# STATIONARY BIOMASS PROCESSORS – CHIPPING ENERGY WOOD WITH LOWER COSTS

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ABSTRACT:
Today, energy wood is 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 chipper biomass processors instead of producing or purchasing the energy chips made by mobile chippers. This paper will represent the comparison of the chipping costs for two solutions producing energy chips from energy wood. In case one the chipping cost of a stationary chipper and a diesel powered mobile chipper is compared. In case two the mobile chipper is converted to electrical powered version and it is compared against the stationary chipper. The investment cost of a stationary chipper is naturally higher than the investment cost of a mobile chipper. It is shown how the lower operating costs of a stationary chipper offset the higher investment costs and make a stationary chipper the most feasible choice for energy wood processing even with relatively low annual production level of the energy chips. Naturally the benefits are larger in higher capacity processes which use stationary biomass processor technology.

Keywords: Energy wood, biomass processor, bioenergy competitiveness, chipping 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: chipping 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 chippers are used.

Chipping at the power plant is a "cold supply chain" whereas chipping with a mobile chipper 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 energy wood processing have been built throughout Europe. Some examples, which included stationary Saalasti energy wood chippers, are Biosyl in Cosne Sur Loire France, Moulin in Monistrol Sur Loire France, Dalkia in Lens France, EON in Meyreuil France, Smurfit Kappa in Biganos France, Ence in Huelva Spain, Ence in Merida Spain, Gestamp Biomass in Garray Spain, Alvarez Forestall in Torrelavega Spain, Smurfit Kappa in Durango Spain, Hamburger Hungary Power in Dunaujvaros Hungary, EON in Örebro Sweden, Swedspan in Koszki Poland.

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, stumps and large diameter energy wood.

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 energy chips corresponding approximately 57% of the total volume. The second largest supply chain is the terminal processing with 29% and the third largest, the cold supply chain, with 14% is the stationary processing.

### 1.1 The energy wood 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 hold the third position with the remaining 11% stake [1, p.3]. In Finland most of the energy wood is processed with mobile chippers in terminals and on road side. The stationary chippers has steadily kept its share unchanged during the latest years [1, p.11]. This trend is against the economic benefits, which are achievable by stationary chipping. For example the chipping cost of the energy woods processed with mobile chippers is 100% higher than processed with stationary chippers according to the Metla [4, p.15].

Energy wood as a source of biofuel for producing energy e.g. in CHP plants have positive and negative properties. Energy woods have highest purchasing price and not attractively high dry solids content. The upside in energy production from energy wood is the low inorganic content and the transportation of the energy wood is relatively effective, because of the good volumetric density of the truck loads. Low inorganic content in the energy wood enables the higher production level than any other woody biomass and on the other hand the maintenance costs are lower per processed MWh than with other woody biomass.

In 2014 the deviation of the different supply chains in energy wood processing in Finland was the following according to the Metsäteho [1, p.15]. A small diameter energy wood was processed on road side 58%, in terminals 34% and in stationary chipping stations 8%. In practice almost all of the energy wood in Finland was processed with mobile chippers.

When the biomass is processed on road side or in terminals, it should be processed as close as possible to the harvesting site. These two supply chains are suffering from the lower transportation density of the processed biomass. According to Laitila&Väätäinen [3, 120p.] the difference in transportation cost of the energy chips is 20% higher, when compared to the transportation cost of the energy wood in typical 50-100km transportation distances in Finland. In euros this cost difference corresponds approximately 1.5-2.0 €/MWh with energy wood within mentioned transportation distances. In addition to the lower transportation costs of the energy wood in many cases the stationary chipping would be more cost efficient way to produce energy chips, where mobile chipping technology is used today. As Metsäteho's former researcher Kärhä K. [7] stated in 2011, that stationary processors will be more and more attractive supply chain for the boiler plants when the consumption of the energy chips are large. Kalle K. also wondered then and wonders today [2 and 5] that why the stationary chipping supply chain has not increased its popularity more because of the lower chipping costs in many cases.

## 2 THE CHIPPING COSTS

A good example of a stationary processing is a power plant, which produces fully or partially the energy chips for its boiler. In stationary processing in cold supply chain the harvested biomass is transported directly to the power plant from the road-side energy wood storages. In stationary processing the main advantages are self-controlled logistics and lower transportation costs, higher capacities and lower chipping costs plus the increased negotiation power against the energy chip providers. The stationary chippers do not have restrictions in design e.g. in weight as the mobile processors do have. This is because of the required mobility function of the mobile chippers. Typically the mobile chipper investment costs are lower but the total chipping costs per MWh are higher. The main reasons for this are the shorter lifetime of the chipper, higher maintenance costs and the more expensive fuel costs.

### 2.1 The cost comparison mobile versus stationary chipper

To compare the chipping costs with mobile chipping technology and stationary chipping 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 chipping cost comparison between a cost efficient and high capacity mobile chipper and the medium size Saalasti's stationary chipper solution in two cases.

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

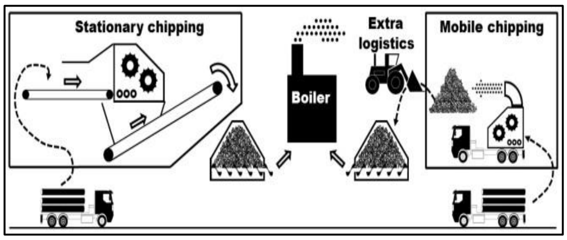


**Figure 1:** The flow sheets of the case one's chipping processor options compared in the cost analysis.

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

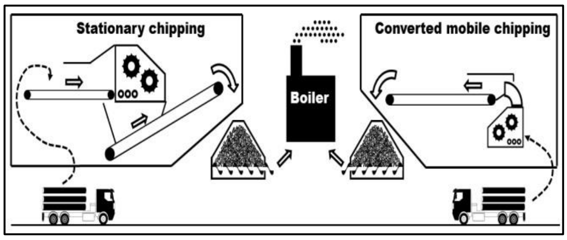


**Figure 2:** The flow sheets of the case two's chipping processor options compared in the cost analysis

To make the comparison as objective as possible in both cases the chippers are producing energy chips 100% from energy wood. 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 chipper are determined based on the Poikela [6].

### 2.2 The main characteristics in case one

The calculation characteristics of the mobile chipper option are presented in the Table I below. The mobile chipper's annual processing volume has been fixed to the level where the 8 years operation time would mechanically possible. At latest after the 8 years of continuous operation the mobile equipment must be renewed according to the Kärhä [5] and Poikela [6] with the selected production level. The payback calculations with mobile chipping option were done with four, six and eight years. Eight years payback time is included to the analysis to represent the maximum lifetime of the mobile equipment. In case one: the mobile chipper's chipping cost calculation is 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 chipper. In other words the chipping cost of a diesel powered mobile chipper is analyzed, when it is operated inside the power plant without any auxiliary equipment. There added an additional parameter to the chipping cost of the mobile chipper because of this most simple processing scenario. This parameter is manual handling of the processed energy chips, which is estimated to 0.7 €/MWh. The value is based on the estimation given by Heinjoki A. [8] to calculate average cost for manual conveying of the processed material with a front loader instead of the discharge conveyor system to the storage.

**Table I:** The calculation characteristics of the 2x mobile chipper option

| **The Costs of a Mobile chipper** | | |
|---|---|---|
| Processed Biomass | Energy wood | |
| Investment cost | 1300000 | Metsäteho € |
| DrySolidsContent | 60 % | |
| Annual capacity | 376359 | MWh/a |
| Annual capacity | 78000 | BDT/a |
| Annual capacity | 487500 | loose-m3/a |
| Fuel cost | 1,00 | €/l |
| Fuel cost | 176889 | €/a |
| Maintenance | 120000 | Metsäteho €/a |
| Amortizing of the investment | 4,6,8 | years |
| Interest % | 5 % | |
| Labor cost | 40000 | Metsäteho €/a |
| Insurances | 16200 | Metsäteho €/a |
| Management costs | 20000 | Metsäteho €/a |

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

In the stationary chipping investment calculation the whole process line equipment was included. In addition to the previous mobile chipper 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 chipping 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 1x Saalasti's stationary chipping process line option

| **The Costs of the Stationary Chipping line** | | |
|---|---|---|
| Processed Biomass | Energy wood | |
| Investment cost | 1738000 | € |
| DrySolidsContent | 60 % | |
| Annual capacity | 376359 | MWh/a |
| Annual capacity | 78000 | BDT/a |
| Annual capacity | 487500 | loose-m3/a |
| Cost of Electricity | 75 | €/MWh |
| Electric power cost | 81900 | €/a |
| Maintenance | 52650 | €/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 chipping cost reduces with both the mobile and the stationary options along the longer amortization period. The stationary chipper option is more cost efficient in all amortization periods regardless the higher investment cost.

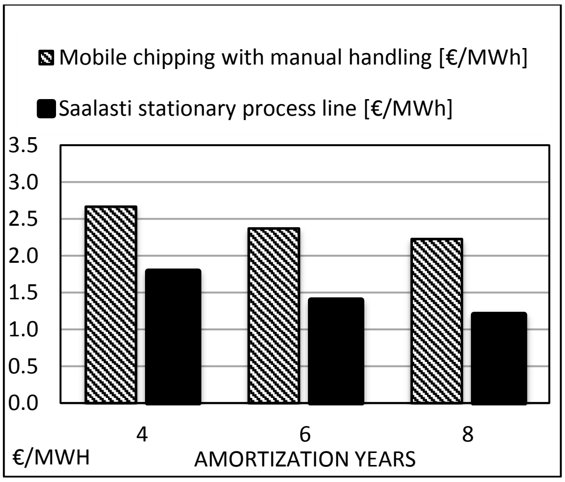


**Figure 3:** The results of the chipping cost analysis of the diesel powered mobile chipper and Saalasti's stationary chipper process line, case one.

With mobile chipper 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 eight years of operation the chipping equipment must be renewed, then the chipping cost throughout this 8 year period with mobile chipper option is 2.23 €/MWh with the manual handling of the energy chips as presented with 8 year amortization in figure 3. This would be the cost of processing half of the annual capacity (65 000 AsReceivedTons/a) with one mobile chipper. Corresponding chipping cost with 8 year amortization with stationary chipping line option is 1.20 €/MWh. The chipping cost efficiency is favoring clearly the stationary chipper process line, when the cost of extra logistics of manual handling of the energy chips to the storage is taken into account:

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

- Four years amortization, 49% less cost
- Six years amortization, 70% less cost
- Eight years amortization, 86% less cost

The most significant difference in chipping costs come after the amortization period of the investment. According to Kärhä [5] and Poikela [6] the maximum expected life time of the mobile chipper in continuous processing is eight years. If the eight years lifetime expectation of the mobile chipping equipment is taken into account the chipping cost, the figure 4 presents what the chipping 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 chipping cost of the stationary process line, where the reinvestment of the chipper is not required which is not the case with the mobile chipper option.

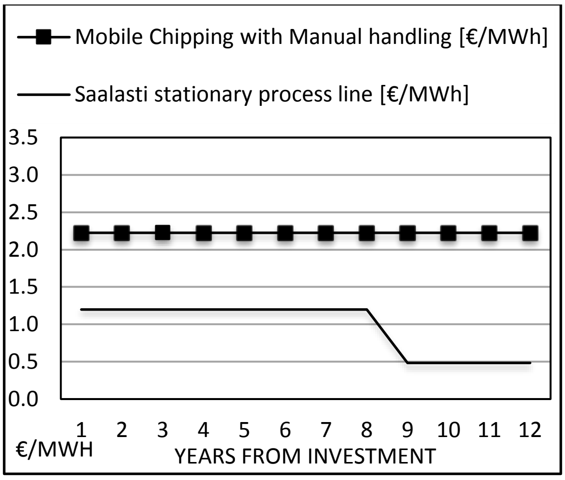


**Figure 4:** The chipping cost over time with the diesel powered mobile chipper and Saalasti's stationary chipper process line, case one.

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

In case two the diesel engine powered mobile chipper is converted to the electrical motor powered version in the cost comparison between a converted mobile chipper and Saalasti's stationary chipper option. Also all mobility functions are excluded from the converted mobile chipper and the chipping cost is calculated based on the minimum process environment requirements for the converted mobile chipper. The following cost characters are included to the converted mobile chipper 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 chipper 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 chipper is used
- dust removing unit, automatic lubrication, pneumatic compressor and noise cancellation were not included

The calculation characteristics of the converted mobile chipper option are the same as the costs in Table I but the total investment cost is increased to value 1 800 000€ to cover the minimum process environment requirements with two converted mobile units listed above and the electric power cost is correspondingly decreased to value 81 900 €/a because of the more cost efficient energy. The outcome of the chipping cost analysis from the case two is presented in the Figure 5.

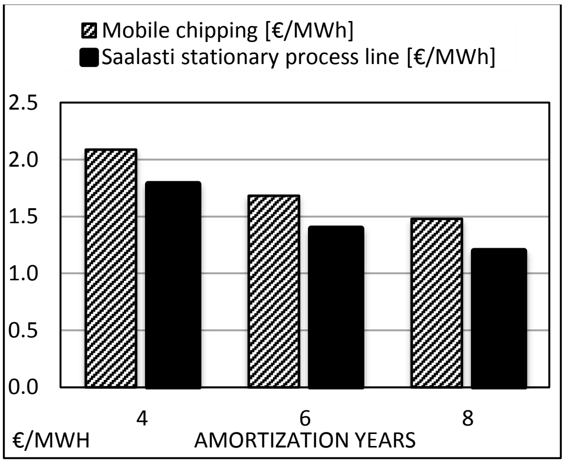


**Figure 5:** The results of the chipping cost analysis of the converted mobile chipper and Saalasti's stationary chipper process line, case two.

The chipping cost efficiency is again favoring clearly the stationary chipper again regardless the amortization period:

- Four years amortization, 17% less cost
- Six years amortization, 21% less cost
- Eight years amortization, 24% less cost

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

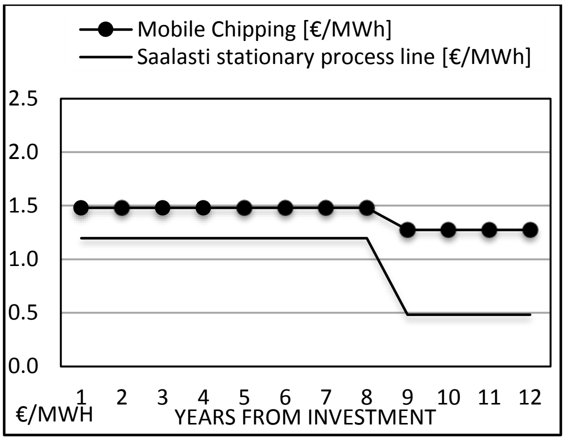


**Figure 6:** The chipping cost over time with the electric powered mobile chipper and Saalasti's stationary chipper process line, case two.

It can be seen from the figure 6 that renewing only the mobile chipper after eight years operation sets the chipping cost to the 1.27 €/MWh while the Saalasti stationary chipping cost is 0.48 €/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 chipper process line

To analyze the sensitiveness of the decreased annual processing capacity of the stationary chipper process line the following analysis was done. The annual production of the stationary option was decreased from the 376 359 MWh/a to the 188 179 MWh/a, which equals to the mobile option max capacity. These values correspond to the annual energy chip consumption of the 13 MWe and 6.5 MWe biomass boiler or in as received tons 130 000 t/a and 65 000 t/a in 40% moisture content. All other characteristics were kept untouched. The outcome from the adjusted case one analysis of the chipping cost for 8 years payback time is presented in the figure 7 below.

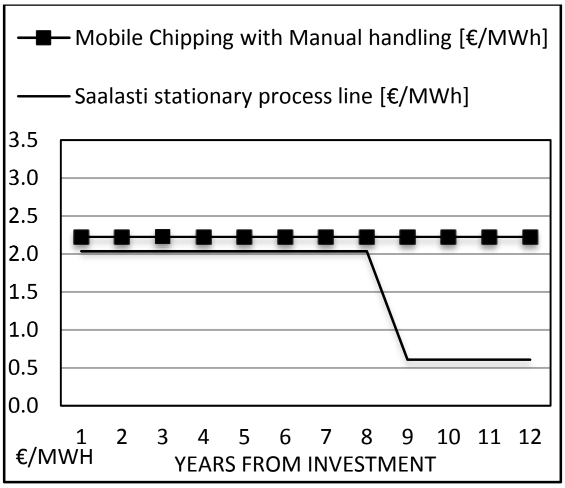


**Figure 7:** The chipping cost over time with the diesel powered mobile chipper and Saalasti's stationary chipper process line, case one with reduced annual production of the stationary chipping line.

The chipping cost during the eight years payback time is slightly lower with the stationary chipping process line than with the plain diesel powered mobile chipper. After the 8 years payback time the chipping cost with stationary chipping process line is 0.61 €/MWh and the corresponding cost with diesel powered mobile chipper with the cost of manual handling is 2.23 €/MWh.

The equal analysis was also done for the case two and the results are presented in the figure 8. The equal production levels 188 179 MWh/a for the both stationary chipping process line and for the converted mobile chipper were used. The investment cost of 950 000€ was used for the one mobile chipper process line as described in 2.2.

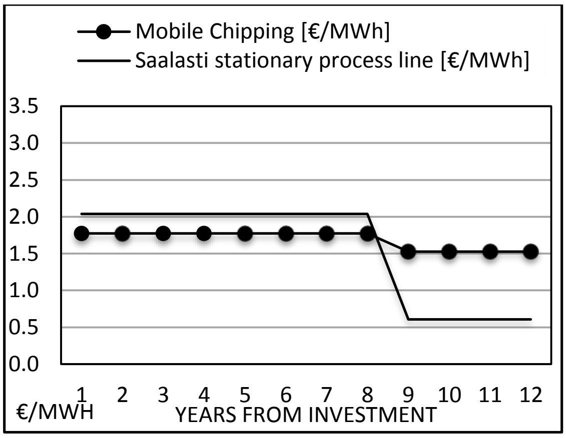


**Figure 8:** The chipping cost over time with the electric powered mobile chipper and Saalasti's stationary chipper process line, case two with reduced annual production of the stationary chipping line.

The chipping cost with converted mobile chipper process line during the 8 years payback time is 1.77 €/MWh and for the stationary chipping proses line the chipping cost is 2.04 €/MWh. After the eight years of operation the corresponding chipping costs are reduced to following values: 1.53 €/MWh with converted mobile chipper process line and with the stationary chipping proses line 0.61 €/MWh.

# 3 THE CONCLUSIONS

Main differences in chipping costs are generated from the maintenance costs, energy costs, production levels, and the shorter lifespan of the mobile equipment. The stationary chippers are designed for stationary use and don't have the limitations in e.g. weight. The converted mobile chippers have same drawbacks as mobile chippers since they are built originally less robustly for mobile usage. Stationary chippers 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 chipping is more cost efficient for energy chip production in both analyzed cases. With eight year amortization the chipping cost would be 86% higher diesel powered mobile energy wood chipping when compared to the stationary chipping even higher investment cost of the stationary chipping 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 chipping costs. The difference in chipping costs has decreased from 86% to 24% in case two between stationary chipping and converted mobile chipping. The chipping cost is still clearly higher with converted mobile chipper than the stationary rival.

The stationary chipping 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 13MWe boiler consumes the amount of biofuel, which has been determined to the annual production of the stationary chipping process line option, which equals the two mobile chipper's annual production in the calculations.

Later, in sensitivity analysis of the case one and two, the annual capacity of one mobile chipper has been used for the annual production of the stationary chipper process line. The stationary chipping option would be feasible solution up to analyzed 6.5 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 chippers' 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.

The maximum capacity for the one Saalasti stationary chipper line would be three times higher than the maximum capacity of the mobile chipper presented in this paper. With eight year amortization the chipping cost would be 138% higher diesel powered mobile energy wood chipping corresponding the 20MWe boiler capacity. If the boiler consumes more than determined for the medium sized stationary chipping process line's maximum capacity, the larger stationary chipper line options are available from Saalasti and they can process energy chips even lower costs and with significantly higher production volumes.

This analysis was done with only one biomass, the energy wood. In normal bioenergy production the boilers are run with certain material spec including a set of different types of biomass. The Saalasti stationary chipper can process efficiently wide range of different wood based biomasses e.g. loose forest residues, forest residue bundles even pre sliced stumps. The benefits in chipping costs will apply with all these woody biomass with the Saalasti stationary chipping solution.

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