CASE OAKWOOD PARK ESTATE IN ENGLAND

Background

This study is part of an IEE (Intelligent Energy Europe) project called Woodheat Solutions (IEE/07/726/SI2.499568). Woodheat Solutions (WhS) aims to inspire investment in wood-based heat (and CHP) generation particularly from undermanaged forest. The project plans to transfer best practice from experienced EU Member States, namely Finland and Austria, through demonstration of case studies, training, engagement events and one-to-one support. The project will establish a network for long-term co-operation on biomass energy, offering tools and support that can be applied across the EU.

An Energy Centre on the Oakwood Park Estate could provide some or all of the buildings on the estate with electricity and/or heat. Most of these buildings are educational buildings like schools and colleges. The most likely generation sources could be gas (Combined Heat and Power) or biomass – or a mixture of the two. Solar and ground source heat pumps should also be considered.

Heat could be circulated through an estate-wide hot water heat main and electricity via an estate electricity network. Electricity grid connection could be maintained in order to export electricity at times of low load on the estate and to improve supply security.

Other options could be investigated such as a data-centre on the site to provide lower energy and cost data storage and processing, and possibly making use of the waste heat. Provision of central cooling could also be considered.

Because the estate is still mostly parkland it should be possible to find space for an Energy Centre, and excavation to lay heat and electricity mains should be less expensive than in a more urban environment.

Potential Benefits

- Significant CO_2 savings
- Lower cost energy for buildings on the estate
- Possible income to KCC through energy sales, Feed in tariffs, Renewable Heat obligation, Renewables Obligation certificates or rent.
- Better energy and price security

Potential Barriers

Although all of the buildings on the estate can be viewed as publically owned, responsibility for the buildings is spread amongst a diverse group of organizations. The project would be financially risky unless a good degree of commitment is received from all or most of the relevant organizations which would become either shareholders or customers.

The project would be capital intensive and a long term view on recovering the financial investment would be needed.

Timing may be complex as there is a lack of clarity about when or if Building Schools for the Future will have an impact.

Preliminary techno-economic assessment of the biomass utilisation option

This assessment deals with the biomass utilisation option that was mentioned in Chapter Background. Table 1 shows estimated annual energy spend in terms of costs and energy. In addition, the associated CO_2 emissions have been calculated and shown in the same table.

The annual fuel input is slightly over 15,000 MWh, resulting in 1.73 MW as average fuel input throughout the year. Taking into account that the overall efficiency of the boiler system is probably 84% (boiler efficiency 88%, network losses 4%), the average energy consumption is ~ 1.5 MW.

Figure 1 illustrates a typical annual consumption plot that shows how many hours a year the heat consumption is higher than any selected value of it. For instance, the consumption is higher than 60% of its maximum during about 1,300 hours. Or correspondingly, the consumption is higher than 40% of the maximum in about 3,800 hours. Figure 1 can be used to calculate annual total and average energy consumption, if the peak load is known. The surface area under any selected period of time represents energy consumption during that particular period of time. For instance, if the peak load is known to be 1 MW (100% boiler output), the heat consumption during the first 2,000 hours in the figure would be roughly 0.75 MW * 2,000 h = 1,500 MWh. Where 0.75 MW is the average consumption during the 2,000 hours of the highest consumption throughout the year. Further on, the average annual energy consumption can be calculated by integrating the whole curve and dividing it with the number of hours in one year (8,760 h). This integration yields 0.38 MW as annual average consumption (38% of the maximum) and the annual total energy consumption ~ 3,300 MWh.

Table 1. Present estimated annual energy spend and CO_2 emissions.

Establishment	Estimated annual energy spend (£)	Estimated annual energy spend (MWh)	Estimated annual CO2 emissions (tonnes)
Astor of Hever School	95,070	1,980	523
Oakwood Park Grammar School	67,870	1,415	373
St Francis Roman Catholic School	17,570	365	97
St Simon Stock primary School	91,170	1,900	501
Oakwood House	75,000	1,565	500
Mid Kent college	151,104	3,150	756
University for the Creative Arts	229,356	4,780	1,147
Total	**727,140**	**15,160**	**3,897**

Now for this particular Oakwood Park Estate case, the average consumption is 1.5 MW as was calculated above. This again is 38% of the maximum, implying that the maximum consumption is 1.5/0.38 = 3.95 MW. Maximum boiler output is correspondingly 4.1 ~ 4 MW. Calculations will be made corresponding to 4 MW boiler plant maximum output in heat production. This will not cause any problems since the existing gas boilers provide adequate capacity to fill the small gap during peak load.

The size of the boiler is reasonable to choose to be clearly less than the peak load of the year. Firstly, the boilers normally do not work properly if the load is less than 20% of its maximum output, and consequently another boiler should be in use for such loads. Secondly, the investment cost will be significantly lower. Figure 1 shows an example when boiler's maximum output has been selected to match with 60% of the peak load of the energy consumption. In this case, if the maximum heat consumption load would be 1 MW as mentioned, the boiler's maximum output should correspond to 0.6 MW. The line-filled areas in Figure 1 represent the annual amount of energy that has to be produced using back-up boiler or other means. That amount is normally only 10 – 20 % of the total, as indicated in Figure 1. An oil or gas boiler for instance can be used for that purpose, and its output should be at least 40% of the maximum heat consumption (and 40% of maximum boiler output). For Oakwood Park case this means that the gas boiler's capacity should be at least 0.4 * 4 MW = 1.6 MW. The additional investment for such a gas boiler is many times lower than if the biomass boiler's capacity would have been chosen to be 4 MW instead of 0.6 * 4 = 2.4 MW. Even though the gas boiler's capacity would be chosen to be 4 MW in order to back-up also the biomass boiler, there would be significant savings in the investment costs. In this case it will not be necessary to invest for an additional gas boiler at all since there are existing gas boilers, and it is assumed that they can provide adequate back-up.

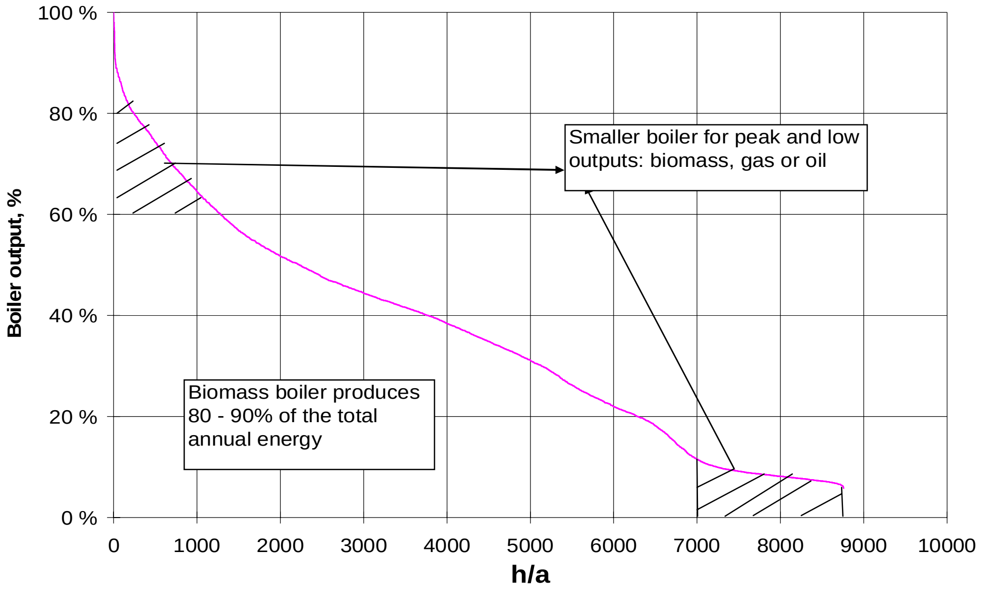

Figure 1. Heat consumption as a function of cumulative operating hours.

The before-mentioned concept is widely in use in Finland, and Figure 1 is valid for the heating and hot water production in the climate of southern Finland, where heating season is normally about 7 months. However, it can be employed with relatively good accuracy in these calculations as well.

Profitability calculations

These calculations compare two options:

- investing for a new 2.4 MW biomass boiler and using the existing boilers with the biomass boiler during the peak and low loads, and as back-up for the biomass boiler
- investing for a new 4 MW gas CHP boiler plant, and using the existing gas boilers with the new gas boiler for peak loads (heat) and and as back-up for heat production

Annual fuel consumption for the biomass plant was estimated above, being 15,160 MWh, and annual average energy consumption and boiler output 1.5 MW, and the peak output 4 MW.

Since 4 MW gas CHP plant and existing gas boilers have to produce the same amount of heat as the biomass plant, and at the same time it generates elctricity, its annual fuel consumption is higher. It is assumed that the electricity/heat ratio is 0.3/0.7. Therefore the annual fuel consumption is 15,160/0.7 = 21,660 MWh, since the total efficiency has been assumed to be 84% for both plants. Thus both plants produce heat 0.84*15,160 = 12,730 MWh, and in addition the CHP plant generates electricity 0.3/0.7*12,730 = 5,350 MWh.

Investment costs for the new 2.4 MW biomass boiler including fuel storage, foundation, building, unloading and conveyors are according to discussions with boiler manufacturers 1.9 million €, and for 4 MW gas CHP plant 1.4 million €. Following parameters have been used in annual costs calculations:

- Share of biomass and gas in annual fuel use of the first option are 85 and 15%, respectively
- Interest rate is 5 %
- Investments will be paid in 10 years
- Annual labour costs in the first option have been calculated according to 1.0 man year for the biomass boiler plant and 0.2 man year for the gas boiler(s)
- Annual labour costs in the second option have been calculated according to 0.5 man year for the gas CHP plant and 0.2 man year for the gas boiler(s)
- Labour costs 4,000 €/person/month
- Maintenance costs correspond to 2 % of the boiler plant investment and 4 months labour per year
- Fuel prices: biomass 33 €/MWh, gas 29 €/MWh
- Losses: boilers 12% and network 4% of the fuel input
- Total cost as supplied to the customers without taxes and profit

The annual costs are shown in Table 2. The total costs in the second option are higher than in the first option, but on the other hand, more energy is produced and the unit cost of energy are clearly lower.

Table 2. Annual energy costs: options biomass plant vs. gas CHP plant.

Costs, €/year	**Biomass boiler plant:** **biomass 85%, gas 15%**	**Gas CHP boiler plant:** **Gas 100%**
Investment	**246,000**	**181,000**
Labour	**57,600**	**33,600**
Fuel	**491,000**	**628,000**
Maintenance and service	**90,000**	**56,000**
Electricity for the plant	**27,500**	**17,300**
Total	**912,000**	**916,000**
Cost, €/MWh	**92**	**50**

Finally, Table 3 compares the profits in the two options. It has been assumed that:

- Heat produced with biomass gets an incentive of 6.5 p/kWh
- Heat sales price is assumed to be 60 €/MWh
- Electricity sales price is 84.5 €/MWh

Table 3. Profits from energy production: options biomass plant vs. gas CHP plant.

Revenue, €/year	**Biomass boiler plant:** **biomass 85%, gas 15%**	**Gas CHP boiler plant:** **gas 100%**
Heat sales	**764,000**	**764,000**
Electricity sales	**0**	**461,000**
Incentive/heat	**827,000**	**0**
Total	**1,591,000**	**1,225,000**
Annual costs	**912,000**	**916,000**
Annual profit	**679,000**	**309,000**

The comparison indicates that the investment in the biomass plant is clearly more profitable because of the high incentive for the heat generated from biomass.

Annual savings in CO_2 emissions

Since the annual energy production rates are different in the two options, the savings in CO_2 emissions are calculated corresponding only the heat production that is the same in both options. The emission factor for natural gas and biomass are 54 and ~ 0 t/TJ, respectively. Therefore the savings in the CO_2 emissions are 15,160/(1000/3.6)*54 = 2,950 tonnes a year.

Fuel storage and supply

Typical Finnish (and Nordic) wood chip supply chains for small-scale plants are presented in the picture below. Both professional forests machines and agricultural tractors equipped for harvesting operations are used in mechanized harvesting. Manual harvesting is mainly used on sites of cleaning type thinning or where an average diameter of felled trees is very small (<9 cm).

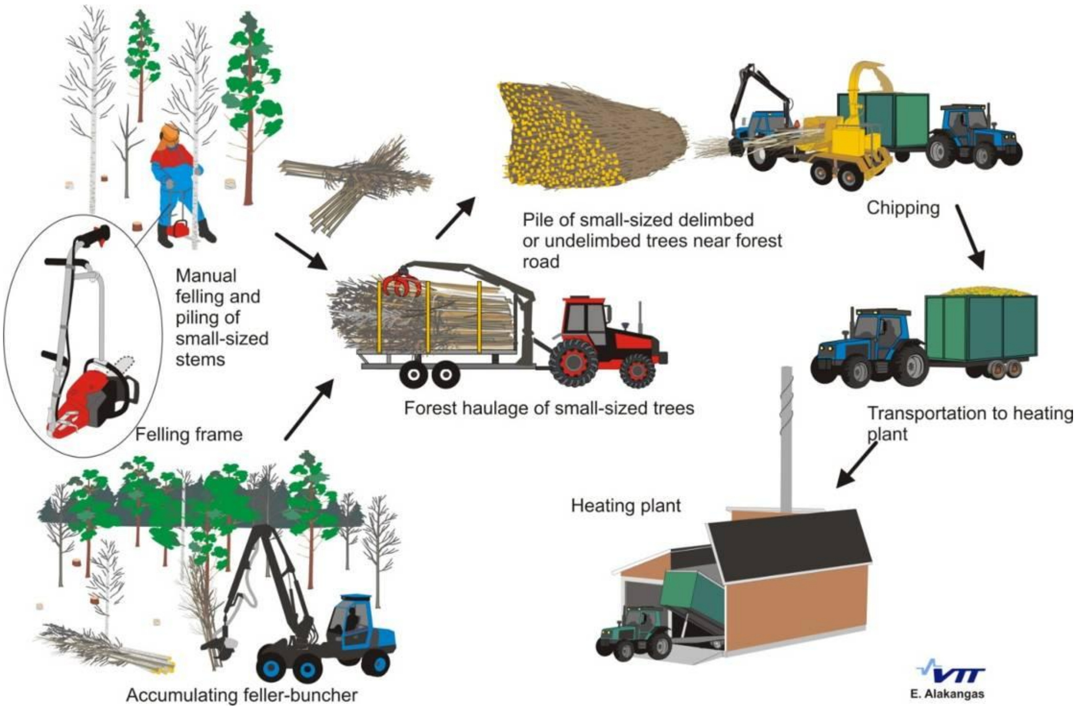

Figure 2: Typical Finnish supply chains of wood chips for small-scale heating plants.

Because storing and chipping are usually done in the woods, heating plants can be made very simple and thus cost-effective. Both the boiler and store are put in the same building, yet in different compartments separated with a wall. It is very common to use a so called ‘walking floor’ for conveying chips to the main auger. This kind of floor can be installed onto the whole storage area, and therefore no handling of chips is needed after delivery. Chips are simply dumped on the floor directly from a truck or tractor which makes delivery fast and easy. If tipping trucks are used, the store including the door needs to be of a significant height, at least 5-6 meters high or to have an opening roof.

The following pictures show typical heating plant solutions in Finland.

Figure 3: A 0.7 MW heating plant. Photo: Jyrki Raitila, VTT.

Figure 4: A chip store (boiler right behind the wall). Photo: Jyrki Raitila, VTT.

Figure 5: Energy wood stacks on the road side, covered with water proof paper to prevent from rain and snow. Photo: Jyrki Raitila, VTT.

Figure 6: A walking floor consists of horizontal bar dischargers moving back and forth. Photo: Jyrki Raitila, VTT.

Figure 7: Chips being delivered; the truck has bar conveyors for unloading. Photo: Jyrki Raitila, VTT.

In this particular case the same principles can be applied. According to Forestry Commission there should be enough fuel wood resources within a reasonable road transport distance (<50 km) from the estate. About one third of woodfuel consumption could be provided from nearby forests. If the road transport distance is shorter than 25 km, woodfuel could be delivered even with tractors as shown in Figure 1.

Because the planned heating plant would be in an urban area (Figure 7), it is recommended that all chipping is done already in the forest. In Finland storing and chipping of timber/whole trees is usually done in the woods. In most cases it is not only the most convenient way but also the most cost-effective way to do it. These are some of the benefits:

- No need to store wood (stems, etc.) at the plant
- Energy wood can be seasoned (= air dried) while in the woods
- Both fuel wood and timber can be harvested at the same time with the same machines (or manually) and stacks can be left in the woods (on the forest road side)
- Harvesting and chipping can be done with effective machines by using professional contractors

It should also be noticed that the planned boiler needs about 70 loose-m3 of wood chips a day, equalling 1-2 truck loads, while working at its full capasity. On average there should be 3-6 deliveries every weeks, depending on the transport equipment. Therefore logistics require careful planning and organization.

Figure 8: Aerial photo of Oakwood Park Estate.
Photo: Provided by FC.

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