Case Study

Biomass Boiler Installation at Plockton High School, Plockton

Project Highlights

A 400kW wood pellet biomass boiler and 30,000 litres of thermal storage have been installed at Plockton High School, Plockton, Highlands. The system feeds the High School buildings and the School Hostel which also houses the Sgoil Chiùil na Gàidhealtachd, the National Centre of Excellence in Traditional Music, via district heating pipework. Fuel and heating supply security are critical issues and, due to the remoteness of the School & Hostel, permanent back-up is provided by a 400kW oil boiler.

A view of Plockton High School

Introduction

Plockton High School, on the northwest coast of Scotland, provides education for secondary school children in one of the largest catchment areas in Europe, from Applecross in the north to Glenelg in the south. The current school roll is 320 pupils, with 52 teaching and support staff. It is a focal point for the community and is used for a wide range of cultural and sporting activities. Plockton High School has a high profile for Gaelic with all pupils studying Gaelic in their first two years. A Hostel within the School grounds provides boarding for pupils during the week and also houses the Sgoil Chiùil na Gàidhealtachd, the National Centre of Excellence in Traditional Music. Both fuel and heating supply security is a critical consideration at this remote site which, unlike most schools, is unable to send pupils home if the heating fails.

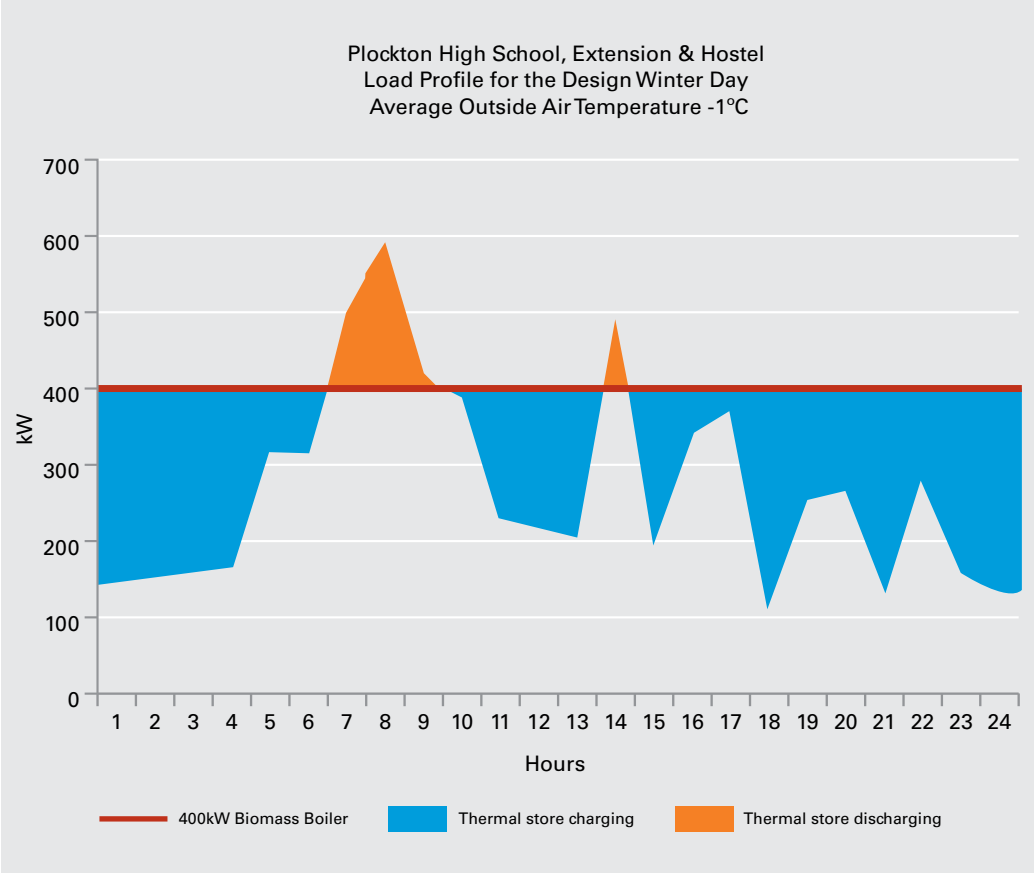
The Campbell Palmer Partnership Ltd (CPp) was engaged by the Carbon Trust's Biomass Heat Accelerator (CTBHA) programme to undertake a biomass feasibility study, initially for the School and subsequently to include the Hostel. The Carbon Trust & Highland Council contracted CPp to design a biomass system in a new boilerhouse and oversee its hydraulic integration with the two existing plantrooms in the School and Hostel linked to the new boilerhouse by district heating pipework. A separate design team was appointed to design the building services for a new extension linking the two School buildings, with their design responsibility commencing at the secondary side of the plate heat exchangers in each plantroom. The aim of the biomass element of the project was to eliminate, as far as possible, fossil fuel use at the School and Hostel, reducing CO_2 emissions in support of the Council's renewable energy policy in the process. While it was intended that this site would be heated 100% by biomass and supported by a portable oil boiler in the event of a biomass failure, the need for heat security resulted in the installation of a 400kW oil back-up boiler within the boilerhouse as well as provision for the portable oil boiler.

Extensive fabric upgrades to both of the School buildings had previously resulted in a reduction in the winter design day peak load from 860kW to 590kW, while the School's average daily heating load between 08:00 and 16:00 varied from 210kW in winter to 135kW in spring and autumn. The output from one 900kW boiler on low-fire was 360kW and the average annual load factor for one boiler was 15%. The feasibility study calculated that the 30 year old 900kW oil boilers in the School were operating at a seasonal efficiency of 55%, a figure which is consistent with the value obtained from the CIBSE boiler efficiency chart[1]. Building owners and operators should be aware that when a substantial building fabric upgrade is implemented both the design day load profile and the minimum winter and summer loads should be re-calculated, and the burner nozzles reduced in size accordingly to avoid a reduction in boiler seasonal efficiency if fossil fuelled boilers are to be retained.

[1] CIBSE Guide B 2005, Figure 1.4, Typical seasonal LTHW boiler efficiencies at part load.

Biomass Boiler System Sizing Tool

The Carbon Trust Biomass Heat Accelerator engaged CPp and the Energy Systems Research Unit at the University of Strathclyde to develop a software design aid to help designers optimise the sizing of biomass boiler systems. A detailed heat loss model of the School & Hostel was created to produce a heat load profile for the design winter day, and this was used as an input to the Tool to size the biomass system. The Biomass Decision Support Tool[2] was used to size the biomass boiler and thermal store to achieve 100% of the annual heating energy from the biomass system based on an external winter design temperature of -1°C. While the peak load was calculated as 592kW, the tool indicated that a biomass boiler rated at 400kW in combination with 30,000 litres of thermal storage would be able to supply 100% of the annual energy required. The very large thermal store allows the biomass boiler to fire for long periods storing excess heat when the heat demand is less than the boiler's peak output as illustrated below.



In view of the very cold weather experienced during the winters of 2009 & 2010 when temperatures at Plockton fell, briefly, to -20°C, in agreement with the Council the system demand curve was recalculated for a daily average temperature of -13°C with a minimum of -16°C which produced a peak start-up load of 840kW for a period of up to 2 hours. If these conditions were to pertsist for a period of one week the biomass system would still produce 99% of the annual energy required, and the combination of biomass boiler, oil back-up boiler and portable oil boiler would provide sufficient redundancy in the event of failure of any one boiler. In these conditions the continuous baseload would be exactly 400kW with the biomass boiler operating continuously at full load and one of the oil boilers supplying the remaining load to achieve a minimum continuous internal temperature of 20°C.

Design Principles & System Operation

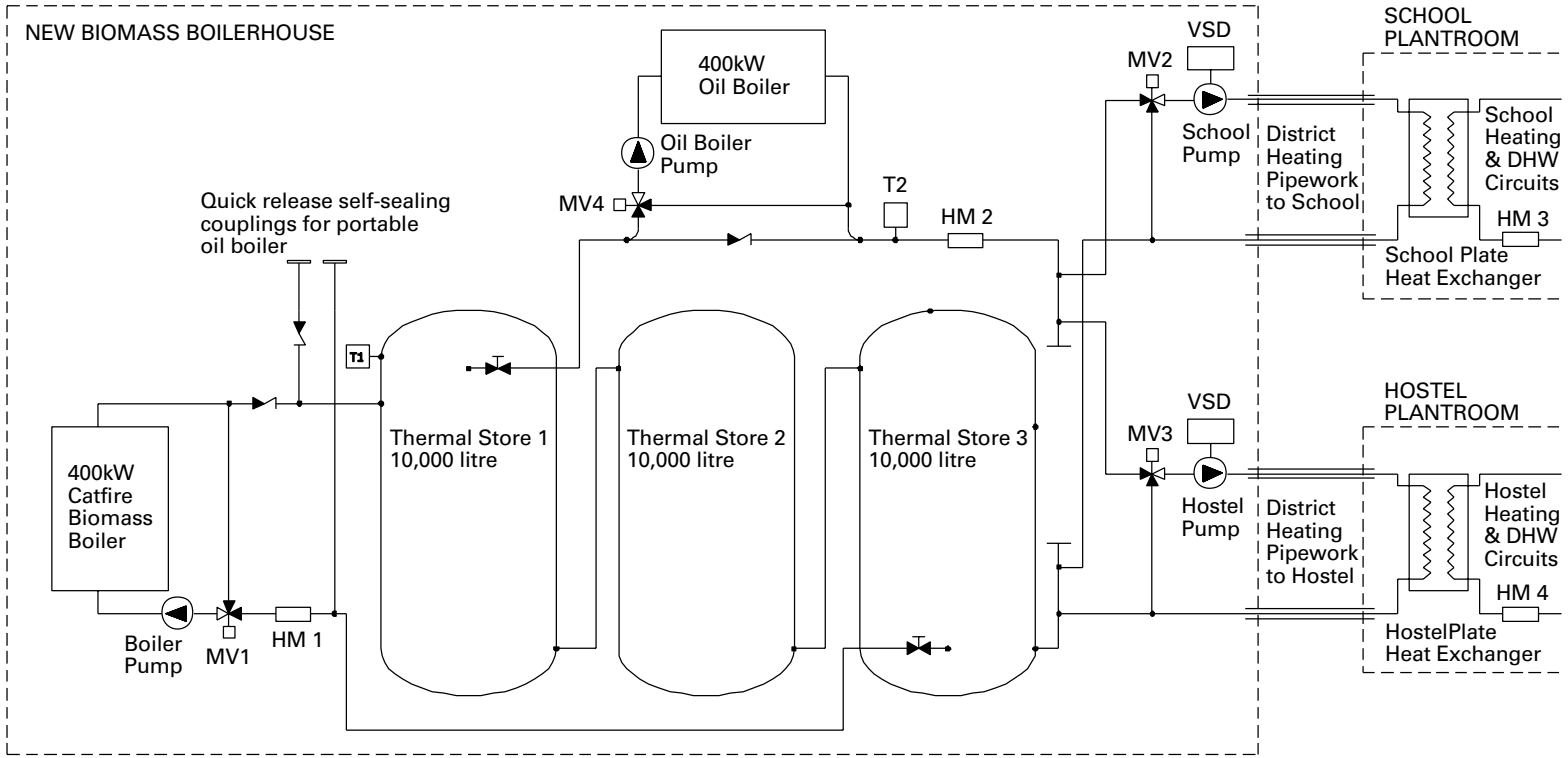
In cold weather the biomass boiler will run continuously within its modulating range (minimum output of 110kW) charging the thermal stores. At other times the biomass boiler will operate to recharge the thermal stores to meet the heating & DHW demands. Being an automatic ignition biomass boiler the firebed will extinguish during periods of no load while the flow temperature at the biomass boiler will be maintained by the biomass boiler firing occasionally. The calculated biomass boiler system seasonal efficiency when operating in this way is expected to be 88% while meeting 100% of the annual energy demand at temperatures down to -1°C.

Referring to the schematic diagram below, the key operating features of the system are:

- The biomass boiler has been sized to fire continuously charging the thermal store 24 hours a day operating at its maximum flow temperature of 90°C throughout the winter months;
- For as long as the temperature measured at T1 (near the top of the thermal store) is greater than 75C the oil boiler is disabled;
- The total load on the boilerhouse is measured by HM2, and when this exceeds 400kW and the temperature measured at T1 falls to 75°C (indicating that the thermal stores have been fully discharged) the oil boiler is enabled. The oil boiler fires and MV4 modulates to maintain the temperature measured at T2 at 84°C. Using a motorised mixing valve with a turndown of 100:1 results in a continuously modulating output from the oil boiler from 4kW to 400kW with very accurate flow temperature control. The oil boiler operates until the temperature measured at T1 has returned to 88°C;
- Motorised valve MV2 mixes return water from the School circuit with water from the thermal store to maintain a temperature of 80°C as measured at the secondary side of the School plate heat exchanger (PHE). The speed of the School pump is controlled by heat meter (HM) 3 to match the demand on the School circuit;
- Motorised valve MV3 mixes return water from the Hostel circuit with water from the thermal store to maintain a temperature of 80°C as measured at the secondary side of the Hostel PHE. The speed of the Hostel pump is controlled by HM4 to match the demand on the Hostel circuit;
- Provision has made for a portable oil boiler which will normally be located at the School and available as a second back-up boiler.

[2] The Tool can be downloaded from the Carbon Trust's website.

Outline schematic of the biomass boiler system and its integration with the oil boiler and load circuits



The Biomass Installation

The Catfire 400kW automatic ignition biomass boiler was selected following a competitive tender process. The boiler has vertical fire tubes with an automatic mechanical fire tube cleaning mechanism; no manual fire tube cleaning will be required outside of annual maintenance periods. While the boiler can accept either wood pellets or woodchips up to 35% moisture content, the fuel drying zone is contained within a small cylinder of refractory material making the boiler up to 2 tonnes lighter than other 400kW boilers. The small quantity of refractory lining also results in a thermally responsive boiler with a turndown ratio of 3.6:1. The biomass boiler has full MODBUS connectivity enabling a comprehensive read out of boiler functions and parameters for display on the building management system (BMS). The back-up oil boiler is connected in series with the outlet from the thermal stores where it can act both as an auxiliary boiler (supplementing the biomass boiler) or as a full back-up boiler because of the fully modulating injection circuit controlled by MV4. Two separate district heating circuits were installed, one to the school plantroom and another to the hostel plantroom. The existing oil boilers were removed from both of these plantrooms and plate heat exchangers installed using the connections vacated by the oil boilers.

The system is designed to operate on wood pellets and a 'V' shaped wood pellet store capable of holding 25 tonnes (almost 3 weeks' fuel supply at the design winter conditions) was incorporated within the boilerhouse structure. Supplied from a 16 tonne pellet delivery vehicle by blowing, one week's fuel supply (9 tonnes) will remain at the refilling point. Low voltage laser level sensors within the fuel store connected to the BMS will allow the Council to measure the fuel level within the store and reorder in sufficient time that one week's pellet supply will always be available on site.

Project Costs & Savings

The capital costs for the biomass element of the project, which was financed wholly by Highland Council, are detailed in **Table 1**.

The calculated annual heat energy demand of the school and hostel, including the new extension, is 820,000kWh with the biomass plant designed to generate 100% of this. Prior to the installation (and the construction of the extension), the school & hostel consumed £67,033 of fuel oil (at current prices Dec 2011) whereas the calculated annual fuel cost from wood pellets (for the extended school plus hostel) in the first year is £33,809 giving an annual saving of £33,224. At a net seasonal efficiency of 88% the cost of heat from the boiler is 3.91 pence per kWh.

Table 1 ***Project Costs***

Project Costs for 400kW Biomass Boiler System	
New boilerhouse	£123,840
400kW wood pellet boiler	£111,953
Wood pellet silo & fuel transport auger	£16,160
3 x 10,000 litre thermal stores	£30,871
Flue system & cyclone grit arrestor	£27,692
Oil boiler, oil supply & flue	£82,000
Mechanical installation	£50,159
Electrical installation & BMS	£29,093
District heating network to School & Hostel	£88,302
School plantroom mechanical installation	£29,015
Hostel plantroom mechanical installation	£25,108
Building warrant & planning application	£2,500
Plant hire	£2,885
Testing, commissioning & operator training	£2,654
Documentation	£1,731
Total Project Cost	£623,963

The installation will attract inflation linked Renewable Heat Incentive (RHI) payments, but these can be paid for the heat consumed by the buildings only and not for the losses on the district heating network. Excluding district heating losses the calculated annual energy consumption of the School, extension and Hostel is 780,000kWh: the corresponding RHI payment is detailed in Table 2, below.

The effective total annual energy cost saving from installing biomass is calculated to be more than £64,000.

Table 2 ***RHI Payment***

Tariff Name	Heat Generated per Tariff (kWh)	Tariff (p/kWh)	RHI Value per year
Medium biomass	Tier 1 heat generation = 1,314 hours x boiler rating (400 kW) = 525,600 kWh	4.9[3]	£25,755
Medium biomass	Tier 2 = 100% of annual heat demand less Tier 1 = 780,000 kWh – 525,600 kWh = 254,400 kWh	2.0[4]	£5,085
			£30,840

[3] The Tier 1 tariff as at November 2011 is 4.9p/kWh and will be inflation linked for 20 years.

[4] The Tier 2 tariff as at November 2011 is 2.0p/kWh and will be inflation linked for 20 years.