Summary Report

Garth House, Bicester

Low-energy, in-situ refurbishment of a historic building

Key results:

- Much improved comfort for the building occupants
- Energy Consumption reduced by 58%
- Carbon emissions reduced by 48%
- A doubling of the air tightness whilst improving the air quality
- Building remained in full occupancy during the works

Garth House received an innovative and energy saving refurbishment over the winter of 2013/14. This was followed by twelve months of detailed monitoring of the building's performance and occupants' satisfaction.

The project was funded by central government to research and develop solutions for low energy refurbishment of historical and non-domestic buildings.

Owned by Bicester Town Council, Garth House is an 1840s hunting lodge in North Oxfordshire. It is currently used as offices and for social functions such as weddings. The building typified the triple challenge of: reducing energy consumption; remaining sensitive to the historic character of the building; and minimising business disruption to the occupants during the construction.

The central approach of the project was to create a new and continuous thermal envelope around the building. This creates an insulated and air tight barrier that improves the internal environment by significantly reducing lost energy. This was achieved though a combination of innovative materials and methods of application. Additional ventilation measures were also installed to mitigate a risk of overheating and improve air quality.

The works were completed on time and within budget. The process caused greater disruption to the occupants than planned due to unforeseen problems associated with the old building . Greater integration of the project team could have reduced the impacts of these challenges.

The building was monitored for twelve months and the performance met and exceeded expectations.

Contents

"Garth House demonstrates how the energy efficiency of historic buildings can be significantly improved without destroying the external appearance or internal layout"

Council Leader

"The air quality is much better than it used to be. The MVHR has improved the air quality considerably from the way it used to be in both winter and summer"

Occupant

"The outcome is above what we expected"

Manager

The existing building

Victorian era Garth House was built as a hunting lodge in 1830. It is currently owned by Bicester Town Council and provides it, and other tenants, with office accommodation. Only the half in use by the council was refurbished . Garth House is in a conservation area of local historical importance and is well loved by the people of the town. However, the building is not heritage listed and therefore has no formal protection.

The construction of the building is solid brick and stone on the ground floor. The second floor and roof is timber with clay tiles. The ground floors are solid with no cellar. Phase one of the project involved extensive monitoring and environmental modeling of the existing building.

Key Findings of Existing Building Monitoring and Performance:

- High fuel bills
- Cold in the winter with heating on 24 hours a day
- Stuffy with many windows no longer opening
- Overheating in the council chambers and some offices during the sumer
- Little or no control of the internal environment

Context and funding

The refurbishment works were awarded funding as part of Innovate UK's Invest in Innovative Refurbishment programme and funded by the Department of Energy and Climate Change. Garth House was particularly suitable as it typifies the challenges faced in improving the older existing building stock of the UK.

The challenge

Improving the energy efficiency of Garth House had two primary challenges:

How to respect the historical character of the prominently located Victorian building. There are approximately three hundred and seventy-five thousand listed buildings in the UK and many more like Garth House with non-protected heritage importance. In order to meet carbon reduction targets it is critical to develop techniques that can improve the internal environment without damaging the historical character of the building.

How to minimise the disruption to the business activity of the occupants during the works. Typically, a refurbishment of this nature would require the whole building to be emptied and for the occupants to relocate for several months whilst the works are carried out. For many businesses this is simply not a practical or an affordable possibility.

In response to this the project team developed an innovative approach which integrated cutting-edge and traditional approaches.

The approach

The central strategy was to create a new airtight and continuous thermal envelope that carefully integrates with the existing structure. This ensures that only minimal heat and warm air escapes through the walls, windows, floors and roofs. This reduces drafts and improves thermal comfort. Key to the integration was the sensitive placement of the new elements that avoided the concealment or damage of historical features.

The measures were:

- Laser measured and CNC cut wall insulation
- Ultra thin aero gel floor insulation
- Sensitively designed internal secondary glazing
- Additional ceiling and roof insulation to link the insulation between floors completing the thermal envelope
- Works to seal drafts and leaky parts of the construction

The key innovation was WHISCERS™ (Whole House In-Situ Carbon and Energy Reduction System). It is an innovate technique to rapidly apply internal wall insulation whilst the building remains occupied. This is the first time that this technique has been applied to a non-domestic and historic building in the UK.

Laser measured and precision cut insulation

- Each room is measured accurately and quickly with a laser survey.
- The measurements are converted into a waste-reducing cutting schedule
- The rigid insulation boards (Kingspan K18) are cut and labelled accurately off-site
- The boards are installed rapidly on-site as a tightly fitting jigsaw
- This work can be carried out quickly whilst the rooms are still occupied

Ultra thin high performance insulation

The solid ground floor had a 10mm layer of aerogel insulation backed to 18mm chip board applied. This results in a minor rising of the floor level and only minimal height being lost in the room. This mitigates the need for costly and disruptive excavations without compromising performance.

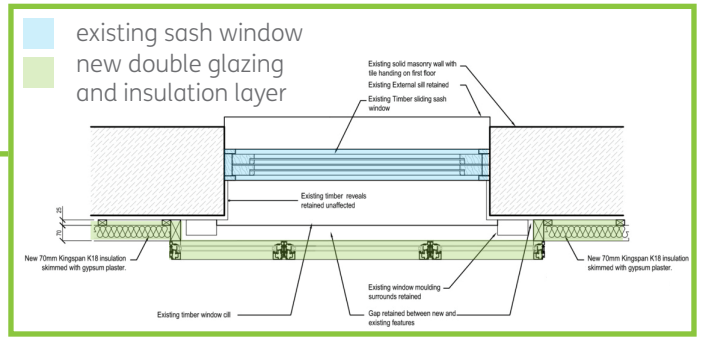
The product was Space Therm C from The Proctor Group.

Secondary Glazing

Double glazed timber windows were installed internally, behind the original single glazed sash windos. This ensured that all internal historical reveals and panelling were retained.

The new windows were designed so that the frames and glazing bars where proportioned and alligned with the original sash windows.

historic features retained behind secondary glazing

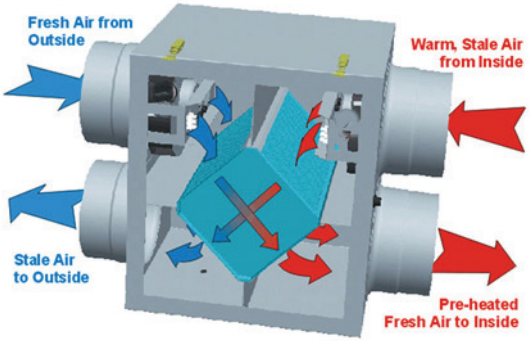


The new highly-insulated building presents a risk of overheating in the summer months. This overheating risk is set to increase due to the onset of climate change. Therefore, measures were put in place to mitigate the risk. These included:

- Reconditioning of the existing sash windows making them far easier to open
- Louvres in certain internal walls to allow cross ventilation
- Automatically opening louvres and roof lights to purge excess heat
- Mechanical ventilation system which recovers heat in the winter and removes hot air during the summer
- Occupant training and simple building user guides

heat dumps vent excess heat from council chambers

lourvres in internal walls allows for cross ventilation and passive cooling of offices



user training

MVHR unit with flexible ducting on 2nd floor

battens and secondary glazing prior to insulation installation

The installation

The installation was completed on time and within budget. Nevertheless, the innovative nature of the works and the historic character of the building made for a challenging installation.

As with all complex building projects it is important to ensure that all of the different measures are integrated and carefully planned. At various times unforeseen circumstances caused disruptions in the construction schedule. These included rearranged weddings, rising damp and discovery of structurally unsound timbers. This caused delays to the WHISCERS™ installation which requires the correct panels to arrive on site at the right time for the right room. When the WHISCERS™ installation went off programme it became very hard to finish one room before moving to the next. Out of hours working was required to bring the project back on schedule.

The WHISCERS™ installation was adapted so that the sub-framing of the windows could be installed first and then used as a reference for the laser measuring. This allowed for additional dialogue between the architect and the building occupants to ensure the new windows did not impede on the historical features.

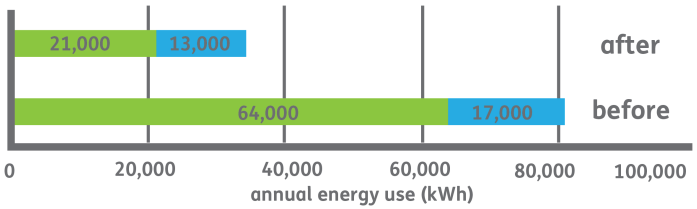
All of the individual innovations installed delivered as expected. Any difficulties arose due to issues of integrating the many different elements. This presented a challenge which required greater collaboration between the entire project team. These are classic problems of the construction industry. The key lesson learnt is that the opportunities of innovative technologies will only be completly realised if they are fully integrated and project managed with a high level of collaboration.

flexible ducting fitted through existing structure

secondary glazing bars aligned with existing arched window

Monitoring and evaluation

The impacts of refurbishing Garth House were closely monitored and evaluated by researchers from the Low Carbon Building Group of the Oxford Institute for Sustainable Development at Oxford Brookes University, to assess the energy use and environmental performance as well as occupant satisfaction before and after refurbishment. To verify the actual energy savings achieved, a web-based remote monitoring system was installed to monitor electricity and gas use, as well as indoor environmental conditions (temperature, relative humidity, CO_2 levels) and outdoor weather (temperature, humidity, solar radiation), every five minutes for twelve months after the refurbishment. The insulation improvements made to the building fabric were tested using air-tightness tests and thermographic surveys. Questionnaire surveys and interviews gathered feedback from occupants, including their levels of satisfaction.



Energy use before and after the refurbishment

The energy monitoring results show that the refurbished building is performing better than expected. There has been nearly 58% reduction in annual energy use and 48% reduction in CO_2 savings over the pre-refurbishment level. Gas consumption has reduced by 67%, while electricity use has reduced by 22%. Although no electricty saving measures were installed the reduction can be partly attributed to users becoming more

savings & reductions

48% CO_2 emissions

58% annual energy

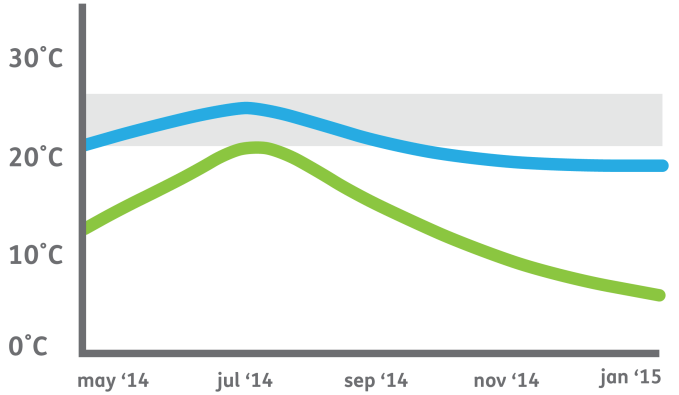
22% electricity usage

67% gas consumption

energy conscious because of the works. Before refurbishment, heating was on continuously, whereas post-refurbishment a strict heating schedule is applied with heating on only during occupancy hours. The air-tightness of the building fabric has improved greatly from 20.5m^3/h.m^2 to 10.6m^3/h.m^2.

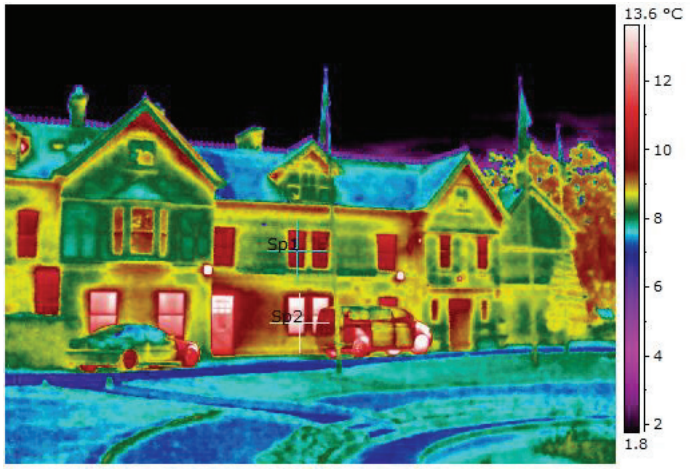
Examples of monitoring equipment used

The monitoring of the indoor environmental conditions has shown that following the refurbishment higher temperatures can be achieved in the rooms during occupied hours even though the heating is on for far less amount of time than before. This is a result of the reduction of heat loss through ventilation and fabric. Indoor temperatures in most rooms range between 15-23°C during winter and 20-26°C during summer. For the majority of the occupied hours, relative humidity was within the recommended levels (40-70%). Indoor carbon dioxide concentrations, used as an indicator of indoor air quality, were within acceptable (<1000ppm) levels in the rooms for most of the time after the refurbishment compared to before the refurbishment.



comparison of internal and external temperatures

Occupant satisfaction survey and interviews conducted after the refurbishment have revealed a very positive opinion of the staff members towards the building, as compared to pre-refurbishment. Most of the occupants find the spaces more thermally comfortable in both summer and winter, as evidenced by the considerably reduced use of individual heaters and fans. This accounts in part for the electricty reduction. Other aspects of the environment rated positively are indoor air quality, day-lighting and control over heating and cooling, including use of windows.



The thermograms show clearly the higher heat loss through the windows and walls of the section of the building that was not refurbished (bottom left)

Conclusions

The project demonstrated that it is possible to make significant energy-saving improvements in a historic building whilst in continuous occupation. The project was completed on time and under budget. There was more disturbance to the occupants than planned. This could have been avoided and the full potential of the innovative technologies could be achieved with greater integration in the construction process. Some material changes, proven in other WHISCERS™ installations, would have been needed to meet the greater stringency of heritage listed buildings.

The project met and slightly exceeded its energy saving targets. Occupants have responded positively to both the improvement of the internal environment and to the retention of historic features. Similar installations could be made more attractive to businesses should the improvement in productivity and well-being of occupants be made apparent. This could be an important incentive in addition to energy bill savings and reduced carbon emissions..

There would need to be policy changes in order to facilitate large-scale uptake of similar installations. Without these it is likely that the majority of similar projects would lack the capital and impetus to execute low energy retrofits in the number required to meet carbon emission targets.

- exceeding energy targets
- on time & budget
- positive building user feedback

Further information

The full report is available on Innovate UK's ***Connect*** platform:

tinyurl.com/hdm8vce or tinyurl.com/zomg93p

For further information on WHISCERS™ contact the National Energy Foundation:

www.nef.org.uk/service/search/result/whiscers

external appearance virtually unchanged

Acknowledgments

The project team would like to thank the Department for Energy & Climate Change and Innovate UK's Invest in Innovative Refurbishment programme for supporting this work.

Project partners

Bicester Town Council
Bicester Town Council is based at The Garth and is actively involved in many aspects of town life. Consisting of 15 councillors and meeting most weeks, Bicester Town Council strives to put its residents at the heart of everything it undertakes, from play areas to summer events, planning consultations to bus stops. Bicester Town Council has been proud to be part of this exciting project that has enhanced the beautiful Garth House for many years to come.

Key people: Sue Mackrell & James Porter
www.bicester.gov.uk

Bioregional – Project Coordination
Bioregional champions a better, more sustainable way to live. We work with partners to create better places for people to live, work and do business.

Our ambition is simple. We want to inspire people to live happy, healthy lives within the natural limits of the planet, leaving space for wildlife and wilderness. We call this One Planet Living. Bioregional developed the One Planet Living sustainability framework underpinned by ten principles covering areas such as health and happiness, carbon and transport, to deliver One Planet Living.

Key people: Alex Towler & Nicole Lazarus
www.bioregional.com

Ridge and Partners LLP – Architecture, Structural Engineering and Building Services
Ridge is an award winning, top 40 multi-discipline property and construction consultancy employing over 450 people in 10 offices across the UK.
Core disciplines include building surveying, cost management, project management, architecture, civil and structural engineering, building services engineering, health & safety, sustainability consultancy, property consultancy, legal support services, traffic and transport.

A dynamic, forward thinking practice, Ridge takes an innovative approach to delivering property and construction solutions for its clients worldwide. Ridge was founded in 1946.

Key people: Adrian Kite, Wayne Harper, Graham Blackburn
www.ridge.co.uk

Innovate UK
Innovate UK is the UK's innovation agency, accelerating economic growth. We know that taking a new idea to market is a challenge. We fund, support and connect innovative businesses through a unique mix of people and programmes to accelerate sustainable economic growth.

Key people: Mark Wray & Julie Meikle
www.innovateuk.gov.uk

Low Carbon Building Group (LCBG), Oxford Institute for Sustainable Development, Oxford Brookes University
The LCBG has an international profile in the field of carbon counting, building performance evaluation, post-occupancy feedback, low-carbon retrofitting and climate change adaptation of buildings and neighbourhoods. Its portfolio of research projects include the evaluation of building energy and environmental performance and occupant feedback in a wide range of domestic and non-domestic buildings, both new-build and refurbishments, and across various life cycle stages. The group's building performance evaluation (BPE) research has helped initiate, steer and develop Innovate UK's £8m national research programme on BPE. The group is a founding member of the national Building Performance Network.

Key people: Prof Rajat Gupta & Mariam Kapsali
www.architecture.brookes.ac.uk/research/lowcarbonbuilding/index.html

Contractors

Kingerlee – Principal Contractor

Proteam Asset Management – Specialist WHSICERS installer