Low carbon headquarters for Scottish Natural Heritage
Introduction

Today, the built environment accounts for around half of all the UK’s carbon emissions. If we are serious about combating climate change, we need to start developing a new ‘low carbon’ building stock constructed to meet future requirements.

Creating buildings that generate fewer carbon emissions is not only socially desirable, they are also more pleasant to occupy, can cost little more to build than conventional buildings and offer significantly lower running costs.

Low carbon design principles involve minimising a building’s energy requirements by exploiting a range of passive heating, lighting and ventilation strategies. These will include:

- the use of natural daylighting
- the design of natural, passive ventilation rather than mechanical ventilation or air conditioning
- minimising the need for heat input through the design of a highly insulated building fabric
- selective materials with a high thermal mass to act as a heat buffer and to minimise temperature swings.

Great Glen House, Scottish Natural Heritage’s new headquarters in Inverness, has a floor area of 6,000m² and can accommodate up to almost 300 staff. The building was completed in summer 2006 and contains office space, library and public areas, meeting areas, labs, workshops and storage areas. It was designed to have an annual carbon footprint of 26.3kg/CO₂/m², 30% better than conventional best practice.

Great Glen House has achieved the highest BREEAM (Building Research Establishment Environmental Assessment Method) for Offices rating for a UK office building, scoring 84% and has been awarded the designation of Sustainable Building of the Year by Building Magazine. However, this was not an experimental project, carried out over a long period, or with extensive research funding. It was a commercial project, developer led, with an integrated design and build contract, working to strict cost guidelines, and to an extremely tight design and construction programme.

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Great Glen House was designed to meet a range of sophisticated technical outputs. But it has to be a good place to work as well - a place that helps us work together well and get things done in a positive atmosphere. It is satisfying to know that we are working in a building which is low carbon and contributes to the health of our environment, but it also brings real benefits for staff every day. The design revolves around creating a light, airy, open space which is also conducive to clear thinking and creativity - lots of glass brings transparency and clarity in many ways.

I do more talking face-to-face with colleagues than I used to, and send fewer e-mails. Everyone’s in open plan - the building needs it to work - and having only two sets of recycling bins and one printer on each floor encourages us to ‘walk the floor’ and meet our colleagues – people from all teams, jobs and levels – and all these quick ‘walk and talk’ catch-up chats are very productive - so I feel more in touch with what’s going on as well.

For example, the atrium is central to the success of the building’s efficiency and has quickly become a public space, where colleagues and visitors and the public can meet and interact.

We’ve learned a lot from developing this building and we’re still learning about working in it, which we can use to make our other offices better.

Business case

A low carbon building can make sound business sense. It will have a lower whole life cost, will protect the building value against future legislation changes, provide reputation benefits and offer a greatly enhanced experience for the occupier.

It is true that by specifying more insulation or higher quality, more energy efficient equipment, some elements of the capital cost will increase. This is offset by a reduction or elimination of equipment costs such as air handling plant, chiller plant, etc. and reduced installation costs. A further benefit of this approach is that it will require smaller plant rooms and service ducts, leading to either a smaller, lower cost building or a greater proportion of productive space within the same envelope. In the case of Great Glen House, it has been estimated that a low carbon building was achieved at little additional capital cost.

With careful operational management, this approach potentially offers significantly lower year on year operating costs through lower energy bills and reduced maintenance costs. In time, less plant will mean lower mid-life refurbishment costs.

A low carbon building will have increased value as a result of an increased probability that it will comply with future environmental legislation. Tenants, keen to enhance their environmental credentials, will increasingly seek out low carbon buildings leading to rental premiums. In addition to these financial benefits, owning or occupying a low carbon building that is responsible for less greenhouse gas emissions demonstrates an organisation’s environmental commitment and delivers an improved environmental reputation.

Importantly, there is an increasing volume of research evidence that naturally lit and ventilated spaces provide more people-friendly, healthy environments that boost productivity and moral. For instance, a Harris Research Centre Study found that 89%* of occupants prefer buildings without conventional air conditioning.

*The British Office Market: Occupier Preference, Richard Ellis/Harris Research Centre

Scottish Natural Heritage headquarters: Great Glen House
Site considerations and passive strategies

The site: Craig Dunain, Great Glen Way

Scottish Natural Heritage required a building that is in full accordance with their own advice on developments and therefore had minimal impact on the natural heritage.

The site put forward by Robertson Property Limited is part of a large old hospital site on the south-west outskirts of Inverness. The site has a regular bus service, good pedestrian and cycle access with recreational facilities in very close proximity. Given the site’s position on the border of open country and its proximity to Inverness city centre with visibility from the castle esplanade, it was important that the design was in sympathy with its surroundings.

In order to best utilise natural resources and site conditions, the building designer considered a number of orientation issues that affect the building’s energy use. These are as follows:

- shelter from prevailing SW winds
- solar shading to minimise glare from the south and west
- maximising heat gains from the east for solar preheat in the winter

Orientation treatment for optimum use of summer/winter sun
Low carbon buildings

Site considerations and orientation of a building are important factors when designing a low carbon building. Design decisions, such as the overall form of the building, the depth and height of rooms, and the size of windows, can have a great impact on the eventual energy consumption of the finished building. By selecting a site carefully and orientating a building to work with its environment, energy consumption can be minimised without compromising the comfort of occupants or the cost of the build. Some aspects of design affected by orientation and site selection are:

- maximising the capacity for natural daylighting and the average daylight factor
- reducing the potential for overheating
- maximising sunlight penetration whilst minimising glare
- accounting for prevailing winds, heat loss and exposure
- exploiting the opportunity for renewable technologies.

In some cases orientation choices can be limited in constricted city centre sites or due to access road restrictions. There is a greater challenge to exploit passive strategies in these circumstances but this is not impossible. The issues remain the same as stated above, but there will be a trade off in terms of what can be achieved.

The subject of site selection and orientation is a detailed one and requires more in-depth study than can be provided in this short case study. For guidance, please refer to the BRE publication Environmental Design Guide for naturally ventilated and daylit offices. Other guidance which may be of use and is freely available from the Carbon Trust website is ECG019 Energy Use in Offices, GPG287 Design Team Guide to Environmentally Smart Buildings and, for refurbishment projects, GPCS Naturally Comfortable Offices.
Fabric and form

Building form

Great Glen House was designed, in accordance with low carbon design principles, to meet the stringent carbon emission target set in the tender documents. The main office building is a highly insulated, three storey, post-stressed concrete structure which gets the benefit of concrete’s thermal mass whilst minimising the use of the material.

In order for passive strategies in ventilation and daylighting to work effectively, the office area is 15m deep and has 3.7m high ceilings with floor to ceiling windows on the east face. Light penetration of the office space is from both the windows to the east and the atrium to the west.

A 10 metre wide, timber framed glazed atrium runs parallel to the office accommodation on the west side which is an essential feature in the ventilation strategy. (See page 8 for more information on ventilation.) This is a multi-functional space that supplies air circulation to the building and allows daylight into the west side of the office spaces. By exploiting the greenhouse effect, heat will gather in the apex that will ‘drive’ the ventilation of the building.

Design considerations

Thermal mass

Buildings containing materials with high thermal mass, such as concrete, have a better ability to store heat and are thus very effective in combating overheating. The amount of heat a cubic metre of concrete can absorb in a single day depends on its constituent materials, its surface area and surface finishes. A modern office with false floors and ceilings, and lightweight wall coverings, will be thermally lightweight. Thermal mass can be introduced by building walls and ceilings using concrete, stone or blockwork.

In order to get the best results from a building with high thermal mass, it needs to be cooled overnight in summer. One way of achieving this is to install mechanically actuated windows that can be opened on those nights when cooling is necessary by the Building Energy Management System (BEMS). This would not occur in winter when we would want to conserve heat in the building.
Design considerations

Energy efficient design

In houses, the main strategy for saving energy is to reduce heating loads by increasing insulation and by controlling ventilation rates, for example by draughtproofing. To achieve larger, low carbon, non-domestic buildings such as offices, a building designer will also have to:

- consider both the depth of the plan and the ceiling heights to ensure passive cross ventilation operates satisfactorily
- consider the use of a thermal atrium or solar chimneys to drive the passive ventilation
- consider the building fabric, providing adequate insulation and thermal mass
- consider the depth of the plan to ensure high levels of daylight penetration and minimise electric lighting load
- provide balanced shading to avoid glare and summer overheating, whilst maximising uninterrupted natural daylight and winter heat gains.

Common areas, not continuously occupied, are on the west side of the building. The library is on the north west corner of the building, which opens out onto the atrium. It is naturally ventilated, using the atrium and clerestory level opening windows. There are manually operated windows in this area to allow user control and it is heated using underfloor heating. The library does not use thermal mass in the same way as the offices but instead uses its height, and the atrium, to ventilate naturally.

The wing on the west of the atrium contains meeting rooms, a staff restaurant, a gym, and the server and communications rooms, all linked by a sunny cloister. The services area, including the plant room and garaging for equipment, opens out onto the enclosed, sheltered courtyard. Solar water heating collectors are mounted on the south facing roof of the west wing.

Building fabric

The office area of Great Glen House is built using prestressed concrete floors with the undersides being exposed. This allows the ceilings to absorb peak daytime heat that can be released at night by opening windows to make use of free night-time cooling of the exposed concrete slab ceilings, slowing down the temperature rise in the offices the following day. During peak summer 2006 when it was 29°C outside, the SNH internal office areas maintained a temperature of 22°C.
Ventilation strategy

Natural ventilation and passive strategies

The relationship between building depth and cross section should be considered. Natural light and ventilation are available to occupiers who are within 5 - 7.5m of the perimeter, depending on the size and location of windows, as long as this distance is no more than 2 - 2.5 times the floor-to-ceiling height. This ratio between floor width and ceiling height is important if the ventilation is to work properly. Comfort in the space which is not within the perimeter zone has to be maintained using artificial light and ventilation, resulting in increased energy consumption.

The plan depth in office areas of Great Glen House is generally 15m. The finished floor to ceiling heights are 3.7m to allow for good air movement in the offices. This criteria fits within the recommended floor plan depth as all office area occupants are within 7.5m of either the windows on the east face or the atrium.

Great Glen House is naturally ventilated to control both temperature and carbon dioxide levels (ventilation is increased when CO₂ concentration exceeds 1,000 ppm) using automatically opening windows which are controlled via the Building Energy Management System (BEMS). In addition, to meet individual comfort needs of staff, all large, lower opening windows are manually operated to provide a degree of local environmental control.

Design considerations

Natural ventilation vs air conditioning

Natural ventilation is preferable to air conditioning for a number of reasons:
- uses less energy
- produces less carbon emissions
- less expensive to install and maintain
- reduces the amount of plant and machinery
- increased user satisfaction due to occupant control and openable windows

The figures below are sourced from ECON 19 and compare energy consumption and carbon emissions for offices.

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<td>133</td>
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<tr>
<td>CO₂ emissions (kg/m²/yr)</td>
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</tr>
<tr>
<td>Total</td>
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<td>39.0</td>
</tr>
</tbody>
</table>

Air simplicity

![Natural cross ventilation diagram]

Sufficient depth to permit natural air exchange
The design of Great Glen House incorporates the use of an atrium with four solar chimneys to draw cool air through the building. The roof of the atrium faces southwest and, from midday, the summer sun will heat the air in its apex. As cooling becomes necessary, the Building Energy Management System (BEMS) will open chimney dampers and automated window ventilators. The hot air within the atrium will escape via the chimneys and therefore provide suction to ‘draw’ fresh, cooler air through the office windows and across the office space into the atrium.

### Atrium from the south

**Design considerations**

**Atriums**

- They can be used to provide a light, airy common area for the building.
- They allow daylight to penetrate the building and provide a natural source of light in office areas.
- The heat, generated in the apex as a result of the ‘greenhouse’ effect, can be used to ‘drive’ passive ventilation through either a vent at the top of the atrium or a solar chimney.

**Solar chimneys**

Solar chimneys provide a stack effect which increases the velocity of escaping warm air and can therefore power natural ventilation systems. However, to work effectively, they need to be large enough to draw an adequate volume of air out of the building and be high enough above the building to generate sufficient velocity to provide the suction for adequate ventilation of the building. In practice, this means its outlet will need to be several metres above the highest floor it ventilates. The chimneys need to be provided with dampers that can be closed to retain heat within the building during cooler weather.
Heat control and provision

The building’s heating and ventilation systems need to operate in two distinctly different modes:

- In hot summer weather the building will need to be cooled - the ‘cooling’ season.
- In cold winter weather the building will need additional heat input - the ‘heating’ season.

Cooling

The building thermal mass is exploited during hot weather to assist with the cooling of the building. During the daytime, particularly for a few hours in the afternoon, the exposed concrete ceilings have the capacity to absorb excess heat, supplementing the cooling effect of the ventilation. However, this stored heat needs to be taken away overnight if the thermal mass is to be exploited once again the following day to absorb heat peaks. This is achieved by activating the ventilation systems at night using high level night vents. This allows cool night air to pass over the ceiling, drawing heat from the ceiling, before being vented from the atrium via the solar chimneys. See diagrams below.

Heating

One of the main objectives of the building’s design was to reduce the amount of time that active heating was required, and the design team’s aim was to reduce the heating season to 17 weeks. The building is a well insulated and air tight construction. Average U-values for the building envelope have been improved 15% on current Building Standards. The office areas of the building benefit from morning heat gains from the east, which help to pre-heat the building in advance of the start of the working day.

Outside the cooling season, the thermal mass of the building will be exploited to provide incidental heat storage in its structural floors to enhance the building’s heating season energy performance. The building also achieves air tightness levels 50% above current Building Regulations. This means there will be fewer draughts, and heat losses will be minimised.

The main source of heat is from high efficiency gas boilers which operate a wet central heating system through underfloor heating in the atrium and library, and radiators in all other areas. SNH did consider installing a biomass boiler but issues regarding security of fuel supply at the time (2003) meant the proposals were unfeasible. However, the heating system has been designed to accommodate a biomass boiler at a later stage and storage facilities for the pellets/chips have been considered. As a result, when the current boiler comes to the end of its useful life, it can easily be replaced by a biomass system.

Cooling 1: Excess daytime heat is absorbed by thermal mass
Renewable technologies

Great Glen House is a low carbon building and this has been achieved without the need for significant investment in renewable technology. This is because the primary aim of the building’s designers was to minimise its energy demand by exploiting passive technologies. By minimising the energy required to run the building, they managed to achieve the target of producing 10% of the building’s energy demand from renewable sources through the use of solar thermal hot water heating.

A feasibility study was carried out to determine which renewable energy options were suitable for the site. The outcome of the feasibility study was that solar thermal hot water was the most cost effective, efficient way to incorporate renewables into the building. Photovoltaics and small scale wind power were considered but were not adopted. However, provisions were made to allow these technologies to be incorporated in the future.

The solar thermal water heating system uses energy from the sun to pre-heat any hot water needed in the building. This provides between 65% to 85% of the building’s domestic hot water needs. It is located on the south facing roof of the west wing and is approximately 15 m². The system is a Schott evacuated tube system which uses energy from the sun to heat the building’s hot water to the required temperature. In winter months, the temperature of the hot water is topped up via energy from the gas boilers.

Solar thermal hot water

Solar water heating systems gather energy radiated by the sun and convert it into useful heat in the form of hot water.

Systems have been available in the UK since the 1970s and the technology is now well developed with a large choice of equipment to suit many applications. Solar water heating systems work alongside conventional water heaters to provide hot water.

There is a range of different system types and configurations for solar hot water systems. There are two different types of solar collectors: flat plate and evacuated tubes. Flat plate systems have an efficiency of around 30 per cent and are cheaper to install. Evacuated tube systems occupy a smaller area and have an efficiency of approximately 40 per cent but are generally more expensive.

Solar water heating

Cooling 2: Nighttime ventilation cools the thermal mass
Lighting

SNH brief for lighting

- Building has a plan depth of no more than 15m and ceilings are 3.7m in height to allow for adequate daylight penetration.
- Use best practice figure of greater than 4% average daylight factor with 0.4 uniformity. Compliance with EN12464 for visual comfort.
- Electric lighting should be 400 lux at the working plane, uniformity of 0.8 or better, 6W/m² power consumption.
- Must be in compliance with BS EN12464 which takes into account glare control, uniformity of light distribution, colour rendering, maintenance and the acknowledgment of the importance of daylight.

Daylighting and shading

Sunlight is both very intense and highly directional, and creates glare which is very difficult for the human eye to deal with. If we are to exploit natural light successfully, then it is necessary to manage glare. Great Glen House has been provided with external louvres on the south and west, the angle of which has been carefully calculated to allow adequate daylight penetration and solar heat gains in winter, and yet control glare and excessive heat gains in summer. Fortunately, the designers are helped in this matter because the sun’s elevation is low in winter and high in summer.

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<th>Design considerations</th>
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<tr>
<td>Lighting design</td>
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A successful lighting scheme, whether it is daylighting or electric lighting or, as is more usual, a combination of the two, needs to satisfy a number of often conflicting requirements. This means considering each of the requirements against the constraints, balancing one against the other until the best solution emerges. To facilitate this process, the ‘lighting design framework’ has been created which contains the following six elements (although others may need to be introduced for particular applications):

- visual function
- visual amenity
- architectural integration
- energy efficiency
- installation maintenance
- costs (capital and operational).

Source: GPG 272 Lighting for people, energy efficiency and architecture - an overview of lighting requirements and design

Electric lighting controls

Daylighting will not save energy unless lights are switched off when they are not needed, so appropriate switching controls are needed to realise energy savings. The choice of strategy for controlling lights depends on the type and duration of occupancy. However, as automatic control systems become increasingly sophisticated, their potential energy savings are not being fully achieved. This is often the result of the design philosophy not being clearly communicated to the building management staff. One key conclusion is that individual occupants or small groups should have control of their own local task lights.

Window and panel cladding distribution on the east face
Dynamic simulation modelling

Thermal, ventilation and daylight modelling of the building produced integrated feedback on energy, daylighting and natural ventilation, enabling the design team to observe interactions throughout the design process. For example, by using the results of the simulation, modelling designers were able to make provisions in the atrium and open plan areas for maximising natural daylight all year round whilst minimising the effects of glare. The modelling, using detailed Inverness weather and light data, was further enhanced to take into account global warming predictions for the next 25 years.

The daylight targets for the building were an average daylight factor of 4% (a very well daylit space) and a uniformity factor of 0.4. (The uniformity factor means that it must be well daylit throughout the floor plans and not just close to the facades with windows.) The modelling carried out in the design phase of the building demonstrated that the building met the daylighting targets set. The modelling software used was EDSL TAS.

<table>
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<th>Design considerations</th>
<th>Dynamic simulation modelling</th>
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Building planning and design is a difficult task derived from the interaction between form and fabric, service plant, control systems, occupants and climate. How can the performance of such a complex system be evaluated at the design stage when the building exists only as an idea? Energy modelling and simulation can help by allowing designers to create a virtual building in order to explore alternative design approaches. Essentially, simulation involves three steps:

- problem analysis and model creation
- simulation
- results analysis.

Once the model has been created, the building design can be changed to check how a change, for example intended to improve the daylighting performance of the building, will affect ventilation or thermal performance of the building.

The energy consumption, thermal/visual/acoustic comfort, passive/active solar potential, indoor air quality, environmental impact and much more can then be investigated. Energy efficiency opportunities can then be highlighted and designed into the building from the outset.

Electric lighting

The building is fitted out with T5 fluorescent tubes and high frequency ballasts throughout. There is a lighting management system which can control all of the lighting in the building, most of which is on daylight and occupancy sensors to minimise usage. The lighting is zoned in office areas to allow separate control, for instance the centre of the room will require more top-up lighting than the perimeter of the office space next to windows or the atrium. There is also manual local control for every four work stations to give occupants override controls to adjust lighting if required. The lighting system has been adjusted and fine tuned through seasonal commissioning, which SNH chose to undertake in accordance with best practice principles.

A comprehensive Building Energy Management System (BEMS) manages the energy in the building and provides monitoring data for energy usage to be compared with the carbon target set for the building.
Materials

SNH was clear on the importance of minimising the embodied energy from materials used in the building. To reflect this corporate commitment, the tender documents stated that the design needed to consider the environmental impacts of the materials used in the construction and operation of the building. Developers were required to meet the following targets as a minimum:

1. Specify, using The Green Guide to Specification*, A rated construction materials for the following key elements: external walls, windows, roof and upper floor slabs. Note: where a B or C material specification was essential to achieve the operational carbon target, this took priority over specification for minimising embodied energy.

2. Specify A rated construction materials wherever possible for all other building components.

3. Show significant use of crushed aggregate, masonry or alternative aggregates to deliver positive aspects of the design.

4. Demonstrate that timber and wood products, used in structural and non-structural elements, are obtained from well-managed sources, or utilise reused or recycled timber (including any temporary timber elements).

5. Procure products which do not contain ozone depleting materials and have minimal global warming potential except where there is no alternative. The following benchmarks should be achieved as a minimum:
   - All refrigerant types to have an ozone depletion potential of zero.
   - All refrigerant types have a global warming potential of below 5.
   - Specify insulating materials which avoid the use of ozone depleting substances and substances with global warming potential of 5 or more in either manufacture or composition.

The design team responded to this brief by specifying A rated materials for the external walls, windows and roof. Floor slabs were unable to achieve an A rating due to being concrete and an integral part of the heavy weight building structure providing thermal mass to regulate the temperature in the building. Slates from the original building were reused as external cladding on the stair towers.

Caithness stone was used on the atrium floor and A rated carpet for the main office areas. Timber, reclaimed from the original building, has been re-used in the new building for internal timber finishes. All new timber used in the building was from certified sustainable sources and the vast majority (350 tonnes of Scottish Larch) was procured from local estates and locally converted.

All demolition waste was segregated and catalogued in terms of destination and distance to destination. Fluorescent lights, sanitary ware, timber and radiators were all stripped from the original building and taken off-site for recycling. Construction waste was segregated on-site and all energy and transport emissions were logged as part of the environmental management system.

Scottish Larch cladding on the library

*The Green Guide to Specification is a book that assesses the environmental impact of construction materials, with A being the construction types with the least environmental impact.
## Technical information

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Please note that at the time of going to press, a post-construction review had not yet been carried out.
The Carbon Trust works with business and the public sector to cut carbon emissions and capture the commercial potential of low carbon technologies.

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