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Welsh Government

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Case Study 07

Lion House

Owner:
Defra Estates Division

Sustainability Advisor:
Element 4

Architect:
Frank Shaw Associates/Gibberd

Location:
Alnwick, Northumberland, UK

Building Type:
Offices

Renewable & Low Carbon Technologies

- PV array
- Wind turbines
- Biomass boiler
- Solar thermal collectors

Project Description

This exemplar office building was designed and built for the Department of Environment, Food and Rural Affairs (DEFRA) to replace the existing 1960's building which was deemed to be economically unviable, and refurbishment unfeasible due to a prevalence of asbestos in the building.

Amongst other sustainability objectives and targets for the project, DEFRA required that the site achieve a BREEAM Offices 2006 rating of Excellent, with a minimum score of 70%, making sustainability a key design aspect.

Key Drivers

Options for the provision of adequate office accommodation to replace the 1960's office building were required that would facilitate efficient energy and water management.

As set out in its third Sustainable Development Action Plan covering the period November 2008 to March 2011, Defra aimed to make a strong contribution to sustainability. As a public figure in environmental policy, developing an exemplar public building in terms of sustainability was a key driver for Defra. Since the change of government in 2010, the coalition government has specified "Greening Government" commitments which include a 25% reduction in greenhouse gas emissions from the whole government estate.

Key Features

- 48 kW biomass boiler;
- 110m^2 building integrated PV panels;
- Evacuated tube solar thermal collectors; and
- Three 15 kW wind turbines.

Lion House offices with wind turbines in foreground
Reproduced with permission of DEFRA

Other sustainable features include:

- High thermal performance building fabric;
- Mechanical Ventilation with Heat recovery (MVHR);
- Rainwater harvesting technology and low water consumption fittings; and

"Put sustainability at the top of the agenda. Make sure it is considered throughout the lifetime of the building"

Carolina Butler, Development Manager, DEFRA

- Passive solar design to maximise the use of daylight.

Procurement

The development was procured using the NEC Contract, Option A (priced with activity schedule), with Kier Northern appointed as project contractors.

A key procurement issue for Lion House related to securing a reliable fuel supply for the biomass boiler. Woodchip fuel for the biomass boiler is locally sourced. A contract is in place between Defra and English Wood Fuels Ltd who purchase woodchip on Defra's behalf according to a specification. Fuel is typically sourced within a 6 mile radius of the site and English Wood Fuels additionally ensure that all locally sourced woodchip fuel is stockpiled at depots within 30 miles of the site.

The BRE deem any fuel supplier within a 20 mile radius of the site to be carbon neutral as all carbon emissions derived from fuel transport can be offset by operation of the biomass boiler.

Scheme costs and finance

The scheme was constructed between 2007 and 2009 with the total cost of the development at £4.2 million, equating to approximately £2,000 per m^2.

Due to the considerable installation costs of some renewable and low carbon technologies, a Whole Life Cost (WLC) assessment was undertaken to determine anticipated 'payback' period of the chosen renewable and low technologies.

A payback period is the time required for the return on an investment to "repay" the original sum, taking into account operational savings made through generation of renewable energy, maintenance costs and fuel price inflation.

Technology selection process

A primary objective was to first maximise the opportunities for passive building design. Following specification of an energy efficient building envelope, a secondary aim was to maximise efficiency of appliances and lighting. Finally, renewable and low technologies were specified for the development to meet residual heat and electricity demands. By implementing the hierarchical approach of demand reduction → efficiency maximisation → renewable generation, any renewable and low carbon technologies selected could be utilised to maximum efficiency.

During the early stages of the design, feasibility assessments were undertaken on a number of low carbon and energy efficiency solutions, evaluating the practicality and benefits of each major technology and the potential carbon savings. Findings of the studies were then used to determine the optimal combination of technologies to theoretically achieve a 'carbon neutral' (or net zero carbon emissions) building.

The BRE defines "carbon neutral" as net zero carbon emissions from regulated sources. However, the Lion House development aimed to surpass this definition and achieve "true zero carbon" by obtaining an Energy Performance Certificate (EPC) rating of A+ (–14) to account for carbon emissions originating from both regulated and unregulated sources.

Six suppliers of biomass fuel were identified within six miles of the project site, which made a biomass boiler a logical selection for heat provision for the development. The unusually high number of fuel suppliers in close proximity to the site meant that long term security of supply could be guaranteed and carbon dioxide emissions arising from local fuel transport could be offset by operation of the boiler.

The carbon emissions for the building taking into account the selected renewable and low carbon technologies were anticipated to be 48% less than the Building Regulations Part L 2006. In order to achieve better than 'carbon neutral' status, three 15 kW wind turbines were selected, generating a further 60 MWh of electricity per year and thus achieving "true zero carbon" as defined by BREEAM.

Woodchip fuel storage area
Reproduced with permission of DEFRA

The biomass boiler was sized to provide approximately 80% of the building heating demand. A gas fired back–up boiler was installed to supplement the biomass boiler during periods of peak heating demand. By sizing of the biomass boiler to provide 80% of the demand (rather than 100%), the biomass boiler is able to provide all of the heat demand for a large proportion of the time, with the gas fired boiler supplementing the biomass boiler at times of peak load.

Evacuated tube solar thermal collectors were installed to provide 40% of the annual buildings hot water demand. These were selected over flat plate collectors due to their higher efficiency and smaller roof space requirements.

It was decided to use Building Integrated PV (BIPV) panels as a 'brise soleil' to provide both solar shading and electricity generation. This innovative solution meant that the cost of constructing solar shading could be offset against the cost of the PV array. Additionally, the orientation of the building meant that during summer months when maximum shading was needed, the PV array on the south façade would be optimally positioned at an angle of approximately 35 degrees to harness the suns energy.

Finally, integrating the PV array into an external solar shading system has advantages over other BIPV systems such as glazing replacement, which can result in unwanted heat transfer from the PV array to the indoor environment during the summer.

BIPV system at Lion House
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Planning constraints necessitated the use of the three smaller wind turbines in preference to a larger 25 m mast wind turbine. Agreeing a suitable location for the wind turbines was critical, as without the wind turbines, the building could not achieve neutral carbon status and wind shadowing from the building was a potential issue. Extensive modelling and trials were carried out and the Estates Division team worked closely with project consultants and the local planning department to identify the best solution.

Modelling of the predicted energy use of the new Lion House development showed that the new building would be capable of an approximate 108% improvement on carbon dioxide emissions relative to the former building.

Monitoring and operation

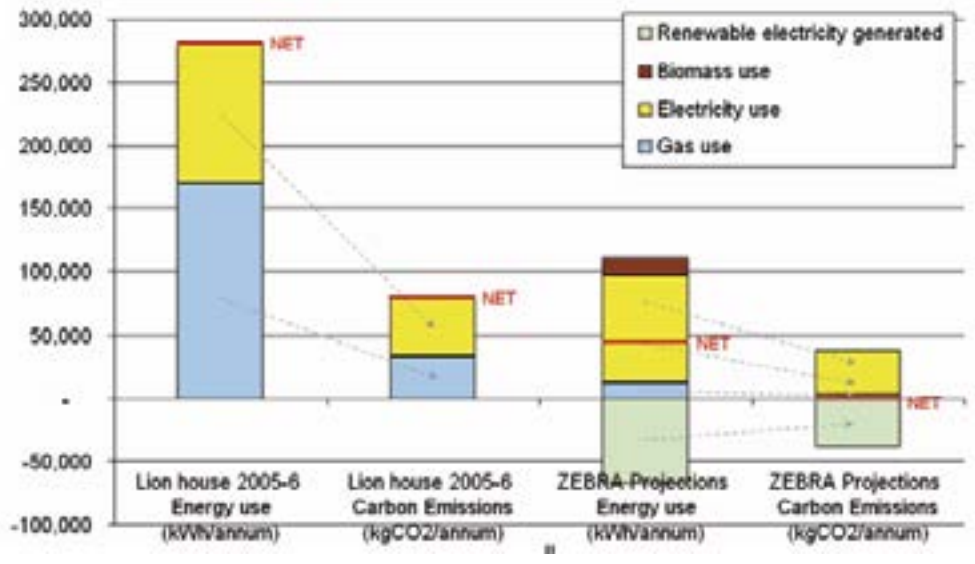
Real time displays of energy performance and generation are located in the reception for staff and visitors to see the contribution these technologies are making.

In this way, daily and cumulative technology output contributions and savings are visually communicated to staff and visitors.

The biomass boiler, capable of running on wood pellets or chips, currently uses around 5,400 kg of woodchip per month during the winter heating season.

erformance monitoring of the PV array has found it to be outperforming its design specification. Surplus electricity generated on site is exported back to the grid. No Feed In Tariff (FIT) arrangement is yet in place although as of September 2011, a contract has been put in place and generation of FIT income is anticipated to start in the latter part of 2011.

Estimated operational energy outputs and carbon dioxide savings (against a Part L compliant baseline) from each of the renewable and low carbon technologies are summarised in the figure overleaf.



Comparison of energy usage and carbon emissions of new Lion House building and former 1960s offices
Diagram reproduced with permission of DEFRA

The net carbon dioxide emissions from the development amount to approximately –6,900 kg CO_2 per annum.

The Lion House development was primarily an experiment to identify how different technologies could work together. The chosen combination of technologies for this development are theoretically capable of generating sufficient energy to achieve true zero carbon, resulting in an A+ EPC rating with a carbon index of –14. However, the building has sophisticated lighting and ventilation systems, intricate commissioning requirements for the biomass boiler, and several renewable and low carbon technologies which had to be successfully integrated with each other. Consequently, operation of the system has required extensive training of the facility managers.

The most recent EPC assessment of the building results in a B rating with a carbon index of 34. While this is below the design A+ rating, this is predominantly due to commissioning and initial operational issues of the biomass boiler and wind turbines, which have now largely been resolved.

Live monitoring display of technology performance
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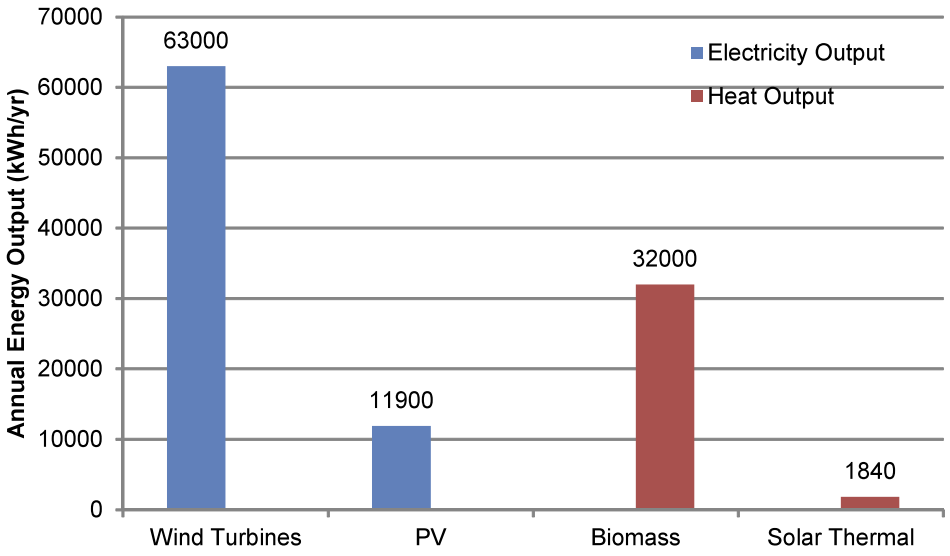
"Sometimes the simplest option is the best solution; a theoretically sophisticated system can be challenging in practice."

Mark Hoult, Carbon Reduction & Energy Efficiency Manager, DEFRA



Emissions saved by renewable and low carbon technologies (kg CO_2 per annum)	Wind	PV	Biomass	Solar thermal
	35748	6764	5409	77

Operational energy (electricity and heat) output and CO_2 emissions savings from Lion House renewable and low carbon technologies
Data provided by DEFRA

Lessons Learnt

Technical supply issues:

- Procurement and siting criteria for wind turbines should be considered from an early design stage in order to resolve technical performance issues and maximise efficiency in the planning process;
- Ensure that a thorough commissioning handover process is undertaken for developments which incorporate a large number of renewable and low carbon technologies; and
- From the outset, sustainability should be fully integrated into the design. Setting targets and objectives in the early stages provides a clear aim for the project whilst allowing performance to be monitored when the project is complete.

Brise soleil on south facade of building
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Occupat involvement

- Engage users – Where possible it is good practice to engage the future building users in the design process to ensure it will meet their needs. The project team consulted with the DEFRA employees regularly to gain their buy–in to the design, improve their awareness of the technologies employed and improve their behaviour in occupying the building to reduce energy consumption; and
- Maintain close liaison and consultation with planning authority throughout project.

Financial lessons:

- Whole Life Costing is an essential tool when costing renewable and low carbon technologies due to their potential to generate income during operation.

Awards and Achievements

- Achieved a BREEAM Excellent (80.72% score on BREEAM Offices 2006);
- First building to be awarded an Energy Performance Certificate Rating of A+;
- Won BREEAM Office category in the 2008 BREEAM Awards;
- 'Sustainable Achievement of the Year' with Property Week;
- CIBSE Low Carbon Performance Awards 2009 "New Build Project of the Year"; and
- North East Renaissance Award for Sustainability 2009 from the Royal Institute of Chartered Surveyors (RICS).

References and Acknowledgements

Lion House, Alnwick Case Study
Department for Environment, Food and Rural Affairs, OGC, 2009

Mark Hoult
Carbon Reduction & Energy Efficiency Manager, Estates Division
DEFRA

Further information

DEFRA website at www.defra.gov.uk

The Office of Government Commerce at www.ogc.gov.uk

Kier Northern at www.kier.co.uk/

These case studies are presented to show examples of how buildings can be designed and built to be low carbon and incorporate renewable and low carbon technologies. This case study is part of a series of case studies supporting a separate practice guidance document on low carbon buildings. **For further information see www.wales.gov.uk/planning**

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