Technical report

Wood Energy Technologies

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Partnership Programmes – TCDC/TCCT - TCP/YUG/3201 (D)

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1 Summary

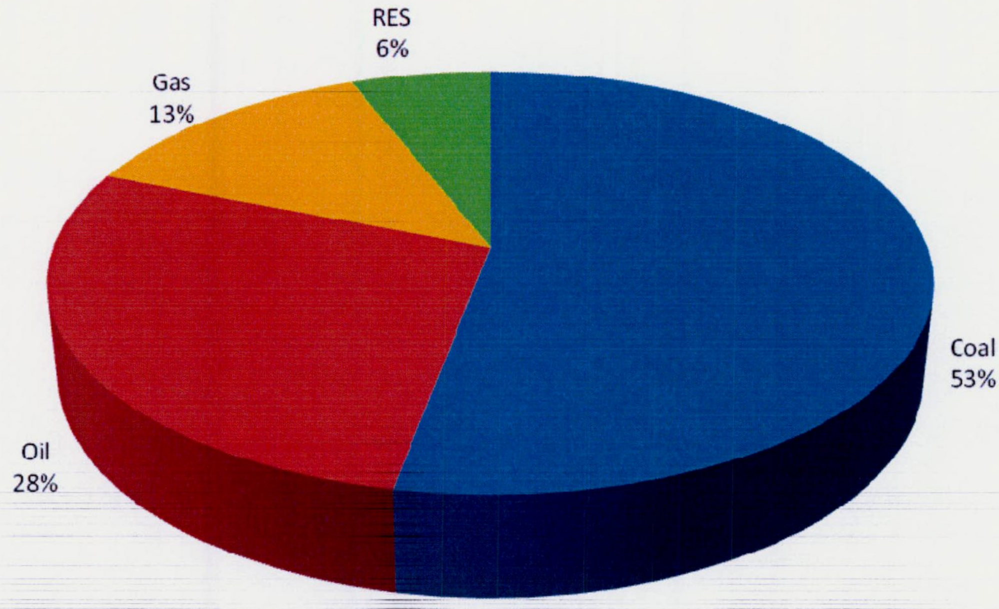
The consultancy on Wood Energy Technologies was carried out in the framework of the Partnership Programmes - TCDC/TCCT - TCP/YUG/3201 (D). The total duration of the consultancy was one month, divided into two parts - first part was one week study visit in Serbia and the second part was preparation of report. Assignment started at the end of January 2001 and ended in March 2011.

Main scope of the consultancy was to assist Serbian forest energy sector in wood energy technologies development. The aim was also to recognize the state of art of technology for production of selected wood fuels in Serbia and to prepare recommendations for further development of cost effective wood fuel production chains. The work was carried out in close collaboration with the national consultants on the wood energy. More specifically, the objectives were to contribute to the development of Serbian Wood Energy sector, following the experiences from Slovenia and some other developed countries.

2 The state of the art of wood energy use in the country

2.1 Introduction

It is estimated, that the share of renewable energy sources (RES) in year 2008 in the structure of gross domestic energy consumption in Serbia was 6% (including the big hydropower plant). This share should increase for 2,2 % till 2012.



Picture 1. Structure of energy sources in final gross energy consumption (Energetski bilans Srbije za 2008 godinu)

The National Energy Strategy for 2015 maps out the path ahead, calling for the development of 150 small hydro plants to provide 100 MW, and 4,000 small boilers to use biomass from industrial, agricultural and forest sources.

The energy potential of the mentioned renewable energy sources in Serbia is very significant and amounts to over 3 Mtoe per year (with the potential of small hydropower plants of about 0.4 Mtoe). About 80 % of the total potential is in the biomass utilization, about 1.0 Mtoe of which consists of the wood biomass potential (woodcutting and wood mass refuse produced in its primary and/or industrial processing), and more than 1.5 Mtoe consists of agricultural biomass (agricultural and farming cultivation residues, including also liquid manure).

2.2 Status quo: Energy production and energy consumption from solid biomass in Serbia

Among RES energy from wood biomass represents 63 %. Wood biomass is used only for heat production. According to data from International energy agency (IEA, 2008) more than 73 % of wood biomass is used in households for heating, 16 % is used in industry and 11 % is used by other (non-specified) users. The main problems are the conventional systems with out of date technologies with relatively low efficiency. Modern technologies are applied progressively. The main barriers are the high investment costs and lack of government scheme to support energy production from biomass.

According to data from study "Analysis of renewable energy and its impact on rural development in Serbia" district heating systems exist in 56 cities of Serbia. They consists of decentralized heat sources, with an installed power of about 6,000 MJ/s, and appropriate distribution networks. The system is used for heating residential and office space of about 582,000 equivalent flats (covering 66 m^2 each).

2.3 Development of the wood energy sector

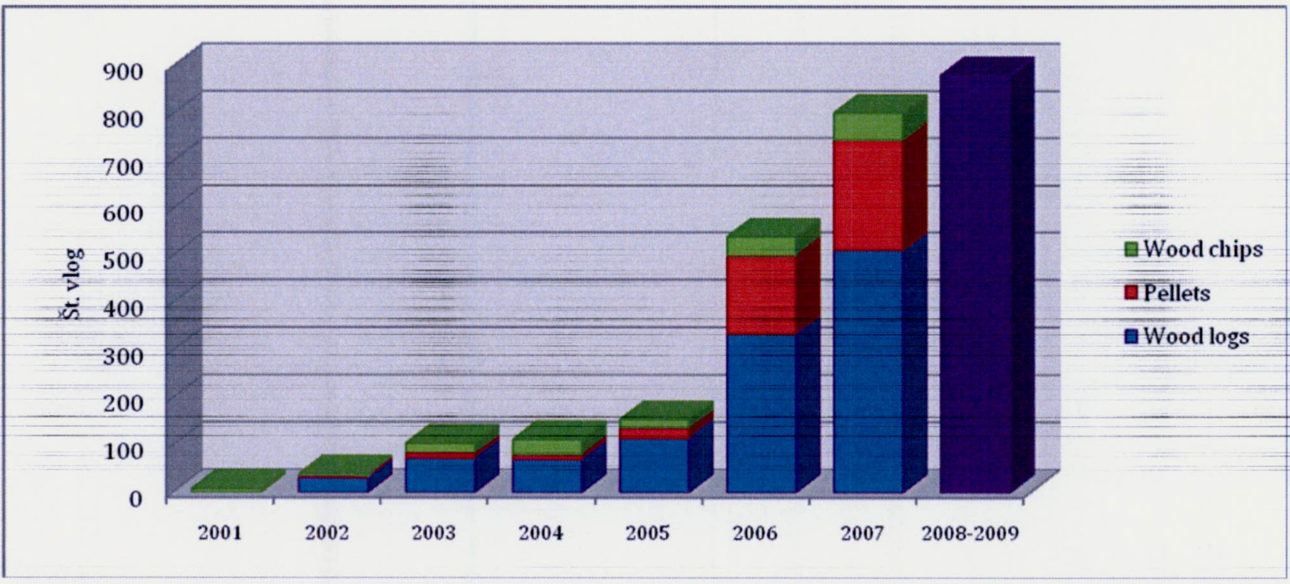
According to official statistics 752.432 t of fuel wood was produced in 2009 in Serbia, around 12.000 t was exported and less than 2.000 t imported. Mainly wood logs are produced for use in households (nearly 80 %). Production of wood chips for energy production started in last year's, it is estimated that production of wood chips in 2011 will reach up to 100.000 t. Pellet production started to grow in last 5 years, the production is estimated to be less than 50.000 t in 2010, but should increase according to installed capacity.

Private forests are covering approximately 47% of the total forest area and **state forests** are covering 47 % of the total forest area.

Mainly three ministers are involved in wood biomass production and use:

- Ministry of Infrastructure and Energy of Republic of Serbia, which is in context of wood biomass responsible for promotion of all renewable sources of energy in general
- Ministry of Agriculture, Trade, Forestry and Water Management of Republic of Serbia is responsible for Rural development program and Forestry action plan.
- Ministry of Environment, mining and Spatial Planning, which cover the area of energy efficiency and investments in renewable energies - also biomass.

The main barrier identified at the moment is no stabile support system for subsides in the field of wood biomass production, storage and use. In the case of Slovenia we can see that the development was seen few year after a system of subsidies for modern biomass boilers, wood chippers and other related technologies were available (see picture 2). After 2004 the Rural development program and subsidies for farmers and forest owners in the frame of this programme busted the development. For example we recorded 4 wood chippers in Slovenia in year 2000 and more than 65 in year 2008 - the majority was bought trough rural development program - where farmers got subsidies up to 60 % of total investment costs.



Picture 2. Number of applications for subsidies for modern boilers in Slovenia (data from AURE till 2007, Eko Sklad data for 2008-2009)

3 The state of art of technology for production of selected wood fuels in Serbia

3.1 Introduction

At the moment we can say that development in wood biomass sector in Serbia is in first phase; there is interest, there are first private initiatives and there is also knowledge. The main barrier is that there is no stabile system of subsides and other state support for new investment in the sector and there is low or no public initiatives for use of wood biomass in public buildings.

The main barriers mentioned by state owned companies (Vojvodinašume, Srbijašume) and by private companies are:

- No market for wood chips,
- Traditional use of wood fuels for energy by households,
- Larger production of pellets (9 pellet producers)
- No use of wood chips for energy production
- No practical experiences for wood chips production – high scepticism
- There is no system of subsidies for modern biomass boilers or modern technologies for wood biomass production.
- No use of wood biomass in public building – no interest and no knowhow
- Strong oil and gas lobby.

In the second part of March 2011 we did an inquiry about existing wood chips producers in Serbia. According to all available data from Forestry faculty, Ministry of Agriculture, Trade, Forestry and Water Management of Republic of Serbia, Serbia Šume and other resources we can estimate that there were only 4 wood chips producers.

Wood chips producers:

1. Jela – Prijepolje – chipper Heizo-hack large chipper on track, bought in October 2009, wood chips are produced mainly from low quality wood and small diameter wood from polar plantation. Wood chips are sold to Kronošpan (the biggest producer of wooden boards) and in smaller extend to local wood pellet producers.
2. Fer Komerc – Novi Slankamen - chipper Heizohack – large chipper on track, bought in November 2010, wood chips are produced mainly from low quality wood and small diameter wood from polar plantation. Wood chips are sold to Kronošpan (the biggest producer of wooden boards) and in smaller extend to local wood pellet producers.

3. Žaličič - Svilajnac - Wood chips are sold to Kronošpan (the biggest producer of wooden boards) and in smaller extend to local wood pellet producers. The producer of wood chipper is not known but the capacity is from 300 to 400 loos m^3 per day. They rae planning to produce up to 40.000 t of wood chips in 2011.
4. MiM Drvoprom Požerac – small chipper with capacity from 3 to 5 loos m3 of chips per hour. Wood chipper is produced in Poland, manual feed-in, with max. diameter 15-20 cm. The company has a contract with state owned company for maintaining river banks. Wood chips are sold to Kronošpan (the biggest producer of wooden boards).

At the moment it is estimated that total production of wood chips will reach around 120.000 t in 2011. Mainly wood chips are produced from wood biomass coming from state owned forests. If market with wood chips will further develop, wood biomass from private forests will become also an important source.

The main problem for all mentioned wood chip producers and potential new investors at the moment is undeveloped wood chips market in Serbia. The main demand for wood chips comes from wood panel industry (Kronošpan) and from some wood pellet producers. None from four interviewed wood chips producer is selling wood chips for direct energy use.

4 Biomass production chains

Working phases and working systems

With reference to forest harvesting operations, it is possible to differentiate between the following working phases:

- felling: cutting a tree from its stump so that the tree falls to the ground;
- processing: delimbing (removing branches from the trunk and topping it) and cross-cutting (cutting the trunk to predetermined lengths);
- skidding: transporting wood from felling site to extraction routes and transporting wood along extraction routes to the landing site;
- debarking: partially or completely removing the bark from a log;
- transporting: moving wood using forest roads and public roads;
- wood fuel production: production of different wood fuels (cutting, splitting, chipping).

The importance of chipping operation has been growing in the last few years. This is due to the fact that chipping makes it possible to exploit and make the most of woody biomass otherwise unused.

There are two main working systems in forest harvesting operations:

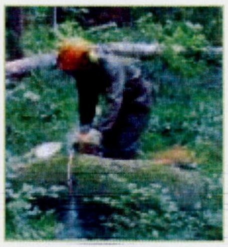
- Short Wood System - SWS: processing is completed on the falling site in the forest, commercial logs are transported;
- Full Tree System - FTS: after felling the whole tree is hauled and processing is performed either on the forest road or on the landing site.

Although in South-eastern Europe SWS is the most predominantly used system, the FTS system is becoming more and more common, particularly in the mountain area, especially when cable cranes are used: with this method, forest residues (branches and tops) are collected either at the roadside or at the landing site, ready to be chipped.

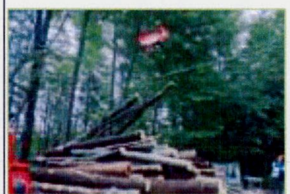
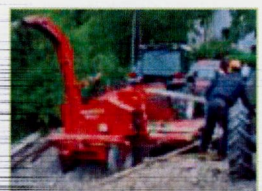
4.1 Machinery and equipment

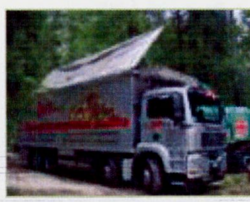
A review of the most important machines and equipment involved in forest harvesting operations, with reference to the Slovenian and Italian context, is presented in next table. For each machinery the range of the most frequent values is indicated, leaving extreme values out. Hourly cost, when specified, includes the staff costs. All prices are in € and exclusive of VAT.

Table 1. Description of machines and equipment involved in forest harvesting operations, transport and wood biomass production

Chainsaw Purchase cost: 500–1.000 € Productivity in high forests: 0,8–1,2 m^3/h (thinning operations) 2–2,5 m^3/h (final cutting) Productivity in coppice forests: 0,4–0,7 stacked m^3/h (average conditions) 0,8–1,8 stacked m^3/h (good conditions) Fuel consumption per hour: 0,6–1 l/h (petrol and oil mixture) Hourly cost ≅ 15–18 €		
Tractor (farm tractor adopted for forest operations) and winch Purchase cost: tractor 45.000–80.000 € Purchase cost: winch 3.000–8.000 € Productivity in high forest: 3–8 m^3/h Productivity in coppice: 3–7 stacked m^3/ h Fuel consumption per hour: 4–8 l/h Hourly cost ≅ 35–45 € (2 del.)		

Tractor (farm tractor adopted for forest operations) and trailer Purchase cost: tractor 45.000–80.000 € Purchase cost: trailer 8.000 - 25.000 € Loading capacity: 5 - 15 t Productivity: 5–12 m^3/h (depending on skidding distance) Fuel consumption per hour: 5–10 l/h Hourly cost ≅ 40–50 €		
Tractor-(farm tractor adopted for forest operations) with processor Purchase cost: tractor 45.000–80.000 € Purchase cost:: processor 45.000 € Max cutting diameter:: 48 cm Max delimbing diameter: 40 cm Productivity: 10–15 m^3/h Fuel consumption per hour: 4–5 l/h Hourly cost ≅ 35 €		
Skidder Purchase cost: 120.000–150.000 € Skidding capacity: up to 3 t Max negotiable slope: 20% Productivity: 8 - 12 solid m^3/h (depending on hauling distance) Fuel consumption per hour: 6–10 l/h Hourly cost ≅ 45–55 €		
Harvester Purchase cost (with processor head): 300.000–370.000 € Max cutting diameter: 65–70 cm Max delimbing diameter: 45–60 cm Max negotiable slope: 35% (wheels) and 60% (tracks) (with optimal soil bearing capacity) Productivity in high forest:: 8–20 m^3/h Fuel consumption per hour: 11–16 l/h Hourly cost ≅ 70–90 €		
Hybrid harvester Purchase cost: of harvester with processor: 240.000 € Max cutting diameter: 55 cm Max delimbing diameter: 50 cm Max negotiable slope: 45–60 % Productivity: 10–15 m^3/h Fuel consumption per hour: 10–12 l/h Hourly cost ≅ 70-80 €		
Excavator-based processor Excavator purchase cost: 170,000 € Processor purchase cost: 60,000 € Max cutting diameter: 65 cm Max delimbing diameter: 60 cm Productivity: 15-40 solid m^3/h		

Fuel consumption per hour: 15 - 17 l Hourly cost ≅ 85 €		
Forwarder Purchase cost: 180.000 – 270.000 € Loading capacity: 10 - 14 t Max negotiable slope: 30 - 35% Logs length: up to 6 m Productivity: 12-20 solid m^3/h (depending on hauling distance) Fuel consumption per hour: 7 - 11 l Hourly cost ≅ 65 - 80 €		
Cable crane with mobile tower yarder **Small:** Purchase cost: 40.000 – 120.000 € Max traction power: 2.000 daN Productivity: 3 – 6 solid m^3/h Fuel hourly consumption: 5 - 6 l Hourly cost ≅ 25 – 40 € **Medium:** Purchase cost: 100.000 – 220.000 € Max traction power: 5.000 daN Productivity: 3 – 12 solid m^3/h Fuel consumption per hour: 6 - 10 l Hourly cost ≅ 40 – 80 €		
Chipper **Small (driven by tractor)** Purchase cost:: 4.500–35.000 € Working diameter. 20 cm Productivity: 2–3 t/h Fuel consumption per hour: 5–8 l/h Hourly cost ≅ 15 – 22 € **Medium (driven by tractor)** Purchase cost: 20.000–85.000 € Working diameter: max 30 cm Produktivnost: 7–15 t/h Fuel consumption per hour: 10–14 l/h Hourly cost ≅ 22 - 30 € **Large** Purchase cost: 85.000 – 400.000 € Working diameter: > 30 cm Productivity: 20 – 35 t/h Hourly cost ≅ 120 - 170 €		 

Saw wood purchase cost: 600 – 2.000 € working diameter: 14 – 25 cm **Log splitter** purchase cost: 700 – 14.000 € Working log length: 0.3 – 1 m Pressure rating: 10 to more than 34 t Productivity: 1 – 5 stocked $m^3$of logs/h **Fuelwood processor (saw and split wood)** purchase cost: 7.000 – 70.000 € working diameter: 25 – 60 cm working log length: 2 – 6 m Productivity: 5 – 10 stocked $m^3$of logs/h hourly cost ≅ 20 – 55 €		
Truck and trailer (log transport) truck purchase cost: 110.000 – 150.000 € trailer purchase cost: 20.000 – 30.000 € loading capacity: 18 – 20 t fuel consumption:: 30–45 l /100 km Hourly cost ≅ 60–75 €		
Truck and trailer (wood chip transport) Truck purchase cost: 100.000–115.000 € Trailer purchase cost: 45.000 € Loading capacity: 20–22 t (85–90 nasutih m^3) Fuel consumption: 30–45 l /100 km Hourly cost ≅ 65–70 € with clamshell bucket loader purchase cost: 205,000 € loading capacity: 81 bulk m^3 hourly cost ≅ 70 – 75 €		

The machines that are most specifically involved in the wood-energy supply chain are employed for log woods and wood chip production.

Depending on the operation, machines for log woods production can be distinguished into:

- **Saw wood**: if based on disc saw or chainsaw, they can process diameters bigger than 40 cm and have low cutting loss; if based on disc saw, they can only process smaller diameters and have higher cutting loss;

- **Split wood**: they are equipped with either a wedge or a screw breaking device. Many log splitters consist of a hydraulic or electrical rod and piston assembly and these are often rated by the tons of pressure they can generate. The higher the pressure rating, the greater the thickness or length of the rounds that can be split. Most log splitter models for home use have a rating around 10 tons, but professional hydraulic models may exert 25 tons of pressure or more. The ones with wedge device for domestic use have either 2 or 4 sides, they work keeping the log vertical and can exert up to 15 t of splitting power, while for industrial use the log is kept horizontal and pushed against a wedge, or a grate, up to 16 sides. The ones with screw are equipped with a threaded cone which spins into the wood so as to split it; they are faster than the former, but less precise; safety at work is very important.

- **Combined – fuelwood processors** (saw-split wood): there are mobile models, or stationary machines which combine the two operations: sawing and splitting , allowing automation of process and a higher productivity, working both on logs and on big branches. They are endowed with electric or spark-ignition engine (up to 55 kW), can work logs up to 6 m long and 60 cm of diameter and can produce more than 12 t/h of material.

Processing hardwood requires more power than processing softwood and all types of wood can more easily be split when fresh rather than seasoned.

Chippers

A chipper is a machine that is especially built to reduce wood to chips and can either be stationary or mounted on a carriage, on a trailer, on a truck or on the rear three-point hitch of a tractor. It can be equipped with its own engine or activated by the tractor power take off. Depending on the chipping unit, it is possible to differentiate between:

- **disc chippers**: the chipping unit consists of a heavy flywheel on which are radially mounted from two to four knives. The material comes into contact with the disc at an angle of 30 to 40 degrees to the plane of the disc and the rotating knives, acting against an anvil at the end of the inffed spout, cut progressive slices from the wood that breaks up into chips whilst being cut. Chip size is usually between 0.3 and 4.5 cm and can be modified by an adjustable bed knife;
- **drum chippers**: bigger and more powerful than disc chippers, these chippers can easily work both logs and harvesting residues. The chipping unit consists of a steel cylinder with up to 12 knives installed in tangential position; chip size is more heterogeneous, with lengths up to 6.5 cm. Knives must be replaced every 50–100 t (working with hardwood) or 200–300 t (with softwood);

- **feed screw chippers**: chipping is provided by a big worm of decreasing section with sharp edges that rotates on a horizontal axis. These machines, which are not particularly widespread, can mostly process full trees or logs and produce bigger chips (up to 8 cm) compared to disc and drum chippers.

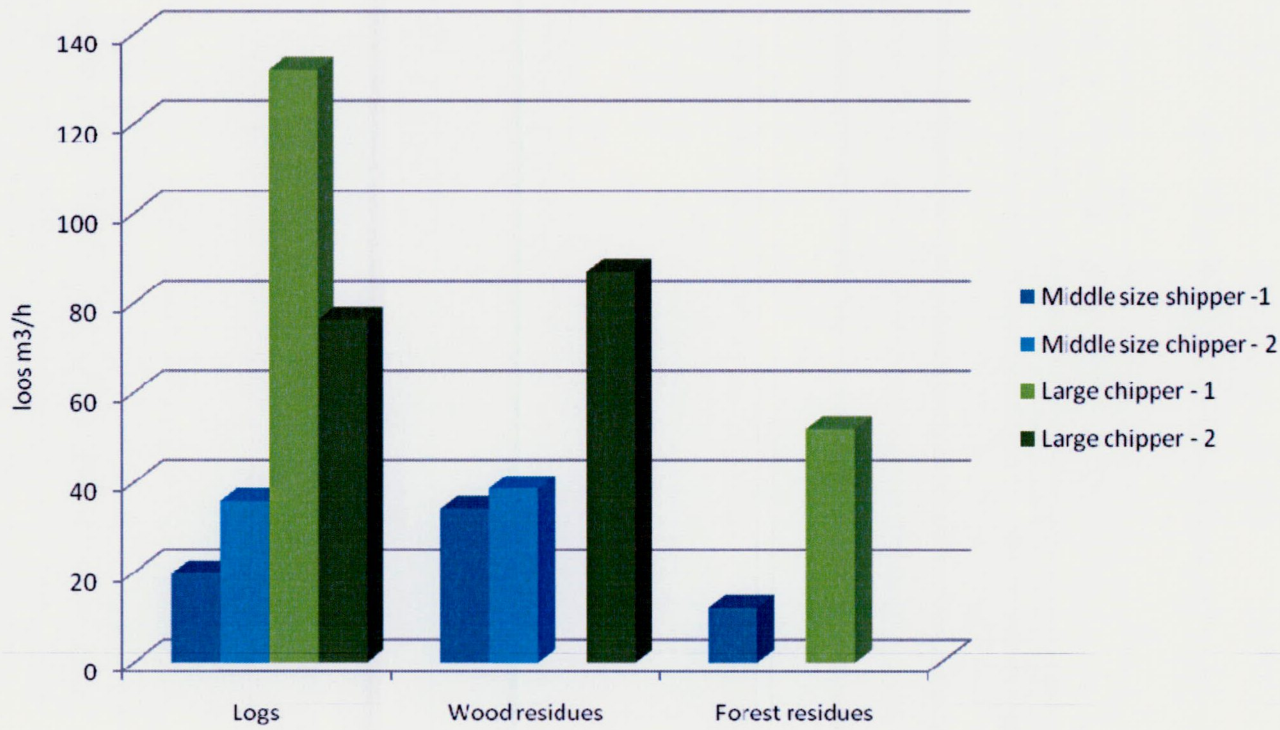
According to the required power, three categories can be identified:

- **small power**: usually installed on the rear three point hitch of a tractor or on a trailer, these chippers are powered by the tractor power take off or by an independent engine (~50 kW). They can only process small diameters (20 cm max) and can produce no more than 10 loos m^3 of wood chips per hour. Mainly they are for domestic use;
- **medium power**: trailer-mounted, usually with independent engine (50-110 kW), or installed on the rear three point hitch of a tractor; they can chip diameters up to 30 cm and produce up to 50 loos m^3 of wood chips per hour;
- **high power**: installed on trailers or on trucks, these chippers are sometimes activated by the truck's engine, but normally they are provided with an autonomous engine (>130 kW); they can chip big diameters (>30 cm) and easily produce more than 100 loos m^3 of wood chips per hour.

The **sieve** is an important tool which makes possible the selection of chips according to their size, thus refining the material but at the same time lowering productivity.

When chipping is performed in a place different from the final plant, chips are transported either by truck or truck and trailer, rarely by articulated vehicle, set up with large cases in light alloy; a clamshell bucket loader can be installed on the truck and trailer to make possible an autonomous loading of the chips.

Austrian studies show that the productivity (bulk m^3) of a high-power chipper varies according to the kind of material to be chipped; average productivity values (picture 3) include waiting times for the truck and trailer to unload the chips. These times have been calculated to account for about 20% of total time. These results were tested also in few case studies in Slovenia (Bezovnik, Kucler).



Picture 3. Comparison of productivity for 4 chippers according to different material (Kucler, Bezovnik, Stampfer/Kanzian)

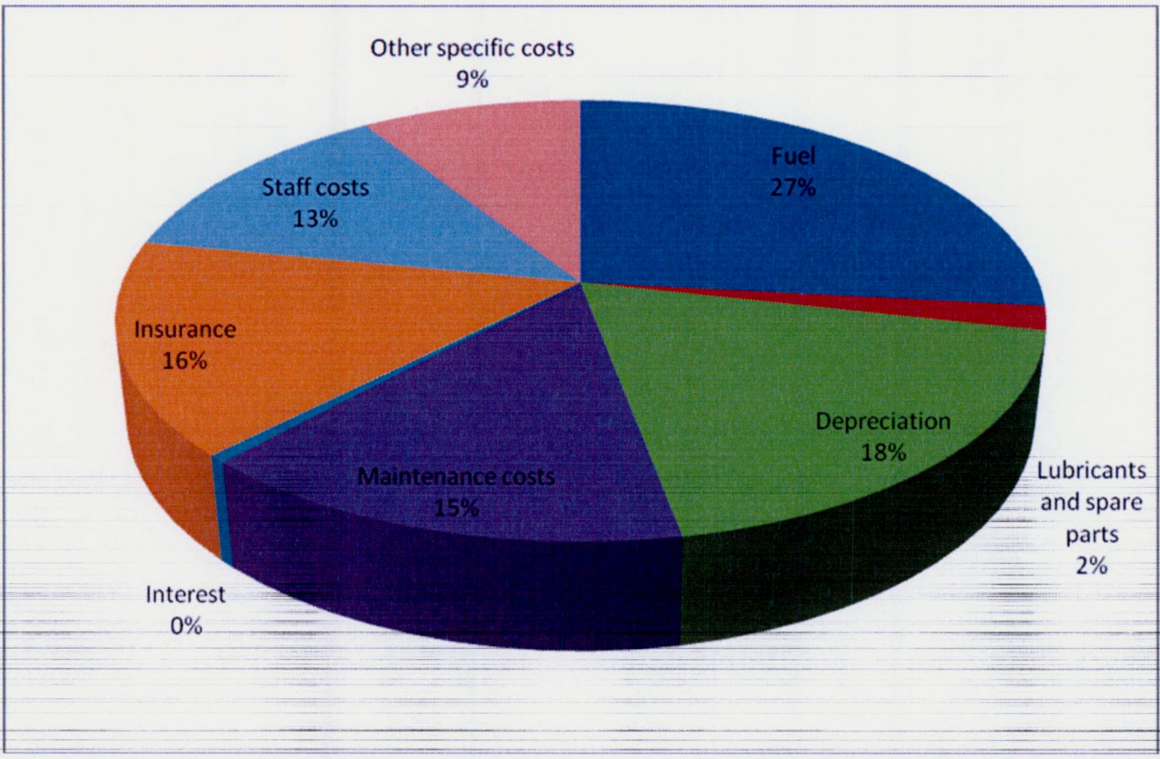
Wood residues – residues from wood processing industry
Forest residue – residues from forest production (branches, tops, ...).

The differences occur also among wood chippers of the comparable size. The main reason is in wood biomass preparation. As it was stated by KUCLER (2010) the chipper couldn't have higher efficiency while logs were not stored by the road and a lot of time was spend for unnecessary handling of logs. While in second case the effect of the some type of wood chipper (BEZOVNIK) were nearly twice higher, while wood biomass was stored by the forest road and in the way that it didn't took much time for handling.

5 Costs for wood fuel production

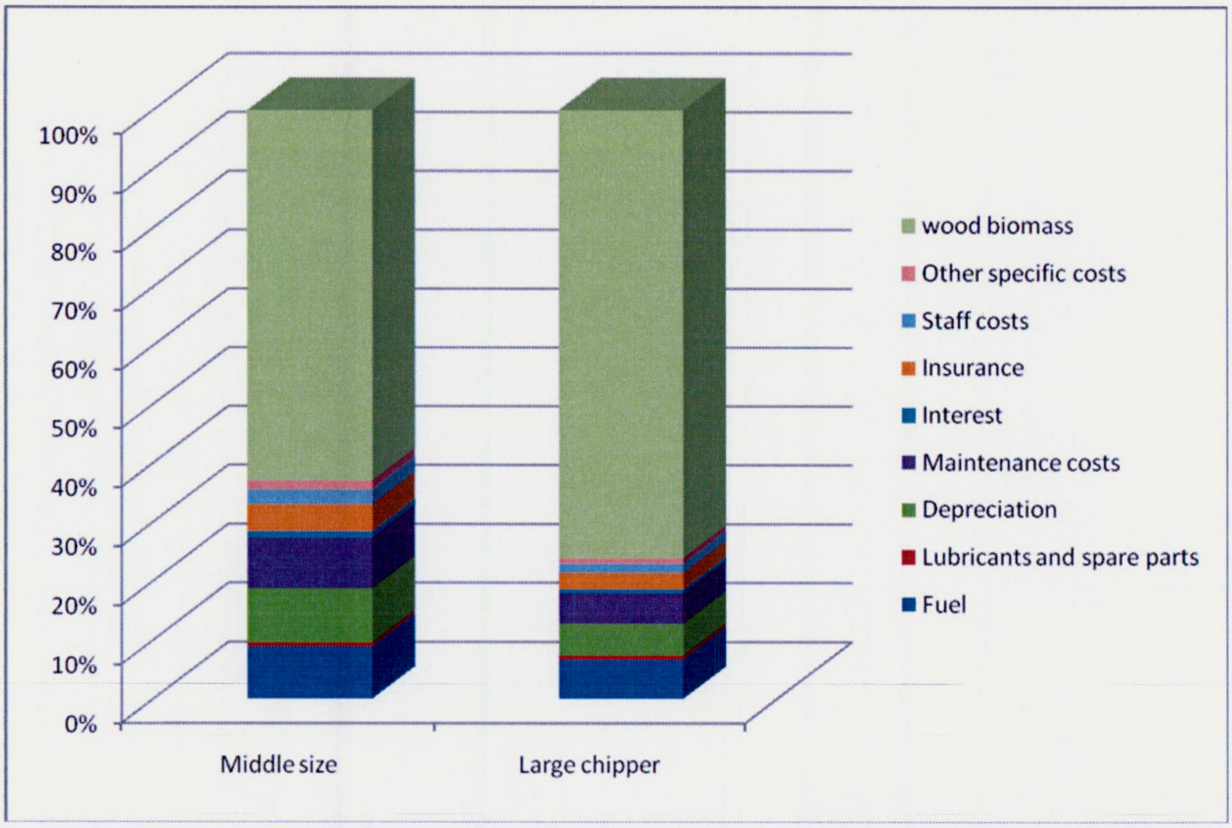
5.1 Analyses of technology parameters for production of selected wood fuels in Slovenia, with recommendations for increasing efficiency of existing technology in Serbia

Among all costs categories for middle size wood chipper (picture 4) fuel represents nearly 30 %, followed by depreciations and maintenance costs. Labour and biomass costs are not taken in to consideration in this calculation costs.



Picture 4. Structure of costs for middle size chipper (data for Slovenia, 2010)

If we consider also labour and biomass costs the structure change significantly. Wood biomass represents the largest cost, followed by fuel and depreciation. Structure of costs varies according to wood chipper capacity. Larger chippers have lower material costs per working hour and wood biomass represents more than 70 % of all costs.



Picture 5. Structure of costs for middle and large size wood chipper (data for Slovenia, 2009 and 2010)

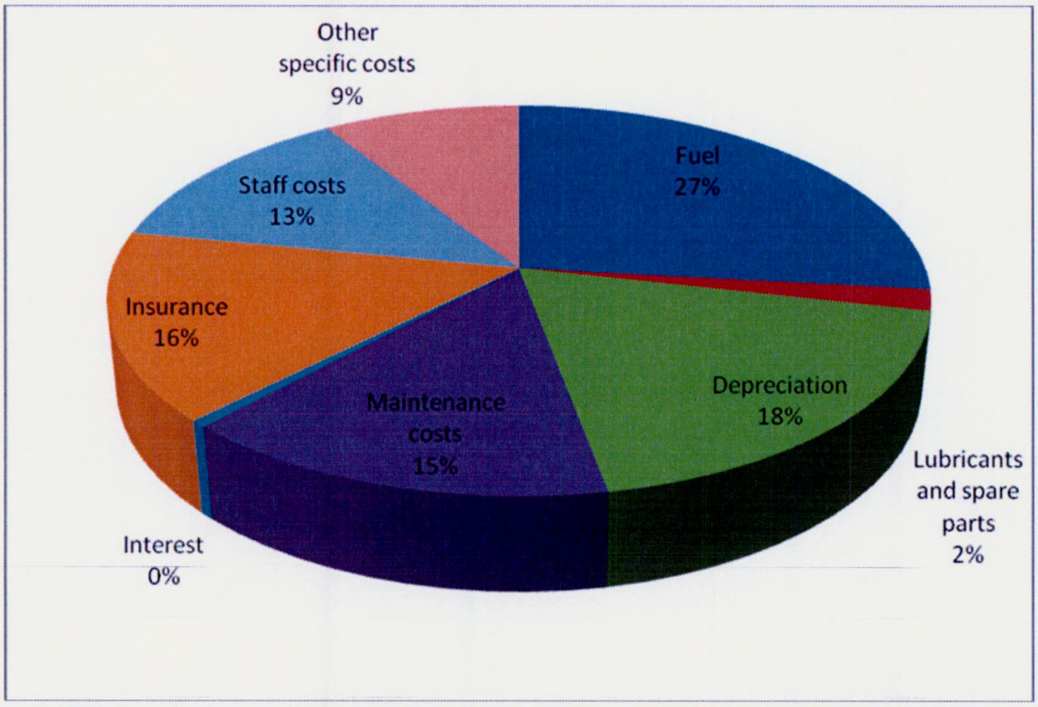
The main open question is how we can lower the costs of wood chips production per hour. According to cost distribution shown in picture above (picture 5) we can lower the costs by buying larger chipper with larger capacity. We can rich higher productivity per hour and subsequently lower the costs per unit with preparation of wood biomass and with right selection of wood biomass (see picture 3). We can lower the maintenance costs by training of wood chips operator - so that they are able to change knifes when necessary, they can handle wood biomass and prevent break-downs because of stones, metal or other impurities mixed with biomass.

5.2 Technology costs in total price of selected wood fuels in Slovenia (fuels cost, maintenance cost, amortization, transport cost, etc)

Wood chippers

In the cost calculation we took in to account the costs of fuel, costs of spear parts and lubricants, costs of depreciation (the life time is different for different machinery, in the case of wood chippers the life time is 10 year in the case of wood fuel processor we took 15 years). The insurance represents

3 % of depreciation and interests on capital invested in to machinery represents 5 % of depreciation.



Picture 6. Structure of costs for middle size wood chipper

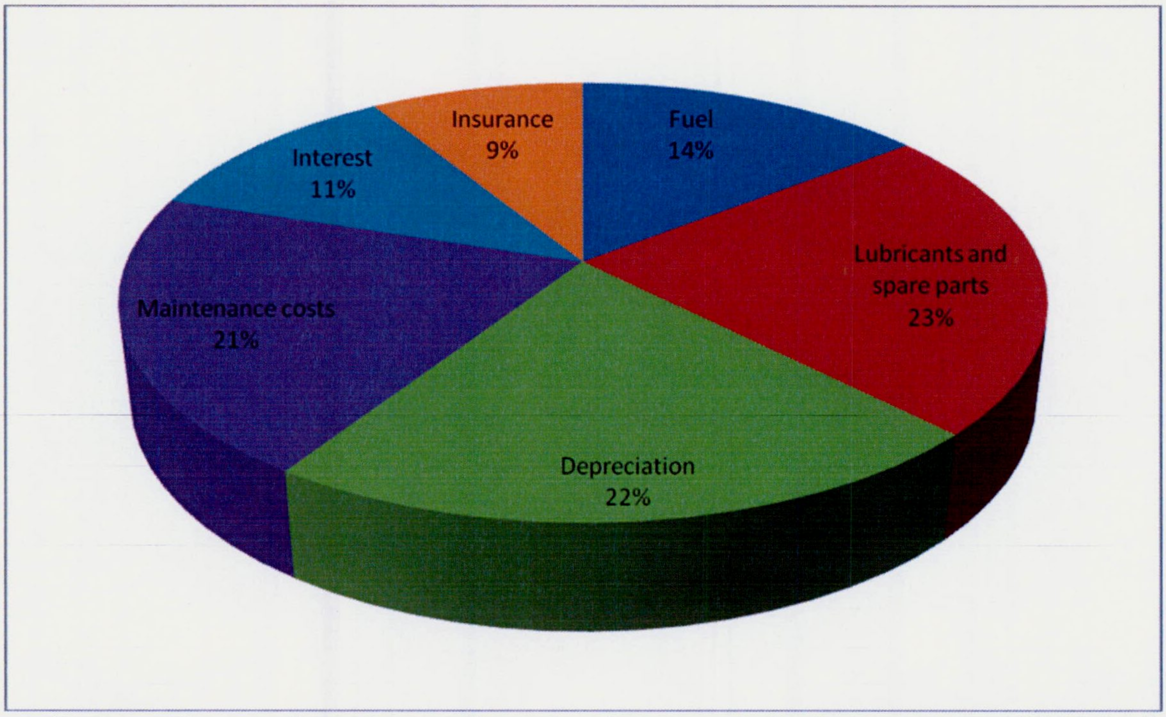
Table 2. Example of costs for middle size chipper (based on data from KUCLER 2009)

Cost categories	€/loos m^3
Fuel	1,49
Lubricants and spare parts	0,10
Depreciation	1,00
Maintenance costs	0,80
Interest	0,03
Insurance	0,90
Staff costs	0,79
Other specific costs	0,59
Total	5,60

Fuel costs represent the largest part of costs in cost calculation. According to results of study done by Kucler amount of fuel used for production of wood chips vary according wood biomass type – when wood chips are produced from wood waste (from sawmill) less tha 1 l of fuel is used per loos m3 of wood chips. This amount can increase to 1,3 l/loos m3 in the case of forest residues.

Wood fuel processor

In the calculation of costs for wood fuel processor we have foreseen that wood fuel processor is driven by a tractor. So we calculated that the capacity of wood fuel processor is 8 stock m of logs per hour. So the total cost of wood fuel processor is 1,9 €/stock meter (without staff costs).

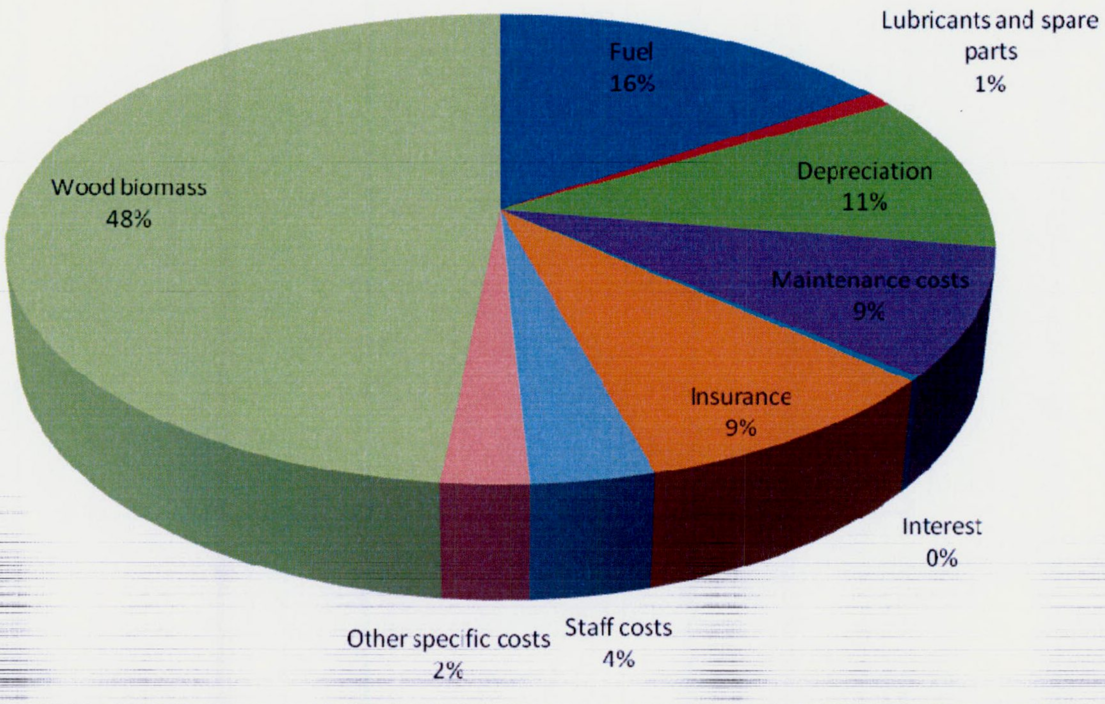


Picture 7. Structure of costs for wood fuel processor (driven by a tractor with 4 while drive)

If we take in consideration also costs of wood biomass (48 €/m^3), the costs rises up to 36 € per stock m^3.

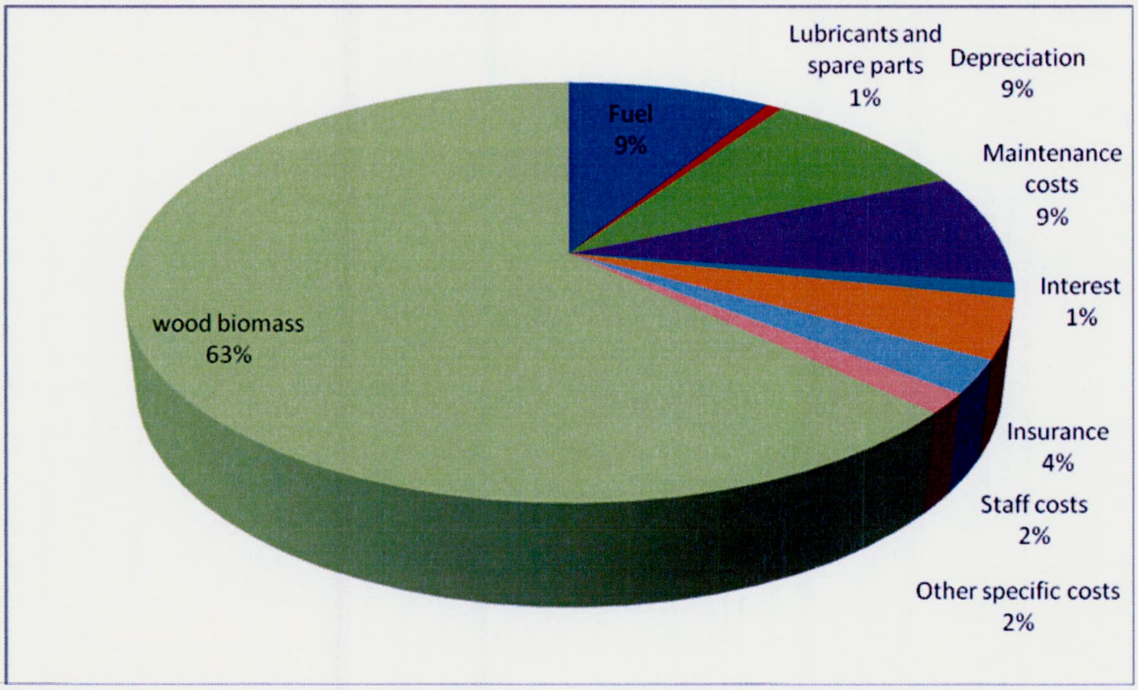
5.3 Direct costs for preparation of raw materials for fuelwood and wood chips production, direct material costs of individual machines for wood chips and fuelwood production

In the calculation of costs for wood chips production in Serbia we foreseen that the costs of wood biomass (logs) is 12 €/m^3 and staff costs are 0,7 €/loos m^3. All other costs categories are the same as in previous chapter.



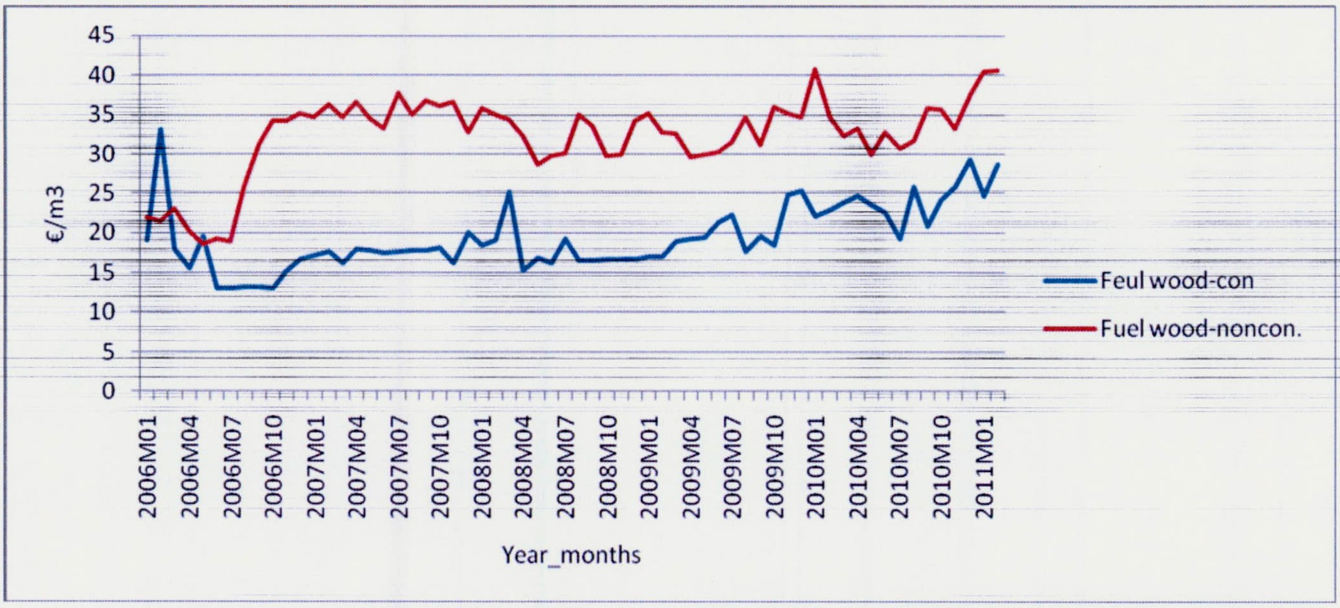
Picture 8. Structure of costs (€/h) for middle size chipper driven by a tractor – estimations for Serbia (%)

If we take in consideration all costs we estimated that total costs of wood chip production with middle size wood chipper vary from 5,8 up to 9,9 €/loos m^3. The structure of these costs is shown in picture 8. The main difference in costs is caused by wood biomass type (as already mentioned in previous chapters). The lowest costs are in case of wood chips from wood wastes (sawmill residues) and the highest in the case of forest residues. The total costs of wood chips production with large size wood chippers are from 5,1 to 7,1 €/loos m^3 – the main reason for cost variation is wood biomass type.



Picture 9. Structure of costs (€/h) for middle size chipper driven by a tractor in Slovenia (KUCLER)

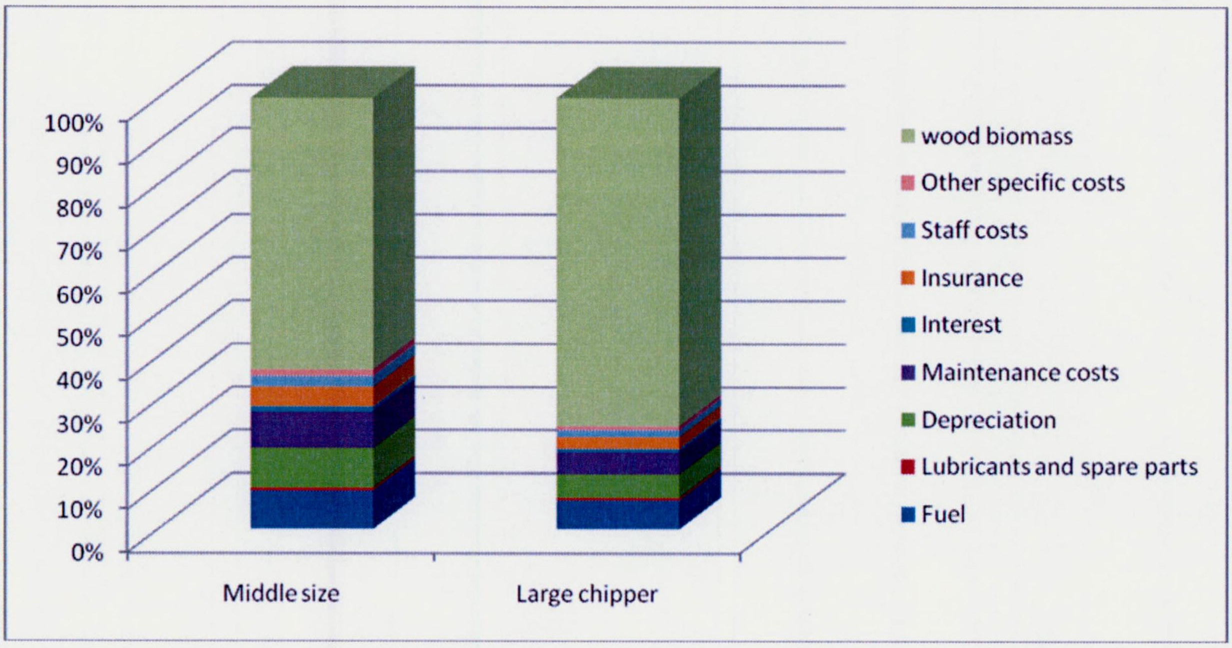
In the case of Slovenia the total costs of wood chips production are higher (from 8,6 to 13,4 €/loos m^3) due to higher staff costs and higher prices of wood biomass (picture 10).



Picture 10. Monthly prices of fuel wood in Slovenia (on forest road) (Soure of data: SORS, 2011)

The prices of fuel wood (especially fuel wood of non – coniferous trees) are changing through the seasons but also through the years. In 2011 the increase is seen – the main reason is low winter temperature in the first month and also higher demand for this wood from Italy. The most powerful driver for wood biomass prices at the moment is price of heating oil on the market (picture 11) in Slovenia.

Picture 11. Prices of heating oil (€/l) in last 5 years in Slovenia

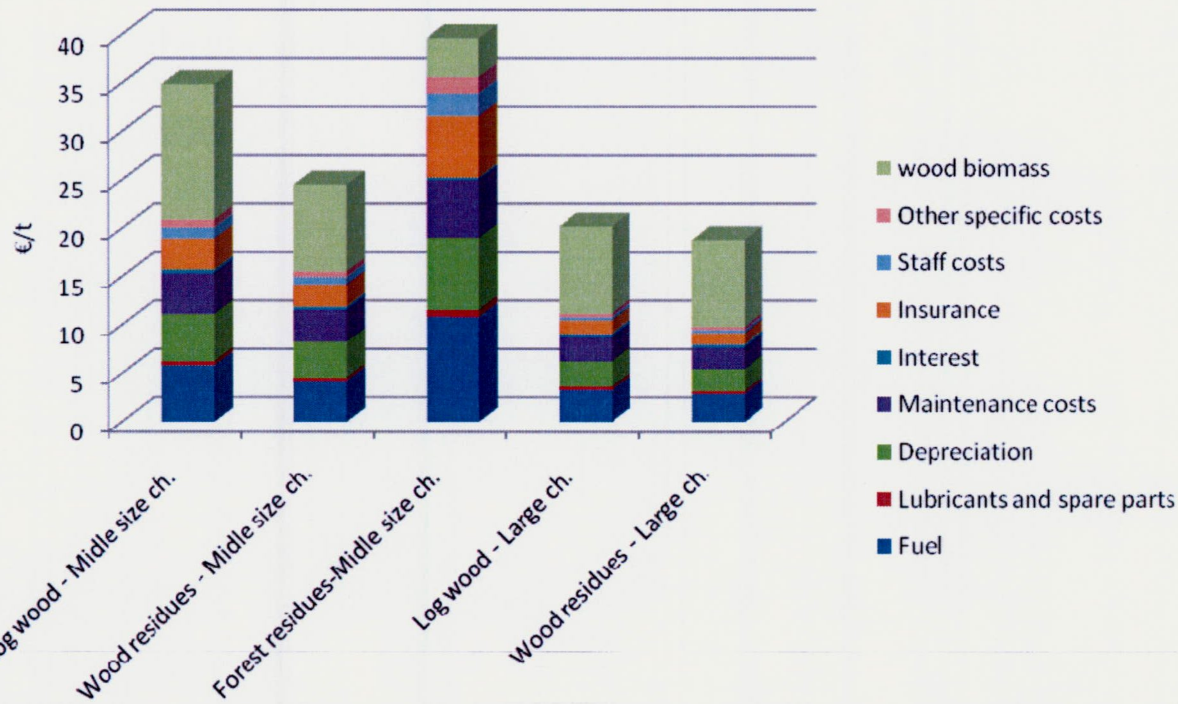


Picture 12. Structure of costs (%) for middle size chipper (driven by tractor) and large size chipper on a truck (Bezovnik)

It is recommended that wood chips are sold by weight and water content and not by volume. That's why we decided to present costs of wood chips preparation also by ton (picture 12). For the practical recalculation of loos m^3 to tons or solid m^3 we can use data in following table.

Table 3. Example of conversion factors for wood chips (G30 w=35%) (Source: Austrian energy Agency).

	w (%)	Loos m³	Round wood eqv.	Dry matter	Fresh matter	Caloric value		Units
Wood chips (G30, mixed coniferous and nonconiferous)		Loos m³	m³	t	t	MWh	GJ	
	35 %	1	0,400	0,256	0,167	0,811	2,921	Loos m3
		2,500	1	0,641	0,417	2,028	7,302	m³
		3,906	1,560	1	0,650	3,165	11,393	t
		5,988	2,398	1,538	1	5,235	18,846	t
		1,233	0,493	0,316	0,191	1	3,600	MWh
		0,342	0,137	0,088	0,053	0,278	1	GJ



Picture 13. Comparison of costs structure (€/t) for wood chips production with middle and large size chipper (estimations for Serbia)

Even the costs of forest residues are very low we have to considered lower productivity of wood chipper and also lower quality of wood chips (larger percentage of smaller particles, higher percentage of bark, more impurities, ...). According to different studies done in the past we can conclude that it is cost efficient to use wood forest residues in the case of larger clear cuts (for example in poplar plantations) and in the case of skidding with cable crane. In both cases we have larger concentration of forest residues on one spot and usually we have to handle them if we want to finish the production cycle.

6 Prices of wood chippers

To have a comprehensive overview on wood chippers available we did a short study on available technologies mainly on European market. We included more than 129 different types of wood chippers from 25 wood chippers producers.

All wood chippers are divided in three main groups which correspond to groups mentioned in chapter 3. Data from analysed wood chippers are summarized in tables below.

Table 4. Main characteristics of wood chippers

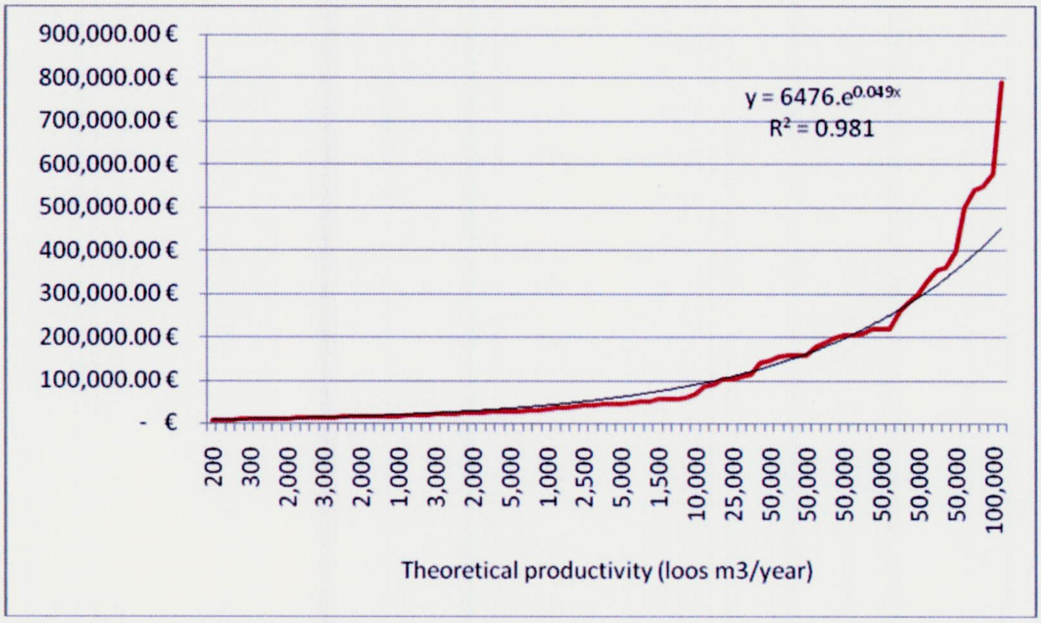
Category of wood chippers	Power requirement (kW)	Average productivity (loos m3/h)	Average no. of working hour in life time	Price range (€)
1	from 15 up to 55	from 5 up to 30	4930	from 8.000 up to 60.000
2	from 30 up to 500	from 30 up to 100	7363	from 12.000 up to 250.000
4	from 240 up to 550	more than 100	10675	from 260.000 up to 800.000

Category of wood chippers	Max. Diameter of wood biomass (cm)	Feed opening (cm):		Size of wood chips (mm)	Weight (kg)
		- width	- height		
1	from 2 to 37	from 16 to 65	from 12 to 35	from 9 to 45	from 210 to 2500
2	from 15 to 75	from 24 to 165	from 18 to 300	from 17 to 57	from 880 to 24000
4	from 45 to 100	from 66 to 208	from 60 to 300	from 17 to 105	from 19000 to 46000

We included wood chipper from 25 different producers – listed below.

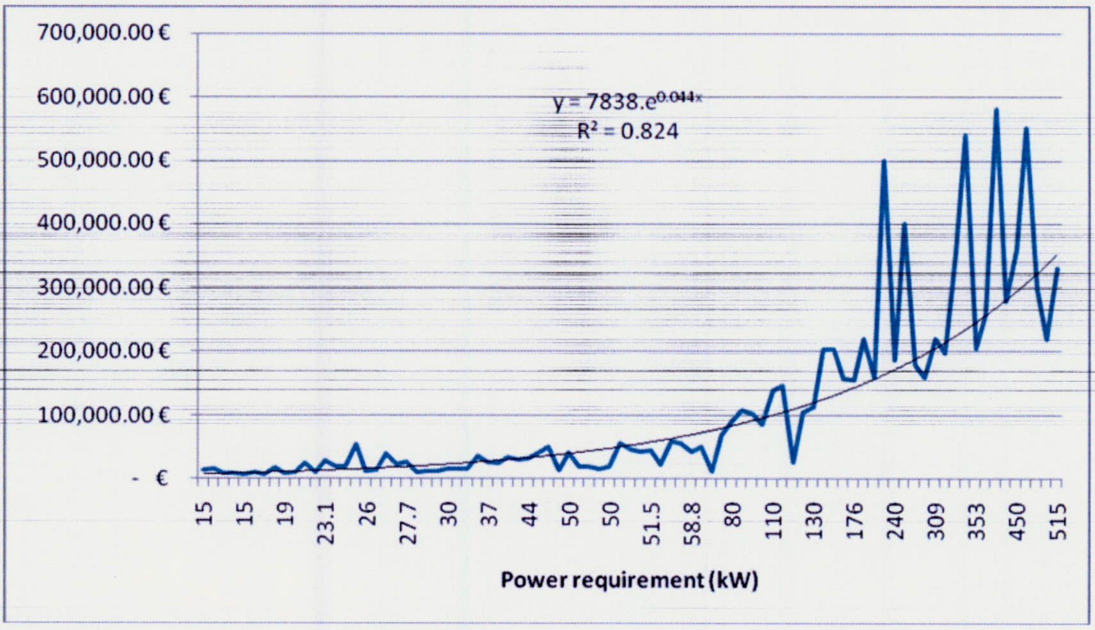
AHWI Eurochipper	Jenz
Berkili	Kirchmayr
Bruks-Klöckner	Komptech
CBI (Continental Biomass Industries)	KRONE
Doppstadt	Laimet
Dutch Dragon	MUS-MAX
Eschlböck	Pezzolato
Euroklip	Schliesing
Hakkuri	Silvatec
HAMA	Starchl
Husmann	Stark
Jensen	Willibald
	Wüst

The investment in wood chipper depend on many parameters like source of power (tractor, diesel engine, truck,...), way of fid-in of row material, conveyors, splitter (for large diameter logs), ... The analysis showed that the investments is in close correlation with productivity of wood chipper.



Picture 14. Correlation between theoretical productivity of wood chipper and investment

The investment costs are also in close correlation to power requirement. But this correlation is not as high as in the case of productivity. The main reason for that is the energy source which can be a tractor, independent engine (diesel or electric) or truck. The investment costs are the highest in the case of chippers powered by track.



Picture 15. Correlation between theoretical productivity of wood chipper and investment

The whole list of wood chippers with main characteristics included in this analysis is Appendix 1.

7 Recommendations for the most efficient way of using specific technologies for selected wood fuels

7.1 Examples of forest energy business models

a) CHIPPING AND SHREDDING/GRINDING AND TRANSPORT

Wood biomass transported to terminals (larger storage places) where wood chips are produced and sold to end users

- Companies are specialized in using terminal-sized machines or effective chippers (larger size)
- Based on contract work
- Transport often provided

b) CHIPPING AND TRANSPORT

- Companies are specialized in chipping and transporting of chips
- Customers are heating plants and organizations supplying fuel for plants

c) (BUYING) + HARVESTING + CHIPPING + TRANSPORT

- Specialized in harvesting, chipping and transporting energy wood

d) (BUYING) + HARVESTING + CHIPPING + TRANSPORT + PRODUCTION AND SUPPLY OF HEAT

- Turnkey basis = management of the whole value chain
- Heating entrepreneurship

According to present situation in Serbia the b) and d) business model can be the most recommended. Model b) is mainly for those working in state owned forests (Srbiašume or Vojvodinašume). The model d) can be recommended for private companies working in private forests or private companies working as subcontractors in state owned forests. Mode d) is more flexible and gives more opportunities for SME's to find their own market niche.

8 Quality control and quality assurance for wood fuels

8.1 Standards for wood fuels

Qualitative classification of solid biofuels was defined at European level by Technical Specification CEN/TS 14961 (*Solid biofuels, fuel specification and classes*, 2005). In last few years a new package of standards was prepared in the frame of European committee for standardization. For the first time, this series of standards offers a uniform, Europe-wide tool for the standardisation of solid biomass fuel that may be used for energy production. The up to date list of standards and other normative documents is in table 2 and 3.

All CEN standards and normative documents can be divided into 6 groups:

- **Terminology** – EN 14588 (1 standard, published)
- **Fuel specification and classes** – EN 14961 multipart standard (6 standards, 5 published,1 under voting)
- **Quality assurance** – EN 15234 multipart standard (6 standards, 1 standard published and 5 under voting)
- **Sampling and sample preparation** (EN 14778 and EN 14780, published)
- **Physical and mechanical properties**, 15 standards (most published)
- **Chemical properties** (6 standards published)

Table 5. List of available standards and technical specifications (CEN, March 2011)

CEN/TS 14778-1:2005	Solid biofuels - Sampling - Part 1: Methods for sampling
CEN/TS 14778-2:2005	Solid biofuels - Sampling - Part 2: Methods for sampling particulate material transported in lorries
CEN/TS 14779:2005	Solid biofuels - Sampling - Methods for preparing sampling plans and sampling certificates
CEN/TS 14780:2005	Solid biofuels - Methods for sample preparation
CEN/TS 15370-1:2006	Solid biofuels - Method for the determination of ash melting behaviour - Part 1: Characteristic temperatures method
CEN/TS 15149-3:2006	Solid biofuels - Methods for the determination of particle size distribution - Part 3: Rotary screen method
CEN/TS 15150:2005	Solid biofuels - Methods for the determination of particle density
CEN/TR 15569:2009	Solid biofuels - A guide for a quality assurance system

EN 14961-1:2010	Solid biofuels - Fuel specifications and classes - Part 1: General requirements
EN 14918:2009	Solid biofuels - Determination of calorific value
EN 15103:2009	Solid biofuels - Determination of bulk density
EN 14774-1:2009	Solid biofuels - Determination of moisture content - Oven dry method - Part 1: Total moisture - Reference method
EN 14774-2:2009	Solid biofuels - Determination of moisture content - Oven dry method - Part 2: Total moisture - Simplified method
EN 14774-3:2009	Solid biofuels - Determination of moisture content - Oven dry method - Part 3: Moisture in general analysis sample
EN 15148:2009	Solid biofuels - Determination of the content of volatile matter
EN 14775:2009	Solid biofuels - Determination of ash content
EN 15210-1:2009	Solid biofuels - Determination of mechanical durability of pellets and briquettes - Part 1: Pellets
EN 14961-5:2011	Solid biofuels - Fuel specifications and classes - Part 5: Firewood for non-industrial use
EN 15234-1:2011	Solid biofuels - Fuel quality assurance - Part 1: General requirements
EN 14588:2010	Solid biofuels - Terminology, definitions and descriptions
EN 15149-1:2010	Solid biofuels - Determination of particle size distribution - Part 1: Oscillating screen method using sieve apertures of 1 mm and above
EN 15149-2:2010	Solid biofuels - Determination of particle size distribution - Part 2: Vibrating screen method using sieve apertures of 3,15 mm and below
EN 15210-2:2010	Solid biofuels - Determination of mechanical durability of pellets and briquettes - Part 2: Briquettes
EN 15104:2011	Solid biofuels - Determination of total content of carbon, hydrogen and nitrogen - Instrumental methods
EN 15289:2011	Solid biofuels - Determination of total content of sulfur and chlorine
EN 15105:2011	Solid biofuels - Determination of the water soluble chloride, sodium and potassium content
EN 15290:2011	Solid biofuels - Determination of major elements - Al, Ca, Fe, Mg, P, K, Si, Na and Ti
EN 15297:2011	Solid biofuels - Determination of minor elements - As, Cd, Co, Cr, Cu, Hg, Mn, Mo, Ni, Pb, Sb, V and Zn
EN 15296:2011	Solid biofuels - Conversion of analytical results from one basis to another

Table 6. CEN standards for solid biofuels under development or approval

WI number	Project reference	Title	Candidate citation in OJEU*	Current status	Foreseen date of availability
00335064	prEN 16126	Solid biofuels - Determination of particle size distribution of disintegrated pellets	No	Under Approval	2012-04
00335065	prEN 16127	Solid biofuels - Determination of length and diameter for pellets and cylindrical briquettes	No	Under Approval	2012-04
00335067	EN 14961-2:2011	Solid biofuels - Fuel specifications and classes - Part 2: Wood pellets for non-industrial use	No	Approved	2011-03
00335068	EN 14961-3:2011	Solid biofuels - Fuel specifications and classes - Part 3: Wood briquettes for non-industrial use	No	Approved	2011-03
00335069	EN 14961-4:2011	Solid biofuels - Fuel specifications and classes - Part 4: Wood chips for non-industrial use	No	Approved	2011-03
00335071	FprEN 14961-6	Solid biofuels - Fuel specifications and classes - Part 6: Non woody pellets for non-industrial use	No	Under Approval	2012-01
00335073	FprEN 15234-2	Solid biofuels - Fuel quality assurance - Part 2: Wood pellets for non-industrial use	No	Under Approval	2012-01
00335074	FprEN 15234-3	Solid biofuels - Fuel quality assurance - Part 3: Wood briquettes for non-industrial use	No	Under Approval	2012-01
00335075	FprEN 15234-4	Solid biofuels - Fuel quality assurance - Part 4: Wood chips for non-industrial use	No	Under Approval	2012-01
00335076	FprEN 15234-5	Solid biofuels - Fuel quality assurance - Part 5: Firewood for non-industrial use	No	Under Approval	2012-01
00335077	FprEN 15234-6	Solid biofuels - Fuel quality assurance - Part 6: Non-woody pellets for non-industrial use	No	Under Approval	2012-01
00335079	FprEN 14778	Solid biofuels - Sampling	No	Under Approval	2011-07
00335080	FprEN 14780	Solid biofuels - Sample preparation	No	Under Approval	2011-07
00335084	FprCEN/TR 15149-3	Solid biofuels - Determination of particle size distribution - Part 3: Rotary screen method	No	Under Approval	2011-09
00335085	FprEN 15150	Solid biofuels - Determination of particle density	No	Under Approval	2011-11

Characteristics such as water content, ash content, calorific value and the quantity of certain elements (e.g. chlorine, nitrogen and sulphur) play an important role in the quality of the fuel, which is ultimately responsible for biomass plants operating efficiently and with low emissions.

Upgrading of TS to EN standards was carried out during 2007–2010. The main standard for solid fuel classification is EN 14961, which is subdivided into a general part (Part 1) and five short and easy-to-understand product standards and is also supported by a series of further EN standards. These govern the taking and processing of samples, testing and analysis procedures and the quality assurance of solid biofuels (e.g. testing the ash content of wood chips in accordance with EN 14775).

8.2 Solid biofuels - Sampling

New standards for sampling and sample preparation for solid biofuels are under approval at the moment. At this point of time 4 normative documents on sampling preparation are available at EU level:

CEN/TS 14778-1:2005	Solid biofuels - Sampling - Part 1: Methods for sampling
CEN/TS 14778-2:2005	Solid biofuels - Sampling - Part 2: Methods for sampling particulate material transported in lorries
CEN/TS 14779:2005	Solid biofuels - Sampling - Methods for preparing sampling plans and sampling certificates
CEN/TS 14780:2005	Solid biofuels - Methods for sample preparation

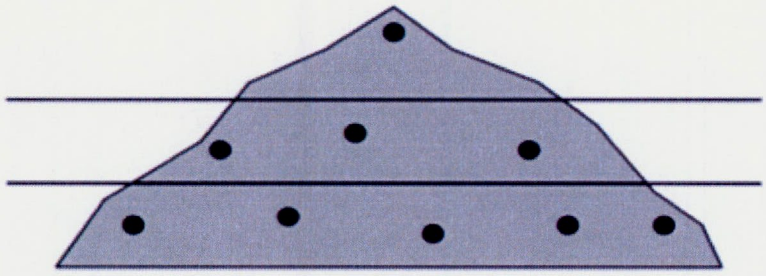
But to be more practical we can summarize the main instruction for wood chip producer.

The critical factor in taking a sample is that it should represent the whole load. For example: there should have the same distribution of particle sizes in the sample as exist in the load, and the sample should have the same moisture content as the surrounding material. The main principle that should be considered is: Every particle in the lot should have an equal probability of being included in the sample.

In a large stack of fuel, there will be variations in the moisture content throughout the stack and sample should be taken from more than one place to allow for this. You should take a minimum of 5 samples, taking material from the upper, middle and lower parts of the fuel stack. Ignore any material from the lowest 30cm of the stack as this is likely to pick up additional moisture and other contamination from the ground.

Samples of wood chips can be taken from:

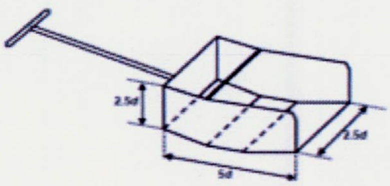
a) **A stocked pile:**



b) Moving streams

c) **Lorry during unloading**

Equipment for sampling



The minimum number of increments to be taken from a lot or sub-lot depends on the heterogeneity of the material to be sampled.

The number of increments shall be calculated:

- for wood chips and wood pellets in smaller stocks:

$n = 10 + 0{,}040 * Mlot$

- for sampling from moving material (from moving strips or unloading trucks):

$n = 5 + 0{,}040 * Mlot$

where:

n is the minimum permitted number of increments, round off to the nearest whole number;

M_{lot} is the mass of the lot or sub-lot in tones (defined quantity of fuel for which the quality is to be determined).

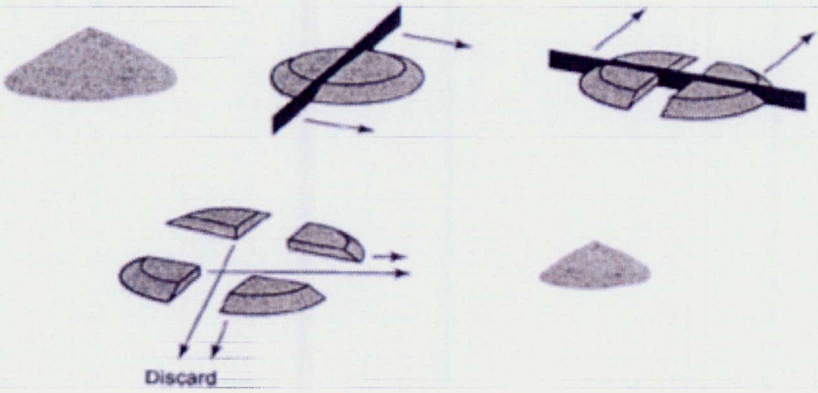
The minimum size of the test sample for the determination of the size distribution shall be 8 l and shall be sampled according to EN 14778-1. For biofuels, where 100 % of the particles will pass the holes of a 45 mm aperture size sieve, a smaller sample size of minimum 4 l can be used.

The minimum size of the test sample for the determination of moisture content - Oven dry method shell be at least 500 g.

The minimum size of the test sample for the Determination of bulk density has to be determined according to measuring container (for example 13 l).

In general we can recommend that larger samples are taken and then reduced for laboratory tests. Mass reduction can be done manually or by special equipment.

Manual mass reduction



All the increments are placed directly into one container to form a combined sample, which is sent to the laboratory. In this case the combined sample is also the laboratory sample.

Moisture content and particle size distribution are the most important quality parameters for wood fuels that why they need special attention by producers.

8.3 8.3 Moisture content

[M] -> Designation for moisture content as received on wet basis,

[U] -> Designation for moisture content in dry basis *(Ud),[w-%]*

Conversion formulas
The following two formulas are used to calculate u from M and vice verse.

$$u = \frac{100 * w}{100 - w} \quad (w \text{ v } \%) \qquad \text{and} \qquad w = \frac{100 * u}{100 + u} \quad (u \text{ v } \%)$$

M %	15	20	25	30	35	40	45	50	60
u %	18	25	33	43	54	67	82	100	150
u %	15	20	30	40	50	65	80	100	150
M %	13.0	16.7	23.1	28.6	33.3	39.4	44.4	50.0	60.0

Assuming that the mass of fresh wood is made up half by water and half by wood substance, wood has moisture on w.b. (M) of 50% and moisture on d.b. (u) of 100%.

Although the gravimetric method (see EN 14774-1:2009) is the only recognized reference method for an exact determination of wood moisture[1], today technology offers a series of portable practical tools for a rapid determination of the water content. Such tools are useful in the implementation of contracts for supply by weight. The accuracy of results is of course dependent on both the representativeness of the sample and the carefulness with which measuring has been carried out. Special care must be taken in the initial setting of tools and correction factors.

[1] The gravimetric method is applied in the laboratory and consists in weighing a sample before and after complete drying in a boiler at 105 °C for 24 hours.

Log wood

For log woods and small diameter long-wood it is possible to use pin type meters that measure the electrical resistance between two electrodes (nails). Between electrical resistance and wood moisture content there is a correlation that is maximum in the hygroscopic field (M 0-23%). Measurement is made solely within the space between the two electrodes at their insertion depth (up to about 5 cm).

The most recent specific models can determine the moisture of the sample within a M 10-60% (u 11-150%) range with a 0.1% resolution.

As with chip, you should choose logs to give a representative section of the load. There is potentially a much greater variability between, and within logs than with other woodfuels. In the case of logs that have been seasoned before cross cutting, you should remember that logs cut from the end of the length will be significantly drier than those cut from the middle.

Moisture content is likely to vary between logs with different: size, species, number of split faces, and cracks, as well as where they occur in the stack.

You should pick a minimum of two logs to test per cubic metre. The logs should be chosen from the middle of the stack and not have been in contact with the ground.

Wood chips

The instruments used for wood chips are contact instruments that measure the dielectric constant (electrostatic charge). The higher the moisture content is, the higher the dielectric constant will be. In the last few years some dielectric hygrometers have been developed specifically for wood chips, sawdust, wood shavings, bark. Such instruments can measure wood chips size classes P16 and P45, with a maximum moisture of 60%. First the material is weighed so as to identify the correct calibration curve for the instrument. Once this has been done, wood chips are put into a container in which they cross a week electromagnetic field that is influenced by the moisture of the wood. In a few seconds it is possible to read the measurement of the moisture of the sample on the display.

8.4 Determination of particle size distribution – wood chips

Size class is determined in the laboratory using special vibrating sieves arranged in series that meet the requirements set by Standard EN 15149 that consists from 3 parts:

EN 15149-1:2010	Solid biofuels - Determination of particle size distribution - Part 1: Oscillating screen method using sieve apertures of 1 mm and above
EN 15149-2:2010	Solid biofuels - Determination of particle size distribution - Part 2: Vibrating screen method using sieve apertures of 3,15 mm and below
CEN/TS 15149-3:2006	Solid biofuels - Methods for the determination of particle size distribution - Part 3: Rotary screen method

The dimensions and shape of the wood chips, the amount of fine fraction and proportion of oversized pieces are of great importance, due to the risk of blocking the storage infeed and outfeed systems. Wood chips are available in different sizes on the market. A distinction is made between fine wood chips (G30/P16), which are especially suitable for small systems, medium-sized wood chips (G50/P45), which correspond to the industrial wood chips from lumber mills and are mainly used in larger plants, and coarse wood chips (G100/P63-100), which are used in large and industrial plants.

Table 7. Size classes for wood chips

Dimensions (mm), FprEN 15149-1			
	Minimum 75 w-% in main fraction, mm [a]	Fines fraction, w-% (< 3,15 mm)	Coarse fraction, (w-%), max. length of particle (mm), max. cross sectional area (cm^2)
P16A	3,15 ≤ P ≤ 16 mm	≤ 12 %	≤ 3 % > 16 mm, and all < 31,5 mm The cross sectional area of the oversized particles < 1 cm^2
P16B	3,15 ≤ P ≤ 16 mm	≤ 12 %	≤ 3 % > 45 mm and all < 120 mm The cross sectional area of the oversized particles < 1 cm^2
P31,5	8 ≤ P ≤ 31,5 mm	≤ 8 %	≤ 6 % > 45 mm, and all < 120 mm The cross sectional area of the oversized particles < 2 cm^2
P45A	8 ≤ P ≤ 45 mm	≤ 8 %	≤ 6 % > 63 mm and maximum 3,5 % > 100 mm, all < 120 mm The cross sectional area of the oversized particles < 5 cm^2

[a] The numerical values (P-class) for dimension refer to the particle sizes (at least 75 w-%) passing through the mentioned round hole sieve size (FprEN 15149-1).

When samples of wood chips for determination of size distribution are taken at least 8 l of sample should be taken. It is recommended that at some time also samples for wood moistures are taken. Before measurement of particle size distribution we have to be sure that moister content in sample is not higher than 25 % (sample can be left in open air for a few days).

8.5 Measurement of chips bulk density through sampling

Bulk density is used for piles of wood fuels (log woods and wood chips) that create voids among the wood pieces which may be bigger or smaller depending on the size and shape of the latter.

It is expressed in either kg/stacked m^3 or kg/bulk m^3, depending on whether the pile is stacked or bulk.

Measurement of chips bulk density through sampling

a. Use a bucket of known volume (ie. 13 l) and a balance.
b. Take a representative sample from the truck or container ie. 3 buckets from a 40 m^3 container (ref. CEN/TS 14778-1)
b) fill in the bucket without compacting the chips
c) weight the samples and divide the mean value of them (kg) to the known volume (l)
ie. (3.25 kg x1 000 l) : 13 l = 250 kg/bulk m^3

The bulk density determines the energy density and enables conclusions to be drawn about the necessary storage capacity and the amount of space needed during transport, which ultimately determines the handling costs. This in turn has an impact on the amount of wood that needs to be conveyed into the combustion chamber per unit of time and that has to be burned in the combustion chamber in order to achieve the same heat output. While oak and beech wood chips (with a water content of 20%) have a calorific value of around 1,100 kWh per bulk cubic metre, poplar wood chips have a significantly lower value of approx. 680 kWh per bulk cubic metre. Correspondingly, in order to meet the annual 44 MWh requirement of an apartment block, either 40 bulk cubic metres of oak or beech wood chips, or 65 bulk cubic metres of poplar wood chips must be supplied.

Table 8. Bulk density (EN14961-4:2011)

	Water content / Units	8-18	18-25	25-35	35-45
Bulk density - coniferous	kg/loosm^3	160-180	180-200	200-225	225-270
	BD class	BD 150	BD 150	BD 200	BD 200
Bulk density – non-coniferous	kg/loosm^3	225-250	250-280	280-320	320-380
	BD class	BD 200	BD 200	BD 200	BD 200

9 Storage of quality wood fuels

Storing wood fuels presents three fundamental risks: (1) the growth of mould, which poses a health hazard, (2) losses in mass through decomposition, and (3) losses of energy value.

For the production of quality wood fuels (wood chips of logs), it is important to ensure that the fuel wood that is processed is as dry as possible.
Wood biomass is best dried naturally by the effects of sun and wind. Technical drying is, in most cases, a difficult process from an economic viewpoint and is generally only worthwhile if cheap waste heat from energy generation or process heat (e.g. from a biogas plant) is available.

Log woods storage
During wood processing and log woods stack preparation it is important to avoid, as much as possible, 'dirtying' the log woods. The processing yard must be provided with a firm and stable flooring (either cement or asphalt). Log woods can be seasoned either in open yards or under ventilated cover, but in any case it must be protected from soil moisture and rain.

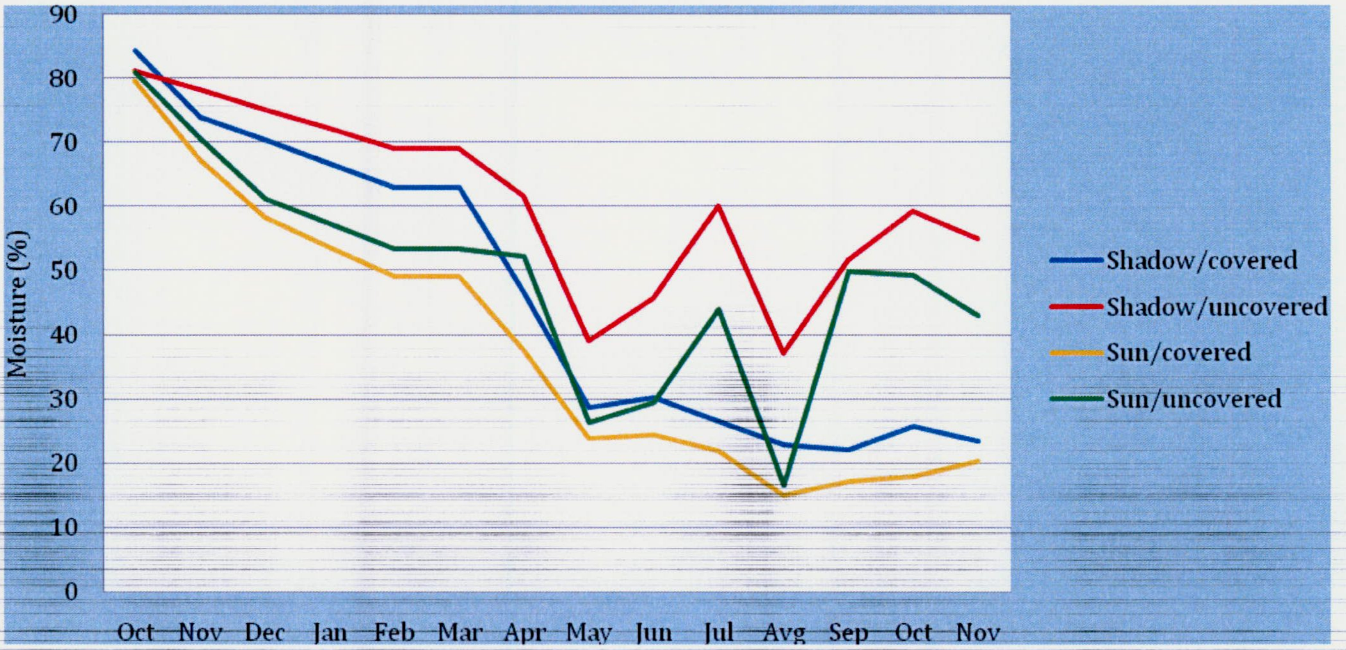
Main prescriptions for log woods storage:

- The ground (flooring) must be kept dry; if possible, the passage of air must be favoured by lifting up the stack from the ground with wood supports (beams, logs)
- It is preferable to store the wood in places open to the air and sun (e.g. at the edge of the wood, in the yard)
- There must be at least a 10 cm distance between the single stacks and between the stacks and the walls of the storage structure (figure 4.6.3)
- The exterior walls of the structure must be kept open (slotted)

- Whenever possible, it is advisable to store the log woods for daily use in the boiler room so as to have it preheated.

Different types of containers for split log woods storage, seasoning and transportation are available on the market. Among the most interesting, also from an economic point of view, are containers made of a basal wood pallet to which a square-mesh wire netting is applied that serves as a wall; the upper part is covered by a second pallet which is insulated from the outside by nylon. Such structure is 2 m high and can contain 2 bulk m^3 of split log woods; this is put in directly from the log processor conveyer.

Slovenian forestry institute together with a student (SPRUK 2007) has conducted a one year monitoring of wood logs drying in four different locations. Two piles of wood logs were stored in sunny locations (one of them was covered and one not) and two piles of wood logs were stored in shadow (one of them was covered and one not).



Picture 16. Results of one year monitoring of drying of wood logs in 4 different locations

The main massages that can be taken from this results are:

a) If wood logs are properly stored they need less than 6 months to dry (moisture under 25 %)
b) Covering the stock of wood logs can substantially help to keep wood logs dryer also in rainy season

c) Wood logs stored in shadow had to high moister content also after one year.

Storing and seasoning of wood chips

The best way to store and season wood chips is to lay them on a waterproof surface (cement and/or asphalt) protected by a cover located in a sunny and ventilated site.

Recommendations for storing wood chips:

- Store round wood that is intended for chipping for at least one summer in a well-ventilated, sunny location (natural drying)
- Wood for chipping that is stored over the summer should have a water content of 25% to 30% at the time of chipping in late summer
- Plan storage locations in sunny spots that are exposed to the wind
- Pre-store/pre-dry wood in unchipped form wherever possible
- If the summer months are especially rainy, covering the wood is recommended
- Avoid storing wood chips with a high green waste content (mould and fungal infestation)
- Keep the storage duration of the wood chips as short as possible (natural decomposition process)
- Cold air drying, cold ventilation and storage in well ventilated, covered warehouses have all been proven to work well in practice
- Keep the proportion of fine fraction as low as possible (means better ventilation)
- Ensure that the wood chips are stored in an orderly fashion and stipulate the order by which the different batches must be used ("first in, first out" principle)
- When storing the fuel, take care to avoid compaction (heavy machinery)
- Never store wet fuel in storage rooms

10 Examples of direct and indirect employments in application of existing technologies for selected wood fuels in Slovenia

At the moment there was only one study done in Slovenia on the fiel of estimation of cosio-economic aspects of wood biomass. And even this study was not done for the whole Slovenia but only for selected region. In general it is very hard to estimate all aspects of wood biomass on national level while a lot of estimation has to be done. In the study mentioned (KRAJNC, 2005) estimates of 15 different socio-economic and environmental impacts of the increased wood biomass use at the regional level were prepared. The intensity of some impacts was estimated numerically, others only with a five-grade scale.

The socio-economic impacts concern social or economic consequences, or a combination of both. The boundary between social and economic impacts is often hard to define. For example: new jobs are no doubt a social impact, for they essentially influence the life of an individual or community, but at the same time this is also an economic impact, considering that the income both of an individual and community is increased with new jobs. At the moment, the application enables us to estimate the following socio-economic impacts of the increased wood biomass use:

- average annual net income,
- increased public income in the region,
- total number of direct jobs,
- total number of indirect jobs,
- total number of induced jobs,
- possible impact on unemployment,
- reduction of costs due to unemployment,
- additional direct jobs on farms,
- additional activities within the framework of private forest owners (indirect and induced jobs from biomass production from privately owned forests),
- increased power self-supply.

As the estimate of the intensity of environmental impacts are the most difficult task, they are mostly estimated with the five-stage scale. Environmental impacts include all consequences of biomass systems on nature, atmosphere and people who will live in the immediate vicinity of the systems. Through the people's ecological awareness, the environmental impacts are increasingly gaining weight, which is the reason why their estimate is even more difficult for a longer period of time. One of the characteristics of the environmental impacts lies in the fact that they can also act in a restrained manner on the introduction of biomass systems. The proposed application enables a momentary estimate of the intensity of only 5 environmental impacts:

- contribution to the forest management,
- impact on wood residue use,
- impact on use of other wood biomass in the region,
- reduction of refuse dumping costs,
- reduction of CO_2 emissions.

The result of a study done in Logarska valley (KRAJNC 200) is an assessment of 15 socio-economic and environmental impacts, which are supposed to be the consequence of the increased wood biomass use. In our selected region, two remotely controlled wood biomass-heating systems are already in use. Two new systems, however, are also planned to be built. After their construction, the wood biomass production, processing and use in the region should bring 19 new direct jobs, 36 indirect jobs, and 45 induced jobs in the region. Direct jobs are closely associated particularly with the phase of wood production and processing, while induced jobs are usually created due to high incomes in the phase of power production which, however, is the result of the foreseen production of power in one of the planned biomass systems. The results actually corroborate the hypothesis that in our circumstances wood biomass production and processing are labour-intensive activities, while modern power production systems do not create many jobs that originate mainly in the phases of planning and construction of such systems.

According to our experiences in estimation of socio-economic and environmental aspects of wood biomass we can conclude that it is more reliable to prepare estimations on regional or project level that on the state level. So for further development we recommend to prepare separate studies for selected regions where more wood biomass project are planned.

11 Conclusions, proposals and recommendations requiring further in-depth studies

Wood biomass in Serbia is used traditionally in households. The main fuels used in households are logs. Wood chips are less known as a form of solid fuel. At the moment wood chips are produced by limited number of producers but used mainly as row material in production of wooden panels or wood pellets. They are not used in larger or smaller wood hating installations. Private forest owners are producing wood logs for home consumption of for selling on local markets. Local wood chips or wood pellet market is not developed.

According to described situation we recommend that:

a. More emphasis should be taken on promotion of wood biomass in public sector (heating public building and smaller communities with wood)
b. For further development a legislation framework should be further developed taking in to account also possibilities for public support (subsidies schemes for households or private investors) and green procurement legislation
c. More emphasis should be given on training and education of possible market actors (producers and users of wood biomass)
d. The development of supply and demand side should be balanced. Development of production side without development of domestic market will probably lead to larger export of wood biomass and not to development in the country
e. Private forest owners should be educated in the field of effective production and use of wood biomass. Subsidies for modern machinery for wood fuel preparation and modern boilers should be introduced.
f. Analyse of socio-economic and environmental aspects of first planned biomass systems should be prepared. The results of study can be powerful tool for promotion of biomass systems on different levels
g. Further studies on costs of different production chains should be conducted and presented to wider public
h. State owned forest companies should take a leading role in biomass production (especially wood chips) and should become a good practice example for developing wood biomass production chains – from biomass production to energy production.
i. Special emphasis should be given also to production of high quality wood fuels – according to quality standards.
j. Where possible biomass trade and logistic centres should be established. This kind of centres can have a significant influence on regional wood biomass market and can generate further development of demand side

but also can help to mobilise smaller forest owners to start with production of wood fuels for the market.

k. More resources should be invested in research and development project in this field to support development.
l. To avoid "bad practice examples" wood biomass resources available should be estimated by experts always when larger biomass systems are planned
m. First good practice examples of modern technologies for wood biomass preparation and use should be promoted among different target groups.
n. Capacity building among foresters, forest owners, forest entrepreneurs, representatives of local communities, officials and architects should be high on agenda
o. Simple cost calculators should be prepared and promoted between target groups – for simple comparison between technologies available.
p. Key persons should visited good practice example in different countries to see possible development and to speed the development in Serbia.
q. Special emphasis should be given also to development of energy contracting model where wood biomass producer act also as heat sellers and sells wood heat to public or private end users.

The key for success is balanced development of whole wood biomass production chains (for wood logs, wood chips and also wood pellets) taking in to account also present situation in wood processing industry and other related markets.

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Appendix 1: Data from analysed wood chippers

	AHWI Eurochipper HM 950	Berkili B10D oder B10B	Berkili B10Z	Berkili B12D	Berkili B15D	Berkili B15Z	Berkili B20D	Berkili B20Z	Berkili B24D	Berkili B24Z	Berkili Z65-D
Teoreticle production per year	50000 Srm/Jahr	200	200	250	500	500	500	500	1000	1000	1000
Power requirement (kW)	500	15	16	15	25	23	37	30	44	50	48
Feed width (mm)	1200	200	200	220	230	230	255	255	350	350	650
Feed height (mm)	800	200	200	220	150	150	200	200	240	240	150
Max. tree diameter (mm)	700	100	100	12	150	150	200	200	240	240	150
min. chips size (mm)	25	10	10	10	10	10	10	10	10	10	5
max. chips size (mm)	40	70	70	70	70	70	70	70	70	70	80
Min. output (nm3/h)		4	4	6	10	10	12	12	16	16	10
Povprečni učinek (nm3/uro)		6	6	8							
Max. output (nm3/h)	150	8	8	10	12	12	14	14	20	20	20
Machine weight (kg)		1100	210	1100	1350	700	1920	850	2250	850	1550
Price range	220.000 €	15500	8500	18000	21500	10900	27500	12900	34500	15900	
Life time (years)	8	8	8	8	8	8	8	8	8	8	8
Working h in life time	14400	3200	3200	3200	3200	3200	4800	4800	4800	4800	4800

	Bruks-Klöckner 1300 CT	Bruks-Klöckner 600 CT	Bruks-Klöckner 604 CT	Bruks-Klöckner 805 CT	CBI Magnum Force 6400	CBI Magnum Force 6400 Shredder	Doppstadt DH 910	Doppstadt DH 910 K	Doppstadt DZ 750 Kombi	Dutch Dragon EC 6060	Eschlböck Biber 2-12
Teoreticle production per year	100000	8000	10000	100000	100000	100000	100000	120000	50000	10000	200
Power requirement (kW)	522	260	150	331	570	570	450	450	450	410	15
Feed width (mm)	1200	690	690	850	1500	1500			1500	600	210
Feed height (mm)	900	350	350	720	600	600			3000	600	120
Max. tree diameter (mm)	700	280	280	500	600	600	900	900	400	600	120
min. chips size (mm)	25	15	15	25	15	15	15	15		20	10
max. chips size (mm)	40	30	30	40	50	50	40	40	280	120	
Min. output (nm3/h)		50	50	80	120	120	120	150	100	150	
Povprečni učinek (nm3/uro)					200	200					
Max. output (nm3/h)	250	80	80	150	250	250	200	200	200	200	
Machine weight (kg)	40000	3300	3500	33680	32000	32000	25000	30000		10000	510
Price range			159000	539910			360000				9500
Life time (years)	6	5	4	5	5	5	6	6	5	6	4
Working h in life time	12000	9000	10000	10000	10000	10000	12000	12000	9000	10800	4800

	Eschlböck Biber 2-14	Eschlböck Biber 2-14 Motor	Eschlböck Biber 3	Eschlböck Biber 3 Motor	Eschlböck Biber 5K	Eschlböck Biber 5K Motor	Eschlböck Biber 5KL	Eschlböck Biber 5L	Eschlböck Biber 7	Eschlböck Biber 7 plus Z und Biber 7 plus ZK	Eschlböck Biber 70 S
Teoreticle production per year	300	300	500	500	1000	1000	1000	1000	5000	5000	20000
Power requirement (kW)	15	25,7	26	38	33	51	33	33	44	44	162
Feed width (mm)	210	210	240	240	240	240	240	240	560	560	840
Feed height (mm)	140	140	180	180	240	240	240	240	350	350	400
Max. tree diameter (mm)	140	140	180	180	240	240	240	150	350	350	400
min. chips size (mm)	5	5	5	5	5	5	5	30	20	20	20
max. chips size (mm)	15	15	15	15	25	25	120	120	40	40	40
Min. output (nm3/h)											
Povprečni učinek (nm3/uro)											
Max. output (nm3/h)											
Machine weight (kg)	520	1250	830	2100	1450	2450	1550	1450	3150	4800	10500
Price range	9500		13000								
Life time (years)	4	4	4	4	5	5	5	5	5	5	5
Working h in life time	4800	4800	4800	4800	6000	6000	6000	6000	6000	6000	9000

	Eschlböck Biber 70 Z und Biber 70 ZK	Eschlböck Biber 80 RBZ	Eschlböck Biber 80 S	Eschlböck Biber 80 Z und Biber ZK	Euroklip H 680/140	Euroklip H 880/250	Euroklip H 980/300	Euroklip THE 480	Euroklip THE 90 S	Euroklip THE 900	Hakkuri Giant
Teoreticle production per year	20000	50000	50000	50000	200	500	500	50000	10000	5000	100000
Power requirement (kW)	110	353	240	110	15	38	53	68	309	244	370
Feed width (mm)	840	980	980	980	160	310	370	480	900	800	1440
Feed height (mm)	400	550	550	550	140	250	300	350	600	370	600
Max. tree diameter (mm)	400	550	550	550	140	250	300	350	600	370	
min. chips size (mm)	20	20	20	20	5	5	5	10	5	5	
max. chips size (mm)	40	40	40	40	12	25	25	25	40	40	
Min. output (nm3/h)					4	20	55	25	50	40	
Povprečni učinek (nm3/uro)						30					
Max. output (nm3/h)					8	40	65	40	70	65	
Machine weight (kg)	6800	24000	13400	8600	455	1250	1800		10000	7500	31500
Price range	140000		187000	147000	8000						
Life time (years)	5	5	5	5	8	7	6	7	6	6	5
Working h in life time	9000	9000	9000	9000	3200	5600	10800	5600	4800	4800	9000

	HAMA Profi-Hacker 40x42	HAMA Profi-Hacker 55x82	HAMA Profi-Hacker 67x104	Husmann H4-Z	Jensen A 141	Jensen A 141 M	Jensen A 141 XL M	Jensen A 141 XL Z	Jensen A 141 Z	Jensen A 231	Jensen A 231 M
Teoreticle production per year	5000	10000	20000	1000	5000	5000	5000	5000	5000	5000	4000
Power requirement (kW)	50	100	260	15	56,1	51,5	51,5	50	50	56,1	42
Feed width (mm)	400	820	1040		410	410	410	410	410	310	310
Feed height (mm)	420	550	670	140	260	260	300	300	260	240	240
Max. tree diameter (mm)	400	550	670	140	260	260	300	300	260	240	240
min. chips size (mm)	15	15	15	20	5	5	5	5	5	5	5
max. chips size (mm)	50	80	80	40	20	20	20	20	20	20	20
Min. output (nm3/h)	10	40	60		20	20	20	20		15	15
Povprečni učinek (nm3/uro)	15	50	80		25	25	25	25		20	20
Max. output (nm3/h)	20	60	100		30	30	30	30		25	25
Machine weight (kg)	1200	5400	8000		3000	3000	3000	1800	1700	2500	2500
Price range	43000	108000	160000		60340	45190	46570	21700	20300	57165	36240
Life time (years)	6	5	6	4	5	5	5	5	5	5	5
Working h in life time	4800	7500	10800	4800	6000	6000	6000	6000	6000	6000	6000

	Jensen A 231 Z	Jensen A 328	Jensen A 328 M	Jensen A 328 Z	Jensen A 425	Jensen A 425 M	Jensen A 425 Z	Jensen A 521 XL	Jensen A 521 XL M	Jensen A 521 XL Z	Jensen A 530 Nova
Teoreticle production per year	4000	3000	3000	3000	2000	2000	2000	1000	1000	1000	1000
Power requirement (kW)	50	50,7	42	30	27,7	27,7	28	23,1	23,1	20	16,8
Feed width (mm)	310	280	280	280	245	245	245	210	210	210	210
Feed height (mm)	240	200	200	200	180	180	180	150	150	150	130
Max. tree diameter (mm)	240	200	200	200	180	180	180	150	150	150	130
min. chips size (mm)	5	5	5	5	5	5	5	5	5	5	5
max. chips size (mm)	20	20	20	20	20	20	20	20	20	20	20
Min. output (nm3/h)	15	12	12	12	10	10	10	6	6	6	4
Povprečni učinek (nm3/uro)	20	16	16	16	12	12	12	8	8	8	6
Max. output (nm3/h)	25	20	20	20	14	14	14	10	10	10	8
Machine weight (kg)	1400	2000	2000	900	1800	1800	800	1000	1000	500	750
Price range	16815	48960	32375	13980	40270	25405	11570	30250	20700	11320	19363
Life time (years)	5	5	4	4	5	4	4	4	4	4	4
Working h in life time	6000	6000	4800	4800	6000	4800	4800	4800	4800	4800	4800

	Jenz AZ 660 D	Jenz HEM 1000 D-XL	Jenz HEM 561 Z	Jenz HEM 581 Z	Jenz HEM 700 D	Kirchmayr Lignolupo 500	Komptech Chippo 500	Komptech Chippo 7000	Komptech Crambo 3400	Komptech Crambo 5000	Komptech Crambo 6000
Teoreticle production per year	100000	100000	50000	50000	50000	50000	20000	100000	100000	100000	100000
Power requirement (kW)	295	480	132	132	480	243		522	242	328	429
Feed width (mm)	660	1200	990	1200	990	700	1675	1200	2800	2800	2800
Feed height (mm)	1500	1000	650	650	700	500	750	900	2000	2000	2000
Max. tree diameter (mm)	500	1000	560	650	700	450	750	900	700	700	700
min. chips size (mm)	10	20	20	20	20	50	20	20	20	20	20
max. chips size (mm)	120	100	40	40	100	80	100	100	250	250	250
Min. output (nm3/h)	110	200				70	70	110			
Povprečni učinek (nm3/uro)	170		80				120	180			
Max. output (nm3/h)	220	300	120	150	220	150	180	250	240	340	480
Machine weight (kg)	20770	46000	9800	9800	18400	20000	19000	32000	21400	22500	23400
Price range		550000	205000	205000	300000	400000					580000
Life time (years)	6	6	5	5	5	5	5	6	5	5	5
Working h in life time	12000	12000	9000	9000	9000	10000	9000	12000	9000	9000	9000

	KRONE BIG X 650 mit WOOD CUT 1500	Laimet HP-21	Laimet HP-25	Laimet HP-35	Laimet HP-50	MUS-MAX Wood-Terminator WT 10 DLB	MUS-MAX Wood-Terminator WT 10 DLK	MUS-MAX Wood-Terminator WT 10 NMV	MUS-MAX Wood-Terminator WT 10 Z	MUS-MAX Wood-Terminator WT 6 Z	MUS-MAX Wood-Terminator WT 7 Z
Teoreticle production per year	10000	5000	5000	30000	50000	25000	25000	50000	50000	3000	5000
Power requirement (kW)	480	60	120	200	440	515	442	405	200	50	80
Feed width (mm)		315	430	430	700	980	980	980	980	480	620
Feed height (mm)		210	250	400	600	710	710	710	710	370	380
Max. tree diameter (mm)	150	180	230	280	500	700	700	700	700	350	380
min. chips size (mm)	5	20	20	20	60	15	15	15	20	15	15
max. chips size (mm)	28	70	100	100	150	50	50	50	50	40	50
Min. output (nm3/h)		20	40	80	120		100		100		
Povprečni učinek (nm3/uro)			70		150				130		
Max. output (nm3/h)		40	120	140	200	200	200	240	200	40	50
Machine weight (kg)	14200	1100	1800	12000	20000	20000	23000	22000	13000	2820	5500
Price range		12800	27600	220000	280000				160000		
Life time (years)	5	5	5	5	5	5	5	6	5	8	7
Working h in life time	10000	6000	6000	9000	9000	7500	5000	6000	9000	4800	4900

	MUS-MAX Wood-Terminator WT 8 DH	MUS-MAX Wood-Terminator WT 8 Z	MUS-MAX Wood-Terminator WT 9 DLK	MUS-MAX Wood-Terminator WT 9 Z	Pezzolato PTH 900/1000 g	Pezzolato PTH 900/820 g	Rudnick+Enners RE-MGS 570/814	Schliesing 105 ZX	Schliesing 200 MX	Schliesing 220 MX	Schliesing 220 ZX
Teoreticle production per year	5000	5000	10000	10000	20000	10000	100000	1000	1000	2000	1000
Power requirement (kW)	200	120	250	180	322	150	419	15	21	27,7	26
Feed width (mm)	760	760	900	900	900	900	1450	200	240	240	240
Feed height (mm)	420	420	450	450	450	500	650	120	140	160	160
Max. tree diameter (mm)	420	420	450	450	450	500	450	120	140	160	160
min. chips size (mm)	15	15	15	15	14	15	1	20	20	20	20
max. chips size (mm)	50	50	50	50	50	50	150	30	40	40	40
Min. output (nm3/h)					80	60	90				
Povprečni učinek (nm3/uro)					100	80					
Max. output (nm3/h)	60	60	100	100	120	100	200				
Machine weight (kg)	7400	6400	9500	8600	14000	7000	19000	380	980	1250	950
Price range							260000	11420	25540	28850	15120
Life time (years)	7	7	5	5	5	6	6	4	4	4	4
Working h in life time	4900	4900	5000	5000	6000	4800	10800	4800	4800	4800	4800

	Schliesing 300 MX Raupe	Schliesing 330 ZX	Schliesing 350 EX	Schliesing 400 ZX	Schliesing 460 EX	Schliesing 480 EX	Schliesing 500 ZX	Schliesing 550 MX	Schliesing 550 ZX	Silvatec 1700 CH-T	Silvatec 878 CH
Teoreticle production per year	1500	2000	2500	2500	2500	2500	3000	5000	3000	50000	50000
Power requirement (kW)	25,724	30	35,8	35	44	58,8	50	58,8	55	336	205
Feed width (mm)	240	240	240	270	270	300	310	340	340	500	350
Feed height (mm)	160	180	180	200	200	200	240	280	280	800	350
Max. tree diameter (mm)	16	180	180	200	200	200	240	280	280	500	250
min. chips size (mm)	15	20	20	20	20	20	20	20	20	15	15
max. chips size (mm)	40	40	40	40	40	40	40	40	40	35	35
Min. output (nm3/h)										60	100
Povprečni učinek (nm3/uro)											
Max. output (nm3/h)	20									120	180
Machine weight (kg)	1750	840	1710	880	2000	2150	1200	2960	1580	16400	19500
Price range	56270	16300	36620	17600	42540	44840	21250	52340	24850		500000
Life time (years)	4	4	4	4	4	4	4	4	4	5	5
Working h in life time	4800	4800	4800	4800	4800	4800	4800	4800	4800	10000	9000

	Starchl Mk 102	Starchl Mk 37	Starchl Mk 50	Starchl Mk 62	Starchl Mk 74	Starchl Mk 86	Starchl Mk 98	Starchl U-1200	Starchl U-260	Stark SH 4585-Z	Stark SUZ 1000 S
Teoreticle production per year	25000	1500	5000	7500	10000	20000	25000	100000	1000	25000	10000
Power requirement (kW)	125	40	45	50	65	80	100	328	30	100	250
Feed width (mm)	1200	370	500	620	740	860	980	1200	260	850	1000
Feed height (mm)	450	370	450	450	450	450	450	800	370	450	500
Max. tree diameter (mm)	450	370	450	450	450	450	450	800	260	450	500
min. chips size (mm)	5	5	5	5	5	5	5	5	5	20	1
max. chips size (mm)	50	50	50	50	50	50	50	60	50	50	150
Min. output (nm3/h)	70	8	20	30	40	60	70	80	5		
Povprečni učinek (nm3/uro)								140		70	
Max. output (nm3/h)	90	15	35	45	50	85	90	200	10		100
Machine weight (kg)	8200	1700	3200	3900	4200	7500	8200	26000	900	6500	13000
Price range	105000	27000	52000	57000	70000	92000	104000	355000	18000	86000	180000
Life time (years)	5	5	5	5	5	5	5	5	5	5	5
Working h in life time	9000	6000	9000	9000	9000	9000	9000	10000	6000	9000	9000

	Stark SUZ 400 S	Willibald MZA 2400	Willibald MZA 4300	Willibald MZA 4800	Wüst BBHK	Wüst BBHK-Z
Teoreticle production per year	1000	50000	50000	50000	50000	50000
Power requirement (kW)	31	176	316	353	309	130
Feed width (mm)	400	1450	1400	1400	1000	1000
Feed height (mm)	300	350	550	550	580	580
Max. tree diameter (mm)		250	400	400	580	580
min. chips size (mm)	1	60	60	60	20	20
max. chips size (mm)	50	150	150	150	80	50
Min. output (nm3/h)		30	70	80	50	50
Povprečni učinek (nm3/uro)		50	90	120	80	70
Max. output (nm3/h)		70	180	230	120	120
Machine weight (kg)	1750	11000	16000	16000	17500	
Price range		156600	198900	206900	220000	115000
Life time (years)	5	5	5	5	5	5
Working h in life time	6000	9000	10000	10000	9000	9000