Visit of Finnish experts to the UK
Woodheat solutions – IEE/07/726/SI2.499568

Jyrki Raitila, VTT

Veli-Pekka Heiskanen, VTT

VTT
P.O.Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

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Keywords Woodheat, entrepreneurship, district heating

Abstract

Finnish woodheat experts of VTT visited the UK in order to advice on three woodheat projects supported by the Woodheat Solutions project.

Highfield School (Hampshire) is a private school for children aged 3-13 located in Hampshire. The site is currently served by 27 individual oil fuelled boilers (total capacity about 1,350 kW) for provision of heat and hot water. The school had already had a biomass heating assessment made for the estate. It is recommended to improve user-friendliness of the planned system by installing a clearly larger thermal store, e.g. 100 or even 300 m^3 in volume compared to 20 m^3 in the plan). This would enable to decrease significantly oil use during peak load periods of heat. In addition, oil use could be avoided or significantly decreased during the boiler annual down times, which typically are several in case of biomass boilers.

Coley High Rise comprises 3 residential tower blocks situated to the west of Reading center in a relatively poor area. Therefore it is eligible for government funding for energy saving investments. TV Energy Ltd. had provided an outline pre-feasibility to investigate the options for replacing the existing individual electric heating systems with central CHP or heating plant. Having received the feedback by VTT TV Energy has modified their feasibility study. Because TV Energy did not include any assessment of how wood fuel should be stored or brought to the boiler, VTT addressed the most critical issues. In general, this bioheat project seems very profitable and definitely deserves implementation.

Oakwood Parkland Estate, built on the grounds of Oakwood House, is located in the city of Maidstone, Kent. A considered energy plant on the Oakwood Park Estate could provide some or all of the buildings on the estate with electricity and/or heat (1.5 MW total energy demand). VTT compared two options for the estate: 1. 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. 2. 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. If the renewable heat incentive (RHI) is received from the government, the investment in a new biomass heat or CHP system would be very profitable.

VTT
P.O.Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

General

Finnish woodheat experts from VTT visited the UK in order to provide their expert support for woodheat projects chosen by local project partners. These projects were/are being delivered by participants of WP2 and 5 or others made known to the project partners.

Experts gave advice to these projects on the manner new technologies can be introduced and how the economics of new wood fuel supply chains can be optimized. Also contracts to sell heat, plans to store wood fuels and development of local woodheat markets were reviewed. In general, by visiting potential woodheat sites and investors and woodfuel suppliers the projects were to be advanced and barriers resolved.

The project partners in each country had chosen very promising projects that have potential to develop quickly if suitable investors can be found and required permissions can be obtained. Each partner had widely informed the possibility for an expert visit through their existing network and by different activities (e.g. engagement seminars) done in previous work packages. Eventually the hosting partners together with Finnish experts chose the projects from among those that expressed interest for such a visit and that could benefit most from it.

In general, it seems there is more need to give advice to and comment on technical issues than to advice woodfuel supply chains because of a lack of experience of wood boilers and wood fuel heating systems. Woodfuel supply is often done by suppliers of round wood, and therefore their methods are usually professionally developed. On the other hand, in most cases there was a local supplier of wood fuels already. Thus different supply issues were already settled unless specifically addressed in the studies. Therefore the focus of the expert visits was on technical matters like choosing a right kind of boiler, sizing it, and planning of the storage. Yet costs and necessary investments were discussed too.

Finnish experts, Mr. Veli-Pekka Heiskanen and Mr. Jyrki Raitila, visited several potential woodheat sites and agreed to advice to and/or comment on these cases as stated in the project plan. The contents of each study are based on information provided by local stakeholders and project partners. These studies reflect on what was asked for in particular. The Finnish experts also provided support for the greatest needs at this stage of each project. The case studies are included in separate document files and in the appendices.

VTT
P.O.Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

Program in the UK

Monday 7 June, 2010

20:40 Arrive at Heathrow
Accommodation at Groomes

Tuesday 8 June, 2010

9:00 Visit Abingdon Council/Museum; potential heating site

13:00 Visit Coley High Rise Flats at Reading; potential district heating (Mr. Paul, Ben Burfoot, Reading Borough Council)

Wednesday 9 June, 2010

10:00 Visit FC field station, Bedgebury; potential heating site

12:00 Visit Bedgebury Visitors Centre (Kate Harris, Beat Forester); short rotation coppice and wood fuel processing yard

14:00 Visit Oakwood Park Schools (& hospital), Maidstone; potential district heating site)

17:00 Visit Highfield School, Hampshire; potential local district heating site (William Harris, Owner of school)

Thursday 10 June, 2010

9:00 Participate Ecotown design meeting and site visit in Whitehill, Bordon (Wendy Shillam, Project Manager)

13:00 Visit Hindhead, Drummonds reclamation yard, Stafford

16:00 Visit Rodborough School; potential heating site

VTT
P.O.Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

Summary of the visit to the UK

The expert visit to the UK revealed that there are some good examples of installed modern woodheat systems in the country. However, district heating is not very common there yet. Most wood heating is done is in domestic or public buildings either with wood logs or wood chips. Low gas and oil prices and a lack of district heating networks have substantially hindered installing of woodheat systems.

The English partners had chosen good cases to be advised on because all of them were developed enough to have concrete plans to build on. Therefore it was possible to have fruitful discussions with potential investors and users of woodheat on one hand, and receive relevant background information from municipal and regional authorities on the other. Comments and preliminary techno-economic assessments of the biomass utilization options were based on these visits and materials provided by project partners and people involved in each woodheat case.

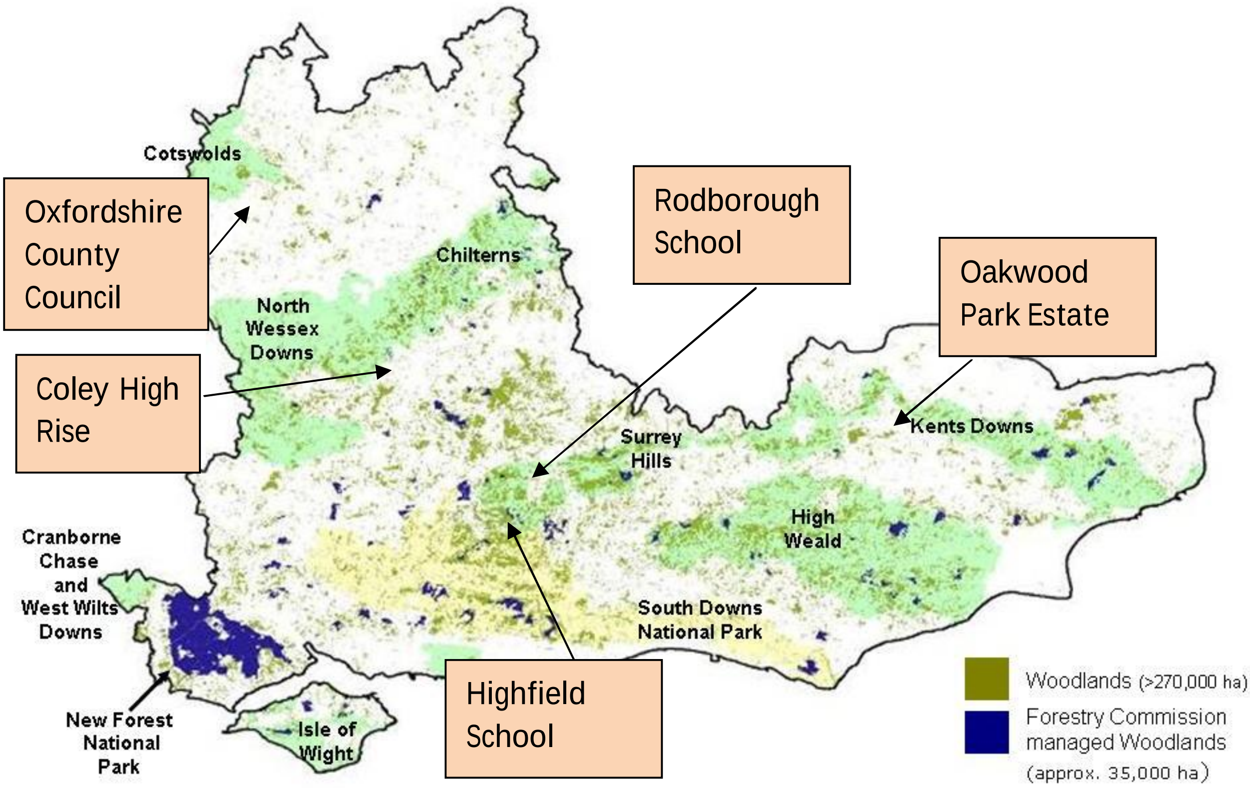

Figure 1: The main woodheat projects advices by Finnish experts.

Those projects that were given detailed advice are described below. Other visited potential woodheat sites included Oxfordshire County Council, Rodborough School and a FC field station Bedgebury. Brief visits were also paid to A Whitehill Bordon ecotown and

VTT
P.O.Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

Drummonds reclamation yard in Stafford. Experts addressed there issues like wood fuel supply methods and costs, suitability of woodheat for suggested buildings, basic technical issues and rough costs of installing woodheat systems to such buildings.

Highfield School, Hampshire

Highfield School is a private school for children aged 3-13 located in Hampshire. The site is currently served by 27 individual oil fuelled boilers (total capacity about 1,350 kW) for provision of heat and hot water. There are several buildings on the site totalling about 5,200 m^2 of footprint. The whole estate also includes gardens, a golf course and some woodland. The school board has taken a concrete step toward replacing the old heating system with a wood fired boiler by asking Mr. Sam Whatmore (Woodfuel Solutions) to make a biomass heating assessment for the school. Because a detailed and meticulous feasibility study was already done, just some minor comments are presented here. However, in order to rapidly move on with this project, the school needed confirmation, or at least a second opinion, about their plans to install a wood fired boiler.

The heating demand was calculated to be 1,170 MWh. Correspondingly, the biomass boiler size has been optimised to be 400 kW. On the other hand, the peak thermal demand is 575 kW. Taking into account that average heating network losses have been estimated to be about 8%, the 400 kW biomass boiler can deliver about 370 kW at maximum to the consumers. Biomass boiler's maximum output accounts thus for about 64% of the peak thermal load. This is technically very well in balance with the annual heat consumption since the hourly heat demand exceeds 370 kW only quite short periods of time. On the other hand, the biomass boilers do not usually work effectively if the boiler output is less than 20% of the rated output.

It was estimated in the feasibility study that the biomass boiler with a 20 m^3 thermal store could deliver 99.8% of the annual demand. This may be slightly too an optimistic estimate. Taking into account that the thermal store capacity is roughly 0.7 MWh, it corresponds only to a little over one hour back-up during the peak heat demand 575 kW, and less than two hours of biomass boiler's peak output. This small amount of oil (3 MWh) and utilisation of 0.7 MWh thermal store cannot back up and fill the gaps between the heat demand and biomass boiler's maximum capacity during the mentioned peaks that account for about 70 – 150 MWh on an annual basis.

One option to improve user-friendliness of the system could be buying of a clearly larger thermal store, like one with 100 or even 300 m^3 volume. The heat in the store would correspond to 3.5 – 10.5 MWh, respectively. This would enable to decrease significantly oil use during the beforementioned peak load periods. In addition, oil use could be avoided or

VTT
P.O.Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

significantly decreased during the boiler annual down times, which typically are several in case of biomass boilers. Therefore larger thermal store would result also in lower costs not only because of the decreased oil use but because of lower operational costs, and would significantly increase user-friendliness of the whole system.

Basically storing and processing of all wood fuels is planned to take place at the heating plant. Although there are some advantages of doing this, e.g. chipping can be done directly into the store, an alternative Finnish model was presented. 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 (timber, etc.) at the plant
- Energy wood can be seasoned (= air dried) while in the woods
- Both energy 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
- If the road transport distance is relatively short (<35 km), delivery of chips can be done with a combination of tractor and trailer

Coley High Rise

Coley High Rise comprises 3 residential tower blocks situated to the west of Reading center within an area ranked in the lowest 10% as measured by the Indices of Multiple Deprivation in England and as such is eligible for capital funding from the Community Energy Saving Program. This program is a central government initiative and aims to permanently reduce energy bills in areas of low income.

Reading Borough Council requested TV Energy to provide an outline pre-feasibility to investigate the options for replacing the existing individual electric heating systems with central CHP or heating plant. VTT experts involved in the Woodheat project also visited the area and familiarized themselves with the current situation. Based on the visit and provided pre-feasibility study comments and suggestions were made.

The estimated average space heating and hot water demands per 2 and 1 bed flats seem to be very high. Given figures for 2 bed flat are 186 and 89 kWh/sq.m/yr, respectively, resulting in 275 kWh/sq.m/yr in total (see page 7 of the report). For 1 bed flat the given figures are even higher, being 268 and 128 kWh/sq.m/yr, 396 kWh/sq.m/yr in total. In Finland for instance, these figures are typically 120-140 kWh/sq.m/yr for space heating and 30 kWh/sq.m/yr for

VTT
P.O.Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

hot water demand. Taking into account the colder climate in Finland, the given figures seem very high. Because of this the total calculated heat demand and sizing of the wood fired boiler seem too high as well. Having received the feedback by VTT TV Energy has modified their feasibility study.

The pre-feasibility study by TV Energy does not include any assessment of how wood fuel (=wood chips) should be stored or brought to the boiler. No suggestions of a place of the heating plant and the wood chip storage are given. In an urban setting, in particular, these issues should be addressed.

In the study there were two options for a biomass boiler, 700 kW or 800 kW. The biomass boiler fuel consumption was estimated 786 or 1,262 tonnes/year respectively. With a truck of 15 t payload this would mean 52 or 84 deliveries a year. Because most wood chips are consumed in winter, in practice there would be 2-4 deliveries a week. At a peak output such a boiler would use about 1 loose –m^3 of wood in every hour. This means that in order to avoid holiday, weekend and daily deliveries the store should be able to hold about 80 m^3 of wood chips. In practice, the storage space should then be over 100 m^3. It is recommended to build a store high enough (>6 m) for effective unloading where a truck can drive in and tip the chips into the store. Delivery trucks also need enough room for manoeuvering like turning and reversing. In any case the boiler house with reasonably high smoke stacks and the wood fuel store should be built in a way they do not disturb residential buildings and local traffic too much.

Oakwood Park Estate

Oakwood Parkland Estate, built on the grounds of Oakwood House, is located in the city of Maidstone, Kent. It contains seven schools or similar buildings like a collage that could all be heated from one central heating plant. This energy plant on the Oakwood Park Estate could provide some or all of the buildings on the estate with electricity and/or heat. The most likely generation sources could be gas (Combined Heat and Power) or biomass – or a mixture of the two.

An assessment made by the Finnish experts deals with the biomass utilisation option only. According to the provided information, 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. In the assessment the following, most feasible options were compared:

VTT
P.O.Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

- 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.

Calculations show that without incentives the cost of energy generated from gas would be 50 €/MWh and 92 €/MWh if produced from biomass. However, with an anticipated renewable heat incentive (RHI) 6.5 p/kWh the investment in the biomass plant is clearly more profitable. The biomass plant could make two times better profit that the natural gas plant. In addition, the savings in the CO_2 emissions would be 15,160/(1000/3.6)*54 = 2,950 tonnes a year if biomass is used for energy production.

VTT
P.O.Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

Appendices

CASE HIGHFIELD SCHOOL IN ENGLAND

Backgound

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 practise from experinced 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.

Comments on feasibility study of Woodfuel Solutions

Since for this case a detailed and meticulous feasibility study was already done, just some minor comments are presented here.

Boiler and thermal store sizing

The biomass boiler size has been optimised to be 400 kW. On the other hand, the peak thermal demand is 575 kW. Taking into account that average heating network losses have been estimated to be about 8%, the 400 kW biomass boiler can deliver about 370 kW at maximum to the consumers. Biomass boiler's maximum output accounts thus for about 64% of the peak thermal load. This is technically very well in balance with the annual heat consumption since the hourly heat demand exceeds 370 kW only quite short periods of time. Those excess loads account for about 5 – 10% of the total annual heat demand. That is just a rough estimation based on Figure 5 in the feasibility study. On the other hand, the biomass boilers do not usually work effectively if the boiler output is less than 20% of the rated output. In this case it would mean 80 kW output from the boiler and almost 75 kW delivered to the consumers. This fits again quite well with the minimum heat demand that is the second half of July (see Fig. 5), when the heat demand is about 70 kW.

It has been estimated in the feasibility study that the biomass boiler with a 20 m^3 thermal store could deliver 99.8% of the annual demand. This may be slightly too an optimistic estimate. Taking into account that the thermal store capacity is roughly 0.7 MWh, it

VTT
P.O.Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

corresponds only to a little over one hour back-up during the peak heat demand 575 kW, and less than two hours of biomass boiler's peak output. The widest and highest of the peaks in Figure 5 in January – March exceed the 370 kW heat demand approximately during 5 days by 50 - 100 kW on average. During each such period the heat store should deliver 6 - 12 MWh of heat in addition that the biomass boiler is running at maximum output. Such periods are quite many and they follow each other quite soon preventing the thermal store to fill the gap. Oil consumption was estimated to account only for 0.2% of the total fuel consumption on an energy basis, being annually about 3 MWh (see page 12 and Table 4 on page 23; a slight error on page 3 where it has been stated to be 0.8%). Anyhow, this 3 MWh of oil and utilisation of 0.7 MWh thermal store cannot back up and fill the gaps between the heat demand and biomass boiler's maximum capacity during the mentioned peaks that account for about 70 – 150 MWh on an annual basis.

One option to improve user-friendliness of the system could be buying of a clearly larger thermal store, like one with 100 or even 300 m^3 volume. The heat in the store would correspond to 3.5 – 10.5 MWh, respectively. This would enable to decrease significantly oil use during the beforementioned peak load periods. In addition, oil use could be avoided or significantly decreased during the boiler annual down times, which typically are several in case of biomass boilers. In addition, it would even enable to stop the biomass boiler for the weekends between the period 1 June and 31 October. The total heat consumption during the weekends in question is roughly 8 MWh per weekend (estimated from the Figure 5, calculating 64 hours' weekend). Therefore larger thermal store would result also in lower costs not only because of the decreased oil use but because of lower operational costs, and would significantly increase user-friendliness of the whole system. As to increased losses due to the larger size of the thermal store, they can be roughly estimated to increase in relation to the square root of the volume. Heat losses for the 20 m^3 thermal store has been estimated for about 10 MWh/year (see page 3 in the feasibility study). Thus heat losses for the 300 m^3 store would be $\sqrt{15} * 10 \sim 40$ MWh, accounting for about 2.7% of the annual fuel input on an energy basis (~ 1,500 MWh). The price of the thermal store would increase but not in the ratio of the store volumes but rather in the ratio of their square root like the heat losses. The sizing of the thermal store is finally an optimisation between the increased and decreased costs and user-friendliness and depends also on how much the plant user values user-fiendliness.

Annual savings in CO_2 emissions

The annual savings of 288 CO_2 tonnes on page 4 seem to refer more to CO_2 emissions from natural gas than to fuel oil emissions. The emission factors for natural gas and fuel oil are about 54 and 74 t/TJ, respectively. The feasibility study has estimated the annual decrease of

VTT
P.O.Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

fossil fuel on an energy basis to be 1,400 MWh that corresponds to 5.04 TJ. Thus the annual CO_2 emissions from natural gas and fuel oil would be 272 and 373 tonnes, respectively.

Fuel storage and supply

In general, in the study fuel storage and supply of wood fuel is covered consistently and taking important points into consideration. Basically storing and processing of all wood fuels is planned to take place at the heating plant. Although there are some advantages of doing this, e.g. chipping can be done directly into the store, some questions are raised:

- Is it convenient to have all wood fuel (timber, whole trees, etc.) at the plant? It takes a lot of space, may attract insects, etc.
- Is it desirable to make wood chips at the plant? Chipping is noisy and leaves the area untidy.
- Is there going to be a chipper available at any time? Is the school going to invest in the chipper or is the chipping going to be done by a contractor? If a contractor is used, the chipping can easily be done elsewhere.
- Does the school have a tractor or a front-end loader for moving the chips? Double handling is needed in any case because the feeding system (= spring agitator) requires the moving of wood chips in the store.
- Is it safe enough to have an 'open' store in the school premises?

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 (timber, etc.) at the plant
- Energy wood can be seasoned (= air dried) while in the woods
- Both energy 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
- If the road transport distance is relatively short (<35 km), delivery of chips can be done with a combination of tractor and trailer

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).

VTT
P.O.Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

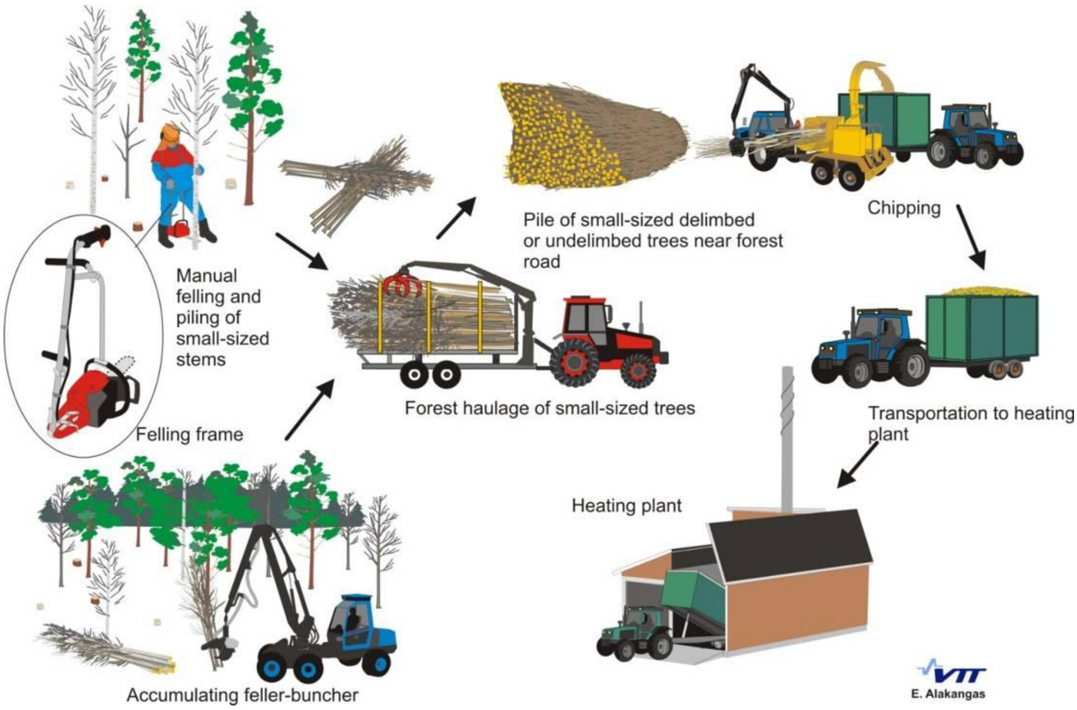

Figure 1: Typical Finnish supply chains of wood chips for small-scale heating plants.

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.

VTT
P.O.Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

Figure 2: A 0.7 MW heating plant. Photo: Jyrki Raitila, VTT.

Figure 5: A walking floor consists of horizontal bar dischargers moving back and forth. Photo: Jyrki Raitila, VTT.

Figure 3: A chip store (boiler right behind the wall). Photo: Jyrki Raitila, VTT.

Figure 6: Chips being delivered; the truck has bar conveyors for unloading. Photo: Jyrki Raitila, VTT.

Figure 4: Wood fuel stacks on the road side, covered with water proof paper to prevent from rain and snow. Photo: Jyrki Raitila, VTT.

VTT
P.O.Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

Jyväskylä 7.7.2010

Jyrki Raitila
Research Scientist, M.Sc. (For.), MA
Technical Research Centre of Finland
Team Leader
Biomass Fuel Production
Tel. +358-40-7195117
Email: jyrki.raitila@vtt.fi

Veli-Pekka Heiskanen
Senior Research Scientist, Lic.Sc. (Tech.)
Technical Research Centre of Finland
Multifuel Operations
Tel. +358-40-547 8960
Email: veli-pekka.heiskanen@vtt.fi

CASE COLEY HIGH RISE 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.

Coley High Rise comprises 3 residential tower blocks situated to the west of Reading center within an area ranked in the lowest 10% as measured by the Indices of Multiple Deprivation in England and as such is eligible for capital funding from the Community Energy Saving Program. This program is a central government initiative and aims to permanently reduce energy bills in areas of low income.

Reading Borough Council requested TV Energy to provide an outline pre-feasibility to investigate the options for replacing the existing individual electric heating systems with central CHP or heating plant.

VTT experts involved in the Woodheat project also visited the area and familiarized themselves with the current situation. Based on the visit and provided pre-feasibility study the following comments were made.

VTT
P.O.Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

Comments on feasibility study of TV Energy Ltd

Since a detailed and meticulous feasibility study for this case has already been made, just some minor comments are presented here.

The estimated average space heating and hot water demands per 2 and 1 bed flats seem to be very high. Given figures for 2 bed flat are 186 and 89 kWh/sq.m/yr, respectively, resulting in 275 kWh/sq.m/yr in total (see page 7 of the report). For 1 bed flat the given figures are even higher, being 268 and 128 kWh/sq.m/yr, 396 kWh/sq.m/yr in total. In Finland for instance, these figures are typically 120-140 kWh/sq.m/yr for space heating and 30 kWh/sq.m/yr for hot water demand. Taking into account the colder climate in Finland, the given figures seem very high. Particularly, taking into account some building approvements as stated in the study: "*Building improvements have been carried out over previous years including the fitment of external cladding providing increased thermal insulation, and PVC double glazed windows*". Now if the figures really are too high, the boiler plant in both options will become oversized, and consequently, the investment costs become much too high. Perhaps the consumption of space heating and hot water could be double-checked and estimated from measured electricity consumptions. Local power company obviously has the figures for annual power consumption for every single flat and/or for individual blocks. After the consumptions have been re-assessed, VTT could make calculations and comparison of the energy production costs for the two options, and furthermore compare the results with the present energy costs.

Figure 1: One of the Coley High Rise buildings

In addition, the calculated space heating capacities for 1 and 2 bed flats have been calculated according to 100 W/sq.m (see table on page 7). On the other hand, in the same table, the estimated annual average consumptions for 1 bed flats are clearly higher than for 2 bed flats, as was mentioned in the previous paragraph. Obviously the capacity for 1 bed flat should also be higher than for 2 bed flat.

VTT
P.O.Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

Some of CO_2 emissions calculations of the first option (page 9) seem somewhat unclear. Emissions from CHP gas consumption, biomass boiler fuel consumption and gas boilers gas consumption are 673, 65 and 129 tonnes/yr, respectively. These figures are correctly calculated and indicated where they come from. In addition to these, there are three other figures for CO_2 emissions. It is not very clear why these figures are included, and how they have been taken into account in calculation of the total CO_2 emissions saving 2,055 tonnes/yr.

Monthly hot water demands (tables on pages 8 and 11) have been given in kWh/year instead of kWh/month. The figures correspond indeed to monthly demands.

Woodfuel logistics and storage

The pre-feasibility study by TV Energy does not include any assessment of how wood fuel (=wood chips) should be stored or brought to the boiler. No suggestions of a place of the heating plant and the wood chip storage are given. In an urban setting, in particular, these issues should be addressed.

While visiting the high rise buildings, it was suggested that the plant and store could be placed in the parking area (parking lot and/or garages) in front of the buildings. An advantage of this location would be a short distance to the towers. Thus, the main heating pipe could be as short as 50-100 m.

However, there are several reasons why this location is not recommended. First, a central location between the towers and other residential buildings would not be appreciated by the residents. Second, the smokestack of the plant should be built extremely tall because of high towers. Third, chip trucks should use narrow streets and lanes for wood fuel deliveries. Fourth, regular chip truck deliveries through a residential area would not necessarily be appreciated by the residents.

During a short tour around the area an alternative place for the plant was found. There was an unbuilt lot of land nearby where the plant could be built. It is recommended to find out whether it is possible.

In the study there were two options for a biomass boiler, 700 kW or 800 kW. The biomass boiler fuel consumption was estimated 786 or 1,262 tonnes/year respectively. With a truck of 15 t payload this would mean 52 or 84 deliveries a year. Because most wood chips are consumed in winter, in practice there would 2-4 be deliveries a week. At a peak output such a boiler would use about 1 loose –m^3 of wood in every hour. This means that in order to avoid

VTT
P.O.Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

holiday, weekend and daily deliveries the store should be able to hold about 80 m^3 of wood chips. In practice, the storage space should then be over 100 m^3. It is recommended to build a store high enough (>6 m) for effective unloading where a truck can drive in and tip the chips into the store. Delivery trucks also need enough room for manoeuvering like turning and reversing.

Jyväskylä 1.11.2010

Jyrki Raitila
Research Scientist, M.Sc. (For.), MA
Technical Research Centre of Finland
Team Leader
Biomass Fuel Production
Tel. +358-40-7195117
Email: jyrki.raitila@vtt.fi

Veli-Pekka Heiskanen
Senior Research Scientist, Lic.Sc. (Tech.)
Technical Research Centre of Finland
Multifuel Operations
Tel. +358-40-547 8960
Email: veli-pekka.heiskanen@vtt.fi

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.

VTT
P.O.Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

- 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.

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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.

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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.

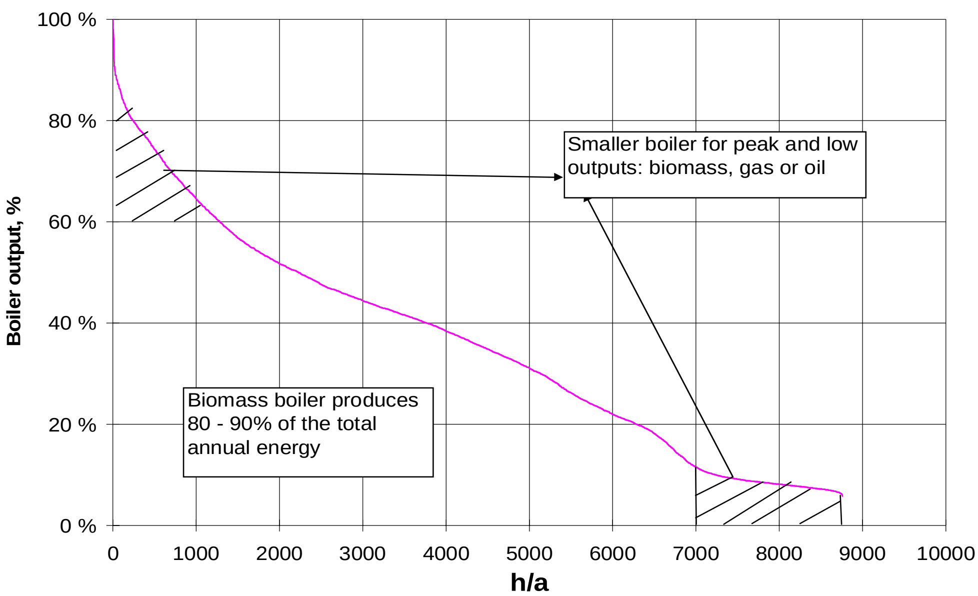

Figure 1. Heat consumption as a function of cumulative operating hours.

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P.O.Box 1603
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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)

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P.O.Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

- 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:

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- 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.

VTT
P.O.Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

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).

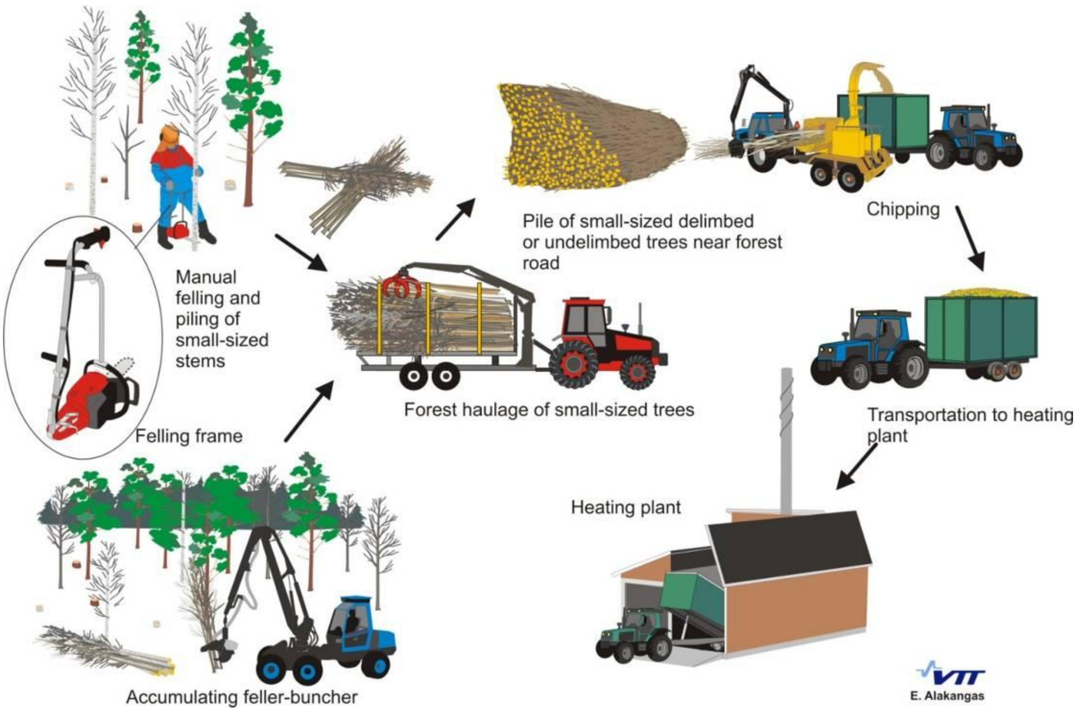

Figure 2: Typical Finnish supply chains of wood chips for small-scale heating plants.

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.

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P.O.Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

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.

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P.O.Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

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

VTT
P.O.Box 1603
FIN - 40101 Jyväskylä
firstname.lastname@vtt.fi
Tel + 358 20 722 111

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Jyrki Raitila
Research Scientist, M.Sc. (For.), MA
Technical Research Centre of Finland
Team Leader
Biomass Fuel Production
Tel. +358-40-7195117
Email: jyrki.raitila@vtt.fi

Veli-Pekka Heiskanen
Senior Research Scientist, Lic.Sc. (Tech.)
Technical Research Centre of Finland
Multifuel Operations
Tel. +358-40-547 8960
Email: veli-pekka.heiskanen@vtt.fi

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firstname.lastname@vtt.fi
Tel + 358 20 722 111