



National  
Trust

## Sustainable technology case study

- direct labour team involved
- new build Energy Centre
- two 145kW wood chip boilers  
(installed capacity 290kW)
- below ground fuel storage bunkers



Calke Abbey,  
Derbyshire



## Biomass boiler

Replacing inefficient LPG-fired boilers and electrical storage heaters  
with a centralised renewable technology, August 2011

# Background

Calke Abbey is a Grade I listed country house. It has been operated by the Trust since 1985.

The intention of this project was to directly address climate change issues and ultimately reduce carbon production on site.

In 2009, Lorien Engineering Solutions undertook an Estate-wide Energy Audit to identify high energy usage across the Calke Abbey site.

The commercially utilised Estate buildings were identified as particular high energy consumers and recommendations were presented to reduce energy usage and ultimately, carbon production.

The Estate buildings which formed the visitor centre portion of the site were dependent on the use of electrical emitters (powered from the National Grid) and LPG-fired boilers (from two LPG tanks) for the generation of comfort space heating and hot water generation.

The LPG primarily served the commercial kitchen, restaurant and servery. A further connection from the LPG tanks served the heating and hot water provision to a domestic tenanted property known as Steward's Cottage.

The Energy Audit identified that the LPG-fired boiler plant to the kitchen was in constant need of servicing and piecemeal part replacement. Servicing was fast becoming parts and labour intensive and was therefore deemed uneconomical over complete replacement. Other associated plant on the system was fast approaching the end of its efficient, serviceable and compliant shelf life.

As the boilers deteriorated, their efficiencies decreased and subsequently more and more unnecessary carbon was being produced.

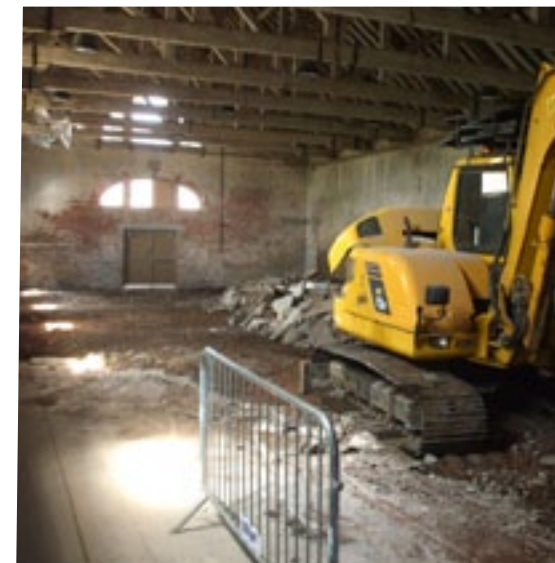


Electrical emitters were used extensively across the Estate buildings for heating. Space heating via electrical means is deemed the highest contributor to carbon production, thus contravening the Trust's Energy policy.

Lorien submitted a comprehensive Alternative Fuel Options study on behalf of the Trust, highlighting the most feasible renewable technology options available to the Estate buildings based on individual environmental, economical and social merits.

Aesthetic, Planning and Listed Building constraints immediately discounted the use of air source heat pumps and wind turbines due to the vast amount of the plant required.

## Above Removing the Riding School floor



Ground source heat pumps were also discounted due to the requirement to increase the size of all plant and emitters within the property to cater for the lower flow temperatures generated. This was further reinforced by archaeological and economic concerns associated with the large scale excavation / infrastructural work that would be required for this type of installation.

Due to the orientation of the building and the construction styles adopted for the roof there was little scope for the use of either PV or solar thermal collectors (kWh output / installation costs = 50+ year payback).

Calke's specific site infrastructure meant that biomass boilers (most notably wood chip) were the option most worth pursuing.

By installing a wood chip boiler Calke Abbey would reduce its dependency on fossil fuels and on the National Grid. Energy security would be improved, exposure to financial risk from rising energy costs and their contribution to climate change and other forms of pollution reduced.

Five options were formulated for the best location of a new centralised Energy Centre in terms of 'buildability', conservation, primary and secondary delivery of fuel, costs and visitor engagement.



# The project

A wood chip biomass boiler system was proposed, with a view to the property having the capability to become self-sustaining within 5–10 years.

The Long Cart Shed to the rear of the kitchen was originally proposed as the front of a boiler room and fuel store, called the 'Energy Centre' – with a glazed front for interpretation purposes. The site was slightly off the visitor route however and following risk analysis it was not deemed safe to have both visitors and kitchen deliveries conflicting in one space. The option of a new build 'Energy Centre' located in the area behind the Long Cart Shed was developed instead.

The project grew from originally serving just the visitor facilities – restaurant, shop and toilets to enveloping the entire north site including the ticket office, learning and activity rooms and Riding School. This area would become heated for the first time, so that the property could offer the space commercially for a wider array of events.

A 'look and style' for the building, in line with the ethos of Calke Abbey, was drawn up and agreed by the Curator and Architectural Panel.



Above and left **The Energy Centre under construction**

These proposals were presented to Planning and Conservation Officers in the pre-application phase for their comments on the size, location and finish.

Planning Permission was sought to provide a sustainable and environmentally efficient heating system for the Estate buildings at Calke Abbey. The installation would consist of a centralised biomass boiler system with two wood chip-fired heating boilers located in the new purpose-built Energy Centre. This would contain a boiler room, fuel store and visitor engagement area.

Listed Building Consent (LBC) was required primarily for the building entry points for the heating service mains, internal fabric penetrations for new services and mounting of new emitters and plant.



# Design

## Wood chip boilers

The centralised biomass boiler system (CBBS) would provide space heating and domestic hot water services (where required) to a number of the Estate buildings across the north portion of the site.

The nominated buildings would be interconnected via an underground network of heating mains (District Heating Scheme). This would supply the following buildings whether connecting to existing systems, replacing electrical installations or providing a new system:

- Kitchen, restaurant and servery – existing system
- Shop – replacing electric
- Visitor amenities – replacing electric
- Riding School – new space heating provision
- Activity room – replacing electric
- Introduction room – new space heating provision
- Training/meeting room – replacing electric
- Conservator's workshop – replacing electric
- Steward's cottage – existing system
- Training office – replacing electric

By installing a wood chip boiler the Trust would reduce dependency on fossil fuels and the National Grid; improve energy security; reduce exposure to financial risk from rising energy costs, and reduce contribution to climate change and other forms of pollution.

All wood chip supplied would be procured from National Forest-managed woodland and plantations. The long term view is that the boilers would be fuelled by timber on the Calke Estate to become self-sustaining.

As much of the existing services pipework, pump sets and controls as possible would remain within the kitchen boiler room. Connections through to the new heat exchanger unit would minimise the requirement for structural penetrations by using existing openings wherever possible. This would allow for a relatively swift plant changeover period, causing minimal disruption to the heating and hot water generation systems.



Any new plant required in the existing boiler room would be 'like for like' – requiring only slight electrical wiring and pipework modifications.

The boiler room would house two wood chip boilers, associated plant and distributing pipework to provide heating and hot water to the designated buildings.

Fuel storage bunkers would be located below ground to cater for optimum delivery in terms of method and speed. Deliveries would utilise the existing gated entrance to the space via the staff parking area.

Above The Gilles boilers inside the Energy Centre

Right Visitors are encouraged to learn about the biomass heating system at Calke



# Design

## Energy Centre

The location for the new boiler room has been chosen for several reasons:

- It allowed for a new build Energy Centre, as opposed to incorporating it into an existing structure;
- It is a central position relative to the buildings to be served – this will maintain system efficiencies by reducing heat loss along pipe runs and reduces the need for extensive trenching and pipe laying;
- It isolates the main body of works from the majority of the site and causes minimal disruption to day-to-day activities during construction and future servicing;
- It allows for adaptation and future expansion;
- Its position is relative to the existing visitor route of the entire site;
- There would be minimal intervention with the existing buildings;
- It allows for the segregation of visitor and working entities – accessibility for visitors from the south and deliveries from the north;
- The existing staff car park access road will be used for the wood chip deliveries, providing sufficient space to manoeuvre the delivery vehicle and tipping trailer;
- The site is on relatively flat land requiring the fuel stores to be sub-ground level. This will aid the delivery process and keep cost and disruption to a minimum;
- The size of the fuel store has been calculated using the projected seasonal energy usage and should provide sufficient fuel storage to allow for optimum deliveries.



## Dimensions

The Energy Centre structure is 8m long by 7m deep. The vertical external wall to eaves is 2.1m with a 40° pitched roof (to match the neighbouring Long Cart Shed) with a ridgeline at 5.15m high – around 150mm below that of the Long Cart Shed.

The boiler room has a footprint of 50m<sup>2</sup> whilst the sunken fuel stores are 20m<sup>2</sup> each with a further 20m<sup>2</sup> for the transfer auger chamber. This equates to a total permissible building footprint of 110m<sup>2</sup>.

## Above District heating trenching works

## Ventilation

The front doors to the Energy Centre are of timber construction; these are full height louvred to allow the required amount of air for combustion to the boilers whilst their size and position are dictated by the positioning of the boilers so that when the doors are open this will satisfy the required access for incremental servicing and maintenance.

## Visitor engagement

Glazed units act as viewing panels into the boiler room for visitor engagement purposes. All painted surfaces are in a black finish to match the profiled exterior.



# Design

## Fuel store

The fuel stores are semi-sunken below ground level. The only visible elements are the fuel delivery hatches, man access chamber lids and the concrete upstands. The stores have been built using massed concrete to provide the necessary structural integrity to act as a retaining wall, as well as storing the wood chip. The hatches are robust, industrial grade galvanized steel with black chequer-plate lids.

The concrete upstand and hatches sit 300–400mm above ground level to enable deliveries to reverse up and tip directly into the fuel storage area.

Each fuel storage area measures 4.5m wide x 4.5m deep and has a floor level of -2.5m below ground level. 50m<sup>2</sup> hardstanding areas to the rear for deliveries.

## Boiler flues

Two boilers are required to provide increased reliability and a broader range of heat output modulation across the site. Each boiler has its own flue which penetrates through the north pitch of the boiler room roof.

The flues have been designed and positioned to minimise their overall height and negate the need for guide ropes. The overall height of the flue ensures adequate draught for efficient boiler operation and complies with legislation for flue gas dispersion.

## Consents

Full Planning and Listed Building Consent applications were produced and submitted. These were required for the new building and flue system, the removal and reinstatement of the Riding School floor, penetrations through existing structures and minor modifications to the outer building fabric.

The Project Team waited for consent to be granted before entering the detailed Design Stage. This enabled the inevitable conditions of the approvals to be effectively managed. This decision proved worthwhile as the consents had an impact on the design of the Energy Centre.



Conditions from the Archaeological, Ecological and Arboriculture surveys also had to be closely adhered to due to the nature of the historic site, presence of bat roosts and the close proximity of the new build to three significantly mature trees.

## Project management

Lorien oversaw the general day-to-day management of the construction by adopting the role of Project Manager, Technical Advisory, Contract Administrator and general point of contact throughout.

Two 145kW wood chip boilers (installed capacity 290kW) were fitted to serve comfort heating and domestic hot water to the restaurant, shop, ticket office, Riding School, learning and activity rooms, training office and Steward's Cottage.

The system required approximately 350 metres of district heating pipework.

Biomass boiler | Calke Abbey

# Cost

- Feasibility/options appraisal: £19,976
- Outline design to Planning and detailed design to Tender: £26,250
- Planning and Listed Building Consent application fee: £1,024
- Planning conditions variations: £4,712

## Construction phase

These are the original let contract values for the works – there were many other associated works packages removed and added to the works whilst the project was in flow:

- Boiler and M & E installation: £283,985
- Builders works: £152,481
- CDM coordination: £1,800
- Direct Labour hours and additional spend on materials: £8,324.75
- Technical Advisory, Contract Administrator: £20,237

- Project Total: £488,689
- Running costs: Approx £13,000 pa
- Renewable Heat Incentive (RHI): Approx £19 - 20,000 pa (£17,900 Tier 1 and £2000 Tier 2) 20 years

## Duration

The original programme was for thirteen weeks. Works actually ran over fifteen or sixteen weeks due to Easter and additional Bank Holidays.

# Carbon reduction

This wood chip boiler system will serve all existing low temperature hot water systems and replace the current electric heating to the nominated Estate buildings. Results of a carbon saving calculation for the project show that the use of wood fuel would release over 90% less CO<sub>2</sub> than LPG in the combustion process. Compared to National Grid electricity a 95% CO<sub>2</sub> saving is achieved.

Putting the existing operations onto a biomass system would equate to a 93% reduction in carbon. With the addition of the Riding School, the projected energy usage may increase by up to 60%, however the carbon production would still be nearly 90% that of the existing operation. It is projected that a total CO<sub>2</sub> saving of 68 tonnes per annum will be achieved.

The carbon saving was approx 90 tonnes CO<sub>2</sub> in year one. In some applications the property was heating spaces which were previously unheated, therefore the total carbon saving was not a linear reduction from fossil fuels.

Below Example of one of the posters created by Creative Studio and Key Stage 2 pupils at Dame Catherine Harpur's School to help promote the new biomass boiler



# Review

## Performance

The boilers have been performing well and Property staff have engaged well with the daily routines.

When new RHI design criteria (with regards to the positioning with Heat Meters) were published post installation, it turned out the criteria was different than anticipated. This meant that remedial works needed to take place to make the system compliant with the new design criteria.

## Energy generation

The boilers are generating the projected heat loads, using approx 100 tonnes of wood chip per year as anticipated.

## Maintenance

At present all of the wood to fuel the biomass boiler is grown within the National Forest and bulk stored less than ten miles of the site; it is hoped that within a decade, 20% of the wood chip for the boiler will come from the Calke Estate itself.

## Engagement

One aspect receiving positive feedback at other installations was the potential for educating visitors, many of which are children on school trips or on days out with their family. A space was therefore created next to the boiler room to form a visitor engagement area.

Interpretation boards tell the story of the project and the operation of the system – reinforcing the Trust's strategy on carbon reduction. Large glazed sections allow visitors to see directly into the boiler room.

Creative Studio worked with Key Stage 2 pupils at Dame Catherine Harpur's School on a project to help Calke Abbey promote its use of sustainable energy. The project produced:

- Table Talker leaflets for the restaurant
- Banner stands for the Riding School
- Posters for general display
- A storybook following the source of fuel from tree to wood chip boiler

## Lessons learnt

Although challenging, the project has been very successful and has utilised the existing buildings to great effect. The new Energy Centre blends very well with the ethos of Calke and the surrounding buildings and is now incorporated onto the visitor route.

More detailed consultation with the Conservation Officer over Listed Building Consent to affirm the exact requirements, especially in terms of the surrounding trees before the initial submission may have quickened things up – but this was a learning curve for all parties involved with the application and has hopefully gone some way in aiding other projects requiring similar approval.

With the amount of variation in the Options Appraisal stage, a top end detailed cost plan review should have been delivered and developed appropriately with the project. The tender return values ended up being above and beyond the feasibility costs anticipated. They did not capture the additional preliminary costs associated with a Civils heavy project. This led to a design review period where works which were deemed to be of too high a cost were re-specified and re-designated.

## Future plans

The Long Cart Shed building is currently being converted into property offices and this shall be tied into the biomass system. Capacity on the system also allows future expansion for catering operations.

# Review

## Recommendations

Any project with substantial trenching requires full time site supervision especially if it is carried out during the height of the visitor season using busy visitor routes.

Factor Design Reserve Contingency (5%) and Construction Phase Contingency (5%) into the cost plan.

Identify other project also being carried out at the property and ensure all parties are aware of any coordination requirements or any conflicts.

The interaction and procurement of external contractors and internal Direct Labour staff was excellent to get the finished article. Using internal tradesmen who intricately know the property and the standards required is invaluable.

Although there was a full time site manager/principal contractor on site their roll did not include the interaction with the property staff and visitors and thus a Project Manager/Clients representative role needs to be included to manage the non-obvious role associated with large construction on National Trust Estates.

## Since completion

Calke will not be able to be fully self-sufficient as originally planned, but it will be able to produce about 20% of the property's fuel demands which will provide greater energy security and a better value for money. In 2014 Calke's woodland was the source of 25 tonnes of the wood chip used in the boiler.

However wood chips still need to be delivered in order to supply the remaining fuel needs. Delivery in the peak heating season occurs weekly, with fewer deliveries in the remainder of the year.

The biomass boiler now also provides heating and hot water to the Property Office (the converted Long Cart Shed) since February 2013 and the Café, a secondary catering outlet, since October 2014.

The property keeps raising awareness of the biomass boiler by increasing its visitor engagement offer. Volunteers have now been trained to give biomass talks which are offered to visitors at peak times. The team is also reviewing the interpretation media produced by Creative Studio as it is looking weather worn and tired.

A key lesson learnt down the line comprises the application process. The application is still in progress now (4 years since project completion) since there was an inadequate provision of information, as part of the contract, to enable a complete application to be made.

While the contractor had been helpful, it has been time consuming to complete a legacy application. Furthermore, the extension of the system to the Property Office and Café means that the application now needs to be restarted. Thus a recommendation would be to adopt the REI programme approach to RHI applications in all future projects to ensure a timely and successful RHI application.

## Contact

General Manager: Stewart Alcock  
Project Manager: Stuart Perry, Lorien  
Building Surveyor: Charles Robinson  
Technical Advisory, Contract Administration: Lorien Engineering Solutions  
Contractors: Lawfields Contracts

## Installation

Boiler and M & E installation: **Instatherm Combustion Services**

## Acknowledgements

Based on a case study by Stuart Perry at Lorien Engineering. Acknowledgments to Ingrid Chesher and Charles Robinson. Images courtesy of Stuart Perry at Lorien and John Conibear at CDA.



Above Energy Centre and the completed fuel stores

If you require this information in alternative formats, please telephone  
**01793 817791**  
or email  
**[buildingdesignguide@nationaltrust.org.uk](mailto:buildingdesignguide@nationaltrust.org.uk)**

Design by Inkcup Design.

**Products and services:** Use of products and services is not necessarily an endorsement by the National Trust.

**Copyright:** National Trust retains copyright for this document. Please do not reproduce/photocopy without prior permission.

The Building Design Guide concept was devised by Rory Cullen and developed by Jonathan Howard with acknowledgements to Jacky Ferneyhough, Ingrid Chesher and Angela Collins.

© 2015 National Trust. Registered charity no. 205846.