission in the UK rose tremendously due to increased use of gas for heating homes during the cold months. It is mandatory to deliver an energy efficient house. The realisation of the implications of cost-effectiveness is a major factor for the future budget to develop an affordable housing equipped with energy-efficient measures. There is a clear need for the application of renewable energy technologies to housing today particularly when low to zero energy homes are concerned. The energy required to operate a house may depend on the occupants' structure and usage patterns related to their behaviour. The requirement of space and water heating is largely dependent on energy demand which seemingly accounts for a number of factors such as climatic variations, and building sizes, types and thermal properties in addition to the human factors. A dwelling with larger rooms may need more energy to heat up the space. There is a potential for future savings in energy demands of housing use if the occupants maintain energy-saving daily life activities.

In addition to human factors, the cost and performance of a house depends generally on design components selected. Thus, design decisions need to be made carefully with due consideration of the current and future value of not only component alternative but also the combined attributes. For instance, proper combinations of passive design techniques for reduction of energy demand and active renewable techniques for power generation are of importance in enhancement of values rather than costs.

PASSIVE DESIGN CONSIDERATIONS
Proper implementation of passive design solutions contributes drastically to reducing domestic operational energy demands and it could be discussed sufficiently prior to relying on the use of building service devices. The following paragraphs include some passive design considerations that affect the energy demands in view of the Government’s Standard Assessment Procedure (SAP) for Energy rating of Dwellings, which has been applied for issuing Energy Performance Certificates in the UK today.

Orientation of building unit: The orientation of a housing unit can be considered as critical for optimal use of solar gains for heating and lighting as well as power generation. Some projects do not allow stakeholders to determine the orientation due to the site constraints. Also, the relationship of a building to the sun and prevailing winds may need to be taken into account while the site and building configurations are planned. The building facades should be oriented in a way that helps maximise solar heat gain in cool and cold climates, yet it needs to be designed to reduce glare and overheating. The optimal use of daylight minimises the need of artificial lighting during the daytime. It is desirable that the zoning and placement of internal spaces should be planned with due consideration of the above aspects.

Built form: The type of built form, such as attached, semi-detached, and detached housing, as well as flat multi-floor residential dwelling unit, needs to be identified for the simulation of energy demand. There is a clear relationship between the exposed area of building envelope and the associated heat loss.
Sheltering sides: The amount of buildings' heat loss is partially related to the level of wind protection of building envelope, which could be affected by trees and buildings surrounding the house in question. The sheltering depends on the height of obstacles surrounding the house, distance between obstacles and the house and the width of obstacles.

Draught lobby: The minimisation of ventilation heat loss is one of challenges and a main entrance may need to be protected by the placement of a draught lobby which consists of two doors that form a lobby. To satisfy the function, the floor area of at least 2m² is required. The draught lobby helps prevent or minimise the entry of direct air into the house every time the external door is used.

Location and size of lounge: To maintain occupants' thermal comfort, the temperature of a lounge/living room tends to maintain 21°C setting in view of SAP calculation. On the other hand, 18°C setting is applied to the rest of the house. The lounge can be placed on the upper floor so as to reduce or minimise heat loss while the size affects energy demand for space heating drastically. The use of an accordion curtain to create a thermal separation between a lounge and the other parts of a house may be considered to be effective.

Size of opening: The size of windows and doors correlates with the amount of heat loss while affecting solar gain and natural light potentials. Moreover, cross ventilation can also be secured by effective placement of openings. Multi-glazed windows are desirable for homes built in cool and cold climates for reduction of the heat loss.

ACTIVE MECHANICAL DEVICES
In cool and cold climates, heating systems are almost inevitable devices that help maintain occupants' thermal comfort. In addition to them, active mechanical devices may also include renewable energy technologies and ventilation devices.

Heating system: A variety of devices to heat buildings are available in the market today. A combi (or combination) gas boiler is one of the most popular heating systems being installed in homes in the UK.

It is a compact system applied for heating water and space, saving space. Ground source and air source heat pump systems are also available. The installation of a typical ground source heat pump system would cost between £9,000 and £17,000. The air source heat pump has the efficiency of 220%-300% and absorbs heat from the outside air even when outside temperature is as low as -15°C. The installation of an air source heat pump system would cost between £6,000 and £10,000. Biomass heaters can be fuelled up by wood pellets, logs and chips. Wood chips can be used to heat larger dwellings or a group of houses. Wood pellets can be easily handled if compared to logs and the boilers can run automatically. Pellet costs depend mainly on the size and method of delivery. If a few bags are bought at a time, it costs more than buying in a bulk. If there is enough storage space to store the bulk of pellets, the cost can be lowered down to £190 per tonne in most parts of the UK.

Ventilation system: Ventilation systems can fall widely into two approaches: natural and mechanical ventilation. The former does not require the use of electricity while the latter has a clear linkage to electricity consumption when the house comes into operation. The specific fan power, efficiency and ductwork arrangements have significant impact on energy consumption particularly when a mechanical ventilation with heat recovery (MVHR) system is concerned.

Photovoltaic (PV) power generating system: PV generates electricity and the panels can be installed in roofs and walls of a dwelling unit. The amount of electricity generation depends on PV solar panel size, type, orientation and sloping angle in addition to the availability of sunlight.

The above-mentioned systems can be combined to extract additional values of each system. For instance, an MVHR system can be linked physically to PV to develop a PV thermal air system (PV/T) which can provide capacity for space heating, i.e. PV MVHR. There is a synergy between MVHR and PV/T systems. PV generated electricity can contribute to the operation of an MVHR system while the ventilator can help extract fresh air heated by PV. The combination helps create healthy comfortable living environment while the total energy load for space heating could be reduced (Fig.1).
For demonstration of PV/T architectural integration, the use of PV tiles was considered as a practical solution. PV tiles available in the UK today can be fitted to standard wooden battens using traditional roofing practice. The size of PV roof panel was assumed to be 420 mm in width and 1,220 mm in length. The module efficiency of mono-crystallised silicon PV is estimated at approx. 14%. The Individual unit possibly weighs 8 kg; however, when the tiles are laid at gauges, the weight possibly becomes nearly 20 kg/m². It is assumed that the efficiency of PV systems reduces by about 0.5 - 0.7% every year.

Some companies in the UK can supply similar products with a 10-year warranty and the power output could be guaranteed for 25 years from date of commissioning.

The wooden battens on the roof sheathing should be placed in such a way that the vertical air flow from the bottom of the PV roof to the ridge can be well secured and the cavity should be sealed to enhance the extraction of fresh air heated by PV (Fig.2).
PV MVHR SYSTEM PERFORMANCE

Today, a large section of MVHR products are readily available on the market; thus, for the further performance assessment, some typical systems were selected in view of the specific fan power and efficiency variations that range from relatively low to high levels (Table 1).

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<thead>
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<th>PRODUCT</th>
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Table 1: Profile of MVHR products selected

The selected products were studied in order to identify the effects on energy consumption, operating energy cost and carbon dioxide (CO₂) emission levels. Moreover, the assessment extended to a situation that the MVHR products are also combined with heating and micro power generating systems such as a PV system. In this study, a combi-boiler has been considered as the standard heating system of a conceptual test house. The combi-boiler selected runs under mains gas and the efficiency was assumed to be 90.3%.

As for PV, a 4kWp system was selected assumed to be mounted on south oriented roof with a tilt angle of 30°. The 4kWp PV coverage was considered to be 28.57m² (8m in width and 3.58m in length) accompanied by the ventilated roof air flow of 0.5m/s or 432m³/h. The potential thermal energy generation of the 14% efficient PV/T roof based in Scotland was considered to be 3,440 kWh per annum according to the author’s previous study.
In this study, 19 options were developed for the further assessment (Table 2). The effects of each option on the annual energy consumption, operating energy cost and carbon dioxide (CO₂) emissions were assessed by making use of SAP 2009 (Table 3). The options that do not concern PV show a drastic increase in domestic energy requirement as well as annual operating energy cost (Options 1, 2, 5, 8, 11, 14 & 17) as opposed to options that include PV combined with an MVHR system selected (Options 3, 6, 9, 12, 15 & 18). Moreover, when PV thermal is added to the combination options, there is further reduction in the energy use which in turn contributes to reducing operating energy cost (Options 4, 7, 10, 13, 16 & 19).

<table>
<thead>
<tr>
<th>OPTION</th>
<th>Combi-Boiler</th>
<th>MVHR</th>
<th>PV Electricity</th>
<th>PV Thermal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A   B       C</td>
<td>D   E</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
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<td>x</td>
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<tr>
<td>4</td>
<td>x</td>
<td>x</td>
<td>x</td>
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<tr>
<td>19</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

Table 2: PV MVHR System Options Examined
The results indicate that options that include a PV/T system can be considered to be highly cost-effective when the saving of operating energy cost is appreciated. When PV is completely excluded, energy requirements and associated CO$_2$ emissions become relatively high. This tendency could be explained by the constant electricity use for the operation of an MVHR system. In SAP calculations, CO$_2$ factor of electricity is considered to be 0.517 kg CO$_2$ per kWh while that of mains gas is 0.198 kg CO$_2$ per kWh. This clearly shows that the use of electricity leads to 2.6 times more CO$_2$ emissions than mains gas. Accordingly, in terms of CO$_2$ emissions, a house equipped with a mains gas combi-boiler and MVHR system whose SFP is high, e.g. 1.2 w/l/s (Option 11), is marginally different from a house with no MVHR (Option 1).

<table>
<thead>
<tr>
<th>Combinations</th>
<th>Delivered Energy (kWh/year)</th>
<th>Primary Energy (kWh/year)</th>
<th>PV Generated Electricity (kWh/year) (negative quantity)</th>
<th>PV/T Generated Heat (kWh/year) (negative quantity)</th>
<th>Annual Cost of energy (£)</th>
<th>CO2 Emissions (kg/year)</th>
<th>Dwelling Emission rate (DER) kg CO2/m2/yr</th>
<th>Target Emission rate (TER) kg CO2/m2/yr</th>
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<tr>
<td>Opt1</td>
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<td>10645</td>
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<td>Opt11</td>
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<td>10727</td>
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<td>-3440</td>
<td>-11</td>
<td>-407</td>
<td>1</td>
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</tr>
</tbody>
</table>

Table 3: Delivered & Primary energy, Operating energy cost, DER & TER assessment results of 19 alternatives selected
COST-EFFECTIVENESS ASSESSMENT

The future worth is the value of an asset in the future. It determines the worth for a given sum of money at a specific time to which an assumed rate of interest is applied. In this study, the future worth of each design option was estimated using the following formula:

\[ FW = AC \times (1 + i)^n \]

Where,

\( FW \) = future worth of the option selected \\
\( AC \) = annual energy cost \\
\( i \) = interest rate \\
\( n \) = number of the year in question

Moreover, in comparison to the benchmark option (OPT 4), the cost-effectiveness of all other design options has been assessed using the following formula:

\[ CE_{OPT \, x} = (AC_{OPT \, 4} - AC_{OPT \, x}) \times (1 + i)^n \]

Where,

\( CE_{OPT \, x} \) = cost-effectiveness of annual energy cost difference \\
\( AC_{OPT \, 4} \) = annual energy cost of the benchmark option (OPT 4) \\
\( AC_{OPT \, x} \) = annual energy cost of the option selected (OPT X) \\
\( i \) = interest rate \\
\( n \) = number of the year in question

The future worth (or value) of the options has been calculated based on an assumption that the interest rate is 10% applicable to a period of 10 years. In this assessment, the negative values imply benefits to the house owner while the positive values indicate that the owner is required to pay for the energy use. The results help identify the best possible combination amongst the options given in view of the future economic value based on the operating energy cost. In comparison to the benchmark option (Option 4 in this study), cost-effectiveness was calculated and the negative values indicate inefficiency in energy output (Table 4).

<table>
<thead>
<tr>
<th>Option</th>
<th>Cost-effectiveness (( CE_{OPT , x} ))</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPT 1</td>
<td>-1328</td>
</tr>
<tr>
<td>OPT 2</td>
<td>-1159</td>
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<td>OPT 3</td>
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<td>OPT 8</td>
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<td>OPT 9</td>
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<td>OPT 12</td>
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</tr>
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<td>OPT 13</td>
<td>-205</td>
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<tr>
<td>OPT 14</td>
<td>-1305</td>
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<tr>
<td>OPT 15</td>
<td>-329</td>
</tr>
<tr>
<td>OPT 16</td>
<td>-109</td>
</tr>
<tr>
<td>OPT 17</td>
<td>-1320</td>
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<td>OPT 18</td>
<td>-345</td>
</tr>
<tr>
<td>OPT 19</td>
<td>-137</td>
</tr>
</tbody>
</table>

Table 4: Future worth and cost-effectiveness assessment results of design alternatives compared to Option 4 as the benchmark.
Conclusions
This article highlighted passive design elements that should be considered for lowering operational energy demands of housing. Moreover, some active building service devices were selected and the significance of the potential hybrid application to housing in cool and cold climates was articulated. Today, solar photovoltaic (PV) systems installed in houses in the UK are mainly applied for the supply of electricity alone even if PV actually generates not only electricity but also heat which can be used potentially for space heating. Studies about PV thermal (PV/T) residential applications are far from new; however, there had been no practical guideline that housing suppliers today can follow for installation of the theoretical emerging heating device. Accordingly, this study was initiated with the aim to identify how PV/T systems can perform under Scottish climate conditions and how the technology can practically be applied to a housing unit. There is a synergy between MVHR and PV/T systems. PV generated electricity can contribute to the operation of an MVHR system while the ventilator can help extract fresh air heated by PV. The combination helps create healthy comfortable living environment while the total energy load for space heating could be reduced. This study articulated the significance of the hybrid application and the economic value of PV generated heat, which had been ignored in most PV practices in Scotland to date. This study helped visualise the effects of each option on the total housing energy consumption, operating energy cost and carbon dioxide (CO₂) emissions. The cost-effectiveness of each option was also carried out based on the operating cost. In this study, the future value was calculated using a future worth method based on the time value of money concept, e.g. a period of 10 years and 10% interest rate. To optimise the performance of the PV/T roof system proposed in this study, PV roof ventilation cavity should be sealed properly to enhance the extraction of fresh air heated by PV, while the air flow should be retained higher than 0.5m/s to secure the expected amount of heat extraction to supplement indoor space heating. Bypass arrangement may be required for prevention of overheating on hot summer days. Not to mention, insulation of ducts is essential for optimal performance of heating and MVHR systems. The MVHR system design is out of the scope of this feasibility study so the system design and installation methods should be studied further.

Acknowledgements
The author would like to thank Kajal Dhamne and Anushree Rohatgi for their immense contribution to data analysis and value visualisation required for development of this article.
Options Appraisal Tool for Architects (OATA): A Simplified and Dynamic Assessment Method for Building Heating System Selection, Design and Control

Professor John Counsell and Dr Gavin Murphy, University of Strathclyde Glasgow
Professor Alan Pert and Sean Counsell, NORD Architecture

Introduction
The OATA project was proposed to tackle a gap in the provision for energy performance appraisal tools for the smaller architecture practices when designing new or refurbished homes. Of particular interest is the gap in provision for simplified dynamic simulation tools that can readily plug in to the government’s existing Standard Assessment Procedure (SAP) that all architects have to use to comply with UK building regulations, although these regulations differ slightly between the ‘England and Wales’ and Scottish regions. The BRE Centre of Excellence at the University of Strathclyde through a BRE Trust funded PhD programme has developed a simplified dynamic simulation approach named Inverse Dynamics Energy Assessment and Simulation (IDEAS) to evaluate the relative energy, running cost and carbon emission associated with architects design designs that influence the performance of specifically heating systems.

In commercial buildings which from design concept to build often cost in the region of £1 to 1000 Million are huge projects requiring huge resources and warrant a very detailed modelling and totally integrated energy systems analysis. This part of the market is very well covered by a number of professional and research tools such as IES and ESPr [Strachan, 2008] at the University of Strathclyde. These tools a comprehensive and their only short coming is their complexity for small projects such as designing or refurbishing a home. These tools either are expensive to buy and/or require significant training to become fully up to speed and competent with them to reliably use for energy comparison studies.

They are ideal for virtual prototyping from the conceptual to the detail stages of large building design, but somewhat of a sledge hammer trying to crack a nut with a relatively simpler building such as a home. That is not under estimate the task of fully understanding energy consumption in a home, it is highly variable and highly sensitive to manner design parameters, environmental conditions and occupant behaviour. This challenge of energy assessment of homes has been tackled to create the simplified model BREDEM BRE’s Domestic Energy Model. BREDEM is at the heart of the SAP procedure [Anderson, 2001] and consequently it is sensible and incremental to add a dynamic model as in the IDEAS approach to the SAP method.

Another problem with the professional tools is that they are not yet fully integrated with CAD tools for design so it is time consuming to integrate CAD with these tools for a small building. The data for the building design has to be by law entered into the SAP procedure so it is logical step to introduce more efficiency in the design process by piping the SAP data in to the IDEAS approach for dynamic simulation.

This project involved The BRE Centre and NORD Architecture to explore how IDEAS could be used in the selection of a heating system for a specific home to be refurbished, in this case a choice of an Air Source Heat Pump or Gas Condensing Boiler.
This partnership would also explore and establish the most important architecture design choices that influence heating performance. Of course design choices also influence lighting energy use in the home, however in homes over 50% of the energy is still for heating and with advent of the super energy efficient LED lighting, heating particularly in Scotland is still going to be the dominate energy use in the home. For this reason OATA the study described in this report has focussed on an appraisal tool for heating systems performance evaluation using a simplified dynamic simulation method that builds on the best practices and baseline energy estimations set by the government’s SAP method.

**Specific Aims Addressed in this Report**

Through a process of consultation meeting between BRE centre research staff and Nord Architecture management and architects the following specific aims were established:

1. The IDEAS methodology [Murphy, 2012] was too sensitive to errors in initial conditions of building fabric temperatures specified at the start of the simulation run. For this reason a method of solving the IDEAS differential equations would be introduced using a method of small perturbation analysis. The IDEAS method would then have to be re-calibrated against the SAP baseline. The outcome of this aim is described in section 2.

2. The IDEAS methodology [Murphy, 2012], was also a little vague in the important definition of thermal comfort, thus a task to align the thermal comfort calculation with CIBSE and BSI standards was required. This work is also described in the full CiCstart report for this project.

3. The modelling of air-source heat pumps is very complex due to these systems being so sensitive to occupant behaviour, outside temperature changes and outside relative humidity changes. Thus, whilst there are a lot of peer reviewed articles on modelling heat pumps it was agreed to use data from the extensive trials carried out by the Energy Savings Trust (EST). EST carried out these trials with the consultancy company EA Technology who did the very first air-source heat pump trails to the UK as far back as 1991.

In order to fully understand heat pump performance, the BRE Centre participated in a Nuffield Student Bursary programme with EA Technology in the summer of 2011. The results of this study have been transferred to create an IDEAS heat pump model.

4. NORD architecture is particularly interested in design decisions associated with the refurbishment of the older homes in the UK. For this reason an old solid wall home was chosen and modelled in the IDEAS method. The home, its geometry and IDEAS parameters are described in the Case Study section.

5. The partnership concluded that the following performance comparisons should be carried out on the refurbished home using the modified IDEAS method. Through a complementary student internship programme the IDEAS simulation parameters for the case study would be established from existing CAD drawings to enable the following performance studies:

   a. The performance of a gas condensing boiler in the refurbished home
   b. The performance of an Air-source heat pump in the refurbished home
   c. The performance of a gas condensing boiler and air-source heat pump with an increased percentage of southerly facing glazing.

   The NORD architects felt that the choice of south facing glazing on top of everything sensible that can be done to insulate the fabric was one of the major architecture design decisions that could have a significant impact on the energy performance of the home.

A modified IDEAS approach to simplified dynamic modelling and simulation

Introduction to IDEAS

Inverse Dynamics Energy Assessment and Simulation is a dynamic modelling approach [Murphy, 2012] which has been developed as a method for assessing the energy utilisation of a building and its servicing systems.
While other energy performance packages such as SAP consider the building to be operating in steady-state, the IDEAS methodology is a dynamic model. The fundamental difference in the approach taken in this methodology is the use of inverse dynamics (ID) taken from the RIDE control algorithm [Counsell, 2010]. The use of ID and RIDE allows IDEAS to solve for the energy consumption and temperatures at each simulation time-step. This concept is illustrated in Fig. 1.

![Diagram](Plant^{-1})

**Fig. 1.** Inverse dynamics – calculates the input based on a required output

Simplified symbolic assessment methods have been shown to be relevant for controllability analysis [Tashtoush, 2005 and Counsell, 2010] and for the assessment of energy utilisation in buildings [Tindale, 1987]. A benefit of symbolic modelling is that a symbolic model can rapidly and thoroughly determine the effect of disturbances such as free heats gains or external temperature. Relatively simple symbolic models are preferred in the buildings industry, as their fast computational time and ease of use allow for rapid iteration of a buildings thermodynamics and energy systems and minimise error due to incorrect data entries [Hitchin, 2010].

The European Directive on the Energy Performance of Buildings [European Parliament, 2009 and European Commission, 2010], referred to as the Energy Performance of Buildings Directive (EPBD) stipulates that all European member states must produce an Energy Performance Certificate (EPC) whenever buildings are constructed, sold or rented. In the UK, SAP is the procedure used to generate an EPC for all dwellings whilst SBEM is generally used to produce EPCs for non-domestic buildings.

Studies have shown that there can be variances in results between SAP and dynamic simulation tools [Murphy, 2010]. SAP is based upon empirical data and is the recognisable energy assessment method used by UK building professionals. SAP is predominately steady state and cannot model transient response of temperatures and energy output from energy systems, e.g. heating systems. Assessing the dynamics of such systems, in relation to energy utilisation, is an area where simplified empirical methods of assessing the energy ratings of buildings, such as SAP, are limited.

The IDEAS method uses SAP as a calibration exemplar, and produces SAP compliant results over a wide range of buildings types. By producing SAP compliant results, IDEAS can demonstrate a buildings compliance with building regulations and can also assess the energy performance of that building.

The IDEAS state space model was initially developed for controller design but it can also be calibrated against an existing empirical method to produce results which are compliant with it.
As an exemplar, IDEAS is calibrated with the SAP methodology and looks to suggest where advanced controllability of dwelling systems and a dynamic framework could supplement the SAP methodology (see Fig. 1).

The knowledge for this method has been transferred from design processes and methods used in the design of aircraft flight control systems [Bradshaw, 1996] to establish a modelling and design process for dwellings and its systems. The paper describes a holistic approach to the modelling of the non-linear and linear dynamics of the integrated building and its systems.
As highlighted in Fig. 3 uncertainty is an issue for both complex and simple calculation methods; the new IDEAS methodology will aim to reduce uncertainty where possible by producing a fully transparent and available calculation method.

IDEAS can be represented in state-space and allows the control law RIDE to be employed. This state-space implementation allows IDEAS to be implemented in a number of programs such as Microsoft Excel, MATLAB/Simulink or even in complex detailed Dynamic Simulation Models (DSMs) such as ESP-r and IES. Verification and calibration of the IDEAS model would be possible using results from many other methods such as ESP-r, IES, PHPP, SBEM or SAP.

For this work, IDEAS has been implemented in MATLAB/Simulink and uses SAP as the exemplar comparison. Using this methodology IDEAS will be calibrated with SAP across a range of modelling parameters.

Fig.3. Comparison of uncertainty of results for complex vs. simple calculation methods [Hitchin, 2010]
Modified IDEAS’ Calibration with SAP

IDEAS has been calibrated against SAP over a range of test cases, in this paper two test cases are presented, one for a poorly insulated dwelling and one for a highly insulated dwelling. A poorly insulated dwelling was modelled in IDEAS and SAP, taking a structure U-Value of 2.1 W/m²K as being representative of a poorly insulated dwelling fabric. With standard inputs modelled in IDEAS based upon SAP inputs, the following results were obtained and shown in Figures 4 and 5.

Fig. 4. Poorly insulated dwelling: temperature calibration, 99.5% match

Fig. 5. Poorly insulated dwelling: energy calibration, 102.6% match
It can be seen that there is a match within 5% for air temperature and energy consumption when IDEAS and SAP are compared. Based upon this test case, modelling a dwelling which is poorly insulated there is good match between IDEAS and SAP/BREDEM for both temperature and energy consumption. A well-insulated dwelling was modelled in IDEAS and SAP, taking a structure U-Value of 0.3 W/m²K as being representative of well insulated dwelling fabric. Other dwelling elements such as glazing were also improved from the poorly insulated dwelling test case. With standard inputs modelled in IDEAS based upon SAP inputs, the following results were obtained and shown in Figures 6 and 7.

![Fig. 6. Well insulated dwelling: temperature calibration, 100.04% match](image1)

![Fig. 7. Well insulated dwelling: energy calibration, 100.28% match](image2)
For the well-insulated test case, it can be seen that there is a match within 5% for air temperature and energy consumption when IDEAS and SAP are compared. Based upon this test case, modelling a dwelling which is well insulated there is good match between IDEAS and SAP/BREDEM for both temperature and energy consumption. A good calibration has been achieved between IDEAS and SAP for the two given modelled dwellings, one very well insulated and one poorly insulated.

**Heat Pump Performance Relationships and their Modelling**

One of the initial studies was to investigate the performance of 3 differently sized heat pumps with a varying ambient temperature (heat source). Using the manufactures specification data, a series of graphs relating COP and duty to the ambient temperature of the air were created. Duty is seriously low in areas of low ambient temperatures, with COP and energy provided following the same pattern. Therefore it is important to conclude that a heat pump does not perform well at low ambient temperatures, as more electrical energy is needed at the compression stage. These graphs were repeated for the larger heat pumps, the Bwarm 8000 and Bwarm 12000, and they also followed the same pattern, with the larger heat pump having a higher COP.

The model requires 2 values which are constant, which relate to the specific type of heat pump rather than a physical parameter value of the dwelling. Therefore, for each of the 3 heat pumps, these 2 values needed to be worked out. Once again using Excel, the relationship between COP and ΔT needed to be assessed. ΔT in this case is the difference between flow and outside temperature. For each of the 3 heat pumps in question, the relationship was drawn on a graph. (Figure 8.)

![Figure 8. Showing COP relationships against ΔT in degrees Celsius](image-url)
CASE STUDY

IDEAS Model Parameters from CAD Drawings
The case study involved a school 6th form student internship for Sean Counsell to be placed for one week in NORD Architecture. The student’s task was to study the CAD drawing of the planned refurbished homes, shown in Figure 9 to derive the IDEAS model coefficients using the building’s geometry and the construction material information.

![Figure 9: CAD plans for the refurbished homes](image)

The resulting coefficients compared with the original homes are listed in Table 1.

<table>
<thead>
<tr>
<th></th>
<th>Existing - Single Zone</th>
<th>Proposed - Single Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Wall Area</td>
<td>135.1</td>
<td>144.2</td>
</tr>
<tr>
<td>Wall to Outside Area</td>
<td>115.5</td>
<td>128.6</td>
</tr>
<tr>
<td>Wall to Outside U Value</td>
<td>2.1</td>
<td>0.23</td>
</tr>
<tr>
<td>Wall to Ground Area</td>
<td>19.6</td>
<td>15.7</td>
</tr>
<tr>
<td>Wall to Ground U Value</td>
<td>0.7</td>
<td>0.17</td>
</tr>
<tr>
<td>Window Area</td>
<td>29.9</td>
<td>39.5</td>
</tr>
<tr>
<td>Window U Value</td>
<td>4.027</td>
<td>1.62</td>
</tr>
<tr>
<td>Area of Roof</td>
<td>107.3</td>
<td>144.2</td>
</tr>
<tr>
<td>Roof U Value</td>
<td>2.3</td>
<td>0.175</td>
</tr>
<tr>
<td>Total Volume</td>
<td>344.7</td>
<td>615</td>
</tr>
<tr>
<td>Total Floor Area</td>
<td>55.15</td>
<td>92.5</td>
</tr>
<tr>
<td>Floor U value</td>
<td>1.2</td>
<td>0.17</td>
</tr>
</tbody>
</table>
Results

The Matlab model was run under with the Proposed Single zone parameters to produce the following performance results for the following systems:

System 1 = Gas condensing boiler (88% efficiency) using gas at 0.05p/kWh and a carbon intensity of 0.18 kg/kWh of gas with optimum start controls.

System 2 = A BWarm 8000 ASHP using a standard electricity and E7 tariffs with standard occupancy

System 3 = A BWarm 6000 ASHP using a standard electricity and E7 tariffs with optimum start controls

System 4 = A BWarm 8000 ASHP using a standard electricity and E7 tariffs with optimum start controls

System 5 = Direct Electric heating using a standard electricity tariff

System 6 = A BWarm 8000 ASHP plus 5kW of auxiliary heating using a standard electricity tariff with standard occupancy

For all electric systems the carbon intensity is assumed constant at 0.56kg/kWh. Economy 7 has an off-peak rate of 6p/kWh and on-peak rate of 16p/kWh and the Standard flat rate Electricity Tariff has a rate of 15p/kWh.

<table>
<thead>
<tr>
<th>System</th>
<th>Heat kWh</th>
<th>Fuel kWh</th>
<th>Standard Annual Cost £</th>
<th>Annual Cost E7</th>
<th>Off-peak split %</th>
<th>Seasonal Performance</th>
<th>CO₂ kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>18680</td>
<td>21227</td>
<td>1061</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3821</td>
</tr>
<tr>
<td>2</td>
<td>18630</td>
<td>6520</td>
<td>978</td>
<td>868</td>
<td>27</td>
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<td>6132</td>
<td>920</td>
<td>706</td>
<td>45</td>
<td>3.35</td>
<td>3434</td>
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<td>4</td>
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<td>962</td>
<td>730</td>
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<td>-</td>
<td>2.5</td>
<td>4183</td>
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</tbody>
</table>

Table 2. Matlab IDEAS simulation results for the 6 systems described.
From Table 2 it can be concluded that System 3 with a smaller heat pump using optimum start gives the best performance in terms of kWh consumption of electricity and consequently carbon emissions. Also the optimum start also brings the electricity use in line with Economy 7 off-peak periods so that 45% of the electricity can be utilised at off-peak rates. This is in part due to the air-tightness and of the refurbished home to allow the building to act as a thermal inertia so that the heat pumps radiator temperature can be reduced to deliver higher CoPs at the time of peak time electricity. Without this optimum start control two things result. First the CoPs of the heat pump are hugely reduced to just below 3 due to higher radiator temperatures being required to rise the house temperature more quickly and also there is a short fall in comfort since the maximum heating power in very cold weather drops off as the CoP reduces. Thus as in system 6 an auxiliary heater is required which in turn increases radiator temperatures thus bring even further reductions in the heat pump’s seasonal performance down to 2.5. The minimum size Heat Pump system with optimum start has outperformed the industry’s best practice solution of a gas condensing boiler.

Conclusions

For well insulated and air-tight refurbished home, a correctly sized ASHP system with correctly sized radiators could deliver 10% reductions in carbon emissions and but by utilising off-peak tariffs like Economy 7 could reduce running costs by 30% when compared with the industry’s best practice of a gas condensing boiler. However, with ASHP currently costing between £4k and £6k to install which is nominally £4k more expensive than a gas condensing boiler. Thus, the pay back in the case of the case study in this report is over 10 years. Moreover, the 10% improvement in carbon emissions could possibly be better achieved by spending the capital cost difference between the heat pump and the boiler on better wall and roof insulation or lowering the glazing U values by moving towards triple glazing.

References


BEST PRACTICE CASE STUDIES INVITED

As the next issue of Innovation Review will be the last one published by CIC Start Online project, we are inviting Scottish architectural practices to use this last opportunity to publish articles about their recent sustainable building or refurbishment projects in our online magazine.

The articles can be up to 3,000 words long and include up to 10-12 images. Images should be in JPG format and sent as attachments.

The submission deadline is 15\textsuperscript{th} February 2013. Please send the articles to branka@cicstart.org.
Refurbishment of a granite building to reduce energy costs

Bob Pringle

A project to improve the energy efficiency of a traditional two storey, three bedroom Aberdeen granite house during redecoration, over a period of six years, has reduced the annual energy bill by 40%.
A move to an 1890’s granite house in 2006, in Abergeldie Road, Aberdeen, following retirement, enabled me to use the newly purchased property as a test bed to optimise ways of reducing its energy consumption. By carrying out the energy saving measures when I was redecorating rooms anyway, it was hoped to keep costs to a minimum. I wanted to put my past work experience of designing farm crop stores, to make the house more comfortable, reduce energy bills and reduce our carbon footprint to help save the planet.

The previous house owners had reduced their energy bills between 1998 and 2005, from £2370 to £1840 (@ 2012 prices), by installing a condensing gas boiler, splitting the heating system into two zones so upstairs would only be heated prior to bedtime, replacing incandescent lights with compact fluorescent bulbs and installing roof insulation.

The subsequent reduction in energy costs from £1840 to £1,110, measured from meter readings over the six year duration of the project, involved replacement of doors and windows, extensive sealing of doors, skirting boards, and holes in room linings, replacement of some lath and plaster with insulation board, additional insulation in the loft, roof combs and under the ground floor and the replacement of an open coal fire with a multi-fuel stove. As I did the majority of the work, the improvements were costed assuming the work was done by tradesmen. The resulting capital expenditure that related to the energy conservation part of the home improvements, including VAT at 17.5%, came to £30,620 to achieve an annual reduction in energy bills of £730.

The emphasis for the refurbishment was to seal the internal envelope of the rooms, while ensuring wind pressure could ventilate the wall cavities behind. Fibre insulation above or below vapour-porous lath and plaster, which the cavity ventilation will dry out if wetted due to vapour transmission, was used in preference to board insulation. While some tradesmen involved in the work were technically very competent, others had little understanding of what was required and often said tasks were either not possible or not worthwhile. Work on this type of house is often dirty, confined and fiddly.

While the draughts have gone, the house is more cosy, and the windows, doors and general condition of the house has improved significantly, the payback period, based on the cost of energy saved, greatly exceeds the normally acceptable 10-20 years. Even if specialist contractors can streamline the work to reduce its cost, it is unlikely to be financially viable or to meet the golden rule of the government’s new Green Deal. We cannot simply knock these houses down to build more fuel efficient ones, yet the government is committed to reducing the energy use of our housing stock. While my wife and I feel our investment has made the house fit for our old age, others will simply move to get a warmer house, leaving the next owner with the problem of draughts and excessive heating bills.

To share this experience, and hopefully contribute to the reduction of the carbon emissions from similar old, hard to treat houses, I have produced a 68 page report, “Improving the energy efficiency of a traditional stone house”, available on line at the link. This describes the reasons for deciding what should be done, what materials were chosen and the problems that arose in doing the work.

https://sites.google.com/site/homeenergyrefurb/home
It should come as no surprise that building housing in Findhorn is a lot different from building housing in Glasgow and the central belt. We have government policies which try to encourage ‘a sense of place’ but in building social housing (or should I say when we were last building social housing), we are constrained by requirements set by funding agencies, local and central government which often conflict with trying to create such a sense of place.
The requirement for ‘adoptable roads’ means that housing layouts take more cognisance of the needs of refuse trucks than the people who might live there. Front gardens become paved over for car parking and soft landscaping is only used to fill in the spaces left over, rather than to create pleasant environments. Secured by design standards result in a preponderance of fencing with a landscape designed for surveillance rather than horticulture. In terms of achieving sustainability (much encouraged before by the now defunct Communities Scotland), providing the most economical unit often takes precedence over long term sustainability. We accept that meeting the more onerous Scottish Building Regulation Standards will do much to improve the energy efficiency of our houses. However leadership and direction is needed if our housing is to really take hold of a sustainable lifestyle, one where how we live is as important as what we live in.

Members of the Findhorn Foundation who formed the company ‘Duneland Limited’ have always been conscious of the need to build with nature, to reduce a building’s impact on the environment and to develop a sustainable community. The history of housing in the Findhorn Foundation has shown that they are able to put their ecological ideas into practical realities which work.

Twenty years ago I visited Findhorn and met with John Talbott who had written an excellent book called ‘Simply Build Green’. It described his experience of trying to build ecologically and it recounted both the successes and failures along the way. I learnt a lot from it and appreciated more than anything how he talked about why things did not always work. In this article I’d like to try to explain what I think Duneland are achieving and to touch on some difficulties that I feel everyone can learn from.

What is Duneland?
Since 1981, the Findhorn Foundation Community has been developing the Ecovillage within their ethos of working with nature, not against it. The Ecovillage at the park is a clear demonstration of how they have managed to combine the practical with the social, economic and spiritual aspects of life. In many respects it is a good example of what a community of people working together can achieve.

Duneland Ltd was set up in 1997 as a social enterprise company with 69 shareholders, 44 of whom are resident within 5 miles of The Park. The company purchased the land of the Wilkie estate with the combined aims of ensuring the protection of and public access to, the Dunes, maintaining and developing the existing woodland, while providing a reasonable return to its investors through appropriate development of the ecovillage project in cooperation with the community as a whole. In 2001 it founded the Findhorn Dunes Trust and donated 175 acres of this coastal land and marram grass landscape to allow it to be protected as a nature reserve in perpetuity and it is now also recognised as a site of National Importance for lichens http://www.findhornhinterland.org/ ecology/lichen-survey/.

Following a masterplan prepared by GAIA architects, an area of land known as the Magic Triangle area, north of the Community's "Universal Hall", was identified for development. We were appointed in 2009 to develop 25 houses with a range of mixed types: two and three bedroomed houses; some flats, a number of which will be rented out by Park Ecovillage Trust who are acting as a social landlord; a number of ancillary buildings such as a common room, where members of the housing ‘cluster’ can meet, cook and eat together and be involved in a variety of communal activities; a bike store, a laundry and 7 ‘flexi-units’.
The flexi-units were designed to be workspaces or offices that could be used by people living in the houses. Issues of rates and VAT meant that most of the flexi-units became integral with the houses they were connected to. However it did create a much greater variety of house types. This first phase (known as East Whins) should be completed by the end of this year by the contractor Kier Milne.

Process of Design and Procurement

It was clear from the start that both the Findhorn Community and members of Duneland wanted to be closely involved in the whole design process. There were a number of people who lived in Findhorn and whose skills and input we could draw on. Our approach was to start with 3 days intensive design workshops (or charrettes as they are now called). We would have meetings in the day to discuss different features, key requirements and criteria that Duneland wanted to meet, then in the evening, the design team would develop these ideas into different layouts and approaches. In this process Matt Bridgestock and John Gilbert worked with Chris Morgan of Locate Architects.

After the second day an approach emerged where the houses were to be grouped into small courtyards, protected from the prevailing wind but allowing maximum solar gain to each house. On the third day a design began to take shape placing the access road near the wooded area where it would be in most shade and having the housing in rows providing semi public courtyards, allowing the natural environment to filter in between the houses.

A housing mix was set along with targets for energy conservation and supply, ecology and material requirements. By the end of the three days we had formed a good brief for the project and people were enthusiastic about what could be achieved.

When I look back at this initial period I can see the items that did not come to fruition, as ideas had to be researched and developed then costed to ensure we could achieve affordable housing and still maintain the key features that would make the scheme an exemplar of sustainability. Some of these ‘lost’ features will be discussed in this article.

In addition to the initial design charette we had a number of meetings involving key critical friends such as Dr Sue Roaf from Heriot Watt University. Regular meetings were held with Duneland’s shareholders and the team managing the project. An open public meeting was held and designs and specifications were also approved by the Findhorn Community. The whole design process took 9 months before designs could be formalised sufficiently to apply for planning permission.

It’s worthwhile noting that funding for the development has really come from both Duneland and everyone who has bought into the project. Interested people placed a deposit on their house before anything was built and designs were developed knowing a number of individuals’ requests. We had one prospective owner, a Dutchman, who wanted all the doors in his house to be 100mm higher than our standard door heights because he was a tall person. Although he did not follow through with the purchase we were intending to have the door heights raised. (Interesting that the average height of men in the Netherlands is actually 8mm higher then men in the UK, which is maybe one of the reasons why european housing has higher ceilings than in the UK).

As a group, the occupants of the ‘cluster’ have all had the opportunity to meet and discuss the common features in particular the design of the community room and kitchen which looks over the ‘dancing green’.
A certain amount of risk was involved in this as once the building contract had been agreed, not all the houses had been sold. However once work started, people began to commit. In so doing they often wanted further changes to their house. Minor changes were usually not a problem, but later changes sometimes would have resulted in a claim from the contractor so had to be curtailed. As everyone wanted their own individual kitchen, an agreement was made with a kitchen supplier to work with each owner and provide the kitchen layout and specification, all to the individual’s own budget.

Given that our office is in Glasgow and Duneland is in Findhorn, we had to have frequent skype discussions over the design and individual specifications. However face to face discussions were always best and now that the work is on site we have had to get used to the long travelling time.

The Setting

Truly ‘duneland’, the site lies on ancient shingle ridges, since overgrown with gorse and before that used as part of an airfield for RAF Kinloss. To the West and North is a further expanse of dunes. The site was largely flat although it steps up towards the North where a row of houses steps up to follow the level of the dunes.

Further phases are planned for the site, to the North and to the West, so these had to be planned for when making access arrangements.

There is a band of trees to the South of the site which cast a shadow over much of the site in winter months, so houses had to be laid out to make best use of the low winter sun. Ridge heights were kept as low as possible to prevent shading of the houses behind, and to the south they were more steeply pitched to make most of the winter sun for the solar thermal panels that are fitted for each house.

The housing is principally designed around two main cluster spaces, acting as sheltered social spaces. These cluster spaces will have views out to the adjacent forest, the ‘dancing green’ and the dunes beyond.

As it was agreed at an early stage that the road would not be to an ‘adoptable standard’, being a private road managed by Duneland, we could reduce its width from 5.5 metres to 3.5 metres and also omit a two metre wide pavement. Parking bays (33 in number) are provided along the access road with the understanding that residents will mostly be walking or cycling to their houses. There should be no large fences, as the land around the houses is to be shared and managed by the people in the development. A small area in front and behind each house is distinguished as being more private with a small raised berm. This approach to the environment is refreshing: the lack of fencing allows the houses to relate to the natural surroundings.

The Houses

The design of the houses is influenced by the desire to create buildings which use little energy, produce low carbon emissions, and are products of simple and economic timber construction.

The houses are one and a half storey at the front to give a village scale and also to present a steeper roof pitch for the solar panels, optimised for the spring and autumn equinox, when the use of solar energy is most beneficial.

The houses have a low roof pitch at the rear to reduce overshadowing by reducing the height of the ridge, and to keep the building volume as compact as possible.

The gable ends of the terraces face on to the road, this arrangement has a similar character to traditional fishing villages along the Moray coast. This configuration also maximises privacy to residents and reduces overlooking of the central open communal area.
The character and identity of the development will be added to by the community, in the tradition of the existing Findhorn Foundation Community. The painted timber cladding in a palette of colours will give visual identity to the buildings.

The flats have the same design characteristics as the houses, but with a full two storey structure. The communal stairs spaces will be glazed front and rear. All the houses have a buffer space (lobby) with two doors. The south facing front lobby is designed as a sunroom and the rear north side is a utility space. Barrier free access is provided to all ground floor houses with metal gridded ramps which rise from the footpath level up to each entrance.

The ecovillage consists of 25 houses (all two storey) with the following mix:
10 No 2 bed houses
3 No 3 bed houses
12 No 2 bed flats designed for older people
6 No flexi-units each about 25m² (4 of which are integrated with adjacent houses) plus a large common room with facilities (85m²), bike store, workshop and laundry.

Construction
In the early days of design development we were very keen to try and source products locally. We considered using strawbale construction and had some meetings with the Modcell company who gave a talk to Duneland members. However it was soon evident that costs for its use, even although the panels could be made locally, were still a good deal more expensive than the target budget for the houses.

We also looked into using CLT (cross laminated timber) for the walls, roof and floors, but although we had used it successfully at the Scottish Housing Expo, it also proved to be too expensive. What we ended up with is a bit of a hybrid.

The walls are homegrown timber studs 220 thick with 60mm of tongued and grooved wood fibre covering the kit, finished externally with prepainted larch cladding (Scotlarch from Russwood).

The insulation is warmcell (recycled paper insulation) designed as a vapour permeable wall, used extensively in Findhorn. The prepainted larch boarding has been made in several different colours. We had considered using the pretreated Accoya cladding but found it was too expensive. Costs have always been a factor in the construction and one area we might have changed was the use of nail guns to fix the cladding. These are difficult to control and nails can often be punched too deeply into timbers.

The intermediate floors are solid timber CLT giving a largely clear span between cross walls. In the houses, the timber is left exposed as the ceiling finish, in the flats it has to be covered over for fire protection. The mass of the timber provides a good acoustic performance which we wanted to have for all the houses. It also introduces a degree of thermal mass and locks in carbon storage.

The roof cassettes were from 450 I beams. Originally designed to be filled with warmcell and fabricated entirely off site, but due to concerns over weight they had to be filled with glass wool and in some cases this was done on site. This proved to be not ideal. Our experience with the use of glass wool is that it rarely fills the space between the studs neatly. Gaps can be left and these are often not considered to be important by the person installing it, yet the effect on energy conservation is considerable. Voids can also be left because in very thick depths the wool can slump. Internally the roof cassettes had to be lined with two layers of Fermacell, a dense gypsum fibreboard, to meet acoustic standards because of the nearby airfield at Kinloss.
The foundation types varied, sometimes we had to dig deep to find a solid base, where we could use a raft foundation we used preformed polystyrene formers which are protected with cement board on one side allowing them to be left in place as a permanent shutter. This provides a very well insulated edge reducing the effects of cold bridging that can occur using more traditional methods. The overall thickness of the insulation under the foundations is 300mm.

The pitched roofs are finished in a treated steel sheet which can be recycled. The system looks similar to a zinc roof but is more economical.

We are able to fix the solar panels to the joint fins of the panels. The main disadvantage of the system is that any special welding or forming for outlets is not as easy as with zinc, jointing at such locations is more dependant on sealing with mastic or rubber fixings.

The community rooms that provide facilities for the residents have a flat sedum roof. Sedums are already growing in some areas of the site and we would like to encourage their growth on our roofs. There is however little need for surface water containment as water drains freely into the sand bed layers of the site.
Energy Matters

Our main drive has been to reduce the need for energy use by ensuring we have a very well insulated fabric and reducing air infiltration through the fabric. The houses are not designed as passive houses, but the insulation standards are nonetheless high: U values are as follows: walls 0.14 Wm\(^{-2}\)K, floors 0.08 Wm\(^{-2}\)K roof 0.09 Wm\(^{-2}\)K. The installation of 60mm of fibreboard insulation on the outside reduces the impact of cold bridging from the large timber studs and helps to improve airtightness levels. Assessing the buildings energy use and CO2 emissions gives the following figures:

<table>
<thead>
<tr>
<th>house type</th>
<th>area</th>
<th>energy use per m(^2) per annum</th>
<th>CO2 emissions per m(^2) per annum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground floor flat gable</td>
<td>68.67m(^2)</td>
<td>80 kWh/m(^2)</td>
<td>14 kg CO2/m(^2)</td>
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<tr>
<td>Ground floor flat terrace</td>
<td>74.76m(^2)</td>
<td>51 kWh/m(^2)</td>
<td>9 kg CO2/m(^2)</td>
</tr>
<tr>
<td>Mid terrace house 3 bed</td>
<td>105m(^2)</td>
<td>82 kWh/m(^2)</td>
<td>15 kg CO2/m(^2)</td>
</tr>
<tr>
<td>Mid terrace house 2 bed</td>
<td>95.5m(^2)</td>
<td>58 kWh/m(^2)</td>
<td>10 kg CO2/m(^2)</td>
</tr>
</tbody>
</table>

The passive solar design of the housing ensures that each house has as much sunlight as possible, with larger windows to the south and smaller windows to the north. Houses have been built with integral sun porches which are big enough for a couch (the individual’s requirement!). In the flats there are integrated sunspaces off the living rooms. Here we are using the Danish Windoor system which allows the frameless glazing to be opened out to create an open balcony. Some residents opted for a larger living room without a sunspace. On the ground floor flats, residents can connect directly to the front garden area.

The Findhorn Foundation has always acted well in advance of ideas on energy efficiency and renewable energy. The new development will get its electrical power from the local network (NFD New Findhorn Directions) which is fed by Findhorn Wind Park’s four community-funded turbines, which produce all the Community’s electricity needs and in fact have enabled them to be a net exporter to the grid (it should be noted that SAP calculations do not take into account the origins of the electricity).

We had originally considered installing a communal woodchip boiler, however once grants for this were withdrawn it did not make economic sense. The fact is, the more we insulate our houses the less energy we need to heat them. Had the funds (or grants) been available, then a common biomass boiler could have worked, providing energy not just to East Whins, but also for the Universal Hall and later phases of housing.

In the end we opted for air source heat pumps, one for each house, taking energy from the local network. Heat is then distributed through underfloor heating pipes.

Solar thermal panels are installed on all the south facing roofs at a pitch of 45\(^{\circ}\), these provide energy to hot water cylinders in each house, maximising gains from the spring and autumn sun. The panels are made locally in Forres by AES.
Some residents of the houses have requested an additional flue to allow them to fit a solid fuel stove. This was not factored into the buildings’ heating calculations at design stage, and may cause them some issues with overheating. This conflict highlights the differences between a more traditional mode of rural green living and the more high-tech low-energy approach being fostered by the green agenda.

The need for minimum levels of ventilation under the building regulations did cause a problem, as people in Duneland quite naturally did not want to have to have mechanical ventilation. They were happy enough to rely on opening a window when they were needing to. However installing a system of natural ventilation was going to be difficult as trickle ventilation at window heads alone would no longer meet the technical standards. It made little sense to install large vents through each wall, since we would be losing energy here. In the end we did opt for a mechanical heat recovery system which we hope will not interfere with residents’ lifestyle.

Unlike most housing developments, there is also a common laundry facility. This is integrated with a flexi-unit and the bike store. It has a drying room with large skylights to catch the sun and louvres for cross ventilation to encourage the drying of clothes within the laundry space.

**Conclusion**
The houses should be completed by the end of this year. We expect that people will add their own touches and start to plant and make use of the cluster spaces in between the houses. Time will tell how people settle in to their new houses and we will be keen to know how well the buildings perform in actual energy use. Given the state of social housing in Scotland we would like to see more developments follow this model.

### Development team

<table>
<thead>
<tr>
<th>Role</th>
<th>Company</th>
<th>Key Personnel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Client</td>
<td>Duneland Ltd</td>
<td>Bill Henderson, Jonathan Caddy, Ariane Burgess, David Hammond</td>
</tr>
<tr>
<td>Architect</td>
<td>John Gilbert Architects</td>
<td>Gillies MacPhail, John Gilbert, Matt Bridgestock, Nada Murtic</td>
</tr>
<tr>
<td>Structural Engineer</td>
<td>Fairhurst &amp; partners</td>
<td>Ashley Guy, Bob Ramage</td>
</tr>
<tr>
<td>Civil Engineer</td>
<td>Thomas Clarke Associates</td>
<td>Thomas Clarke</td>
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<tr>
<td>Services Engineer</td>
<td>Greenroom IKM</td>
<td>Neil Pearson</td>
</tr>
<tr>
<td>Quantity Surveyor</td>
<td>Torrance Partnership</td>
<td>Mark Stevenson, Graeme Lyon</td>
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<tr>
<td>CDM Coordinator</td>
<td>Torrance Partnership</td>
<td>Steve Ashbolt</td>
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<tr>
<td>Main Civil Engineering Contractor</td>
<td>International Associates Ltd</td>
<td>Thomas Clarke</td>
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<tr>
<td>Main Building Contractor</td>
<td>Kier Milne</td>
<td>Robert Forbes</td>
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<td>Clerk of Works</td>
<td>Duneland</td>
<td>Michael Sharpe, Simon Clark</td>
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<tr>
<td>Critical Friend</td>
<td>Heriot Watt University</td>
<td>Dr Sue Roaf</td>
</tr>
<tr>
<td>Critical Friend</td>
<td>Locate Architects</td>
<td>Chris Morgan</td>
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**Contract Value (including civil engineering works)**

| £3,907,095

**Total useable built area (all heated spaces, excludes laundry, workshop and cycle store but includes sunspaces)**

| 2537m² net

**Total footprint area**

| 1,936m²

**Total Site Area**

| 0.78 Ha

**Contract Period**

| 40 weeks
CIC Start Online Webinar Sponsorship

The outcomes of our feasibility studies are documented in a final report, and disseminated by means of a seminar which is also broadcast online as an interactive webinar. You can sponsor a webinar with one of three packages:

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Articles

Submission deadline for the articles for the next issue of Innovation Review is 15th November 2012. To discuss the article that you would like to submit, please contact us by email or telephone on the contact details provided below.

Innovation Review is published by CIC Start Online project.  
Contact: Branka@cicstart.org, +44 (0)141 273 1408