BIOENERGY 2015
JYVÄSKYLÄ, FINLAND 2.–4.9.2015

STATIONARY BIOMASS PROCESSORS – CRUSHING STUMPS WITH LOWER COSTS

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ABSTRACT:
Today, stumps are one of the important biomass sources for energy chip production. The consumers and producers of the energy chips would make more money in many cases if they would invest the stationary crusher biomass processors instead of producing or purchasing the energy chips made by mobile crushers. This paper will represent the comparison of the crushing costs for two solutions producing energy chips from stumps. In case one the crushing cost of a stationary crusher and a diesel powered mobile crusher is compared. In case two the mobile crusher is converted to electrical power and it is compared against the stationary crusher. The investment cost of a stationary crusher is naturally higher than the investment cost of a mobile crusher. It is shown how the lower operating costs of a stationary crusher offset the higher investment costs and make a stationary crusher the most feasible choice for stump processing even with relatively low annual production level of the energy chips.

Keywords: Stumps, biomass processor, bioenergy competitiveness, crushing costs

1 THE WOODY BIOMASS SUPPLY CHAINS IN FINLAND

Demand for energy chips for both heating and power plants has been increasing steadily over the past ten years, and today the volumes are impressive. Meanwhile, the supply chain of biomass has undergone a strong development in matching the demand. The location of the biomass processor in the supply chain gives three basic configurations: crushing at roadside, at a terminal or at a power plant. Today the most common biomass processors in the supply chain for processing woody biomass into energy chips are mobile units. Typically in a large power plant's fuel supply chain, and also to some extent in a terminal-based supply chain, stationary crushers are used.

Crushing at the power plant is a "cold supply chain" whereas crushing with a mobile crusher is typically a "hot supply chain". A cold supply chain is easier to manage and adapts well to automatic and self-controlled logistics from the forest to the power plant. The cold supply chains for stump processing have been built throughout Europe. Some examples, which included stationary Saalasti stump crushers, are Kyminvoima, UPM Kaipola, UPM Lappeenranta in Finland and UPM Caledonia in UK, Ence Huelva in Spain, Smurfit Facture in France.

According to the Metsäteho [1] In 2014 the Finnish power plants used 16.4TWh of wood based energy chips. The number has been steadily increased from the year 2000 when the level was 2TWh annually till year 2013. In the year 2014 the usage decreased by 5.2% which corresponds the level in year 2012. The production of 16.4TWh equals 4.4% of the country's annual energy consumption. The main biomass types have been the energy wood, the forest residues and the stumps.

In Finland the main supply chains for the above mentioned biomasses are the road-side processing, the terminal processing and the stationary processing. In 2014 the road-side processing, the hot supply chain, is the largest supply chain of hog fuel corresponding approximately 58% of the total volume. The second largest supply chain is the terminal processing with 35% and the third largest, the cold supply chain, with 7% is the stationary processing.

1.1 The stumps in energy production in Finland

The largest source, the energy wood, represents 55% [1, p.3] of the producing energy from wood based biomass in Finland. Correspondingly the second largest source is the forest residues which represent 34% [1, p.3]. The stumps holds the third position with the remaining 11% stake [1, p.3]. In Finland most of the stumps were processed with stationary crushers from 2004 to 2010, but during the latest years the mobile crushers have increased their share of the main processing technology [1, p.15]. This trend is against the economic benefits which are achievable by stationary crushing. For example the crushing cost of the stumps processed with mobile crushers is 133% higher than processed with stationary crushers according to the Metla [4, p.15].

Stumps as a source of biofuel for producing energy e.g. in CHP plants have positive and negative properties. Stumps have attractively high dry solids content and lower purchasing price, when compared to the most commonly used woody biomass in energy production, the energy wood. The down side in energy production from stumps is the high inorganic content of the stumps and the cost challenges in the supply chain. The impurities of the biomass increase the maintenance costs of all the processing equipment and the low volumetric density of the whole or even pre-sliced stumps increase naturally the transportation costs.

In 2014 the deviation of the different supply chains in stump processing in Finland was the following according to the Metsäteho [1, p.15]. Stumps were processed in road side 13%, in terminals 54% and in stationary crushing stations 33%. In practice two thirds of the stumps were processed with mobile crushers and one third with stationary crushers. The biomass should be processed on road side or in terminals as close as possible to the harvesting site. The largest benefit in these two supply chains is gained from the higher transportation density of the processed loose biomass. According to Vengasaho [3, p.11] the difference in transportation cost of the stump energy chips is 32% less cost when compared to the transportation cost of the pre-sliced stumps in 35km and 70km transportation distances in Finland. Even though the higher transportation costs of the pre-sliced stumps Heinjoki [5] agrees with Kärhä [2] the following: in respect of the total cost of producing crushed stump energy chips the transportation of pre-sliced stumps to the stationary crusher under 70km distance is the most feasible supply chain available today.

2 THE CRUSHING COSTS

In stationary processing typically the power plant produces fully or partially the energy chips for their own boiler. Harvested biomasses are transported directly to the power plant from the road-side storages. In stationary processing the main advantages are self-controlled logistics, higher capacities and lower crushing costs plus the increased negotiation power against the energy chip providers. The stationary crushers do not have restrictions in design e.g. weight as the mobile processors do have, because of the required mobility function. Typically the mobile crusher investment costs are lower but the crushing cost per MWh is higher. The main reasons for this are the shorter lifetime of the crusher, higher maintenance costs and the more expensive fuel costs.

2.1 The cost comparison mobile versus stationary crusher

To compare the crushing costs with mobile crushing technology and stationary crushing technology the following assumptions are made in this paper to make the comparison as objective as possible. The aim of the study is to represent analysis of the crushing cost comparison between a cost efficient and high capacity mobile crusher and the medium size Saalasti's stationary crusher solution in two cases.

In case one: the diesel-powered mobile crusher's crushing cost is compared against the fully equipped stationary crush process line. In Figure 1 the flow sheets of the case one's crushing processor options are presented. The equipment costs, direct usage costs end the investment costs are included to the analysis.

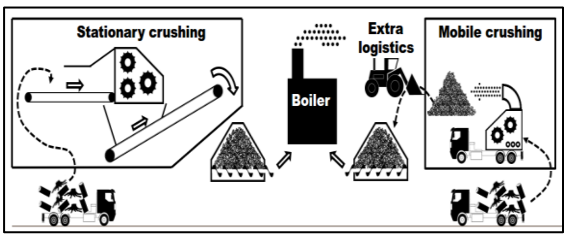

Figure 1: The flow sheets of the case one's crushing processor options compared in the cost analysis.

In case two: the diesel engine powered mobile crusher is converted to the electrical motor powered version in the cost comparison between a converted mobile crusher and Saalasti's stationary crusher processing line. Also all mobility functions are excluded from the converted mobile crusher and the crushing cost is calculated based on the minimum process environment requirements. The converted mobile crush option is converted to the fully equipped stationary process line as in the case 1. In Figure 2 the flow sheets of the case two's crushing processor options are presented.

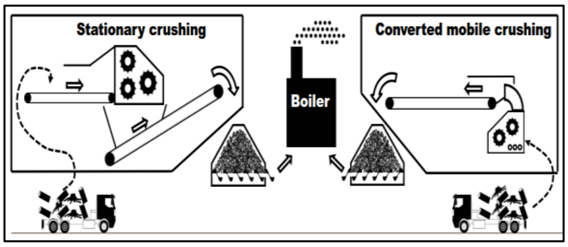

Figure 2: The flow sheets of the case two's crushing processor options compared in the cost analysis

To make the comparison as objective as possible in both cases the crushers are producing energy chips 100% from pre-sliced stumps. The comparisons will enlighten the payback times of 4, 6 and 8 years when the producing the energy chips. All costs of the biomass logistics are excluded because the incoming logistics of the biomasses to the power plant would be the same in this two cases. In the case calculations the fixed costs of the mobile crusher are determined based on the Poikela [6].

2.2 The main characteristics in case one

The calculation characteristics of the mobile crusher option are presented in the Table I below. The mobile crusher's annual processing volume has been fixed to the level where the 6 years operation time would mechanically possible. After 6 years of continuous operation the mobile equipment must be renewed according to the Kärhä [2] and Poikela [6] with the selected production level. The payback calculations with mobile crushing option were done with four, six and eight years. Eight years payback time is included to the analysis as an extra feature if the mobile equipment would have such lifetime. In case one the mobile crusher cost calculation the crusher investment cost is evaluated in the calculation including the direct, capital and fixed costs of the investment.

Typical process environment requirements such as automation system, metal detection, discharge conveyor to the storage, automatic lubrication, pneumatic compressor, insulated shelter building with single girder crane, noise cancellation or dust removing unit were not included to the investment of the mobile crush. In other words the crushing cost of a diesel powered mobile crusher is analyzed, when it is operated inside the power plant without any auxiliary equipment. There is also added an additional parameter to the crushing cost of the mobile crusher. This parameter is manual handling of the material, which is estimated in this paper to 0.7 €/MWh because there aren't any auxiliary equipment such as e.g. conveyors to the storage.

Table I: The calculation characteristics of the mobile crush option

The Costs of a Mobile crusher		
Processed Biomass	Stumps	
Investment cost	750000	Metsäteho €
DrySolidsContent	75 %	
Annual capacity	246258	MWh/a
Annual capacity	48750	BDT/a
Annual capacity	267857	loose-m3/a
Fuel cost	1,00	€/l
Fuel cost	179464	€/a
Maintenance	81000	Metsäteho €/a
Amortizing of the investment	4,6,(8)	years
Interest %	5 %	
Labor cost	20000	Metsäteho €/a
Insurances	8100	Metsäteho €/a
Management costs	10000	Metsäteho €/a

The calculation characteristics of the stationary crushing option are presented in the Table 2 below. The processing capacity has been set to normal capacity level, which is roughly double compared to mobile crusher option. Saalasti's medium size stationary crusher is able to continue processing over the lifetime of the boiler, which means over 25 years if necessary. For direct comparability the payback calculations with the stationary option are limited also to four, six and eight years.

In the stationary crushing investment calculation the whole process line equipment was included. In addition to the previous mobile crush option calculation characteristics typical process environment requirements such as automation system, metal detection, discharge conveyor to the storage, automatic lubrication, pneumatic compressor, insulated shelter building with single girder crane, noise cancellation, dust removing unit were included to the investment costs of the stationary crushing line. Also an electrical transformer, frequency converters, electrical motors, mechanical erection, civil works, electrification were included. In other words the investment cost of a turnkey stationary process line is analyzed.

Table II: The calculation characteristics of the Saalasti's stationary crushing process line option

The Costs of the Stationary Crushing line		
Processed Biomass	Stumps	
Investment cost	1690000	€
DrySolidsContent	75 %	
Annual capacity	492516	MWh/a
Annual capacity	97500	BDT/a
Annual capacity	535714	loose-m3/a
Cost of Electricity	75	€/MWh
Electric power cost	58500	€/a
Maintenance	102375	€/a
Amortizing of the invesment	4,6,8	years
Interest %	5 %	
Labor cost	20000	Metsäteho €/a
Insurances	7000	Metsäteho €/a
Management costs	20000	Metsäteho €/a

The outcome of the analysis in case one is presented in the Figure 3. The crushing cost reduces with both the mobile and the stationary options along the longer amortization period. The stationary crush option is more cost efficient in all amortization periods regardless the higher investment cost.

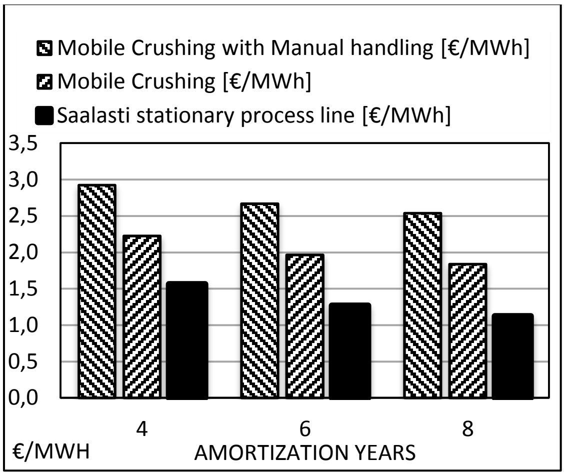

Figure 3: The results of the crushing cost analysis of the diesel powered mobile crusher and Saalasti's stationary crusher process line, case one.

With mobile crusher option the eight years amortizing period has been analyzed even it is uncertain if the mobile equipment will be able to process that long with normal maintenance. If it is assumed that after six years of operation the crushing equipment must be renewed, then the crushing cost throughout this 6 year period with mobile crusher option is 1.96 €/MWh without manual handling of the energy chips and 2.66 €/MWh with the manual handling as presented with 6 year amortization in figure 3. Corresponding crushing cost with 6 year amortization with stationary crushing line option is 1.27 €/MWh. The crushing cost efficiency is favoring clearly the stationary crusher process line. If the cost of extra logistics of manual handling of the energy chips to the storage is taken into account the difference is clearly larger:

The stationary crushing cost compared to the mobile crushing without the extra cost of manual handling

- Four years amortization, 42% less cost
- Six years amortization, 55% less cost
- Eight years amortization, 63% less cost

The stationary crushing cost compared to the mobile crushing with the extra cost of manual handling

- Four years amortization, 87% less cost
- Six years amortization, 110% less cost
- Eight years amortization, 126% less cost

The most significant difference in crushing costs come after the amortization period of the investment. According to Kärhä [3] and Poikela [9] the probable life time of the mobile crusher in continuous processing is six years. If the six years lifetime expectation of the mobile crushing equipment is taken into account the crushing cost, the figure 4 presents what the crushing costs would be within 12 years analysis period from the investment. In the figure 4 it can be seen the effect of the Saalasti's stationary solution longer lifetime to the crushing cost of the stationary process line, where the reinvestment of the crusher is not required which is not the case with the mobile crusher option.

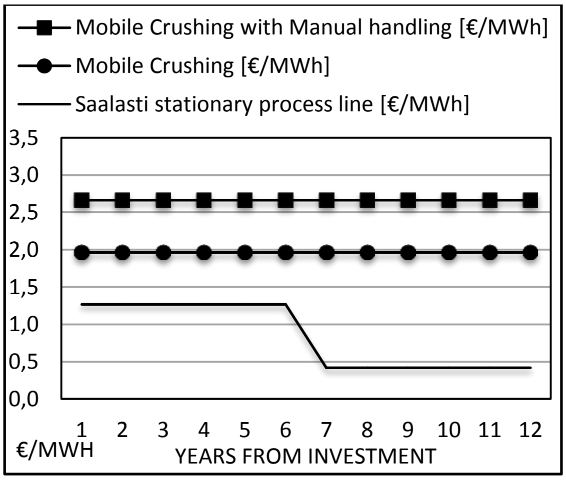

Figure 4: The crushing cost over time with the diesel powered mobile crusher and Saalasti's stationary crusher process line, case one.

2.2 The case two, the cost comparison between a converted mobile crush versus a stationary crush process line

In case two the diesel engine powered mobile crush is converted to the electrical motor powered version in the cost comparison between a converted mobile crush and Saalasti's stationary crusher option. Also all mobility functions are excluded from the converted mobile crusher and the crushing cost is calculated based on the minimum process environment requirements for the converted mobile crusher. The following cost characters are included to the converted mobile crush option:

- the cost of fuel is based on the electricity consumption
- maintenance, labor, insurance and management costs are the same as in diesel powered mobile crush option
- discharge conveyor to the storage, insulated shelter building with single girder crane, an electrical transformer, frequency converters, electrical motors, mechanical erection, civil works, electrification are included
- the automation of the converted mobile crusher is used
- dust removing unit, automatic lubrication, pneumatic compressor and noise cancellation were not included

The calculation characteristics of the converted mobile crusher option are the same as the costs in Table I but the total investment cost is increased to value 1 200 000€ to cover the minimum process environment requirements listed above and the electric power cost is correspondingly decreased to value 29 250 €/a because of the more cost efficient energy. The outcome of the crushing cost analysis from the case two is presented in the Figure 5.

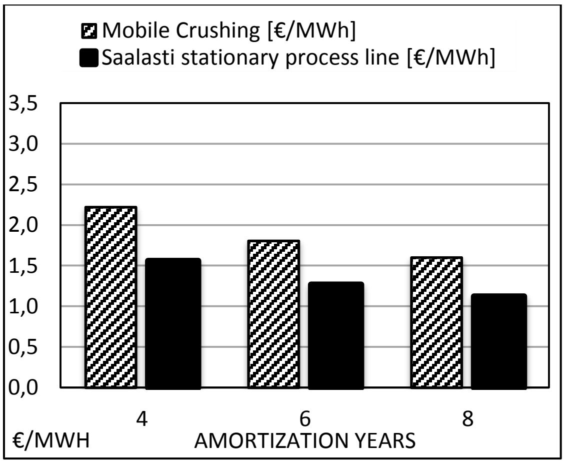

Figure 5: The results of the crushing cost analysis of the converted mobile crusher and Saalasti's stationary crusher process line, case two.

The crushing cost efficiency is again favoring clearly the stationary crush again regardless the amortization period:

- Four years amortization, 42% less cost
- Six years amortization, 42% less cost
- Eight years amortization, 42% less cost

If the twelve years crushing costs are analyzed with the case two, the mobile crusher must be renewed after six years operation but the auxiliary equipment wouldn't require reinvestment. The outcome of the analysis is presented in figure 6 below.

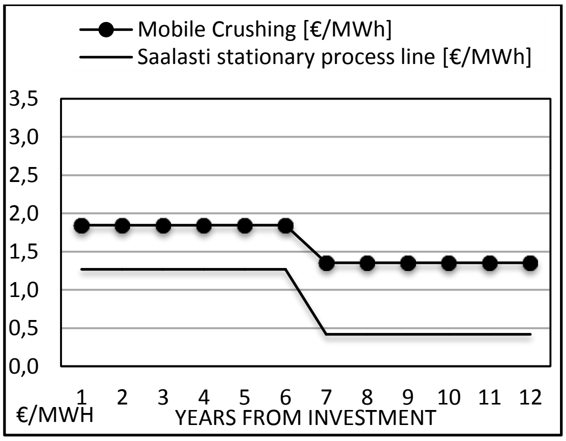

Figure 6: The crushing cost over time with the electric powered mobile crusher and Saalasti's stationary crusher process line, case two.

It can be seen from the figure 6 that renewing only the mobile chipper after six years operation sets the crushing cost to the 1.35 €/MWh while the Saalasti stationary crushing cost is 0.42 €/MWh. The difference is smaller than with the case one but still strongly favoring the stationary process line option.

2.3 Reduced capacity with stationary crush process line

To analyze the sensitiveness of the decreased annual processing capacity of the stationary crusher process line the following analysis was done. The annual production of the stationary option was decreased from the 492 512 MWh/a to the 246 258 MWh/a, which equals to the mobile option capacity. These values correspond to the annual energy chip consumption of the 10 MWe and 5 MWe biomass boiler or in as received tons 130 000 t/a and 65 000 t/a. All other characteristics were kept untouched. The outcome from the adjusted case one analysis of the crushing cost for 6 years payback time is presented in the figure 7 below.

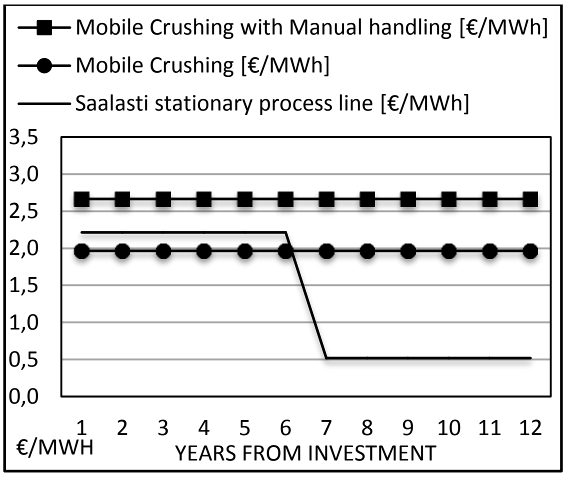

Figure 7: The crushing cost over time with the diesel powered mobile crusher and Saalasti's stationary crusher process line, case one with reduced annual production of the stationary crushing line.

The crushing cost during the six years payback time is slightly higher with the stationary crushing process line than with the plain diesel powered mobile crusher. If the effect of the manual handling is added to the crushing cost with diesel powered mobile crusher option then the crushing cost with stationary crushing process line is clearly lower. After the 6 years payback time the crushing cost with stationary crushing process line is 0.52 €/MWh and the corresponding cost with diesel powered mobile crusher is 1.96 €/MWh and with the cost of manual handling 2.66 €/MWh.

The equal analysis was also done for the case two and the results are presented in the figure 8. The equal production levels 246 258 MWh/a for the both stationary crushing process line and for the converted mobile chipper were used.

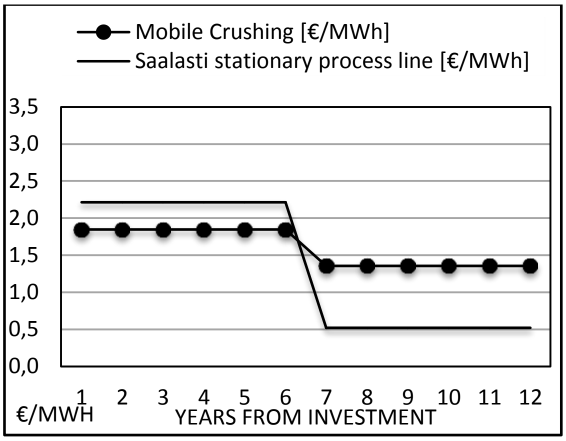

Figure 8: The crushing cost over time with the electric powered mobile crusher and Saalasti's stationary crusher process line, case two with reduced annual production of the stationary crushing line.

The crushing cost with converted mobile chipper process line during the 6 years payback time is 1.85 €/MWh and for the stationary crushing proses line the crushing cost is 2.21 €/MWh. After the six years operation the corresponding crushing costs are reduced to following values: 1.35 €/MWh with converted mobile chipper process line and with the stationary crushing proses line 0.52 €/MWh.

3 THE CONCLUSIONS

Main differences in crushing costs are generated from the maintenance costs, energy costs, production levels, and the shorter lifespan of the mobile equipment. The stationary crushers are designed for stationary use and don't have the limitations in e.g. weight. The converted mobile crushers have same drawbacks as mobile crushers since they are built originally less robustly for mobile usage. Stationary crushers are always powered by electric motors. The usage of the electric motors instead of diesel engines has significant effect on the cost of producing energy chips.

The stationary crushing is more cost efficient for energy chip production in both analyzed cases within all analyzed amortization periods. With six year amortization the crushing cost would be 55% higher diesel powered mobile stump crushing when compared to the stationary crushing even higher investment cost of the stationary crushing option which included all possible requirements of the sophisticated process line. The gain is little less if the amortization period is shorter.

Converting the mobile chippers to electrical power reduces the crushing costs. The difference in crushing costs has decreased from 55% to 42% in case two between stationary crushing and converted mobile crushing. The crushing cost is still clearly higher with converted mobile crusher than the stationary rival.

The stationary crushing scales upwards very efficiently and would be the most profitable option for even relatively small power plant of producing energy chips for itself instead of purchasing them in ready chipped form. The 15MWe boiler consumes the amount of biofuel, which has been determined to the annual production of the stationary crushing process line option, which equals the two mobile crusher's annual production in the calculations.

Later, in sensitivity analysis of the case one and two, the annual capacity of one mobile crusher has been used for the annual production of the stationary crusher process line. The stationary crushing option would be feasible solution up to analyzed 8 MWe power plants in the long run, but the benefits will melt slowly with the decreasing annual production from there. On the other hand the stationary crushers' high capacity enables the possibility of limiting the process time to the office hours if the power plant is located e.g. close to an urban area. If the boiler consumes more than determined for the stationary crushing process line in cases one and two, the larger stationary crusher line can process energy chips even lower costs and with significantly higher production volumes.

This analysis was done with only one biomass, the stumps. In normal bioenergy production the boilers are run with certain material spec including a set of different types of biomass. The Saalasti stationary crusher can process efficiently wide range of different wood based biomasses: forest residues, stem wood and even round wood. The benefits in crushing costs will apply with all these woody biomass with the Saalasti stationary crushing solution.

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