Subject review

Current state and development possibilities of wood chip supply chains in Austria

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Abstract – Nacrtak

The importance of forest wood chips as fuel for energy production will increase relative to sawmill by-products. The additional production is not a question of potential (harvesting residues, wood from thinning, coppice stands and short rotation forests) but more so a question of economic feasibility. The analyses of different chip production systems resulted in the identification of two major challenges: (1) the design of the chipping and transport interface, and (2) the need to reduce transportation costs.

Chipping and transportation are the key processes for production and can be completed in closed or interrupted work chains. Direct chipping into the transportation machine requires larger operating areas and results in operational delays of the chipper (20% of the total work time) and the truck. In mountainous areas the separation of chipping and transportation can be appropriate and reduce costs by 24–32%.

The increasing fuel demand will result in a larger supply area for the energy producer and lead to increasing transportation costs. An improved utilization of the load volumes can be achieved through drying the material, compressing of harvesting residues as well as higher payloads. Drying wood on storage areas near the forest increases the transportation productivity by 50%. Bundling of harvesting residues pays off especially by larger transportation distances.

Keywords: *wood chip supply, chipping, energy wood transport, bundling technology*

1. Introduction – *Uvod*

Austria is currently experiencing a boom in the area of woody biomass for energy production. The Green-Energy-Law of 2002, as amended in 2006, caused a planning and building euphoria of energy production capacities. The feed-in tariffs are secured by law and their value is related to the type of renewable resources. In addition to subsidies for energy production from wind and solar and small hydro stations, thermal energy production using bio-fuels is also subsidized. The goal of these laws is to provide 10% of electricity production from renewable resources by 2006, excluding electricity produced by hydropower (Green-Energy-Law – as amended in 2006). An increase ranging between 1.6 and 5.0 million cubic meters is expected in energy wood demands for combined heating plants (CHP) by 2007. The total use of fuel wood in 2000 was 10 million cubic meters and according to some estimates it should be double by 2010 (Katzensteiner and Nemestothy 2006).

Sawmill by-products and residues have been the primary source of energy fuel; however the importance of forest wood chips as a fuel source will increase in future. The reasons lie in decreasing volumes of available sawmill byproducts as well as in attractive subsidy conditions for energy production. An increase of woody biomass, ranging between 28% and 56% of the total demand of wood resources, is expected in the regions of Lower Austria and Vienna. There are various options as to where this increase should come from. Potential woody material sources include thinning and coppice stands as well as harvesting residues. Additional materials can also come from short rotation forests.

The additional production is not a question of potential but rather of the economic feasibility. Difficult terrain conditions – a large part of Austria's forest is located on very steep terrain – small harvest volumes driven by silvicultural requirements and small farmer-based forest ownership structures result in high production costs (Rohrmoser and Stampfer 2003, Stampfer et al. 1997). The use of information on systems found in Scandinavia (Hakkila 2004) is of limited applicability under these conditions. Systematic comparison for wood chip production systems is available for Scandinavian conditions; for the mountainous area, however, such comparison may only be made on the basis of case studies.

The purpose of this paper is to analyze wood chip production in mountainous areas and to discuss the most important future development challenges.

2. Production Systems – *Sustavi pridobivanja iverja*

A wood chip production system is a series of various steps, including processing, transportation and decision making, with the goal of converting forestry woody biomass into fuel and providing transport of this resource from the forest to the plant.

Woody biomass can be differentiated as harvest residue and energy wood (Figure 1). Harvest residue (branches, tops and waste wood) is a by-product of conventional timber harvesting and its advantage is that the extraction costs are covered by roundwood products. The volume of forest residue relative to the volume of timber harvested is very variable. In deciduous stands the biomass component was 6 to 26% of the total harvest (Kanzian et al. 2006). In forest stands dominated by softwoods, Kanzian (2005) determined a range of 10 to 15%. A Finnish study showed the harvest residue in pine and spruce stands to be 20 to 30% in thinning, but only 4 to 5% in the final harvest (Hakkila 2004).

The utilization of harvest residues can result in ecological risks (Krapfenbauer 1983) as well as in poor regeneration (Sterba 2003), as valuable nutrients are removed from the forest. Based on this consideration, 30% of the harvest residue should remain in the stand as a general rule in Finland (Hakkila 2004).

Comparison of energy wood is possible when all materials harvested are used for the purpose of generating thermal energy. The first thinning in both softwood and hardwood stands falls into this category, as well as silvicultural measures in coppice stands. Efficient biomass production is typically difficult due to small dimensions of wood, but such harvests are often required for improving forest stands.

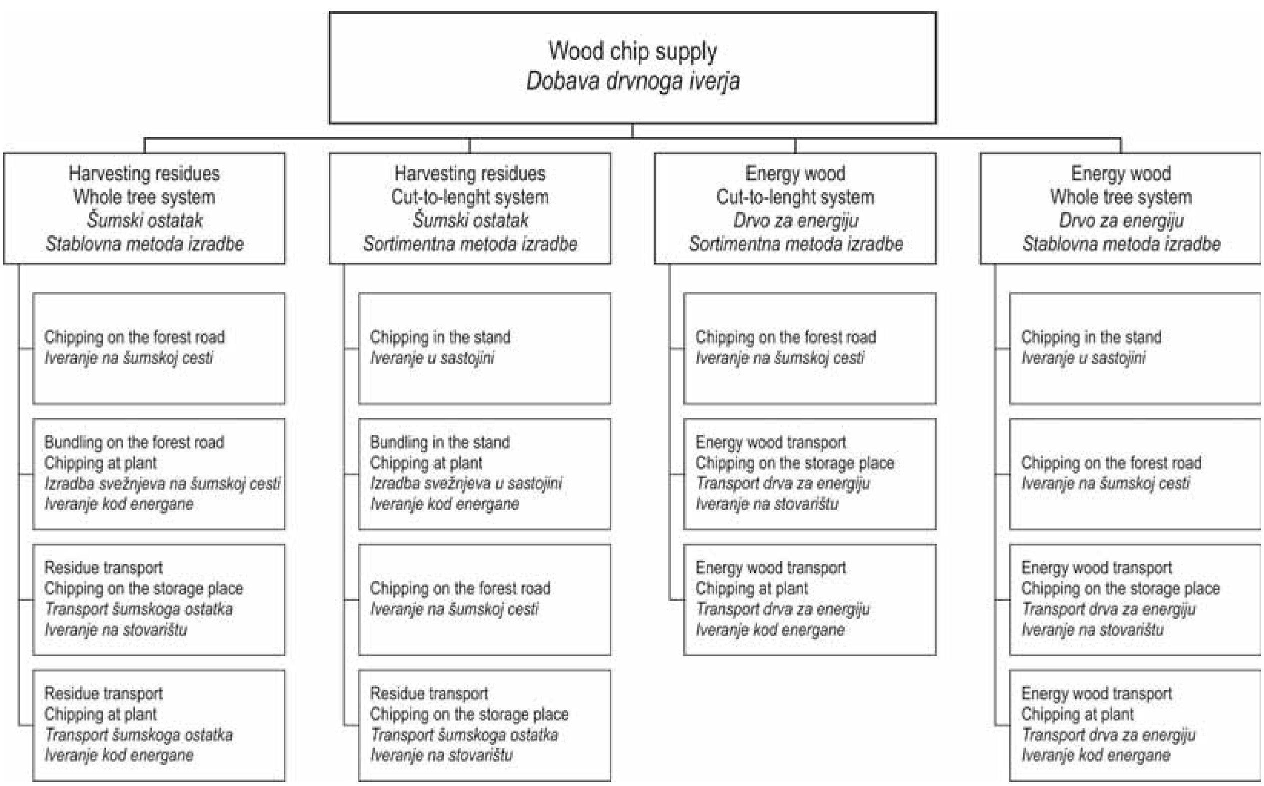

Fig 1. Forest biomass production systems based on source, location of chipping and type of biomass in transportation

Slika 1. *Sustavi pridobivanja šumske biomase prema porijeklu, mjestu iveranja i vrsti prevezene biomase*

Wood chip production systems are typically organized around the chipping operation. The position of the chipper within the whole system determines the type of biomass to be transported, and whether or not the subsequent machines can work independently of the chipper. Chipping location can be in the forest, at the forest roadside, at a separate central storage area or at the plant. This biomass can be transported in the form of harvesting residues, roundwood, pressed bundles and chips. The resulting load density and transport distance are the factors that will determine success.

Chipping in the forest stand is seldom used in mountainous conditions. In Denmark however this system is often used in thinning and small tree diameter harvests (Talbot and Suadicani 2005). The felling and bunching of trees is carried out by a feller-buncher in the extraction corridors. After being dried for about 20 weeks, the material is chipped with a chipper capable of operating in the stand and transported to the forest road with an integrated container, or with machines carrying separate containers. From there it is transported to the plant with truck containers. Silversides and Sundberg (1989) suggest that the greatest advantage may be realized in chipping of multiple stems simultaneously. In this case the chipper is less susceptible to the negative cost-effects of the »piece-volume-law« (which states that increasing piece size typically results in increased production).

The most common option in the production of woody biomass is chipping at the forest roadside and transportation of chips. About 70% of the annual woody biomass production in Finland is produced in this way (Ranta and Rinne 2006, Junginger et al. 2005). In the largest Central-European combined heating plant in Simmering, Vienna, 50% of the total volume will be delivered as roundwood and 50% as chips. Direct chipping into the truck that is to be used for transportation is widely used. This closed work chain results in the dependence between individual machines. Operational delays can be caused by the chipper waiting for the truck, as well as the truck waiting for the chipper. The challenge from a logistical point of view is to organize the whole process in such a way as to minimize these operational delays.

A further problem in mountainous conditions is the limited space available on forest roads. Loading the truck directly with the chipper requires the machines to be positioned next to one another, so sufficient space is required. One solution is the separation of the work process (interrupted work chain), whereby the machines become independent from one another. However, additional costs occur in the loading of the truck. Another solution is the pre-concentration of material to be chipped at a central landing area.

Provision of centralized processing areas close to the forest that can be provided with minimum infrastructure changes makes good sense. This is especially true in mountainous conditions and with small ownership structure of Austria forests. The primary purpose of these centralized storage areas is the concentration of quantities, drying of material and securing a more continuous supply of chips to the energy plants. Larger quantities have a positive effect on both productivity and utilization of the chipper. Drying results in a quality improvement of chips as well as increased utilization of truck volume in transportation. Central landings near to the public road infrastructure also enable the use of non-specialized means of transportation (e.g. semi-trailer configurations with containers) for the transportation of woody biomass. The buffering effect of the centralized processing area is especially important in winter in the mountainous areas. The additional cost of preparing the centralized processing / storage area can be covered by these positive effects.

In Scandinavia the harvest residues are bundled with special machines so as to increase the load density for transportation and to increase productivity when chipping. The bundlers are built on forwarder chassis and work is carried out in the forest stand (Johansson et al. 2006, Kärhä and Vartiamäki 2006, Ranta and Rinne 2006, Cuchet et al. 2004). In mountainous conditions the bundler was designed and built for a truck chassis to work on the forest road (Kanzian 2005). In Scandinavia the wood chip preparation with bundler technology is very common and a viable economic alternative (e.g. 18% of forest wood biomass is produced in this way in Finland), but an Austrian study showed the opposite (Kanzian 2005). The low production level of just 9–13 bundles per PSH_{15} is however based on a study with an inexperienced operator and partially unorganized preparation of harvesting residues (e.g. impurity of materials, quality of the residue piles). Scandinavian studies typically achieve higher production ranging between 13 and 26 bundles per PSH_{15} (Johansson et al. 2006, Kärhä and Vartiamäki 2006). Different hourly machine rates are significant and they are often just 40–50% of the Central European level (Johansson et al. 2006, Kärhä and Vartiamäki 2006, Ranta and Rinne 2006, Kanzian 2005, Cuchet et al. 2004). Reasons for this lie in a higher level of machine utilization, shorter relocation distances and larger harvest areas. The less than satisfactory machine utilization is a general problem in the production of roundwood and energy-wood in Austria.

Chipping at the plant makes the chipping and transportation processes independent of one another. The biomass is transported in the form of harvesting residues, whole trees or cut-to-length form. Low residue load densities are a significant system disadvantage. The use of stationary large scale chippers allows all types of biomass to be chipped at high production rates. This advantage increases with the number of roundwood used, but it is also related to high up-front capital costs (Hakkila 2004).

3. Principle system representation – *Osnovni sustavi pridobivanja iverja*

3.1 Harvesting Residues – Whole Tree Extraction – *Pridobivanje šumskih ostataka pri stablovnoj metodi izradbe*

Whole tree extraction with a cable yarder or skidder system is carried out on the forest road. The remaining residues are transported with a timber truck that has been fitted with sides (steel or wood mesh panels). Residues are then taken to an appropriate location where they can be concentrated into large piles. The chipped material is blown directly into a chip truck and transported to the plant (Figure 2). Storage of the harvesting residues and air-drying over the summer months proved to be good. It has been shown by Kanzian et al. (2006) that through summer storage moisture content was reduced from 40–50% to 15–29% and a positive effect was observed on the increased loading capacity.

The advantage of this system is that the felling and extraction costs are associated with the conventional harvest, and therefore they are relatively inexpensive for the biomass. Also when considering forest protection it is reasonable to remove material that is susceptible to bark beetle infestation. Disadvantages are the removal of nutrients, and therefore this system cannot be used in all locations (e.g. forest stands with nutrient deficient soils).

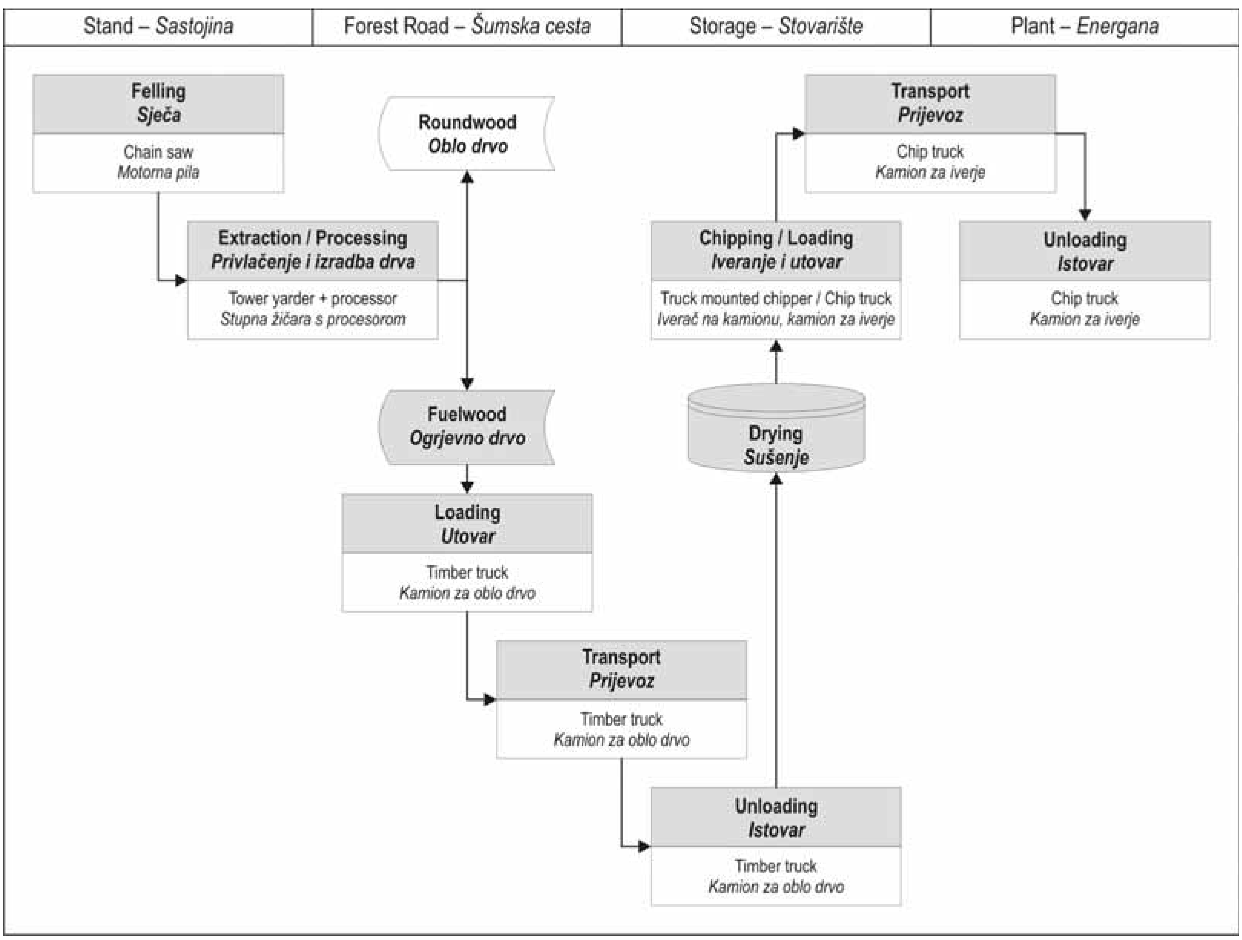

Fig. 2 Utilization of harvesting residues after cable extraction of whole-trees; concentration of materials with timber truck; direct chipping into chip trucks

Slika 2. *Korištenje šumskih ostataka nakon iznošenja stabala žičarom, skupljanje šumskih ostataka kamionima, neposredno iveranje u kamione za iverje*

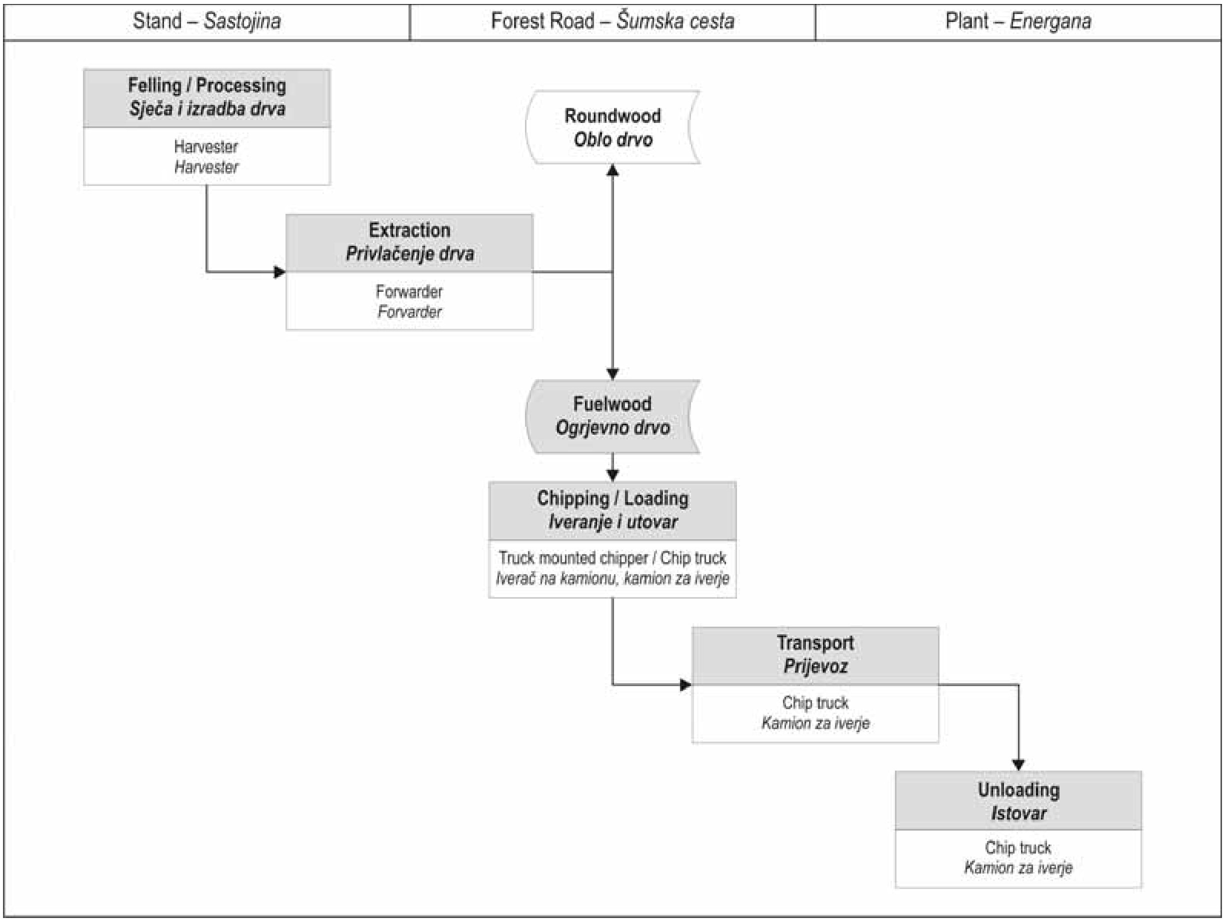

Fig. 3 Utilization of harvesting residues after fully mechanized harvesting in cut-to-length extraction; direct chipping into chip trucks

Slika 3. *Korištenje šumskih ostataka nakon potpuno mehaniziranoga pridobivanja drva sortimentnom metodom, neposredno iveranje u kamione za iverje*

3.2 Harvesting Residues – Cut-to-length extraction – *Pridobivanje šumskih ostataka pri sortimentnoj metodi izradbe*

The remaining harvest residues resulting from harvester felling and forwarder extraction is pulled by the forwarder to the forest road. A truck mounted larger-sized chipper blows the material directly into a chip truck that transports the chips to the power plant (Figure 3).

Since the material is still in the stand, additional costs are incurred for the extraction to the roadside. The pros and cons with regard to forest protection and nutrient removal are the same as for harvest residues – whole-tree extraction. The system is limited to trafficable terrain.

3.3 Energy Wood – Cut-to-length extraction – *Pridobivanje drva za energiju pri sortimentnoj metodi izradbe*

All material harvested in a thinning operation is converted to wood chips. The felling and processing is carried out with a harvester (Figure 4). The logs as well as residues are taken by the forwarder to the processing area at the road-side. After a storage period of one month the material is chipped by use of a tractor-driven chipper. Trucks with roll-off system and roll-on / roll-off containers are loaded directly and finally the chips are transported to the energy plant.

The energy wood production from thinning in small diameter trees is only marginally economic, and in Scandinavia this is subsidized as a silvicultural treatment (Hakkila 2004).

3.4 Energy Wood – Whole Tree Extraction – *Pridobivanje drva za energiju pri stablovnoj metodi izradbe*

All material extracted in a first thinning, mainly small diameter trees, is used to produce woody biomass. A shear-head mounted on a tractor with a trailer fells the trees, and lays them on the forest floor in bunches (where required, the trees are cut again in

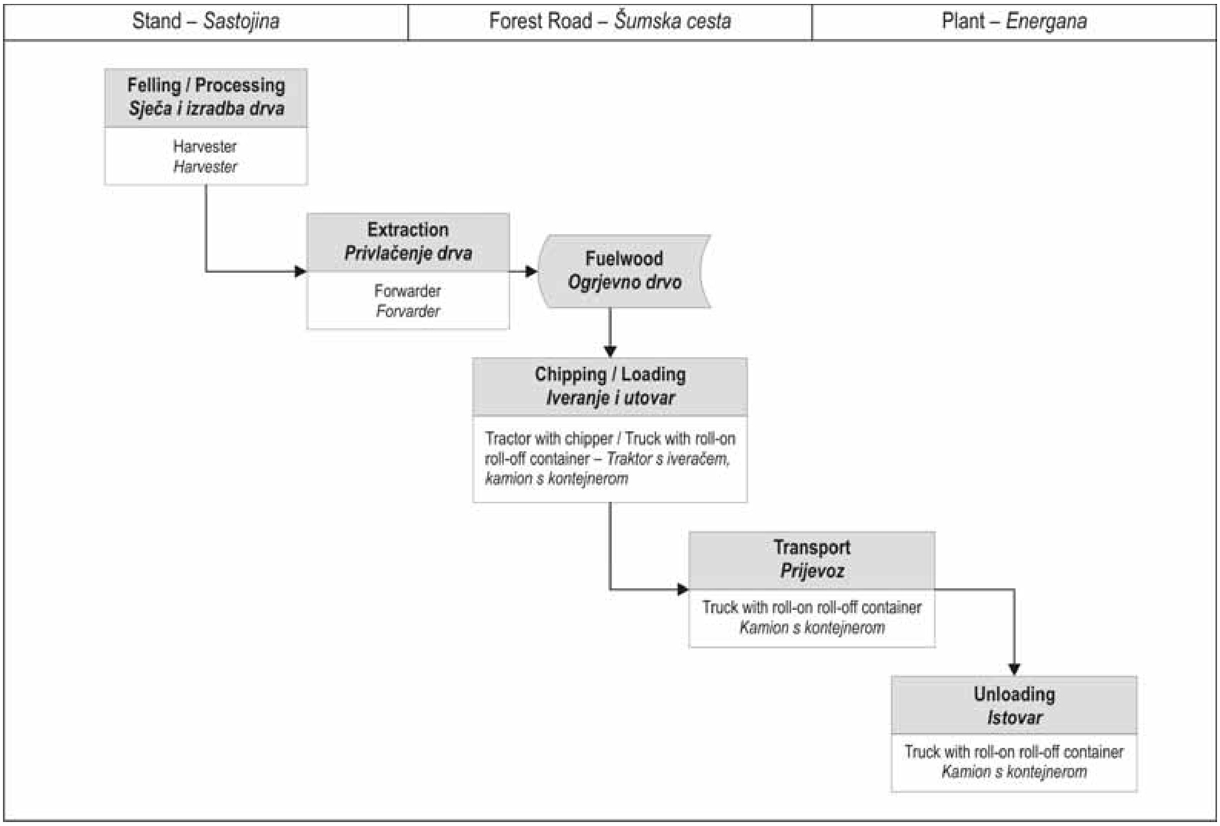

Fig. 4 Utilization of energy wood with harvester and forwarder in cut-to-length extraction; direct chipping into truck with roll-on/roll-off containers

Slika 4. *Korištenje drva za energiju pri sortimentnoj metodi izradbe u sustavu harvester – forvarder, neposredno iveranje u kamione s kontejnerom*

the middle) and then the trees are loaded directly into the trailer. When fully loaded the material is transported to a road-side processing area and stored for 3–4 months to facilitate drying. A larger sized mobile chipper blows the chips directly into a chip-van, which is then directly transported to the energy station (Figure 5). In Finland they are convinced that felling heads with multi-tree processing function are the only efficient solution for the production of wood chips in small diameter forest (Kärhä et al. 2005, Hakkila 2006), however there is little experience with these machines in Central Europe.

The utilization of small diameter trees is also possible in cable terrain. The felling is carried out with chainsaw and the extraction with the cable yarder. This system is in most cases not economically viable.

4. Future Challanges – *Budući izazovi*

4.1 Operational delays of the chipper – *Prekidi rada iverača*

Empirical studies were carried out to establish chipper productivity in relation to various raw material options as well as to establish the operational delays when chipping directly into waiting chip transporters. In total 118 hours (PSH_{15}) of chipping were recorded and a total of 9246 m^3 of chips was produced. The productivity varied between 52 and 111 m^3/PSH_{15} (Figure 6). The highest production was achieved by chipping bundles and roundwood. Figure 6 also shows the increased potential with reduced operational delays. The chipper spent 20% of the total work time for waiting on the truck. 90% of the waiting times ranged between 9 and 16 minutes, with an average of 12.6 per loaded truck.

4.2 Closed and interrupted work chains – *Zatvoreni i prekinuti proizvodni lanac*

One solution for the reduction of operational delays is the separation of chipping and transportation (interrupted work chain). In this way, the process steps become independent from one another and therefore the space requirement is less, however additional costs occur because of the loading process.

Table 1 shows the comparison of technical data for two chip truck systems. Higher tare weight of the chip truck with loader, in comparison to the con-

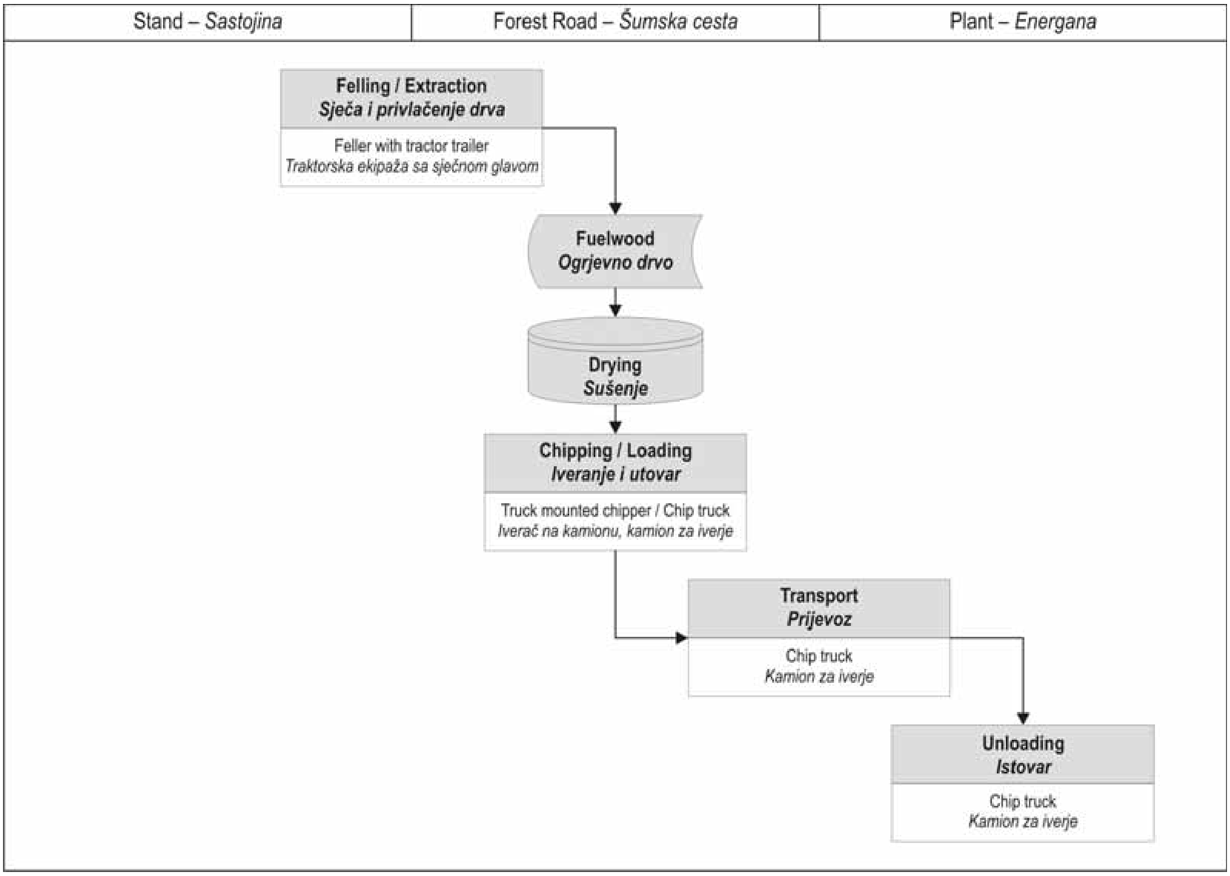

Fig. 5 Utilization of energy wood with shears and tractor trailer in whole-tree extraction; direct chipping into chip trucks
Slika 5. *Korištenje drva za energiju pri stablovnoj metodi izradbe pri radu traktorske ekipaže sa sječnom glavom, neposredno iveranje u kamione za iverje*

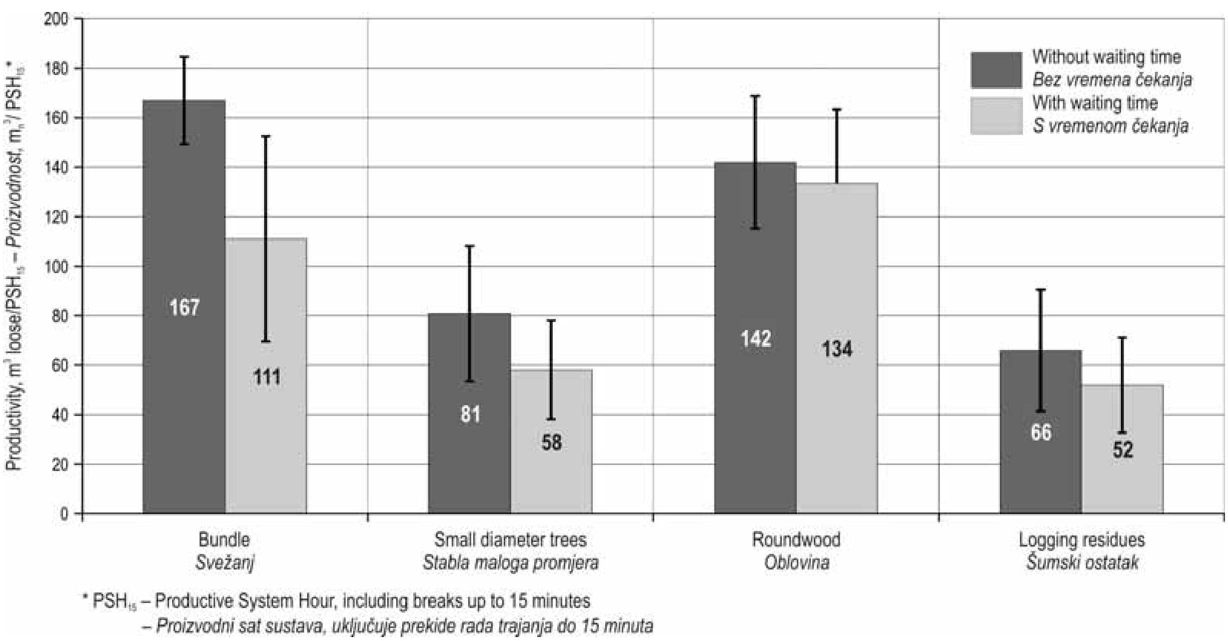

Fig. 6 Chipper productivity in relation to various raw material options with and without operational delays
Slika 6. *Proizvodnost iverača u ovisnosti o različitim izvorima drvnoga materijala, s prekidom rada i bez prekida*

Table 1 Comparison of chip trucks (Kanzian et al. 2006)

Tablica 1. *Usporedba kamiona za iverje (Kanzian i dr. 2006)*

Description *Opis*	Chip truck *Kamion za iverje*	Chip truck with bucket loader *Kamion za iverje s korpom za utovar*
Technical Data – *Tehnički podaci*		
Unloaded mass – *Masa vozila*:	18 500	20 800
Payload – *Nosivost*, kg	19 500	17 200
Capacity – *Kapacitet*, m^3	87	81
Drive System – *Formula pogona*	6 x 2	6 x 6

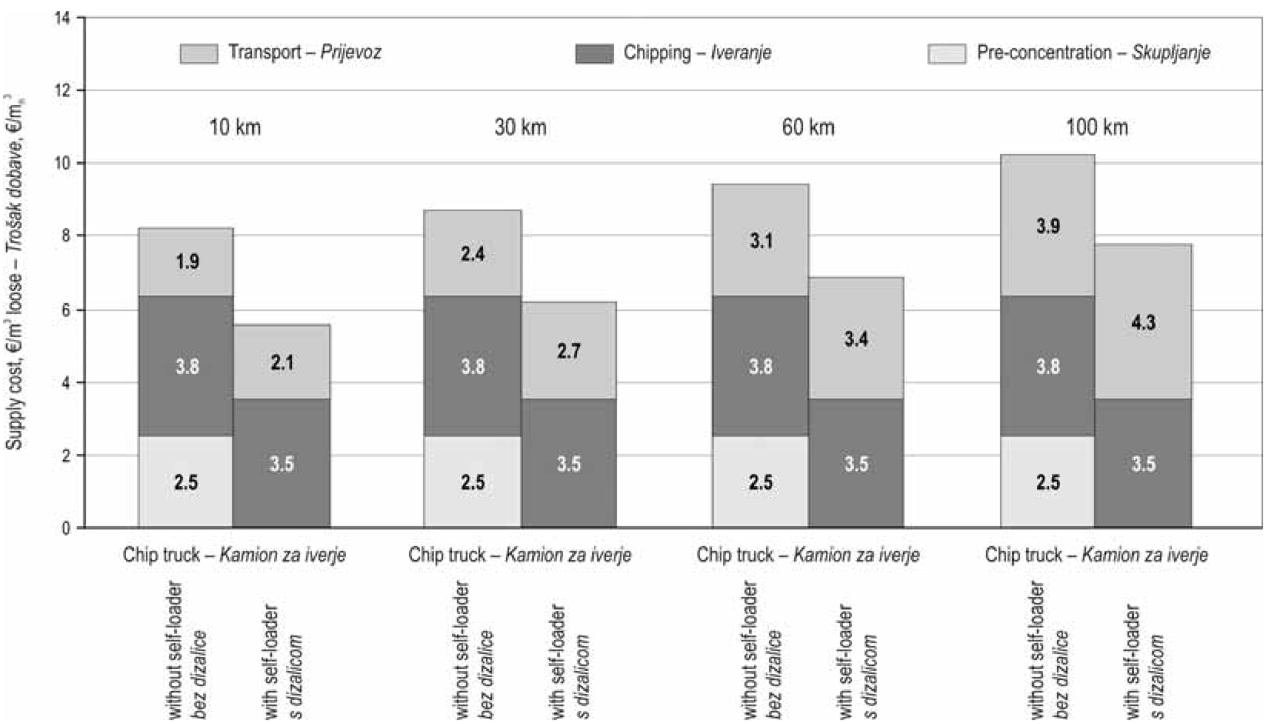

Fig. 7 Costs for various production systems of softwood-tree landing residues

Slika 7. *Troškovi za različite sustave pridobivanja šumskih ostataka drva četinjača* ventional truck, is not only caused by the loader with the clamshell bucket but also by the all wheel drive system of the truck.

The actual hourly rates of the contractors are used (excl. taxes) for comparison calculations. The costs for the pre-concentration of harvesting residues are 2.5 €/m^3. The chipper operating costs are 240 €/h. The chip truck without self-loader (60 €/h) is a little cheaper than with self-loader (65 €/h).

The production of harvesting residues – softwood, was modelled using the two truck options and for a transportation distance of 10, 30, 60 and 100 km. The travel times are estimated using the model developed by Friedl et al. (2004). The loading time for the chip truck without self-loader is the same as the production of the chipper (60 m^3/PSH_{15}). Operational delays of 9% are included in this estimate. The number of trucks to be used is calculated based on the round-trip time. The unloading time of 20 minutes is kept constant for all variation. Relocation costs of the chipper and trucks are not taken into considered in this calculation.

Figure 7 shows that the calculated supply cost for wood chips from softwood using a chip truck with self-loader is lower than the direct loading option (24–32%). The main reasons for the cost difference are the process pre-concentration of residues and chipping.

Chipping with direct loading of the chip truck requires the machines to be close to one another, and therefore the pre-concentration of material is required at appropriate landing areas. The additional pre-concentration costs can be only partially compensated by higher chipper production. At the same time, with the direct loading system, operational delays occur and this again increases the cost. For the self loading truck the lower payload capacity results in lower comparable productivity, which in turn increases the unit costs.

4.3 Full utilization of truck capacity for transportation – *Potpuna iskoristivost transportnoga kapaciteta kamiona*

The question of efficient production of wood chips is tightly connected to the reduction of transportation costs. In the past this problem was overcome by keeping transportation distances very short. With the recent boom in bio-energy and construction of larger bio-energy power plants, the total woody fuel needs within a region have increased, and the required supply region has become larger. Transportation distances and costs have increased accordingly (Asikainen et al. 2001, Kanzian and Holzleitner 2006). The best possible utilization of the truck capacity will become a key factor for remaining competitive. The capacity can be improved through higher payloads or increased on-truck load density.

Figure 8 shows the productivity of a chip truck dependant on transportation distance and bulk density. A 50 km drive distance and an average density of 370 kg/m^3 result in a productivity of 11.1 m^3/h. By an increase in allowable legal total truck mass from 38 to 42 tons for woody biomass transportation, we can achieve an increase in production of 2.0 m^3/h or the equivalent of 18%. Drying of woody biomass prior to transportation decreases the bulk density, and this has an even higher impact on increasing possible productivity than just the increase of the allowable truck weight limits. The productivity increase is 50%, at a density of 210 kg/m^3, or 16.8 m^3/h at an average transportation distance of 50 km (Kanzian and Holzleitner 2006).

5. Conclusions – *Zaključci*

The goal of this paper was to analyze the current state of wood chip production in Austria. On the basis of increasing fuel demands by the energy industry, the importance of wood chips from the forest will increase with respect to sawmill byproducts. Harvesting residues and timber from thinning operations, as well as coppice stands, are a clear option for raw material resources. The main goal is to produce the wood chips in the most cost efficient way.

The position of the chipper within the work chain determines the type of biomass that will be transported. Chipping at the forest roadside and the subsequent transportation of the chips is the most common system. Direct chipping of the material into waiting trucks results in operational delays in the order of 20%. The highest chipper production was recorded when chipping roundwood (134 m^3/PSH_{15}) and bundles (111 m^3/PSH_{15}). Direct chipping requires the chipper and truck to be placed close to each other, and this is not always feasible in mountainous areas. This is why the raw material should be concentrated at a centralized processing area, which creates additional costs.

If chipping and transportation is carried out independently, then additional costs occur for the loading of the chips, however operational delays are reduced and it is possible to operate on narrow roads and/or within very limited space. The result of a model simulation showed that the transportation of wood chips in mountainous areas separate from the chipping operations can lead to cost savings of 24–32%.

In Austria an increasing number of larger bio-energy power plants is being built, which increases

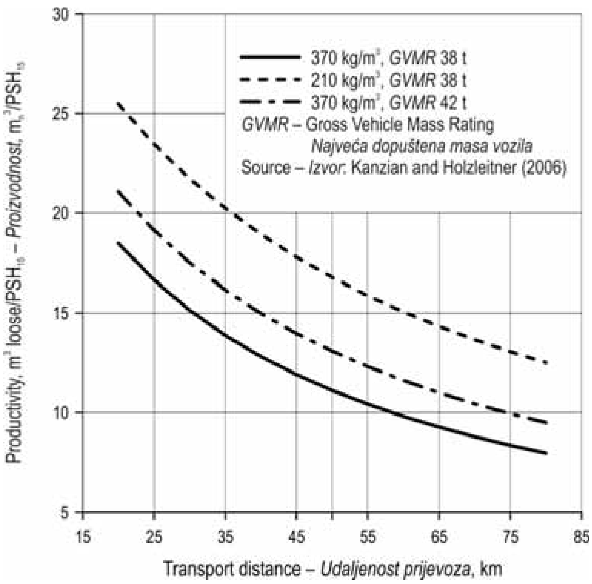

Fig. 8 Productivity in relation to the bulk density of the material transported and the maximum allowable total truck mass

Slika 8. *Proizvodnost kamiona za iverje u ovisnosti o nasipnoj gustoći prevezenoga drvnoga materijala i najvećoj dopuštenoj masi kamiona*

the required supply area and therefore results in an increase of transportation distances and costs. The utilization of truck capacity must therefore be maximized. Dry woody-biomass can increase the productivity of the truck by 50%. On the basis of this consideration, the introduction of central storage areas makes sense. In addition, these centralized storage areas increase product volume and ensure a more continuous supply, also in the winter months.

Bundling of landing residues is a further possibility to increase the loading density for transportation. In Scandinavia the production systems based on bundling technology are clearly advantageous in longer transportation distances. These systems have not been cost-effectively demonstrated in mountainous conditions. The production levels and calculated hourly rates are clearly different between Scandinavia and Austria. Lower hourly rates result from an increased machine utilization and fewer relocation costs and both of these factors are considerable problems in Central Europe.

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Sažetak

Sadašnje stanje i mogućnosti razvoja lanca dobave drvnoga iverja u Austriji

Cilj je rada analiza sadašnjega stanja pridobivanja drvnoga iverja u Austriji. Zahtjevi za povećanjem energije znatno pridonose važnosti šumskoga drvnoga iverja, koji se pridobiva u prvom redu iz šumskih ostataka, drva iz prorednih sječina i šuma niskoga uzgojnoga oblika. Pri tome je glavni cilj pridobivanje drvnoga iverja na troškovno najisplativiji način.

Mjesto iveranja određuje vrstu šumske biomase za daljinski prijevoz. Iveranje na šumskoj cesti te daljinski prijevoz iverja najučestaliji je sustav pridobivanja. Najveća je proizvodnost iverača zabilježena pri iveranju obloga drva i svežnjeva šumskih ostataka. Neposredno iveranje u kamione uvjetuje prekide rada iverača do 20 % od ukupnoga vremena rada. Također, neposredno iveranje zahtijeva blisko postavljanje iverača i kamiona, što nije uvijek moguće u planinskim područjima. Zbog navednih se razloga preporučuje skupljanje i iveranje drvnoga materijala na glavnom stovarištu, ali se time stvaraju i dodatni troškovi.

Ako se iveranje i prijevoz iverja odvijaju neovisno, dodatni se troškovi pojavljuju pri utovaru drvnoga iverja, ali se smanjuju prekidi rada uz mogućnost rada na uskim šumskim cestama s ograničenim radnim prostorom. Primjenom ovoga sustava pridobivanja iverja troškovi se smanjuju od 24 % do 32 %.

U Austriji se neprestano povećava broj bioenergetskih postrojenja, što povećava područje dobave iverja te time udaljenost prijevoza iverja i troškove. Stoga je potrebno koristiti potpuni kapacitet kamiona. Sušenje šumske biomase može povećati proizvodnost kamiona za 50 %. U tom se smislu organizacija glavnog stovarišta čini opravdanom. Također glavno stovarište osigurava povećanje proizvedene količine drvnoga iverja i kontinuiranu dobavu iverja u energanu tijekom zimskih mjeseci.

Izradba svežnjeva od drvnih ostataka jedna je od mogućnosti povećanja nasipne gustoće tovara. U Skandinaviji je navedeni sustav pridobivanja najprihvatljiviji pri duljim udaljenostima prijevoza, ali nije troškovno isplativ u planinskim uvjetima u Austriji. Razina proizvodnosti i trošak strojnoga rada bitno se razlikuju između Skandinavije i Austrije. Manji trošak strojnoga rada povećava godišnju iskoristivost stroja te oba čimbenika čine značajni organizacijski problem pridobivanja drvnoga iverja u zemljama središnje Europe.

Ključne riječi: *dobava drvnoga iverja, iveranje, prijevoz drva za energiju, izradba svežnjeva*

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