

The following report is an official output from the Carbon Trust-funded Low Carbon Buildings Performance (LCBP) research programme 2006 - 2010. Twenty three projects were awarded DECC grants for testing the application of renewable energy systems in non-domestic buildings. Five building post-occupancy reports were written by BSRIA's Roderic Bunn in 2011. They were reported in *Building* magazine but never hosted anywhere else. Roderic Bunn has reproduced the original reports for the Usable Buildings Trust as free downloads.

North Wales Police headquarters

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by Roderic Bunn



The business of law enforcement is not all about criminals and flashing blue lights. The average felon creates a lot of paperwork. The police need offices to handle this bureaucracy just like any other public sector organisation.

And like many bodies in the public sector, the police are still using offices that go back 40 years or more. Where a commercial business would have long since migrated into something more appropriate for 21st Century working, public bodies are often forced to struggle on with outmoded buildings.

The 4267 m² administration building for North Wales Police (NWP), located in Colwyn Bay, was typical of the breed: a 1970s leaky and draughty concrete-framed building with high solar gains, especially on the South and West facades. It consumed a lot of energy and delivered very poor comfort conditions.

The building at least had some pretensions to energy efficiency. The mostly cellular offices were predominantly naturally ventilated, and only corridors and core areas were mechanically ventilated. The office heating was very 1970s: inefficient warm air convectors. There were no local controls on the heating system, so in winter the rooms either got too hot or too cold. Due to the highly glazed facades and the lack of solar control glazing or external shading, overheating in summer was a major problem.

The decision was taken to refurbish the building rather than demolish it. The client's requirements centred on resolving the wide-scale summer overheating problems, and

improving the heating system in winter. The project also involved general modernisation of the working environment.

As the existing boilers were recent modular units, innovative technologies like biomass boilers and ground-source heat pumps weren't needed. In any case these technologies (especially ground-source heat pumps) are not easy to retrofit for reasons of space and access. Solar water heating was also rejected, as the hot water demand of the administration block is very small.

The refurbishment began by improving the performance of the building envelope – specifically insulation and fabric airtightness. External solar shading and glare control were similarly important, as, of course, was reducing the building's energy consumption and carbon dioxide emissions – both of which were poor. Had the old building been studied for a Display Energy Certificate, the outcome would have been an 'E'.

The Carbon Trust was involved with the refurbishment from feasibility stage through to operation – a six-year period – as a case study within the Trust's Low Carbon Building Accelerator (LCBA) programme. The object of the exercise was to identify the key successes and challenges associated with a low carbon office refurbishment.

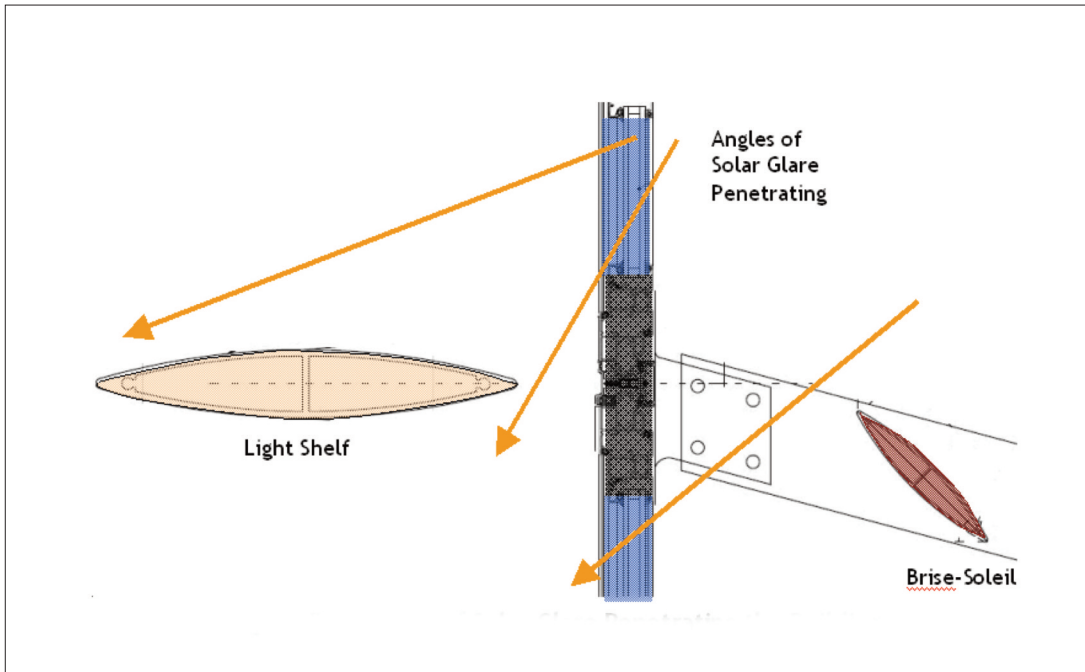
Procurement

The budget for the refurbishment was set at around £2.4 million. North Wales Police appointed Capita Symonds as the Project Manager with the design team comprising FSP Architects, Buro Happold, WS Atkins, and Faithful+Gould.

The construction phase was beset by severe delays, and the targeted completion date moved from October 2007 to August 2008. The major problems were a fire in the roof plant room, and the liquidation of the main contractor, David MacLean, in October 2008. The appointment of the replacement contractor, City Build, inevitably led to further delays in procurement and construction.

Commissioning was repeatedly delayed. It eventually took place at several times from September 2009. Commissioning days were often cancelled or postponed as other works needed to be completed.

The original planned construction period for the refurbishment was estimated to take nine months. As of February 2011 (four years on), building handover had still not taken place. All in all, not the smoothest of projects.



Angles of solar glare calculated to enter the building.

Environmental design

There was a commitment to reduce carbon emissions had been signed at the very beginning of the design by all the project stakeholders. The main focus of the design was to reduce solar gains to ensure summer comfort without mechanical cooling, and to reduce heat losses and improve lighting – both in terms of daylighting and in the provision of electric lighting.

The building's external walls, roof and the windows were all improved to meet the insulation standards of *Part L2A* 2006. The proportion of glazing was reduced by the addition of insulated spandrel panels to reduce heat losses in winter and solar gains in summer. A target air permeability rate of $7 \text{ m}^3/(\text{h}\cdot\text{m}^2)$ at 50 Pa exceeded the minimum *Part L2A* requirement.

The extreme temperatures experienced in the old building –in excess of 34°C – were significantly above the threshold temperatures for offices. High temperatures during the night and at weekends indicated that heat accumulated during the day was not being purged.

A system of brise-soleil solar shading was provided for the East, South and West facades. Combined with the reduced area of glazing, the brise soleil reduced the solar gains enough to avoid the need for mechanical cooling and for the natural ventilation strategy to be retained.

Windows were replaced with units that provided a manually openable bottom pane and a motorised toplight, the latter under the control of the building's building management system (BMS). This provided user control of natural ventilation during the day, and a purge cycle at night run by the BMS.

The glazing itself is of clear low-E double glazing, with a maximum window U-value of $1.9 \text{ W}/\text{m}^2\cdot\text{K}$.

The designers opted to separate the two windows by an internal light shelf designed to reflect daylight to the ceiling, assisting in the penetration of daylight and improve the consistency of daylight across the room. The electric lighting is controlled by occupancy sensors, and is automatically dimmed using daylight detectors. The lighting load was

driven down to between $10\text{--}12 \text{ W}/\text{m}^2$ by using low energy fluorescent lighting.

While the eight Stelrad modular boilers were still serviceable, the heating emitters, distribution system and controls all needed upgrading. Out went the inefficient perimeter warm-air convectors, and in came radiators equipped with thermostatic radiator valves, enabling individual control of room temperature by the occupant. The building was split into 16 weather-compensated control zones, with local fine-tuning via the TRVs.

The old distribution circuit was replaced by a primary constant-temperature circuit serving a distribution header. This supplies four variable temperature secondary circuits, and a constant temperature pumped secondary circuit. The only air-conditioned areas are the ground floor conference rooms and computer suites.

The building management system (BMS) was replaced, incorporating standard building controls, optimum start/stop, multiple scheduling and multiple zoning throughout the building, and weather-compensation control.

On advice from the Carbon Trust's advisors Hoare Lea & Partners and Environ, North Wales Police set a carbon dioxide emissions reduction target of 20 per cent over the old building. This target was based on the modelling of various options undertaken by both the NWP design team and the Carbon Trust. It was considered to be a minimum standard that the design team were encouraged to exceed.

The 20 per cent target included the computer suite's emissions, which were not covered by the refurbishment project. If the computer suite's emissions are excluded from the total, the 20 per cent reduction target would correspond to a 38 per cent reduction in emissions for the rest of the building.

Ultimately the building was designed to achieve a 30 per cent emissions reduction. This meant the annual electricity consumption of 910,000 kWh needed to be cut to 604,000 kWh, and annual gas consumption slashed from 405,000 kWh to 88,000 kWh. In carbon dioxide terms, total annual emissions aimed to be cut from 463 kgCO_2 to 273 kgCO_2 .

Initial building performance

The Carbon Trust was keen to make sure that some key elements of the NWP building were commissioned properly. The Trust issued good practice commissioning guidance notes covering window actuators, heating zone actuators, meters and sensors, daylight and PIR sensors, and the building management system.

Room temperature loggers installed in two rooms showed that the refurbishment has reduced summer room temperatures by approximately 1 - 2°C compared with a comparative period of weather for the old building. The reduction in maximum temperatures is significant (greater than 5°C at peak times). The survey also demonstrated that internal temperature does not increase substantially throughout the day.

Measurements show that the building's ventilation rate has been improved through the openable sash windows and the automated high-level windows. In contrast, the night cooling has been less successful. In practice the windows have only been opened for one to two hours in the morning and evening due to security risks, the building operators may be able to open the windows for longer periods during the peak summer months if they can win support from the security department.

Despite the brise soleil, building users initially suffered glare problems. The combined brise-soleil and light shelf were found to be ineffective at blocking the sun at certain angles. A gap between the light shelf and the window was wide enough to enable solar rays to penetrate into the office. The lack of a blind for the toplight caused the glare.

Also, the height of the top pane window and/or the width of the light shelf itself were not appropriately sized: low solar angles would penetrate the room and disturb occupants seated next to the room back wall. Again, the lack of an internal blind didn't help. Some building users found it necessary solve the problem by taping strategically-positioned sheets of cardboard to the toplight.

The problem was treated as a defect by the sub-contractor, and the difference between the design drawings and the installation were managed and fixed. The gap between the light shelf and the top pane window was reduced in accordance with the tender drawings.

The lighting was originally commissioned to deliver 500 lux. NWP reduced this to 300 lux as the lighting was deemed too bright. This gave a quick win in terms of reducing energy consumption.

Energy use

Figure 1 shows the calculated energy consumption breakdown for the refurbished building against the building's Energy Performance Certificate and various benchmarks. The administration building can be classified as an *Energy Consumption Guide 19 (ECON 19) Type 1 building*: a naturally-ventilated cellular office.

The designers intended the energy consumption of the refurbished building to be lower than the *ECON 19* benchmarks for a good practice and typical practice naturally-ventilated office. The reductions are primarily due to reduced lighting energy consumption, more efficient control of the space heating, and better use of natural ventilation. Energy-hungry desk-top fans are no longer required. Overall, the building is performing approximately 24 per cent better in electrical energy consumption compared



The external brise soleil and internal light shelves.



Some building users found it necessary solve glare problems by fitting sheets of cardboard to the toplight.

with the old building.

Electrical energy is dominated by the computer suite. This suite serves the whole police force and is not only dedicated to this building. It is also a process load that was not included in the building's refurbishment works. If the computer suite energy consumption is removed, the reduction in energy use jumps to 26 per cent.

However, as Figure 1 illustrates, electricity usage is around 22 per cent higher than the design prediction – a 128 MWh disparity. Current performance also shows that the administration block consumes 288 MWh more gas than expected, an approximate 350 per cent increase over the design prediction.

The energy data comes with a health warning, especially the figures for gas consumption. Delays to the project caused difficulties for energy monitoring, and therefore the accuracy of the carbon dioxide calculations. NWP environmental team manually recorded the electricity consumption from installed electricity meters from approximately May 2010 on a monthly basis. As part of this process, it took them a number of months to locate all of the meters on-site.

The building is equipped with six gas meters, nine heat

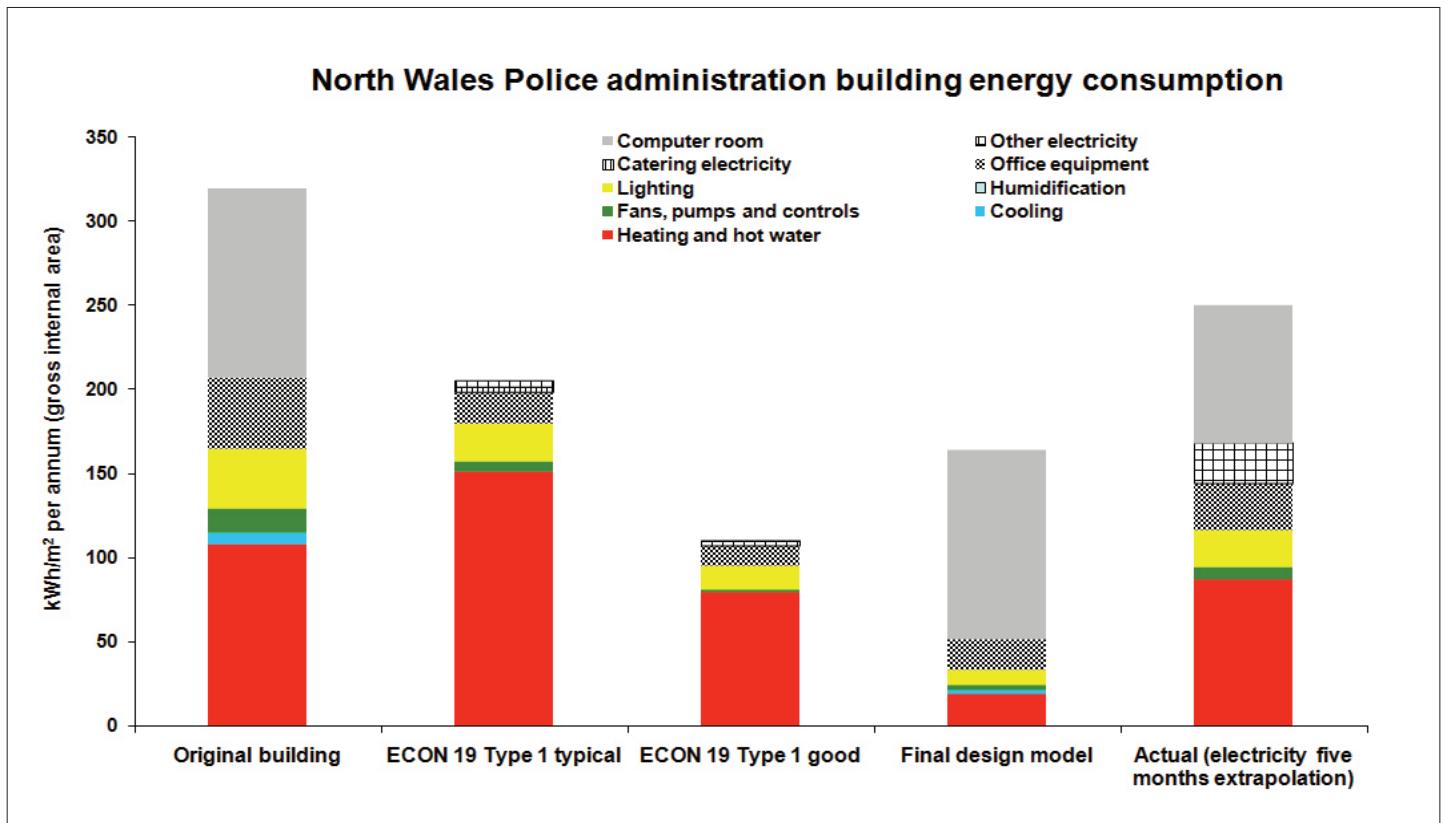


Figure 1: Energy breakdown of the NWP administration building compared with relevant benchmarks and the design prediction. Consumption is based on a gross (treated) floor area of 4267 m².

meters and 68 electricity sub-meters. Thirty-three internal temperature sensors and an external weather station enable the monitoring of internal and external conditions. Despite this provision, early analysis of the data found discrepancies in the way energy use was being reported.

Depending on the meter, the Carbon Trust's research team had between two to seven months end-use electricity consumption data. And (approximate) building energy consumption breakdown was only available for two months.

The kilowatt-hour meter readings for the small power and lighting sub-meters, located in the east riser on the ground to the third floors, were found to be multiplied by a factor of 10. The small power and lighting sub-meters in the west riser are the same type of meter as those in the east riser, but these meters have no multiplication factor. This indicates a discrepancy in meter calibration that needs to be addressed.

Heat meters installed to measure the performance of the heating system have also malfunctioned. For example, the heat meters serving the East and West zones sometimes spin in reverse. Until the problems are rectified the readings from all four heating risers cannot be trusted.

If the computer room energy consumption is excluded from the energy total, the electricity consumption at NWP HQ could be lower than *ECON 19* good practice and typical practice benchmarks. That said, the building would still require some form of computer room, even if it was located off-site.

While gas consumption has fallen by 9 per cent compared with the old building, the new system has a number of defects that prevent it from performing as well as it could. Once the problems are fixed and the heating system re-commissioned, gas consumption could be more in-line with the 'typical' benchmark (Figure 1).

Even so, the Carbon Trust monitoring team believe that gas consumption is unlikely to reach the levels predicted at the design stage, as the thermal models did not take into account energy losses caused by external doors and windows remaining open (and similar inefficiencies that stem from normal day-to-day building operation). The team suspects that a programme of seasonal commissioning could drive a 10 per cent reduction in pump and fan energy consumption and an additional five per cent drop in gas consumption.

Although the BMS is recording data from the various meters and sensors, it is just being pooled within a large data folder. If the BMS was reconfigured it could be used to help track energy consumption and identify areas for further cuts.

Carbon dioxide emissions

The computer suite emitted 44.6 kgCO₂/m² before refurbishment. As this was a process load not included in the refurbishment emissions were predicted to stay the same. In the event, measured emissions dropped to 44.6 kgCO₂/m².

Excluding the computer suite, the building's overall carbon dioxide emissions are 18 per cent lower than the old building (Figure 2) - a significant improvement. However, the large disparity between the modelled prediction of a 47% reduction and actual performance begs serious questions of the validity of the modelled values, and the process by which energy and carbon dioxide targets are created.

Carbon dioxide emissions due to gas consumption are 17 kgCO₂/m² per annum compared with 20 kgCO₂/m² per annum. This is an improvement, but nowhere near the estimation of 3 kgCO₂/m² per annum. Similarly, emissions due to electricity use are 44.6 kgCO₂/m² per annum compared with the design estimate of 18 kgCO₂/m² per annum.

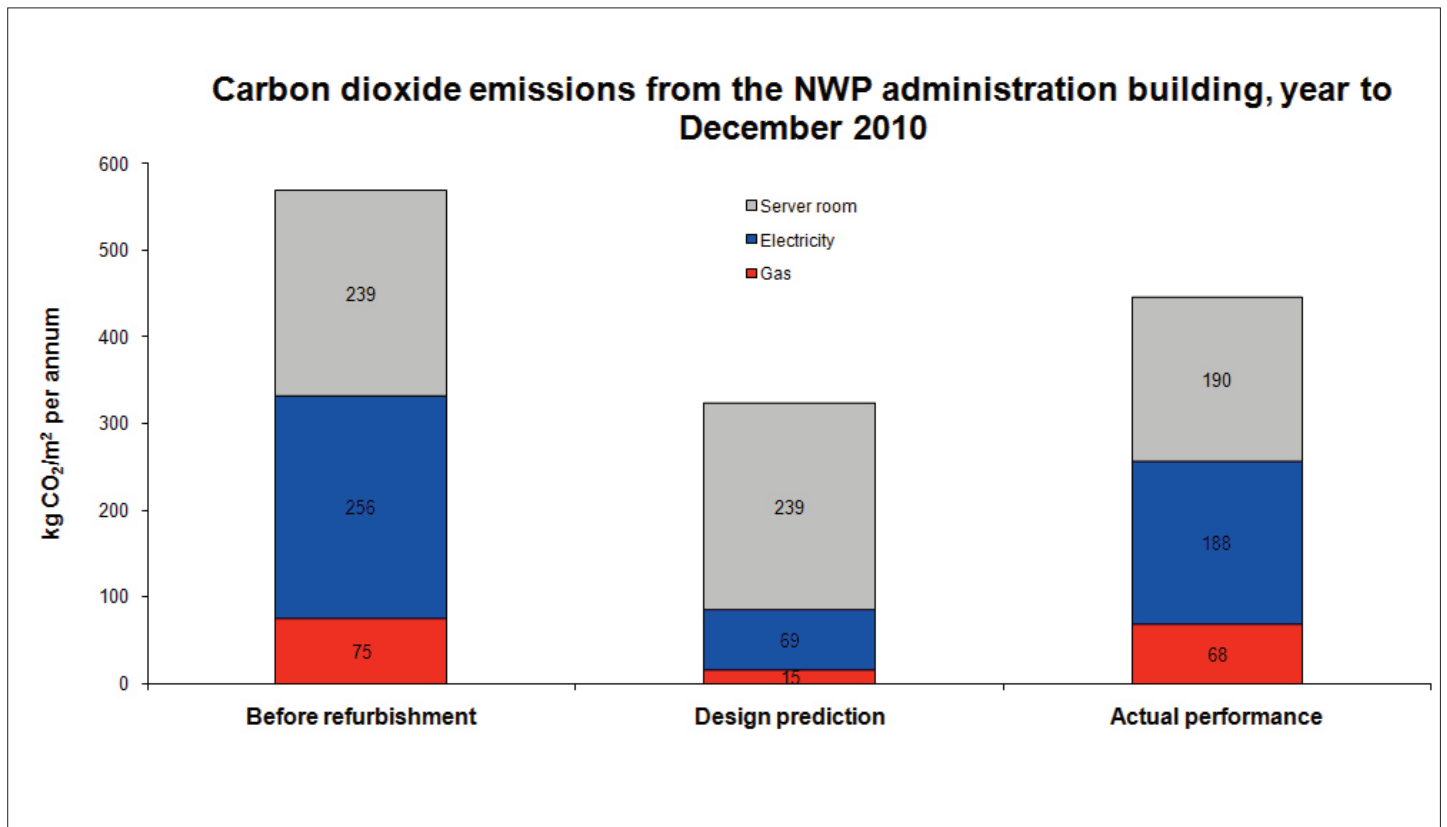


Figure 2: The carbon dioxide emissions for the NWP building compared with design calculations and the pre-refurbished building

Overall, the disparity between estimated and actual emissions is 65 per cent.

Nevertheless the refurbished building is significantly greener than the old one. The active approach from the Carbon Trust enabled a collective approach for achieving dioxide emissions savings, as each stakeholder was fully aware that carbon reduction was one of the primary objectives of the refurbishment.

As the Carbon Trust was involved before the design team was appointed, some pre-design work was carried out. A thermal model was developed, and a wide range of carbon dioxide reduction measures were considered so that the design team had early insight into the techniques and technologies that would deliver the best savings.

The Carbon Trust advisory team believes that more staff training and an awareness campaign could help to reduce energy consumption significantly. Out of hours small power consumption could be cut by turning off equipment overnight, and lighting consumption could be improved by manual switching when leaving a room rather than relying on the infrared detectors to do it some time later.

Occupant survey results

Approximately 300 people are able to work in the administration building. As many of these have part-time or mobile roles, the building is occupied permanently by around 120 people - 40 per cent of staff.

Two Building Use Studies (BUS) occupant satisfaction surveys have been carried out, one in March 2007 prior to the refurbishment, and one in December 2010. Of 105 people available, 65 responded to the 2011 survey. This is a statistically significant sample.

The old building was regarded as very uncomfortable

overall, with temperature and air quality in summer and winter significantly below the UK benchmarks. The building was considered unhealthy and not conducive to productivity.

This overall score for NWP HQ placed it in the bottom 10 per cent of the benchmark dataset. The building's only virtue was its good acoustic performance. The occupant scores for noise were above the UK benchmark, probably a reflection of the cellular accommodation.

The second BUS survey showed that occupant satisfaction had greatly increased as a result of the refurbishment, with the building performing at or above the average benchmark standard for many of the comfort factors (Figure 3). Other parameters of the study that had scored poorly and improved substantially as a result of the refurbishment included space in the building, its design, control over heating, and perceived productivity.

While many of the comfort scores are only around the benchmark average, this is a good result for a refurbished building.

What this tells us

The North Wales Police refurbishment shows that it is possible to improve energy consumption and occupant satisfaction without resorting to new build. The project suffered from unforeseen delays due to the main contractor's insolvency and other problems that seriously affected the programme. Commissioning was also disrupted and delayed, and the building has not been officially handed over in February 2011.

Despite all that, the building's energy use and carbon emissions have been cut significantly – although not as much as the designers had thought possible. The causes of the underperformance are a combination of lots of small things,

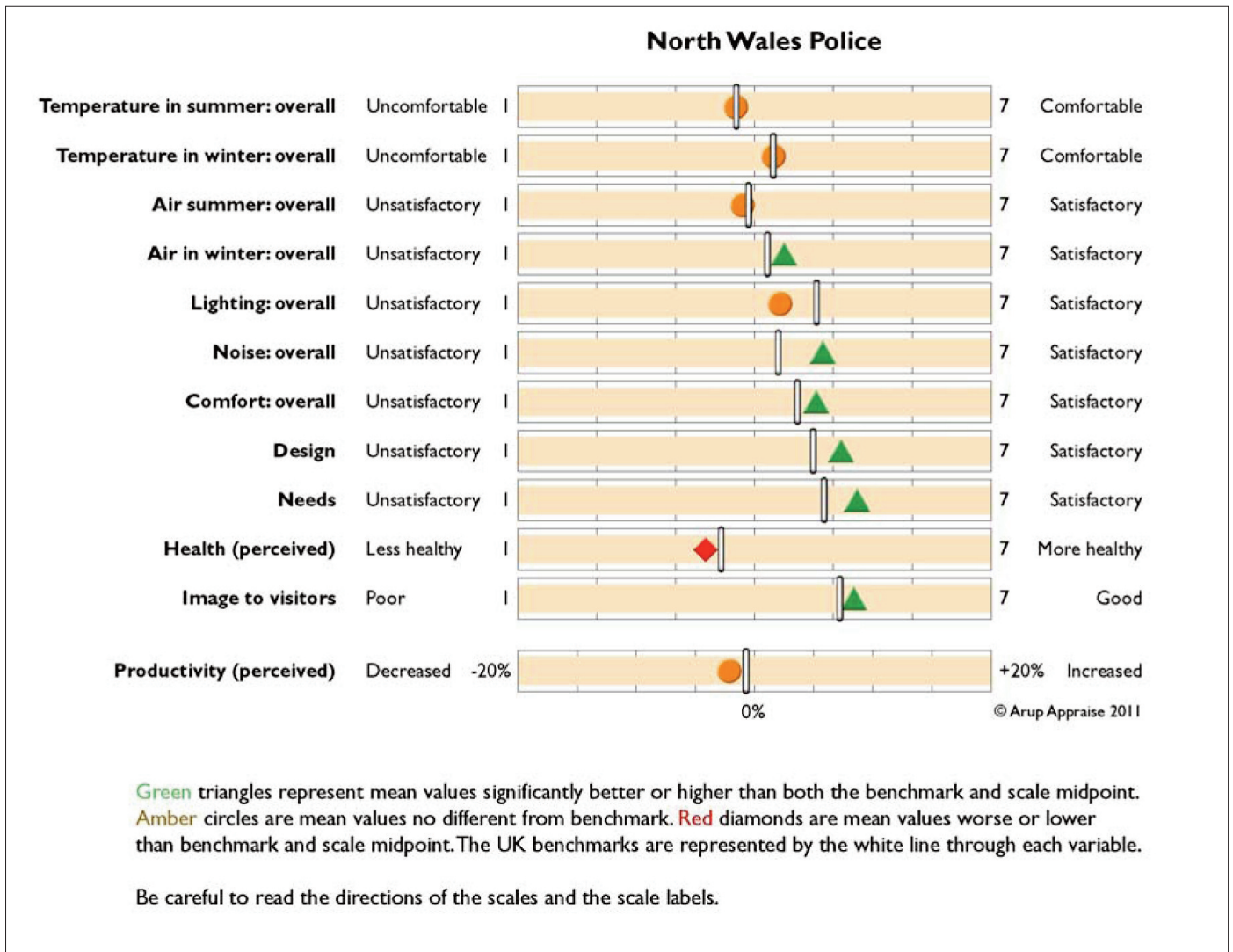


Figure 3: The results of the occupant satisfaction survey carried out in February 2011.

which together conspire to place the building around the typical benchmark for naturally ventilated buildings rather than the exemplary performance hoped for by the project team.

The project demonstrates that the closer one tries to get to the cutting edge of performance, the more important it is to get everything finished off, well commissioned and fine tuned in operation. This includes everything from heat distribution circuits to the heat meters that record the flows. Building performance is more than the sum of all the individual parts, and depends less on the claims of technical specifications and far more on the way they are designed, installed and used.

The Carbon Trust advisory team believe that its active involvement helped to create a collective approach towards reducing carbon dioxide emissions, as each stakeholder was fully aware that carbon reduction was one of the primary objectives of the refurbishment.

The client's clear brief on carbon issues was essential to achieve reductions. The design team's commitment to natural ventilation rather than reaching for mechanical cooling was central to the low carbon design, as was the selection of the construction team.

It was vital that the main contractor took ownership of the carbon dioxide emission reduction target, and that no decisions adverse to that target were taken. Similarly, every tenderer was required to explain their experience of carbon reduction measures during their tender interviews.

A key aim of the project was to improve summer comfort and reduce carbon emissions at the same time. The summer comfort requirement has a direct impact on the feasibility of ensuring comfort by passive means only. The Carbon Trust advisors recommended that the client raised the summer comfort temperature from 26°C to the recommendation in *Part L* of less than 20 hours above 28°C. Carbon emissions and comfort requirements are inter-related and should not be considered separately.

The feasibility of achieving the carbon reduction target within the budget was discussed at the first design team meeting. The work done on thermal modelling during the feasibility stage, as well as the preliminary cost estimate (capital cost and whole-life cost) of all options proved very useful in demonstrating that the target was achievable. It would have been more difficult to demonstrate it without this evidence.

Roderic Bunn EngD is a principal consultant in building performance analysis at BSRIA, working for the Carbon Trust on the Department of Energy and Climate Change's Low Carbon Building Programme. He manages the Soft Landings initiative at BSRIA and is a Building Performance Evaluator for the Technology Strategy Board.

The article is based on building analysis carried out by Hoare Lea & Partners for the Carbon Trust. The design, construction and post-occupancy performance of the North Wales Police was studied by the Carbon Trust under its Low Carbon Building Accelerator (LCBA) initiative. The LCBA aimed to accelerate the take-up of cost-effective, low-carbon initiatives of non-residential building refurbishment projects by gathering data and demonstrating effective energy-efficient solutions. LCBA case studies track projects from original use, through design and construction to post occupancy.

Key lessons

Thermal models have their limits

Thermal simulation modeling assumes ideal building and system operation, and does not take into account energy losses such as external doors and windows remaining open and general inefficient building operation. While every effort is made to prevent these inefficiencies they are still likely to occur as part of standard building operation. Building designers need to take greater account of these realities if their energy predictions are to be meaningful, and not mislead both themselves and the client.

Commissioning is too important to rush

Energy use has fallen as a result of the refurbishment and is now in-line with a typical practice office. Gas consumption is still very high, owing to faults in the system. If the problems can be fixed and the heating system re-commissioned, then the building gas consumption could be in-line with a typical practice building. Metering and monitoring also needs to be set up well. Heat meters that run backwards and building management systems that do not have useful monitoring packages will frustrate attempts by building managers to reduce consumption.

Follow-through and fine-tuning is vital

A staff training and awareness campaign could act to significantly reduce energy consumption. Areas where saving could be made include out of hours small power consumption through turning off equipment, and reduced lighting consumption by turning off lighting rather than relying on the PIR sensors. A campaign could involve staff training and other initiatives to promote energy conservation.

Construct a stable team

The project team was focused on delivering a low carbon building. However, the insolvency of the main contractor demonstrates that financial stability of all project partners should be also be assessed before appointment. North Wales Police will do this on all future projects to prevent a repeat. It was also recognised that the appointment of a local contractor (and possibly the consultants) would be more suited to provide on-going support after handover, and would be quicker to respond to on-site issues.

Occupants matter

Occupant satisfaction with the building as a whole has greatly increased as a result of the refurbishment. This has been demonstrated through carrying out an occupancy survey pre and post refurbishment. Such surveys enable project teams to both focus on the issues that matter most to people, while providing a basis for managing their expectations as the project progresses.