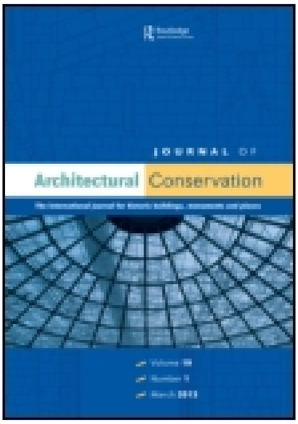

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Conservation and Innovation – The Challenge of 'Eco' Renovation in Heritage Buildings

Caroline Pankhurst and Andrew Harris

In November 2011 the National Trust opened a new visitor centre at Morden Hall Park, south-west London, which is expected to be the most energy-efficient historic building in the country. The Victorian stable yard has been renovated using high standards of restoration work and innovative technology to provide an interactive demonstration centre for learning about sustainable green living, building conservation and new energy-saving products. The goal was to retain the architectural integrity of the stable yard and to minimize intervention in its historic fabric, while introducing a significant number of new and compatible materials and technologies. It was specified that, where possible, materials must be of low embodied energy, from sustainable resources or recycled materials, locally sourced or from National Trust estates, and have a low environmental impact. The outcome is a building that is both saving and generating energy, while also informing and inspiring others to carry out 'eco' renovations in heritage buildings.

Introduction

The challenge of climate change requires that existing buildings are maintained and restored in a sustainable way. Sustainably renovated buildings contribute to carbon neutrality by saving energy, using natural (renewable) energy resources, reducing use of drinking water and using sustainable building materials. The Morden Hall Park stable yard attempts to address this while hoping to inform and inspire visitors. It seeks to increase their technical knowledge and awareness of more sustainable ways in which our buildings can be refurbished and the effectiveness of retro-fit renewable energy.

The stable yard at Morden Hall Park was considered by the National Trust to be ideal as a demonstration building because its Victorian construction mirrored that found in the countless rows of homes and businesses making up suburban Britain. The cut timber roof covered with Welsh slates, buff coloured solid brick walls and timber sashes are all familiar elements with householders and building professionals alike. The project brief included the requirement that the materials and technologies incorporated into the stable yard should be directly transferable to visitors' homes, ensuring that the stable yard is both informative and relevant. The stable yard (Figures 1 and 2) provides a community exhibition space, National Trust offices, craft stalls (Figure 3), a café and eco-toilets (Figure 4).

The renovation formed part of the Livinggreen.eu project, a partnership of five European countries carrying out eco-renovation projects in heritage buildings with the aim of encouraging others to maintain their architectural heritage. Partners are renovating a sixteenth century mansion in Delft, a nineteenth century warehouse in Lille, an old brewery in Antwerp and a former military gymnasium in Ludwigsburg. Further details of the wider project and its lessons learnt can be found at www.livinggreen.eu.

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Figure 1. View of Stable Yard through clock tower. (Credit: Louis Sinclair).

Figure 2. Clock tower and photovoltaic panels. (Credit: Louis Sinclair).

Figure 3. Craft stalls in stable stalls. (Credit: Louis Sinclair).

Figure 4. Innovative toilet with sink in cistern. (Credit: National Trust Picture Library/Jon Whitehead).

National Trust Morden Hall Park

National Trust Morden Hall Park is situated in south-west London. Every year over 750,000 visitors enjoy the meadows, rose garden and Snuff Mill – and now the new energy-efficient stable yard with its Livinggreen exhibition. The Park is located in the London Borough of Merton, already famous for Merton Council's groundbreaking 2003 'Merton Rule' planning policy, aimed at reducing carbon dioxide emissions in the built environment.

For many years the stable yard, built *c.*1879, was an attractive feature of the Park but inaccessible to visitors, being used inefficiently as a park maintenance area. The stable yard is not listed, but is recognized by Merton Council as being of local historical and architectural interest, and is within the curtilage of several other Grade II listed park buildings. The project sought to provide a more sustainable long-term use for the area to help ensure its ongoing maintenance and conservation.

Selecting a suitable design team

The National Trust's project team were conscious that the selection of the right team of external consultants to design and administer the works would be key. The Trust had previously worked with many consultants who specialize in new 'eco build' projects and equally, many who are experts in conservation. However, for this project the Trust needed to engage consultants who had a subtle blend of both disciplines, which appeared to be at opposing ends of the spectrum.

Open invitations for expressions of interest on procurement websites, advice from the National Trust's Architectural Panel (an advisory board of highly respected professionals from outside the Trust) and nominations of suitable practices from the Trust's Environmental Practices Advisers from across the country produced a long list of potential consultants. Following an initial evaluation, a Pre-Qualification Questionnaire was sent to a shortlist of suitable architects, structural engineers, mechanical and electrical (M&E) engineers, quantity surveyors and construction, design and management (CDM) coordinators. Following further detailed evaluation of the submissions, fee tenders were invited on the basis of individual briefs for each discipline.

Submitted fee tenders were evaluated and independently scored by members of the Trust's project team against a range of criteria. Interviews for the role of architect and lead consultant were held at each of the practice's offices to enable the proposed team to be met and to gain some insight into how each practice was set up and worked. Interviews were followed by the taking up of references.

Fee levels were by no means the determining factor in securing a consultant's appointment. Consultants were evaluated using nine equally weighted criteria which included cost, relevance and quality of previous projects, and demonstrative understanding of both sustainability/environmental issues and conservation. Indeed, in accordance with National Trust procurement rules, the project team had to seek written approval from the Trust's Head of Procurement Team to appoint one preferred consultant, who was significantly more expensive than the lowest fee tenderer, because they scored higher in other evaluation criteria.

Although all individual consultants were appointed by the Trust, the architect and lead consultant was responsible for design coordination liaison with the professional design team. Consequently, once engaged, he attended the interviews for the other consultants and provided valuable input into the appointment of the rest of the professional team. This worked extremely well in that a balanced approach was taken to the appointment of external consultants and the architect had real influence over the selection of likeminded professionals with whom he would be working closely over the course of the next two years.

The appointment of the professional team was a long, involved process in which the project team invested much time. Consideration had been given at the outset to inviting fee tenders from suitable architectural practices who would be responsible for assembling their own team of subconsultants and submitting a single fee bid for all services. However, not only was it considered to be more cost-effective for the Trust to appoint and manage individual consultants directly but also the Trust would then have direct control over the selection of such consultants, deemed to be so vital to this project.

The individual appointment of consultants and their subsequent management also took up a great deal of the Trust's project manager's time. However, the Trust believes the benefits have justified this investment. The team of consultants appointed have proved that they possessed the right mix of innovative thinking and clear commitment to sustainable refurbishment, yet demonstrated a clear understanding and sensitive approach to conservation. Although the architect had no direct contractual relationship with the other consultants, he took the role of lead consultant seriously and managed the team well, ensuring good design coordination and liaison.

Design decisions

At an early stage in such a complex project with numerous considerations needing to be taken into account in all design decisions, the Trust's internal project team and external design team struggled at times to make consistent design choices. It soon became clear that a concise set of guiding principles had to be distilled from the consultant's individual briefs. In consultation with all parties, a project 'mission statement' was developed and adopted by all parties. Contained on one side of A4 and in bullet point format, the key objectives of the project were set out along with the criteria against which decisions should be assessed. The production of the 'mission statement' was found to be extremely valuable and provided a concise, useful reference point throughout the project in guiding difficult decision-making and ensuring consistency.

Architectural conservation

Retention of the architectural integrity of the stable yard was the guiding principle underpinning all decisions relating to interventions in the fabric of the building and the incorporation of new materials and technologies. Consequently, very little change was made to the elevations of the building other than removing modern interventions and reinstating them to match the original.

Fenestration was key to maintaining the aesthetic of the stable yard. It was also crucial for the design team to demonstrate to visitors that original timber sash windows can be retained and upgraded without the need for wholesale replacement with PVC-U double-glazed units, as is so often the case in refurbishment of domestic properties.

The original single-glazed sash windows were found to be in generally good condition and were retained, refurbished and draught-proofed. To demonstrate a range of options, the original panes of single glazing were replaced with either super thin 6.2 mm thick double-glazed units (U-value = 1.5) or 12 mm thick sealed double-glazed units (U-value = 1.9), all installed within the original glazing rebates and thus not detracting from the appearance of the original sashes.

A number of other original windows were refurbished and retained, with their thermal performance upgraded by the installation of sealed secondary triple glazing. These high performing tilt and turn units were installed on the inside face of the walls, at the rear of the window reveals.

The importance of preserving the openness of the original cart sheds was also recognized as an important element in the stable yard's aesthetic. This openness was retained by the introduction of large triple-glazed, argon-filled sliding glazed panels (Figure 5 and 6). The sourcing and installation of the large doors did cause some challenges; they had to be sourced from Portugal as they are not currently available in the UK. This took longer than anticipated, as the initial lifting tool chosen to install them was found to be unsuitable and so an alternative had to be found, causing a slight delay.

Figure 5. Triple glazed sliding doors to Livinggreen exhibition and wood burning stove. (Credit: Louis Sinclair).

Figure 6. Cart shed door hinge and reflection of clock tower in triple-glazed doors. (Credit: Louis Sinclair).

Figure 7. Original ventilation turret being refurbished and photovoltaic panel. (Credit: National Trust Picture Library/Jon Whitehead).

The original timber ridge mounted ventilation turrets, which were a feature of the original stable yard, were conserved and reused according to their original intended purpose (Figure 7). The addition of electric actuated dampers within the turrets means that these now control a passive ventilation scheme. However, the system has proved to be largely ineffective in the office areas. Heat build-up from occupation and office equipment, coupled with the high levels of insulation and relatively low areas of free ventilation, has resulted in uncomfortably warm working conditions in the office areas on many summer days. Conversely, over the winter period these high levels of retained heat have meant that for much of the time, additional comfort heating has not been necessary. With the benefit of hindsight, it would appear that the original ventilation turrets are too small and there is insufficient cross-ventilation to provide sufficient free ventilation in the office areas to dissipate the build-up of heat effectively.

Strategy

Planned as a demonstration centre for sustainable refurbishment, the Trust's project team wanted to incorporate as many different sustainable materials and renewable energy sources as possible. In conjunction with the design team, a Sustainability Options Appraisal took place where all possible options were raised and subsequently evaluated against a range of criteria including capital cost, payback, practicality/complexity, visual impact and transferability into visitors' homes/businesses.

Alongside this, sustainability targets were identified based on current typical practice, good practice, best practice and pioneering standards taken from Building Regulations, 'Zero Heating Standard' values (BedZed), etc.[1] These targets included U-values for each building element, levels of on site energy generation, daylighting, ventilation and biodiversity. It was concluded that the project would aim to meet the challenging standards adopted by the project team.

For example, the target U-value (area weighted) for walls was to be 0.14 W/m^{2}K at a time (2009) when typical practice in new build was to achieve 0.35 W/m^{2}K.

At the beginning of the design phase and to set a benchmark, the energy demand for the stable yard was assessed on the basis that it be refurbished to the Building Regulation standards prevalent at the time (2009). The annual load for such a refurbished building was calculated to be 122,020kWh.

Following the design stage, the calculation was re-run based upon the proposed refurbished stable yard being insulated to the project team's challenging standards with very low energy demand. The revised annual load was calculated to be 83,330kWh, saving almost a third compared to the Building Regulation standard applicable at that time. With the space heating and hot water load being met by solar thermal, the wood stove and air source heat pump, the primary energy to be provided by electricity was calculated to be 56,627 kWh per year.

Energy generation

The project team aimed to monitor and demonstrate to visitors a range of renewable energy sources, including solar, that could be directly compared both in terms of aesthetics and performance.

From the outset, there was clearly tension between preserving the architectural integrity of the stable yard and introducing large arrays of solar panels on the roof slopes. This was somewhat relieved by the presence of large, original glazed roof lights in one section of inner-facing roof which interrupted the flow of the roof slopes. The existing roof lights mitigated the impact of introducing new solar arrays and, following consultation with the Trust's Architectural Panel, the design team was asked to incorporate the solar technologies into the roof slopes to make them as discreet as possible.

Options to recess the solar panels in the roof slope by 'notching' out the rafters below while re-roofing were investigated but ultimately ruled out. This was because replacement of the original rafters with new larger sections would have been necessary to retain the rafters' structural integrity to support the roof and new panels. Not only did this have significant cost implications, but from a conservation point of view, would have seen the loss of much of the roof's original fabric. Such an intervention would also not be practical in visitors' homes.

In the end, with the roof being counter battened, a good proportion of the solar panels' depth is taken up within the thickness of the roof build-up, thus reducing their visual impact. Integrating the panels in the roof slope did raise concerns about heat build-up in the west-facing photovoltaic (PV) panels compromising efficiency. However, initial monitoring of energy generation has shown that this is not necessarily the case.

Advantage was taken of the south, east and west roof slopes facing the inner stable yard to enable the three different solar technologies described below to be compared from a single viewpoint.

Photovoltaic slates

A total of 324 individual PV slates occupying 17 m^2 and designed to look like traditional slate roof tiles were mounted on the east-facing roof slope. Although located on a sub-optimal roof slope, they were calculated to produce 1,325 kWh per year. The PV slates have the advantage of blending well with the surrounding roof slates and are therefore appropriate for use in more sensitive locations (Figure 8).

Photovoltaic solar panels

Twelve PV solar panels occupying 18 m^2 were mounted on the west-facing roof slope. These were anticipated to produce 1,510 kWh per year (Figure 7).

Figure 8. PV slates. (Credit: National Trust Picture Library/Jon Whitehead).

Figure 9. PV-T panels, café tables and original windows. (Credit: Louis Sinclair).

Figure 10. Air source heat pump in cycle shed with living green roof. (Credit: National Trust Picture Library/Caroline Pankhurst).

Photovoltaic thermal (PV-T) panels

A total of 22 PV-T panels occupying 31.4 m^2 were mounted on the south-facing roof slope (Figure 9). PV-T panels are combined photovoltaic and solar thermal panels with PV cells on the surface and thermal collectors below. Not only do these combined panels produce two different sources of energy from a single panel (reducing space requirements on a roof) but they also work together beneficially. The efficiency of PV panels reduces in temperatures greater than 25°C, but in PV-T panels, the thermal collectors below reduce the heat in the PV cells increasing performance while producing hot water. This array was calculated to produce 12,570 kWh of useful heat and 3,400 kWh of electricity per year.

Heat generation

A 14 kW air source heat pump (Figure 10) supplies a thermal store which feeds an underfloor heating system (see below). The use of a ground source heat pump was discounted since one already serves the café located elsewhere in the park.

A 13.7 kW wood burning stove is fitted within the exhibition area (Figure 5). This not only provides comfort heating (4.5 kW) but is fitted with a back boiler, providing hot water (9.2 kW). Chosen for its sustainable source of fuel, the stove uses wood from the Park's regular tree maintenance works.

Underfloor heating

Underfloor heating was installed throughout the stable yard because it was the most suitable method of providing good levels of background heating and the least visually intrusive. Heating pipe work is laid in 45 mm thick clay plates overlain with a very thin mesh and screed. These plates are made from recycled crushed bricks (chosen for their recycled nature) and are loose laid directly on the structural slab. The clay plates have the advantage of enabling the heating pipework to be laid very close to the floor surface, reducing significantly the lag between the call for heat and it being delivered within a room. They also have an inherent high thermal mass. To ensure high levels of user control, the underfloor heating system is split into nineteen individually controlled zones.

The installation of the underfloor heating and associated insulation necessitated the removal of all existing floors. Some floors were found to be modern concrete while others had original brick pavers laid on sand. In all cases, the original Staffordshire Blue stable pavers and patterned pavers were taken up carefully, drainage channels, etc. recorded, cleaned and reused.

The excavation of the floors and new drainage necessitated an archaeological watching brief. An initial desktop study had revealed the likely presence of earlier structures within the footprint of the stable yard building. Allowance was therefore made within the contract specification for the contractor to accommodate modest disturbances as a result of any archaeological discoveries. This ensured that, when the foundations of previous structures were revealed within the western range of the stable yard, there was good cooperation, allowing the structures to be recorded without disruption to the programme.

Insulation

For obvious aesthetic reasons, external insulation was completely discounted at the outset, leaving internal insulation as the only acceptable option. Of paramount importance was the material's compatibility with the existing building fabric. Fully aware of the potential risks of introducing a large build-up of insulation on the inner surface of a solid brick wall, interstitual condensation risk analysis was undertaken for each product. This produced a short list of feasibile insulation materials (Table 1).

The choice of insulation to use in which area was driven largely by cost and the need to demonstrate a broad range of materials in the visitor areas. The cork (Figure 11) and recycled wool carpet were evenly distributed across walls to public areas of the building. However, the Aeorogel insulation (Figure 12) was very expensive and was therefore confined to very limited wall areas such as circulation spaces. The original plan was to install two different types of roof insulation in the public areas, but owing to post tender budgetary constraints, hemp-based insulation was used almost throughout as this was the most cost-effective.

Consideration was also given to the risk of damp at the base of the walls which, having been built *c.*1879, contained no damp-proof course. Early suggestions that a remedial damp-proof course should be injected into the base were firmly ruled out by the Trust's project manager. A strategy of good drainage, low external ground levels and retaining high levels of structural breathability was adopted to manage any elevated levels of damp which might occur.

In addition, some walls were found at the initial design stage to have been covered internally with either an impervious cement render or gypsum-based plaster. Clearly, these had to be

Table 1. Comparison of wall insulation properties.

Wall insulation material	Insulation thickness (mm)	Wall U-value (W/m^2K)	Cumulative wall vapour resistance (GNs/kg)
Cork	250	0.14	29.10
Recycled wool carpet	240	0.13	113.91
Aerogel	95	0.13	16.73

Figure 11. Cork insulation. (Credit: National Trust Picture Library/Jon Whitehead).

Figure 12. Aerogel insulation. (Credit: National Trust Picture Library/Jon Whitehead).

removed to maximize breathability before new insulation could be installed. Despite encouraging results from initial confined investigations to assess how easily these coverings could be removed, it became apparent when works began to remove these coverings that some areas adhered solidly to the background brickwork. Not only did this result in unexpected additional cost but it also had programming implications. Although the contractor took care in removing the hard finishes, unavoidable damage occurred to some areas of soft brickwork. As a result, extensive lime mortar repairs had to be undertaken to provide a suitable even base to which the insulation could be installed, without voids and air pockets. More extensive investigation of the render in different locations around the stable yard at the design stage would have enabled greater planning for this issue, which would have helped the smooth running of the contract.

The roofs were insulated with 300 mm of a natural hemp-based product achieving a U-value of 0.12 W/m^2K. The original rafters, which were some 100 mm deep, had to be increased in depth to accommodate the 300 mm thick insulation required. Rather than raise the height of the roof slope and therefore alter its appearance externally, the increase in depth was accommodated internally. With the high ceilings throughout the stable block this was not a problem, but in a domestic situation, this would require careful thought and detailing if such high levels of insulation were to be achieved.

Despite the design team being aware at an early stage that some insulation materials were on long lead-in times and the contractor ordering them in a timely fashion, there were many problems with insulation not being delivered on time, ultimately leading to delays at critical points. While this might not necessarily affect material choices on future projects, it should be taken into account when planning such projects.

Problems were experienced with the installation of the flexible insulation batts due to the soft nature of the bricks to which they were to be fixed. It was originally anticipated that the batts would be fixed directly to the brickwork. However, initial pullout tests of the fixings failed. This was eventually overcome by fixing the first layer of batts directly to the wall and then introducing an inner, solidly fixed timber studwork to retain the first layer and support the second layer. Not only did this incur additional expense and cause a slight delay to the programme, it may have also compromised the overall performance of the insulation across the wall.

The stable yard is primarily a demonstration building aimed at informing and inspiring visitors to improve their own properties and not a scientific experiment. Therefore, no means of monitoring or analysing the performance or moisture content of the upgraded fabric was specified by the project team at the design stage. If deemed to be of real use in the future, perhaps to help inform similar Trust projects, determination of in situ U-values, material moisture measurements and comfort/fabric risk analysis could be undertaken.

Air tightness

To reduce air leakage, all junctions and construction joints were detailed carefully by the architect. In addition, an intelligent membrane was used to provide a vapour check to both walls and ceilings (Figure 13). This innovative product, which has humidity-variable permeability, provides very low diffusion permeability in wintertime when the pores are closed and very high diffusion permeability in summertime when the pores open. Hence, in winter the membrane helps protect the building fabric from increased moisture levels and in summer it facilitates the rapid drying out of moisture from the structure.

All junctions and penetrations through the intelligent membrane were meticulously taped and sealed using the tapes and gaskets specified by the manufacturer. The contractor placed two dedicated, directly employed operatives on this task who were not under the pressure of working to a fixed price, thus ensuring that the high levels of workmanship required were achieved.

An extremely good result from pressure testing was anticipated following the high degree of attention paid to detailing junctions and penetrations. It was somewhat disappointing that, when

Figure 13. Intelligent membrane. (Credit: National Trust Picture Library/Jon Whitehead).

the building envelope was pressure tested at 50pa, it achieved 8.10 $m^3/(h.m^2)$. This is well below the current Building Regulation standard for modern new build (10 $m^3/(h.m^2)$) but should be seen in the context of a structure built *c*.1879.

Energy performance

One year on, the solar PV technologies have only generated some 4,266 kWh per year compared with the predicted 6,235 kWh. Monitoring has revealed that the performance of two of the PV technologies (PV-T and PV slates) is much less than expected. Conversely, the electricity produced from the PV panels is currently exceeding expectations (Table 2).

The low levels of energy generated by the PV slates are of particular concern. The specifying consultants and manufacturers have inspected the installation and confirmed that there is nothing fundamentally wrong with the installation that would account for such disappointing performance.

Table 2. Solar energy generation.

	South-facing PVT	East-facing PV slates	West-facing PV panels	Total
Predicted peak output (as designed) (kW)	3.4	1.78	2.52	7.7
Predicted annual useful heat generated (as designed) (kWh per year)	12,570	–	–	12,570
Actual annual useful heat generated (kWh per year)	3,187	–	–	3,187
Predicted annual electricity generated (as designed) (kWh per year)	3,400	1,325	1,510	6,235
Actual annual electricity generated (kWh per year)	2,138	420	1,708	4,266

The energy level produced by the PV-T panels is also of concern. Predicted to have produced 12,570 kWh per year of heat, meter readings after the first year reveal that only a quarter of the heat expected has actually been produced. Similarly, the electricity generated by the panels is significantly less than expected. This is currently being investigated.

The monitoring of the energy generated by each technology has proved useful in not only determining performance but has also had an unexpected benefit in identifying problems. What were anticipated to be relatively straightforward installations have, in the majority of cases, failed to generate the levels of energy anticipated. This raises questions as to whether the efficiency of the technologies is somewhat overstated or whether the standard design calculations are over-optimistic. While manufacturers' claims are based on laboratory testing, the finding does give rise to doubts about how accurately these calculations reflect real life installations given the vagaries of the British weather and site-specific constraints. It is very disappointing that energy generation by two of the solar technologies should be so much less than expected.

On balance and despite the poor performance of two of the solar technologies, the visual intrusion has been worthwhile. The project team is not aware of anywhere else where visitors can see and directly compare at first hand the aesthetics and relative performance of three different solar technologies in a historically sensitive environment. The PV slates in particular have generated much interest and debate among the general public and professionals visiting the stable yard. The project set out to inform and inspire visitors and that is exactly what has been achieved. Now that the first annual generation figures are available, informed choices can be made by those inspired to install solar technologies in their own local homes and businesses.

Meter readings taken during the first year reveal that the building used only 48,545 kWh compared with the 56,627 kWh originally expected. Although on the face of it, the building is performing better than expected, further analysis of electricity consumption to try to account for the difference makes it clear that so far the building has been used differently to that anticipated at the design stage. For example, energy calculations for the café assumed it would be open almost every day of the year, but in practice it has generally only been open five days a week or less during school term-time. As a large energy user, this has clearly impacted on energy demand. At the design stage, it is important that a realistic assessment of likely building usage and therefore energy demand is made.

Other considerations

The sourcing of suitable materials in this country was a challenge. For a 'green' project, the need to source many materials from abroad with the carbon emissions associated with transport over long distances has been a matter of much debate. It would have been more satisfactory if all products and materials could have been sourced in this country. Unfortunately, many of the high-performing and sustainable materials and products could only be sourced in Europe. Ultimately, the importance of demonstrating the use of high-performing and/or sustainable materials that work with the fabric of an historic building, and which effectively reduce its energy consumption, took precedence over the location they were sourced from. As a result of greater awareness from projects such as this, it is hoped that demand from homeowners and businesses in this country for high-performing and sustainable materials will increase, resulting in products that should become more widely available and be produced more profitably in this country.

The project team and consultants spent a considerable amount of time discussing how the materials and technologies could be sensitively incorporated into the historic building while minimizing interventions and retaining the building's architectural integrity. Such work was often abortive when practical solutions that satisfied all criteria could not be found. When working on such a project that combines so many new materials and technologies, this aspect should not be underestimated, particularly when it comes to consultants' fees. When fee tendering for a project in a competitive environment, it is difficult to balance the desire to win the job with allowing sufficient time that realistically reflects the innovative nature of such a project. Although a clear and comprehensive brief will help to avert claims for additional fees, it is not clear how, in a competitive environment, this can be adequately quantified on innovative refurbishment projects.

Conclusions

The correct choice of building professionals proved crucial in addressing the unique challenges of sustainable refurbishment of the stable yard at Morden Hall Park. Although time-consuming, the considered approach taken to the selection of consultants is thought to have been the right one, with a direct correlation to project outcomes. In addition, by not necessarily appointing the cheapest consultants but those who brought the right blend of demonstrable experience in both sustainability and conservation, is considered to have paid dividends in the longer term.

Energy consumption at the stable yard has been even lower than predicted. However, it is clear that actual usage of energy has been different to that on which design assumptions and calculations were based. This has made it difficult to assess how the building is actually performing in terms of energy efficiency.

Energy generation figures for the solar technologies over the first year are generally disappointing, although the PV panels on the west-facing roof slope are currently exceeding expectations. The clear disparity between the performance of the different technologies and the original design calculations has raised fundamental questions about how such figures are arrived at. It is difficult to know whether manufacturers need to adjust their data on energy generation figures using real data from projects such as this, or whether the computer programs used to design installations need to better reflect individual site constraints and the changing weather patterns experienced in recent years.

The challenge of 'eco' renovation in heritage buildings is clear. Yet National Trust Morden Hall Park has shown that it is possible to overcome the challenges with outstanding results in some aspects of the project:

- The building is generating and saving considerable amounts of energy.
- Over 30,000 people visited the stable yard exhibition in the first year.
- The project has won a number of awards including the RICS London Design & Innovation Award 2012.
- The project was awarded a Building Research Establishment Environmental Assessment Method (BREEAM) Excellent rating in January 2013.

It is hoped that all visitors, whether architects, building professionals, businesses or home owners, will be informed and inspired to carry out their own 'eco' refurbishment and to live 'greener' lives, while also retaining the historic and architectural integrity of the historic built environment.

Biographies

Caroline Pankhurst BA (Hons)

Caroline Pankhurst is the Livinggreen Project Coordinator for National Trust Morden Hall Park. Her background is in sustainable international development, environmental project management and local community development.

Andrew Harris BSc (Hons), MRICS

Andrew Harris is a National Trust building surveyor who managed the construction and building aspects of the Morden Hall Park Stable Yard project. Andrew is a chartered building surveyor and has managed a number of major National Trust conservation projects across London and the south-east.

Note

1. Housing Energy Effiicency Best Practice programme (HEEBPp), *BedZEd – Beddington Zero Energy Development, Sutton*, General Information Report 89, BRECSU, Garston, Watford, UK, 2002. available from: www.bioregional.co.uk/files/publications/BedZEDBestPracticeReport_Mar02.pdf.