Trip Report

Site Visit to Alholmens 240 MW Power Plant

Pietarsaari, Finland

August 29 to September 2, 2005.

Prepared by:

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Note: This report is one of two prepared for a re-evaluation of using surplus MPB killed trees for generating power in B.C. The second report, Feedstock Availability and Power Costs Using B.C.'s Beetle Infested Pine, is available from the BIOCAP Canada Foundation (www.biocap.ca) as a companion report.

Prepared for the

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Summary

In late August to early Sept, 2005, six individuals from Canada visited an engineering contractor, boiler manufacturer and mill site associated with the world's largest existing biomass power plant, the Alholmens 240 MW unit at Pietarsaari using a circulating fluidized bed boiler supplied by Kvaerner Power. The Alholmens plant is designed to operate on 100% biomass and 100% coal and any mix thereof, and has completed performance tests under both conditions.

The funding to support the planning for the trip, the travel for two of the participants, and the preparation of this report was provided by the BIOCAP Canada Foundation in partnership with the Province of British Columbia (BC Ministry of Forests).

The purpose of the trip was to assess whether any technical or logistical barrier existed for the prospective use of surplus mountain pine beetle killed trees in B.C. for large scale generation of electrical power. No barrier was identified up to the proposed plant size of 330 MW of gross power production.

General Comments on the Site Visit

One option to utilize Mountain Pine Beetle (MPB) killed trees in British Columbia that would otherwise go unharvested is to generate electrical power. A previous first stage study commissioned by the BIOCAP Canada Foundation and partially funded by the BC Ministry of Forests and Range (MOF) identified that a large scale power plant (300 MW) could generate power at a cost between $60 and $70 per MWh using chipped MPB killed trees as fuel. Power plant size was identified as a critical cost factor, with smaller sized plants having a significantly higher power cost due to higher capital cost per unit of output.

In the discussions that followed the first stage report concerns were raised about the technical viability of a large scale wood based power plant. One element of a second stage study was therefore to visit the world's largest power plant designed to run on biomass, which is located at the Alholmens Plant in Pietarsaari, Finland. This plant has a nominal gross rating of 240 MW and is designed to run on 100% biomass (wood, wood waste and peat) and 100% coal, and any combination thereof. It produces power both for internal use in the pulp and lumber mill and for export to the Nordpool grid, and has the capability to export low quality heat for use in the Pietarsaari district heating system.

A group of six individuals from Canada spent five working days in Finland, meeting with:

- Electrowatt Ekono, an engineering firm that did the EPC (engineer, procure, construct) for the Alholmens plant.
- Kvaerner Power, the boiler company that designed and supplied the boiler for the Alholmens plant.
- Alholmens, specifically the power plant.
- VTT, a Finnish national research organization that has pioneered in the design of equipment and the analysis of the economics of recovering forest wastes to be used as a fuel.

Participants in the group were:

- Jeff Barker, Manager, Business Strategy, BC Hydro.
- Craig Carlyle, Maintenance Superintendent, Armstrong Division, Tolko Industries.
- Dave Conlin, Director of Generating Plant Development, Epcor (Major Projects)
- Peter Flynn, Professor, University of Alberta.
- Bob Friesen, Assistant Deputy Ministry Tenure and Revenue, MOF.
- Amit Kumar, Assistant Professor, University of Alberta.

The group included four individuals (Barker, Carlyle, Conlin and Flynn) with prior experience in the electric power industry.

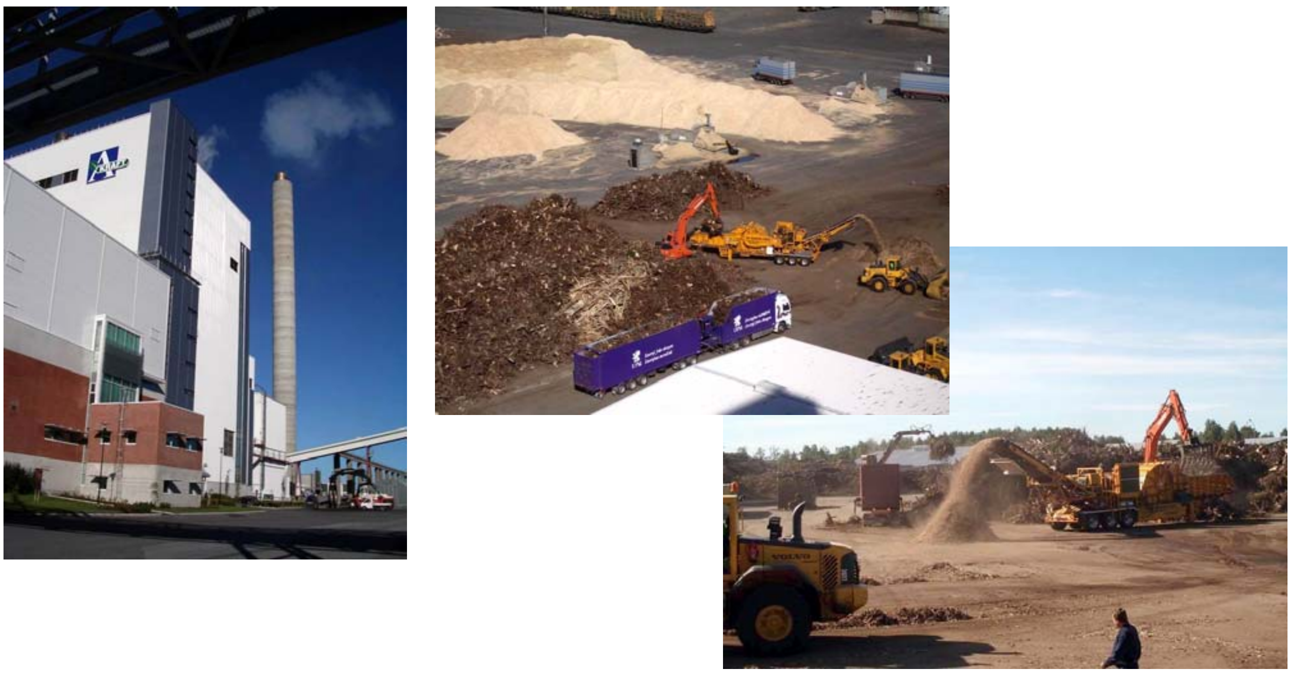

Fig 1. Alholmens power plant, fuel yard (note arriving truck) and stump grinder in the yard.

The key purpose of the trip was to assess the technical and logistical feasibility of a 325 to 330 MW gross / 300 MW net power plant fueled by wood chips. All participants concluded that the Kvaerner Power boiler at Alholmens, nominally designed for 240 MW and achieving more than 250 MW in actual operation, was clearly operating, has operated on 100% biomass as well as 100% coal, has been reliable (with a high availability / on line factor), and has achieved high thermal efficiency (38.5% when operating in full condensing mode, as it was the day of our visit). The boiler design, a circulating fluidized bed (CFB), has been applied in a wide variety of settings and using a wide variety of fuels (coal, peat, wood, wood waste, petroleum coke). At Alholmens it has a 35% turndown ratio (ratio of minimum sustainable operating level to design operating level), low unburned carbon, 0.3%, and very low NOx emissions. There is no evident technical barrier identified by Kvaerner or us that would prevent the scale up of this technology from 240 MW to 330 MW. Two 330 MWe boilers are being designed by

Kvaerner for a petroleum coke fuel project in the US. CFB boilers have more fuel flexibility than Bubbling Fluidized Bed (BFB) boilers, and can be built as a single unit at a much larger capacity (330 MW vs. 100 MW); for both reasons a CFB design appears more appropriate for burning MPB wood, in that a single boiler can accommodate the size and could handle a shifting fuel supply if/when the MPB wood supply declined. (Note that Foster Wheeler is an alternative supplier of CFB boilers and in separate correspondence they also indicated that they see no technical barrier to a 330 MW wood fired power plant. More than one vendor bid on the Alholmens plant, and we believe that Foster Wheeler was one of the bidders.)

Fig. 2. Forest harvest residue recovery (upper left), residue/stump tandem van with self contained loader and variable size rear compartment (upper right), forest thinning machine (lower left), forest harvest residue “logs” (lower center) and piled dry stumps (lower right).

The Alholmens site has limited storage space for boiler fuel, and the yard typically holds only 24 hours of woody biomass and peat fuel supply; an additional ½ hour to 1 hour is in the fuel silos at the boiler. Truck is the predominant method for delivery of forest harvest residues (branches, tops and stumps from the final harvest and thinnings) from outside sources; conveyors move bark and shavings generated from inside the plant. The site has rail service and some logs are moved by rail, but rail shipment of forest harvest residues biomass is not significant. Forest harvest residues and peat are received year round; residues are stored by the side of logging roads or secondary roads throughout Finland, and a network of forest companies and fuel brokers arrange the delivery of fuel. Residue storage sites are selected to ensure that some are accessible even during winter and spring breakup road conditions. Coal is delivered to the Alholmens plant by ship, and we do not know how many days inventory is stored on site.

Power economics and fuel logistics are highly site specific, and cannot be extrapolated to another country. We made the following additional observations, but they do not specifically apply to Canada:

- Alholmens runs a mix of woody biomass from both field sources and its own plant, peat and coal; the cost of power increases in that order from the three fuels. Power cost is influenced by tax treatment that favors woody biomass over peat and coal.

- Alholmens sells power into the Nordpool grid. During the day price exceeds cost, and the power plant runs at full capacity. Most nights the power plant is turned down due to low power costs. The predominant power source in Nordpool is hydroelectric, and the marginal cost of hydro power is lower than all the four fuels used at Alholmens.

- The coal capacity of the plant was originally intended for two purposes. The first was to provide a bridging fuel when road conditions prevented the delivery of woody biomass and peat, since the Alholmens site has very limited on site storage for biomass. The second was to limit the ability of Finland's numerous woodlot owners to extract exorbitant prices for woody biomass. However, today Finland has an excess of biomass burning boilers relative to the supply of biomass, and hence Alholmens runs about 45% coal on an annual basis, not by choice but because of biomass fuel scarcity.

- Finland has an intensive infrastructure aimed at recovering and using field sourced woody biomass, including specialized equipment. Subsidies are applied judiciously and with precision, and at far lower levels than in most of Europe. Peat, for example, is not subsidized but can earn tax relief if burned in conjunction with woody biomass in certain plants. Thinnings, material recovered from thinning a forest about 30 years before final harvest, get the largest subsidy because the cost of collection is highest. The removal of stumps and most but not all forest harvest residues is driven by forest regrowth maximization, but all of this material finds its way into the fuel system. Stump recovery is designed to maximize fuel value; stumps are split to achieve good drying in a one year storage period. Forest landowners do not get any income from the recovery of thinnings, stumps or forest harvest residues, but do benefit from faster growth of their trees.

In conclusion, no technical barrier has been identified for developing a large scale power plant in Canada based on surplus MPB killed trees. A second component of the second phase of study of using surplus MPB killed trees to generate power is a re-evaluation of the economics incorporating feedback from the first study; this work will be issued separately.

Fig. 3. Stump excavator (left) and stump recovery (right).

Detailed Comments

1. Key Contacts and Itinerary

- Petri Halonen, Biowatti (a European fuel broker specializing in sourcing biomass fuels).
- Jouni Hamalainen, Group Manager, Fluidized Bed Combustion, VTT (Finish National Research Laboratory).
- Matti Jarvinen, Business Development Manager, Power and Heat, Electrowatt-Ekono Helsinki Office, the EPC contractor for the overall Alholmens power plant).
- Arvo Leinonen, Chief Research Scientist, VTT.
- Pekka Saarivirta, Production Sales Manager, Power Generation Systems, Kvaerner Power Tampere (boiler supplier to Alholmens).
- Marco Setala, Production Supervisor, Alholmens Kraft Power Plant.
- Hank Sherrod, Regional Manager, Sales and Service, Kvaerner Power North America (Sales and design office for North American sales).

- We visited the Electrowatt-Ekono Office on August 29, the Kvaerner Power Office and Boiler Fabrication Shop on August 30, the Alholmens Kraft Power Plant on August 31, and with VTT at their Jyvaskyla location on September 1 and 2. On September 2 we toured three forest sites to look at stump recovery, thinnings cutting and recovery, and forest harvest residue recovery.

2. Alholmens Power Plant

- On the day of our visit the plant was running a mix of coal, peat and wood and producing 253 MW of power on a full condensing cycle (no heat extraction). The design rating of the plant was 240 MW; in winter the plant has produced 265 MW.

- The plant took just under two years from the decision to proceed (Feb 1999) to startup (January 2001).

- The original planned fuel mix was 45% peat, 45% woody biomass sized to 10 to 15 cm, and 10% coal. The woody biomass is a mix of bark and planer shavings (sourced from within the Alholmens complex) and wood (sourced from outside). Thinnings, forest harvest residues and dried stumps are the primary outside sources of wood. The original design intent was for coal delivered by ship to provide fuel backup in the event of fuel interruption or unavailability at a competitive price. Finland's wood lots are owned by more than 130,000 individual owners, so coal provided a backstop on wood price. The plant has yard storage, delivery systems, fuel silos and fuel feed screws for each of the three types of fuel. This is a major cost and design complexity that would not be incurred on a plant that ran on wood only.

- The plant can (and has) run municipal solid waste (MSW), but EU regulations will restrict ash disposal from any site burning MSW, so this fuel supply, very little at Alholmens in the past, will go to zero.

- There is a high variation in moisture level of woody biomass fed to the power plant, from 10% to 65%.

- The approximate mix of woody biomass includes 30% coming in as bundled forest harvest residues that are chopped at the plant site, and an additional 20 to 25% forest harvest residues that are not bundled.

- Peat supply is low in wet summers due to a lack of drying of harvested peat.

- Wood waste from inside the Alholmens plant (e.g. bark and planer shavings) are moved by conveyor to the fuel yard. Forest harvest residues and peat are predominantly delivered by truck, and deliveries occur on a daily basis around the clock due to the limited size of the storage yard, equivalent to about one day's fuel supply. If the plant were to run on peat only it would require 150 truck deliveries per day. If the plant were to run on forest harvest residue bales only, it would require 600 bales per hour. Many of the delivery trucks have self contained cranes for loading and unloading; the procedure seemed slow within the plant site as compared to tipping. A typical maximum transportation distance for residues is 100 km. Chipping of stumps occurs within the yard, and chips are moved by bulldozer to the conveyor system that takes them into the silo. Wood is chipped to 10 to 15 cm size.

- In 2004 the plant consumed 4.6 TWh of fuel, produced 1.7 TWh of electrical power, and 290 GWh of thermal heat. When operating in full condensing mode without heat extraction the plant can achieve 38 to 39% gross efficiency (gross electrical power out as a percent of LHV of fuel in); the day we were there the efficiency was 38%; cooling water temperature is the determinant of the minor variations in efficiency over the year. Unburned carbon runs about 0.3% of input carbon.

- Parasitic power (internal plant usage) is 18 MW.

- The design basis of the plant is the capability to run on 100% biomass (wood) and 100% on coal. Both extremes have been demonstrated during operating tests.

- The actual fuel mix in 2004 was 45% peat, 25% bark/wood and 30% coal. The reason for the higher use of coal is limited availability of woody biomass; Finland has more wood burners than wood. In terms of economic stacking order, bark/wood has the lowest cost, peat intermediate, and coal the highest. The low effective cost of wood fuel is partially due to favorable tax treatment; peat and coal at Alholmens are not considered "green" fuels and do not get this tax treatment. In some new plants in Finland peat will be treated as a green fuel provided that it is co-fired with wood.

Fig. 4. Stump storage yard at Alholmens plant (upper left), fuel storage silo and conveyor (upper right), chipped forest residues with conveyor belt to boiler (lower left), storage yard for chipped forest harvest residues (lower right).

- The plant has not experienced an ash melting problem. Chlorides in the wood are believed to react with sulfur in the peat and coal. Kvaerner commented that they would expect more problems with ash with agricultural residues (e.g. straw) because of the higher levels of alkali halides (salts) in these as compared to peat and wood.

In this case the Alholmens design, which has the superheater in the top of the primary combustion section, would be relocated to the cyclone area below the main path of the flue gas.

- The ramp rate of the plant is 1.5 MW per minute up and down, hence in one hour the plant can shift generation by 90 MW. The plant can dump steam in the event that the grid connection (and hence most of the power load) is lost.

- The minimum plant turndown is 35% of design capacity. However, the plant is a backup source of process steam for the Alholmens industrial site, so the actual “minimum” turndown is set by reliability concerns at 15% higher than the technical minimum turndown. The plant operates at its practical minimum turndown most evenings and weekends due to the low cost of power in the Nordpool grid. Nordpool has a high fraction of hydro power which has a lower variable operating cost than Alholmens.

- The electrical end of the Alholmens power plant, from the steam end of the boiler through the turbine hall and electrical switchgear, is a conventional design and looks no different than other power plants of a comparable size.

Fig. 5. Turbine hall (left) and cyclones (right) of Alholmens 240 MW power plant

- The plant operates with six shifts (a Finish practice based on a 32.5 hour workweek that would not be typical of Canada). The fuel yard is contracted out; the plant has four operating staff per shift, a power engineer, an operator and two floor operators. Some of this labor ensures the fuel yard is supplying fuel to the silos. The plant has a staff of six maintenance personnel, on day shift: one automation technician, two electricians and three mechanical technicians. The plant has eight office personnel and two lab technicians (day shift only); the primary purpose of the lab is testing of moisture levels.

- Moisture level is the predominant analysis of incoming fuel, presumably to allow a price calculation based on LHV.

- The plant has a high availability (>90%) with one planned shutdown per year. The typical duration of planned shutdown is 2.5 weeks; in 2005 the shutdown was longer due to a lack of availability of refractory personnel. Refractory repairs are required at every turnaround, typically around the feed inlet. The plant had some tube leaks in the superheater due to the "sandblasting" effect which led to refractory being applied as a protective layer. A bridging problem in wood feed silos was corrected with a "carrot screw" feeder at the bottom of the silo. Other than the planned shutdown the availability of the unit is 98.5%.

- The Alholmens plant has many owners who nominate for power individually on an hour by hour basis the previous day; the plant operates at the aggregate level of nominations subject to the constraint that it cannot operate below the minimum turndown ratio.

3. Circulating Fluid Bed (CFB) vs. Bubbling Fluid Bed (BFB) Boilers

- We discussed CFB vs. BFB at length with Kvaerner. Kvaerner is a major supplier of both types of boilers; Foster Wheeler (FW) is a competitor. Kvaerner acquired the Tampele Company, and FW acquired Allstrom.

- BFBs have a low height fluidized bed of sand in which primary combustion air and can burn up to 75% moisture level (ML) fuels and are designed to handle 65% ML. CFBs are limited to 60 to 63% maximum ML.

- CFBs have very low NOx, which has driven many European applications to select CFB. SNCR (selective non-catalytic reduction) of NOx and SCR both work better in a CFB. The Alholmens guarantee level for NOx was 50 mg per MJ of fuel input. High chloride levels, as would occur in agricultural residues, also require a CFB. For this type of application Kvaerner would specify an expensive metallurgy for boiler tubes, AC66, and bury the superheater in the cyclone rather than installing it at the top of the primary combustion area.

- BFBs are a square design, and Kvaerner would not supply a 200 MW BFB as a single unit. BFBs have traditionally been used for mill residues and have been sized to the availability of the mill residue. CFB's are a linear design; higher fuel inputs extend the boiler and add additional cyclones; hence there is no set limit to the size of a single CFB unit. Kvaerner is designing two 330 MW (electrical) CFB boilers for a US client burning petroleum coke and feeding a single 660 MW steam turbine. Typical design values are 165 bar (2400 psi) steam pressure at a temperature ex the superheater of 545 C.

- An estimated 2005 cost for a US brownfield location (within a refinery, hence utilities available at the edge of the site) is $1319 US per kW. Two different cost figures were cited for the Alholmens plant, 710 and 840 Euro per kW, by two different parties. The Alholmens plant uses direct sea water cooling, which would reduce capital cost by as much as 10% compared to a design using cooling towers or air cooling. Kvaerner believes that construction costs are higher in North America than in Finland. (In the second phase analysis of the B.C. project $1890 Cdn per kW / $1575 US per kW in 2005 dollars is the estimated capital cost for a Quesnel B.C. location.)

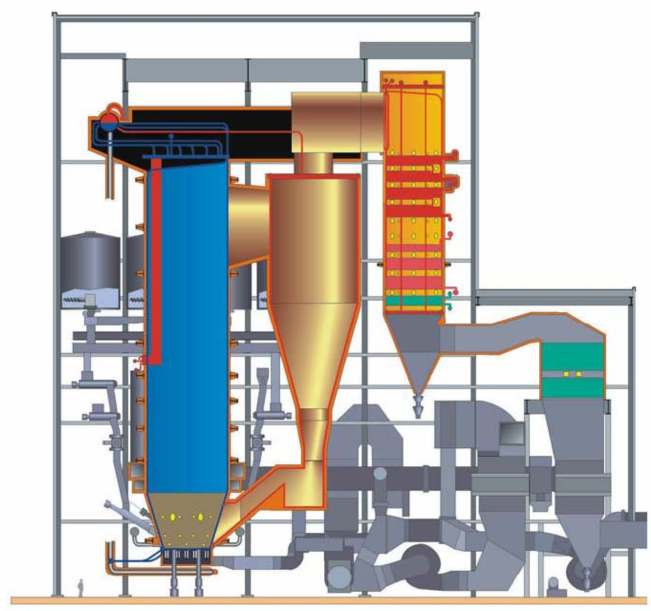

Figure 6. A schematic diagram of a CFB boiler, courtesy of Kvaerner Power. The blue zone is the primary combustion zone; note the red superheater at the top of the combustion zone. The cyclones (tan) return circulating fluid bed sand to the bottom of the primary combustion zone, while flue gas proceeds to the convective tube section of the boiler.

- Kvaerner's standard feed system design is ½ hour to 1 hour of fuel in the silo, and two 70% capacity feed screws per silo. Each feed point typically feeds 70 to 90 MW thermal of fuel; hence a 330 MW boiler would require 10 to 12 feed points. CFB boilers are balanced draft, with the boiler at overpressure (about 15 kPa) and the neutral pressure point occurring at the cyclone inlet. Flue gas velocity in the CFB is about 5 m/s, compared to 2 to 3 m/s in the BFB.

- VTT does research and testing in fluidized bed combustion and gasification at their Jyvaskyla facility with a staff of 30. This group is working with Foster Wheeler to achieve an 800 MW electric single boiler with a supercritical once through steam cycle. They are also working on multi-fuel operation to reduce corrosion from biomass by fuel blending. They do test runs with corrosion probes to support boiler design. They commented that woody biomass ML runs 34 to 55%, that the high calcium content of biomass reduces SO_2 emissions, and that coal ash binds alkali halides and notably protects against chloride corrosion.

4. Supply of Biomass

- VTT has a group of 16 scientists plus support staff looking at all aspects of the supply of biomass as an energy source. They have done extensive research on peat and woody biomass, and more recently have proposed spring harvested reed canary grass as a biomass source. Spring vs. fall harvesting reduces the alkali halide content of the grass.

- One third of Finland is peat; ½% is under harvest. Average peat depth is 2 meters; recovery techniques are similar to practices in Canada: ditch and drain the bog, thinly cut an upper slice of peat and allow it to air dry, grind and transport.

- In 2003 Finland used 80 TWh of wood based fuel. Black liquor was 51% of the total, bark and sawdust 26%, firewood 16%, forest harvest residues (FHR) 5%, and other sources 2%.

- FHR usage was 0.6 TWh (fuel basis) in 1995, 4.3 TWh in 2003, and the target is 10 TWh in 2010. The total FHR potential is estimated at 30 TWh per year. Finland also has an objective to use 0.6 TWh of agricultural biomass by 2010. To set this in context, one cubic meter of solid wood, equivalent to about 2.5 cubic meters of chipped or piled wood, contains about 2 MWh (fuel basis) of energy. The contemplated 300 MW (net) power plant in B.C. using surplus MPB killed trees would use 63 million cubic meter of trees, equivalent to 50 million cubic meters of merchantable timber, in 20 years. This is equivalent to about 6 TWh per year.

- FHR from final felling is 100 MWh (fuel basis) per ha, and receives no subsidy because this fuel is competitive in price with peat. Thinnings, the material recovered about 30 to 40 years before final harvest, yields 30 to 50 MWh/ha, and stumps yield more than 100 MWh/ha. Thinnings receive a subsidy from Finland of 5 Euro per MWh. Stumps also receive a subsidy but the objective is to encourage their removal to for purposes of disease control.

- FHR is stored strategically in the field to minimize access problems in winter and during spring breakup. Trucks carrying FHR run around the clock with crew changes.

- The target recovery of FHR from the final harvest is 50%, with the remainder left in the field to help in reforestation. The landowner gets no payment for FHR, thinnings or stumps; the benefit to the landowner is better yield from trees.

- VTT has done in depth studies of the cost of recovery of woody biomass from the forest. The following costs are in Euros per MWh (fuel basis) for FHR from final harvest (left value) and thinnings (right value); note that these are pre-subsidy, and the subsidy of 5 Euros per MWh for thinnings makes the two sources competitive:

  - Cutting 0.2 / 4.1
  - Hauling to roadside (terrain hauling) 2.2 / 2.4
  - Chipping 2.5 / 2.5
  - Road transport (basis 75 km) 2.9 / 2.9
  - Overheads 0.6 / 0.9
  - **Total** **8.4 / 12.8**

- A typical maximum transport distance for FHR is 100 km.

- FHR has a moisture level of 55% at time of harvest, and dries to 30% ML at the roadside. It is frequently covered in plastic prior to the fall rainy period to control ML. Drying of biomass is thought to reduce ash problems during combustion by leaching alkali halides from the wood.

- Stumps are typically stored in piled windrows for 1 year. They are broken into three or four pieces at time of harvest to speed drying.

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October 31, 2005