INFRES – Innovative and effective technology and logistics for forest residual biomass supply in the EU (311881)

Raffaele Spinelli, IVALSA & Johanna Routa, Luke (Editors)

DEMO REPORTS 8-23 – D4.5

Dissemination Level	
Public	X
Restricted to other programme participants (including the Commission Services)	
Restricted to a group specified by the consortium (including the Commission Services)	
Confidential, only for members of the consortium (including the Commission Services)	

Preface

Natural Resources Institute Finland (Luke) is coordinating a research and development project 'Innovative and effective technology and logistics for forest residual biomass supply in the EU – INFRES'. The project is funded from the EU's 7th framework programme. INFRES aims at high efficiency and precise deliveries of woody feedstock to heat, power and biorefining industries.

INFRES concentrates to develop concrete machines for logging and processing of energy biomass together with transportation solutions and ICT systems to manage the entire supply chain. The aim is to improve the competitiveness of forest energy by reducing the fossil energy consumption and the material loss during the supply chains. New hybrid technology is demonstrated in machines and new improved cargo-space solutions are tested in chip trucks. Flexible fleet management systems are developed to run the harvesting, chipping and transport operations. In addition, the functionality and environmental effects of developed technologies are evaluated as a part of whole forest energy supply chain.

This publication is a part of the INFRES project. The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2012-2015] under grant agreement n°311881.

In particular, Deliverable 4.5 reports about the demonstrations conducted between month 25 and month 36. During this period, contributors to Work Package 4 organized and performed 16 main demonstrations, as follows: stump drill in Finland; mountain technology (winch, forwarder, cable yarder and smart chipper) in Italy; energy wood terminal in Sweden; extra large chip truck in Sweden; Active drying in Finland; extra large chip semi-trailer with electronic steering in Finland; synthetic rope in Spain; multi-tree energy wood harvester in Austria; feller-bundler in Sweden; semi-Automated Process Analysis demonstration in Austria; large nine axle chip truck-trailer unit and the hybrid chipper in Finland; un-motorized full suspension carriage in Italy; transport logistic software demonstration in Germany; wood chip drying using biogas heat in Germany; synthetic cable for wood and biomass extraction in Spain; press Collector in Spain and terminal logistics demonstration in Sweden.

Raffaele Spinelli & Johanna Routa

Joensuu, August 2015

Title	**Title**
Author(s)	Johanna Routa ,Antti Asikainen, Juha Laitila, Jukka Antikainen, Robert Prinz, Mikko Nivala, Jiri Gol, Sami Lamminen, Yrjö Nuutinen, Raffaele Spinelli, Natascia Magagnotti, Carolina Lombardini, Johanna Enström, Henrik von Hofsten, Örjan Grönlund, Lars Eliasson, Dimitris Athanassiadis, Mikael Öhman, Dan Bergströn, Fulvio Di Fulvio, Gernot Erber, Franz Holzleitner, Maximilian Kastner, Josep M. Tusell, Jordi Canals, Diego Almenar, Judit Rodríguez, Isart Gaspà, Pere Navarro, Matti Tuukkanen, Matthias Dees, Juliana Walkiewicz, Eric Jessup, Jyrki Raitila, Matti Virkkunen, Francesca Ziller, Daniele Valentini, Kari Kokko, Petri Kaksonen, Jussi Suutarinen, Janne Immonen, Esa Mononen & Lena Jonsson.
Abstract	The 16 demonstrations conducted within the third year expanded the work conducted earlier on within WP4 and allowed exploring the main trends already described back then with further tests on new machines. The stump drill demonstrated in Finland showed that is possible to minimize soil disturbance during root wood recovery, possibly relieving the strong concerns about heavy metal leaching. At the same time, minimum-impact root wood harvesting would prove suitable to the introduction of root recovery to selection cuts (thinning or maturity harvest), where conventional root recovery techniques are not viable. The demonstrated machine still needs some fine tuning, but the principle is proven and the technology is definitely viable. The demonstrations organized in Italy and Spain showcased a number of new technologies for energy wood recovery in mountain forest operations. These included: synthetic rope for forestry winches, a new high-speed forwarder for two-stage extraction, a highly-mobile tower yarder, an agile chipper trucks for constrained space landings. These technologies are new to mountain operations and especially suited to the close-to-nature forestry management traditionally adopted in the mountains. The environmentally-friendly technologies shown in Italy and Spain can help introduce residue harvesting to sensitive forest habitats, to the benefit of increased financial sustainability. Much work was also devoted to logistics. The extra-large truck demonstrations conducted in Sweden and Finland showed that special new trucks are a viable option to cut energy wood transportation costs and decrease negative impacts on the environment and the traffic. Adoption of extra-large trucks entails a reduction in the number of loads needed to transport a given volume of energy wood, which will be beneficial to other road users as the roads between the terminal and the CHP-plant are heavily trafficked. The technical challenges associated with maneuvering these large convoys on forest roads can be solved with an ETS (Electronic Trailer Steering) system. This enables controlled hydraulic steering of the trailer's rearmost axles, to improve maneuverability and mobility in small forest roads. Equipping these machines (and regular trucks) with air-suspension systems offers additional benefits, such as a smoother ride for the driver and a weight scaling solution. The air suspension gauge can be used by the driver to monitor the weight of the load in real time, thus helping to maximize load size during chipping and make sure that the truck is always running with maximum payload. The demonstrations on logistics also covered inter-modal transportation and the use of terminals for storage and trans-loading. A new terminal was investigated, with a triangular connection to the main track that enabled trains coming from any direction to leave towards any chosen direction as well. The research associated to this demonstration showed that in many instances the number of terminal is too large, and it would be rational to merge terminals and locate them in strategically important places to create sufficient volumes for investments. A further demonstration concerned the use of active drying. To reduce immobilization and weather dependency, wood chips can easily be dried in driers connected to a heating plant. Investment and running costs of a dryer determine how feasible such a drying method is as part of the wood fuel supply chain. Dryers can be quite simple and be obtained by modifying old freight containers or barns. The harvesting of small trees for energy use was demonstrated in Austria and Sweden, using a multi-tree small-scale harvester head and a feller-bundler. Both machines were designed to achieve the very same benefit: increasing the bulk density of bunched whole-trees, either by a cross-cutting the bunches (multi-tree harvester) or by compacting and bundling the trees (feller-bundler). The numbers of these new demos showed a further progress in the capacity of INFRES to attract large audiences. Three demonstrations counted over 100 participants, which was the record number obtained in the second year and was registered only once. In fact, one of the demonstrations of this third year of activity recorded 400 registered participants, witnessing to the ability now achieved by the INFRES partners in conceiving, organizing and advertising their Demos.
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Publisher	

INFRES – Innovative and effective technology and logistics for forest residual biomass supply in the EU (311881)

Robert Prinz, Mikko Nivala, Otto Läspä & Jiri Gol

Finnish Forest Research Institute

Demo report 8- Stump drilling demo in Finland – D4.5

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Joensuu, 26.08.2014

Content

Preface

Finnish Forest Research Institute (Metla) is coordinating a research and development project 'Innovative and effective technology and logistics for forest residual biomass supply in the EU – INFRES'. The project is funded from the EU's 7th framework programme. INFRES aims at high efficiency and precise deliveries of woody feedstock to heat, power and biorefining industries.

INFRES concentrates to develop concrete machines for logging and processing of energy biomass together with transportation solutions and ICT systems to manage the entire supply chain. The aim is to improve the competitiveness of forest energy by reducing the fossil energy consumption and the material loss during the supply chains. New hybrid technology is demonstrated in machines and new improved cargo-space solutions are tested in chip trucks. Flexible fleet management systems are developed to run the harvesting, chipping and transport operations. In addition, the functionality and environmental effects of developed technologies are evaluated as a part of whole forest energy supply chain.

This publication is a part of the INFRES project. The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2012-2015] under grant agreement n°311881.

This report describes the results of a stump drilling demonstration conducted in Finland. The study and demonstration were organized by the Finnish Forest Research Institute (Metla) in cooperation with SLU, IVALSA, Ellettari and a local entrepreneur in Western Finland, near Evijärvi.

Robert Prinz, Mikko Nivala, Otto Läspä & Jiri Gol, Joensuu, August 2014

This publication is a part of the INFRES project. The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2012-2015] under grant agreement n°311881.

Title	**Demo report 4- Stump drilling demo in Finland**
Author(s)	Robert Prinz, Mikko Nivala, Otto Läspä & Jiri Gol
Abstract	The Ellettari stump drill mounted on New Holland excavator demonstrated in Finland represents an alternative solution for stump harvesting of Scots pine (Pinus sylvestris) in peatland areas under Nordic winter conditions. Under these circumstances, harvesting with conventional heavy-duty machinery is difficult, calling for a machine capable of pine stump extraction despite the frozen ground surface. The tested and demonstrated method with innovative technology works under the given condition, however, the machine will need certain technical updates to make the operation more reliable with the given conditions. In general, the productivity of 2.8 solid m3/E_0h without site preparation seems to be lower compared to other methods. However, the limited amount of data collected within this trial does not allow making wider long-term conclusions. Nevertheless, it was demonstrated that the new machine can offer the possibility to harvest formerly unutilized stump biomass resources for energy, as postulated by the original project application.
Date	August 2014
Language	English
Pages	14 p.
Name of the project	INFRES - INFRES – Innovative and effective technology and logistics for forest residual biomass supply in the EU (311881)
Financed by	European Commission – FP7 programme
Keywords	Stump drilling, Stump lifting, Productivity, Time Study
Publisher	

1 Introduction

As overall aim, INFRES concentrates to develop concrete machines for logging and processing of energy biomass to improve the competitiveness of forest energy by reducing the fossil energy consumption and the material loss during the supply chains. In addition, the functionality and environmental effects of developed technologies are evaluated as a part of whole forest energy supply chain. The increasing interest on extractives from Scots pine (*Pinus sylvestris*) stumps and the increased biomass availability of forest energy to achieve the goal of 2020 are other main overall targets (Anttila et al. 2014).

The conducted and described demonstration was organized in Western Finland, near Evijärvi. The study and demonstration was organized by the Finnish Forest Research Institute (Metla) in cooperation with SLU, IVALSA, Ellettari and a local entrepreneur. The former organized the study layout, sites and the logistics, while the latter provided the technology. Ellettari S.P.L. was the guest manufacturer, and IVALSA accompanied Ellettari in order to act as a liaison and assist with communication.

The demonstration and trials were conducted on the 10th of April 2013 at a peatland site, characterized by difficult accessibility under Nordic winter conditions. UPM Kymmene clear cutting sites in the area of Western Finland close to Evijärvi and Lappajärvi were used for the trials.

2 Materials and Methods

2.1 Stump drilling head

The machine on trial was the Ellettari stump drill. This machine was installed on a 22 tonnes New Holland Kobelco E 200 SR excavator (Figure 1). The Ellettari drill was used with a diameter of 40 cm. This drill was specifically designed for drilling of stumps, mainly with tractor based machinery. Under the Finnish conditions, the drill was mounted to a New Holland excavator which made mechanical adjustments, also of the hydraulic systems, necessary.

Figure 1. Ellettari stump drill mounted on New Holland excavator in Finnish sites.

2.2 Study stand

In total, 7 plots with the size of 75 m x 20 m were prepared for the trial. Within each plot, all stumps were tree species identified and marked. All stumps were given Cartesian coordinates with the help of a Trimble GPS data collector and stump diameters were determined by cross measurement in two directions (Figure 2).

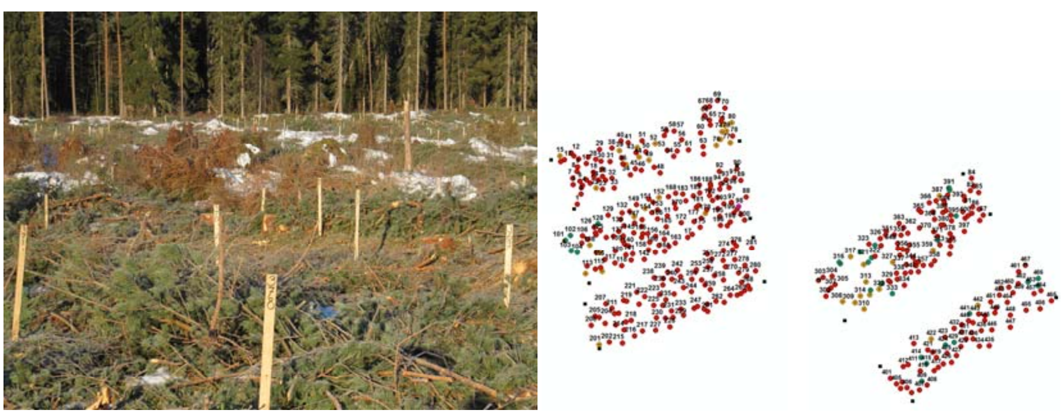

Figure 2. Study preparation and plot set-up.

Thereby, a total of 611 stumps (478 pine, 69 spruce, 63 birch and 1 other species) were marked, however, due to technical reasons only a total of 49 stumps were considered for time study analyses described in the following chapters.

2.3 Stand characteristics

This chapter describes the stand characterisists utilized during the time study with the described machinery. Therefore, a total of 49 stumps were considered for the calculation of the processed stump volume (Figure 3). The average diameter of processed stumps was 24.4 cm (Table 1).

Table 1. Characteristics of time study plot in the trial

	Range
Diameter of stumps on the plot (cm)	15 to 35
Average stump diameter on the plot (cm)	24
Volume of stumps on time study plot (l)	8 to 52
Average volume of stumps on the plot (l)	25
Number of lifted stumps on the plot	49
Number of stumps on the plot	80
Number of stumps per hectare	533

For the calculation of processed stump volumes, the dry mass for each extracted stump was calculated. The function used for volume calculations was the following (Hakkila 1972):

$$\boldsymbol{y} = -\mathbf{2} + \mathbf{0.039} \times \boldsymbol{x}^{\mathbf{2}}$$

whereby:

$\boldsymbol{y}$ = dry mass of Scots pine stump,kg

$\boldsymbol{x}$ = Stump diameter, cm

The conversion from dry mass to volume in cubic meters was calculated using the bulk density of pine stumps of 476 kg/m^3 for the proper stump according to Hakkila's definition (Hakkila 1975). The calculated total stump volume was then multiplied by 0.53 to represent the drilled core of the stump without side roots. The core stump share of 53% for Scots pine was obtained from Hakkila 2004. This method gives in principle the same results as a cylinder estimation assuming a cylinder shape of the extracted stump with a cylinder length of 0.5 meters.

2.4 Time study

Time study material was collected using video recording and a subsequent analysis of material using a continuous time study method. The A_TimeStudies application Version 1.03 (Ari Laurén) was used for the analysis of time elements. Cycle time was divided into the following elements without overlaps between the elements:

- Moving base machine: excavator moving towards the stumps
- Crane movement: movement of excavator crane to navigate the drilling head into drilling position
- Drilling: extraction head drilling
- Stump extraction: excavator crane movement after the drilling with removal of stump from drilling head (hydraulic push of stump out from drilling head)
- Other: other time elements including delays related to unproductive work

Effective time consumption is the sum of all main work elements, as follows: moving of base machine, crane movement, drilling and stump extraction.

3 Study results

The trial lasted approximately 2 hours, including transfers between plots, delays and preparation, in total approximately 30 min of time study material was video recorded. During this period the machine processed 53 stumps, although only 49 stumps were considered for further analysis due to the breakdown of the machine. There were no significant differences between the studied plots for what concerned stump diameter. The lifted stumps were pine: other species could not be processed during the trial due to the machine breakdown (Figure 3).

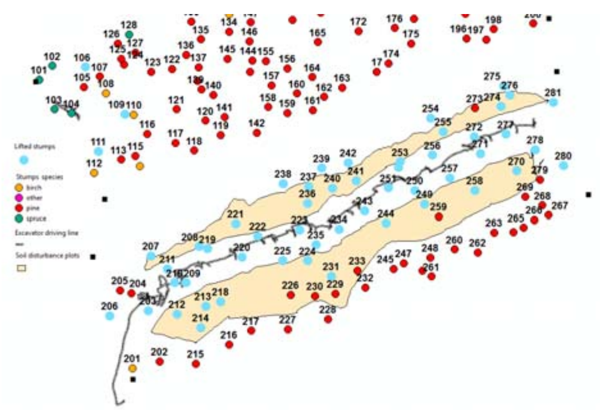

Figure 3. Study and technology testing map included drilled stumps in plots 1 and 2 (part of Figure 2).

Figure 4. Pine stumps extracted with the Ellettari stump drill.

Table 2 shows the result of the volume calculations comparing different methods. For the further analysis and calculation of productivity, results from the volume calculation were used with a total harvested volume of 1.25 m^3.

Actual work represented 0.44 E0 hours. The average productivity (m^3/E_0h) for this trial was 2.8 solid m^3 of extracted stumps per hour, or 111 stumps per hour.

Figure 5 shows the breakdown of main work elements of the machine´s effective working time in the time study conditions. Delays during the trial represented 0.6% of total worksite time and were not considered in the further analysis of data. Delay times related to machine breakdowns were not considered for the trial, as the trial did not continue thereafter.

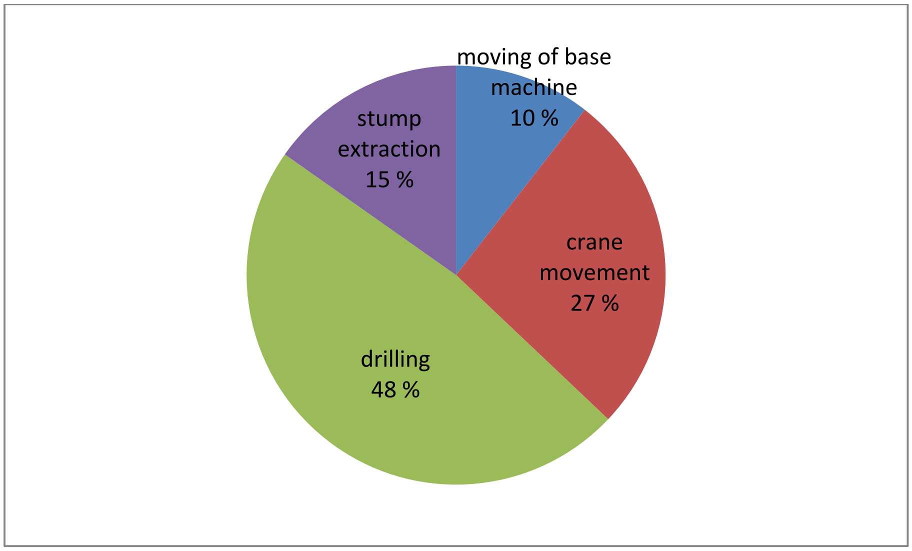

Figure 5. Relative time consumption by main work elements of the machine´s effective working time in the study conditions.

The function describing the time consumption of pine stump processing using the Elletari stump drilling head as a function of stump diameter can be described as follows (see figure 6):

$\boldsymbol{y = 6.7607x^{0.3758}}$ (R^2 = 0.40)

whereby:

$\boldsymbol{y}$ = stump processing time, s/stump

$\boldsymbol{x}$ = stump diameter, cm

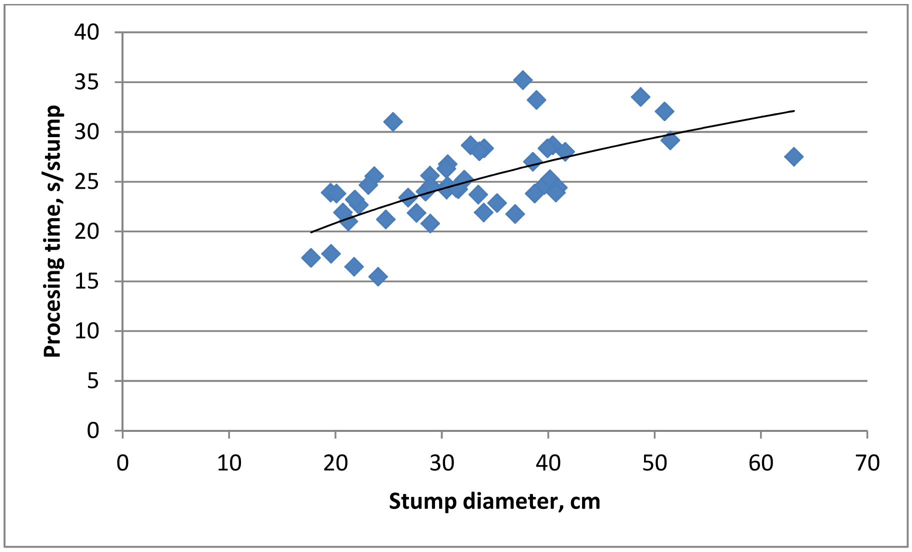

Figure 6. Time consumption (E0) of pine stump processing using the Elletari stump drilling head as a function of stump diameter.

Due to the limitations of available data further statistical analyses and characterization of the model were not conducted.

Fuel consumption was estimated by the operator at around 13 liters of Diesel fuel per working hour, with the described machine set-up.

4 General evaluation

The machine represents an alternative solution for stump harvesting of Scots pine (*Pinus sylvestris*) in peatland areas under Nordic winter conditions. Under these circumstances, harvesting with conventional heavy-duty machinery is difficult, calling for a machine capable of pine stump extraction despite the frozen ground surface.

The tested and demonstrated method with innovative technology works under the given condition, but, the machine will need certain technical updates to make the operation more reliable with the given conditions. It should be mentioned that the machine was Originally designed for farm tractor or similar base machines, most likely the drill used was not designed for the heavy vertical forces from an excavator, and that it was not designed for the high hydraulic pressure that an excavator has. However, these results are also closely related to the limited experience of the operator with this type of machine. Substantial productivity increases are expected as a result of operator adaptation and learning. With a share of 48% of the total effective working time the drilling of pine stumps has the highest potential to improve the current extraction time with the system demonstrated. In general, the productivity of 2.8 solid m^3/E_0h without site preparation seems to beon a similar level compared to a pine stump lifting study from Sweden for similar average stump diameters (Athanassiadis et al. 2011) and approximately 25-35% of the productivity achieved by other methods in spruce stump extraction (Laitila et al. 2008, Kärhä 2012). The results during the conducted study are slightly lower when comparing the results with a study shown by Skogforsk using a stump drilling approach on mineral soil (von Hofsten & Nordén 2007). However, the limited amount of data collected within this trial does not allow making wider long-term conclusions. Nevertheless, it was demonstrated that the new machine can offer the possibility to harvest formerly unutilized stump biomass resources for energy, as postulated by the original project application.

5 Demo results

Despite all the efforts with the machine and technology, a demonstration to a wider audience was not implemented due to the break-down of the equipment. Instead, the demonstration took place during the testing and time study of the used technology with five persons visiting at the site during the drilling study. Overall, valuable feedback was collected during the demonstration and testing.

6 Acknowledgements

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References

Anttila, P., Nivala, M., Laitila, J., Flyktman, M., Salminen, O. & Nivala, J., 2014. Metsähakkeen alueellinen korjuupotentiaali ja käyttö vuonna 2020. Metlan työraportteja / Working Papers of the Finnish Forest Research Institute 313. 55 s. (In Finnish)

Athanassiadis, D., Lindroos, O., Nordfjell, T. 2011. Pine and spruce stump harvesting productivity and costs using a Pallari KH 160 stump-lifting tool. Scand. J. For. Res 26: 437-445.

Hakkila, P., 2004. Puuenergian teknologiaohjelma 1999-2003 (Wood energy technology programme 1999-2003). Loppuraportti. Teknologiaohjelmaraportti 5/2004. 135 p. (In Finnish)

Hakkila, P., 1975. Kanto- ja juuripuun kuoriprosentti, puuaineen tiheys ja asetoniuutteitten määrä. Folia Forestalia 224. 14 p. (In Finnish)

Hakkila, P., 1972. Mechanized harvesting of stumps and roots. A sub-project of the joint Nordic research programme for the utilization of logging residues. Communicationes Instituti Forestalis Fenniae 77, pp. 1-71.

Kärhä, K. 2012. Comparison of Two Stump-Lifting Heads in Final Felling Norway Spruce Stand, Silva Fennica 46(4): 625-640.

Laitila, J., Ranta, T., Asikainen, A. 2008. Productivity of Stump Harvesting for Fuel, International Journal of Forest Engineering 19(2): 37-47.

von Hofsten, H. & Nordén, B. 2007. Stubbfräsen- en anorlunda metod att lyfta stubbar. Skogforsk Resultat Nr.18 2007. 4 p. (In Swedish)

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INFRES – Innovative and effective technology and logistics for forest residual biomass supply in the EU (311881)

Raffaele Spinelli, Natascia Magagnotti & Carolina Lombardini

CNR IVALSA

Demo report 9 - Forest biomass recovery in Alpine forests –D4.5

Dissemination Level	
Public	X
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Firenze, 07.09.2014

1 CONTENT:

2 Preface

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This publication is a part of the INFRES project. The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2012-2015] under grant agreement n°311881.

This report describes the results of an articulate demonstration on the recovery of forest biomass (residues) in mountain operations. The demonstration was organized in Italy by CNR, Pezzolato and Valentini, with the support of other Italian partners, including the Regione Veneto, the regional Loggers Association and a local SME (Bernardi Macchine), which saw the merit of the initiative and joined it their own cost. The demonstration was held on August 29 and 30 2014, at Malga Mezzomiglio near Farra d'Alpago in the Belluno Province (Northeastern Italian Alps).

Raffaele Spinelli, Natascia Magagnotti & Carolina Lombardini

Firenze, August 2014

This publication is a part of the INFRES project. The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2012-2015] under grant agreement n°311881.

Title	**Demo report 9- Forest biomass recovery in Alpine forests**
Author(s)	Raffaele Spinelli, Natascia Magagnotti & Carolina Lombardini
Abstract	CNR organized a demonstration on the recovery of forest biomass (residues) together with Pezzolato and Valentini. The demonstration was joined and supported also by other Italian partners, including the Regione Veneto, the regional Loggers Association and a local SME (Bernardi Macchine), which saw the merit of the initiative and joined it on their own cost. The demonstration was held on August 29 and 30 2014, at Malga Mezzomiglio near Farra d'Alpago in the Belluno Province (Northeastern Italian Alps). The demonstration showed a range of innovative equipment at work in a typical Alpine forest. The technologies on show were: a tractor winch equipped with synthetic cable; the new Valentini cable yarder with remote-controlled chokers; the Pezzolato smart chipper; the newest Alpine forwarder developed by Bernardi in Italy, equipped with a biomass cradle specifically designed for the extraction of forest residues; an innovative forestry trailer for farm tractors, also deployed for the extraction of forest residues. The demonstration was visited by 380 registered participants, including 2 reporters for the Italian and French press. Just before the demonstration and during its preparation, data were collected for estimating the benefits of the on-board moisture-meter installed on the Pezzolato smart chipper. Measurements clearly showed the advantages of the new device and prompted a new study campaign to further improve its accuracy.
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Financed by	European Commission – FP7 programme
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Publisher	

3 Introduction

On August 29 and 30 a new forest machine demonstration was held in Northeastern Italy, with the purpose of showcasing new technologies for Alpine logging operations.

The demonstration was organized by a CNR, Pezzolato and Valentini, with the support of other Italian partners, including the Regione Veneto, the regional Loggers Association (COGEFOR) and a local SME (Bernardi Macchine), which saw the merit of the initiative and joined it on their own cost.

Synergy was developed with another important EU project, namely: Manfor CBD (www.manfor.eu). This was obtained through the direct involvement of Regione Veneto, who are one of the Italian partners for MANFOR. As a result, resources and address lists were pooled, to the benefit of a larger and more visible initiative (Figure 1).

Figure 1. The banner with the logs of all organizers and sponsors of the demonstration.

The program was geared to attracting primarily active loggers, forest owners and certified foresters, making sure that the focused remained on cost-effective forest biomass technology. For this reason, the event spanned over two days – Friday and Saturday – to make sure that loggers had an opportunity to visit the worksite over the festive day. That must have worked, because the registered participants were close to 400, which is the highest attendance yet recorded in Italy for a focused Demo. Participant came from all of Northern Italy, and also from neighboring Austria and Slovenia (Figure 2). Part of this large success was probably due to the good choice of the demo site and the strong technical content of the program.

The demo was run inside a real logging site, where a 130 year-old, over-mature silver fir (Abies alba L.) stand had been targeted for a selective regeneration cut, aimed at removing the aged fir and make space for the beech advanced regeneration, as in the typical beech-fir succession. Most of the stand grew on steep terrain, and therefore extraction was performed by cable yarding. However, part of the crop grew on moderate slopes, which also allowed some forwarding. Therefore, the Demo program included five separate stops, all at actual work stations near the main forest road, where COGEFOR loggers were busy extracting their wood.

Figure 2. An image from the demo (Friday 29th August, morning).

4 Synthetic cable

First of all, the public observed a two-man crew winching trees with a Fendt farm tractor, equipped with the new Bernardi B 850 EH winch (Figure 3). Bernardi have been selling winches for many years now, but the new line is entirely built at their new facility, which allows better control on product quality. The new winches are characterized by an innovative gear reduction in a sealed transfer box and a patented cable spooler, designed for maximum simplification. The winch was fitted with the same Amsteel Blue synthetic cable used by CNR for repeated testing over the past 10 years, with the purpose of showing the durability of the new material, when properly handled. At the end of the demo, the public could stop and handle the cable themselves, while CNR experts explained pros and cons of the new synthetic cable. Large trees were cross-cut and partly delimbed in the stand in order to reduce damage to residual trees during extraction. However, whole tops were winched to the roadside, which were then collected by a farm tractor with a forestry trailer and moved to the chipper.

Figure 3. Winch equipped with synthetic cable mounted on a farm tractor.

5 Cable yarding

Further ahead the new Valentini V600/1000 M3 B10 tower yarder was stationed, operated by a two-man crew. The new machine is mounted on a tracked carriage and features a larger new engine and re-designed drums, which are now equipped with a store section, where unused cable is accumulated in order to reduce cable wear and maximize mainline pull (Figure 4). On most yarders, a store section is only available on the skyline drum, not on the mainline and haulback drums. In contrast, this new Valentini design offers store sections on all working drums, to the benefit of lower maintenance and stronger pulls. In its basic configuration, the new machine offers 1000 m skyline in the 22 mm swaged version, and a maximum mainline pull of 56 kN. The machine on show was also equipped with radio-controlled chokers, in order to make unloading faster and safer.

Figure 4. The compact V 600 track-mounted yarder being loaded on its transport.

6 Forwarding

A further demo site was devoted to forwarding of logs and forest biomass. Working on close-loop trail, visitors could observe the new Alpine Forwarder, produced in Italy by Bernardi and demonstrated here for the first time (Figures 5 and 6). It was however visible at Interforst exhibition this year, but not at work.

The new machine is an 8-wheel model, with a 12-t load capacity. It is powered by 6 cylinder IVECO engine, delivering a maximum power of 180 kW (248 PS) through a classic Sauer-Danfoss hydrostatic transmission. What is more, the new 6-liter engine is Tier IVi-compliant, and satisfies the stricter emission regulations that will be enforced in the next coming years.

Bernardi are certainly planning ahead, because their new machine is built on a cell designed to satisfy future specifications, not just current ones. Not only the engine complies with strict future regulations, but the solid structure is already designed for future upgrades. The solid frame is built on 20 mm-thick steel plate, and it may be extended and fitted with the larger 1500 mm inter-axle bogies, instead of the current 1300 mm inter-axle model (all sourced at NAF). The sturdy frame is quite heavy, which makes the machine very stable, despite its short 2.47 m maximum width. That clearly showed during loading, when the empty machine frame did not budge an inch, as the loader lifted heavy fir logs. Machine width is limited within 2.5 m in order to make it road-legal, thus enabling independent relocation between work sites. For this reason, the Bernardi forwarder features a new gear box, allowing a maximum road speed of 40 kph. The specimen on show in August carried an Italian-made ICAR loader, but the new machine accepts a wide range of forestry loaders, according to customer specifications. The forwarder was demonstrated with its detachable biomass metal-sheet cradle, designed to contain bulky branch loads and prevent dropping branches when moving forest residues along public roads.

Figure 5. The Bernardi forwarder loading forest residues during the Demo

The new forwarder was shown alongside with a 160 kW (118 PS) Massey-Ferguson farm tractor, equipped with an hydrostatic transmission forestry trailer. That is an older Bernardi design, which has pushed the capability of forestry trailers to their upper limits.

Now dating about 10 years, this older design consists of a sturdy trailer structure fitted with a pair of NAF bogies in the 1300 mm inter-axle class. Power for the bogies is sourced from the tractor power take-off, which connects to a variable-displacement hydraulic pump. In turn, the pump powers a hydraulic motor, connected to the bogies through the classic transmission shaft and differential box.

Figure 6. The farm tractor-forestry trailer unit with a load of forest residues.

Basically, the Bernardi forestry trailer is just a forwarder rear train, connected to a farm tractor. The difficult part is to coordinate the separate transmissions of the two units: hydrostatic trailer in the rear and mechanical tractor in the front. That is done through a patented system, where sensors on the tractor and trailer wheels read the respective speeds and send this information to a microprocessor, which acts on the hydrostatic pump plate in order to adjust the speed of the trailer bogies. A dedicated software allows manipulating trailer speed, so that the driver can increase or reduce trailer speed relative to tractor speed, when that may help improving machine mobility. Typically, trailer speed is reduced during downhill movements, so that the loaded trailer “holds” the tractor, contributing to machine stability. In contrast, trailer speed is increased on uphill grades, allowing the trailer to “push” the tractor uphill and improve its mobility. The hydrostatic trailer is road-legal and approved for a 14 t gross weight, which leaves an 8 t payload, after discounting 6 t for the trailer own weight (including the loader). The trailer project was used by Bernardi as a launch pad for their forwarder, because it allowed them to gain substantial experience with hydrostatic transmission design, construction and maintenance. Over the past 10 years, the Bernardi hydrostatic trailer has met with remarkable success among Italian loggers and is still one of their top products. This machine was also demonstrated while moving forest residues.

7 Smart chipper

Besides handling heavy logs, both the forwarder and the tractor-trailer unit delivered forest residues to the Pezzolato smart chipper, an innovative chipper-truck specifically designed for mountain operations. In this new machine, a massive Pezzolato drum chipper (width 1200 mm, diameter 820 mm) is mounted on a compact MAN truck and is powered by the 412 kW (560 PS) engine of the truck itself. The truck features a 6x6 transmission and a reduced width (2300 mm), which allows trafficking narrow low-standard roads. The goal is to take a highly productive industrial operation as close as possible to the forest, despite the challenging conditions of mountain road networks. The smart chipper is equipped with a number of innovative devices, including disposable knives, swing-away counter-knife and a new on-board moisture meter.

Figure 7. The smart chipper demonstrated at Farra d'Alpago.

Tests were conducted just before the Demo in order to gauge the measurement error incurred by the on-board moisture meter, as well as the sampling errors incurred with both the on-board and the conventional method. To this end, 20 samples were collected from each of 9 loads. Sampling was performed by a researcher, who collected 1 kg of chips from under the chipper discharge at 1 minute intervals. The corresponding moisture meter readings were collected and associated with each sample. The samples were then taken to the laboratory and their moisture content was determined with extreme accuracy, using the gravimetric method. Normally, one sample is taken from each load, and its moisture content is accurately determined with the gravimetric method. However, such standard procedure incurs a very high sampling error, because the whole load is represented by one sample only – however carefully that can be taken. The hypothesis is that by representing each load with one single measurement one risks to incur a very high sampling error, which can be gauged by comparing the two extreme measurements in our 20 samples. In contrast, by multiplying the sampling interval through the on-board moisture meter, one may incur relatively small measurement and sampling errors. The results of this preliminary test are reported in Table 1.

Table 1. Sampling and measurement errors for the on-board moisture meter

Load #	Error % Control Sampling	Error % Humimeter Sampling	Error % Humimeter Measurement
1	30	13	11
2	60	9	36
3	105	18	5
4	21	21	10
5	21	21	17
6	22	22	11
7	72	6	3
8	57	10	8
9	90	9	7

This preliminary test showed that the measurement error introduced by the on-board moisture meter is much smaller than the reduction in sampling error achieved through intensified sampling. Normally, the moisture content of a chip load delivered at the plant is determined on a single sample, which entails a sampling error between 20 and 100% In contrast, the on-board moisture meter allows multiplying the number of samples, drastically reducing sampling error. As a result, on-board moisture meter readings can deviate between 5 and 20% off the real value as the combined result of measurement and sampling errors, with a potential improvement over current practice. That may offer significant benefits in terms of supply chain optimization. Further test campaigns have been planned for the coming Autumn, in order to better gauge the potential of this new device, and to produce more accurate calibration curves, which will further enhance its accuracy.

8 Conclusions

As required by law and good practice, all work stations were enclosed with red-and-white tape, and the public could enjoy the Demos in absolute safety. A whole tour lasted about one and a half hour, including all explanations. CNR researchers conducted two tours per day, one in the morning and the other in the afternoon. Between tours, ad-hoc demos were conducted, often on demand. At the centre of the Demo area the organizers adapted the local hunters' hut into a comfortable rest station, where visitors received free food and beverages. Each participant received a bag containing machine descriptions, brochures and the INFRES flyer. Informal chatting with visitors provided much positive feedback, and so did the correspondence with the other organizers after the Demo, since all were quite enthusiastic and many suggested to repeat the initiative on a regular basis. It may be safely stated that the Demo in Farra was very successful, thanks to the synergy developed within the organizing group and the very dense technical content, which covered some of the main new trends in mountain logging operations. The rapid development of the bioenergy sector and the increasing demand for biomass fuel has made forest biomass a very important subject, capable of attracting forest owners and logging contractors alike. That is clearly shown in the attendance list, where these two professional profiles represnet a clear majority. Most of the participants had already heard about some of the proposed innovation (e.g. synthetic cable, radio-controlled chokers and forwarders), but they had no direct experience of that. On the other hand, few have ever heard about chipper-trucks or on-board moisture metering. For this reason, the Demo was instrumental in raising awareness of the technical options available for biomass recovery under mountain conditions, and may favour the modernization a sector that is strategic in terms of local development in mountain regions. With this goal, INFRES collaborated with the local and regional actors in order to achieve a strong synergistic effect, so as to reach the largest possible audience at the lowest cost.

9 Acknowledgements

The authors wish to thank the following people & organizations for their support with the demo and the study: Dr. Antonio Bortoluzzi (COGEFOR) and Mr. Lorenzo De Col (COGEFOR); Dr. Antonio Carraro and Dr. Maurizio Dissegna (Regione Veneto); Mr. Giancarlo Bernardi, Raffaele Bernardi and Luca Bernardi (Bernardi Macchine); Ing. Ilario Valentini (Valentini Snc); Mr. Stefano Laugero and Daniele Bertoglio (Pezzolato SpA); the volunteers of the Local Associazione Nazionale Alpini; the municipality of Farra d'Alpago.

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INFRES – Innovative and effective technology and logistics for forest residual biomass supply in the EU (311881)

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Demo Report 10 – Success factors for forest fuel terminals – D4.5

PHOTO: Stockarydsterminalen

Dissemination Level	
	Public
X	Restricted to other programme participants (including the Commission Services)
	Restricted to a group specified by the consortium (including the Commission Services)
	Confidential, only for members of the consortium (including the Commission Services)

Uppsala, September 1, 2014

1. Introduction

Southern Sweden was hit by two major storms in 2005 and 2007, respectively. These storms caused massive windfalls and the timber had to be stored until the industry could process it. This caused a significantly increased use of terminals and consequently an increased number of terminals for forest biomass storing and refining. Many terminals for storage of storm wood became permanent. Storing forest biomass for energy at a terminal can also enable long-distance transport by rail in case the terminal has a railway connection. Such terminals play an important role in facilitating business between regions. Storage and comminution at sending terminals also offer a solution to the problem of lack of storage space and environmental restrictions at the recipients. With an increasing number of large customers in the market more cost effective logistics solutions for terminal handling and railway transportation are demanded. Approximately 30% of forest fuel in Sweden passed through some sort of terminal 2011 (Eriksson 2012).

Open terminals, owned by logistics companies for the handling and storage of goods, have long been a well-known phenomenon, but when it comes to forest products open terminals have been few in Sweden. However, in resent years, some open terminals have been very successful. This fact, along with structural changes in Sweden such as new regulations for measurements of forest fuel, have triggered a need to find out more about what makes a terminal successful. A review of the current terminal structure for handling forest fuel was also required.

The study, from which results were shown during the demonstration, was carried out in cooperation between Skogforsk and SLU. The study consists of an interview part and a map analyze. Thirteen respondents representing different companies participated in the interview study. One of them were Stockarydsterminalen AB where the demonstration was held. The company runs an open railway terminal for forest products in South Sweden (figure 1) since 2008. Around 200 trains are loaded at the terminal yearly. The establishment is an efficient terminal for forest fuel that is continuously developing.

The aim of the demonstration was to spread knowledge and good practice about terminals for forest fuel by showing a successful terminal and presenting the results of the study.

Figure 1. An overview of Stockarydsterminalen. The left track belongs to Stockarydsterminalen AB and the right to Stora Enso. The ditch in the middle separates the two parts. A triangular track is visible at the top of the photo and a measuring station that is used to measure incoming materials is seen at the bottom. PHOTO: Stockarydsterminalen AB.

2. Materials and Methods

Structured in-depth interviews were held with respondents from 5 forestry companies, 4 energy companies and 4 logistic companies (who were running open terminals). Each interview took between 2-3 hours. The interviews concerned the following matters:

- What factors lie behind successful establishment of terminals?
- When is it advantageous to own a terminal, and when is it better to make use of an open terminal?
- What do forestry companies think about their ownership of terminals?

The study also contained the question:

- What are the possibilities for new establishments of terminals for forest fuel (possibly in combination with other products) and if so, which regions would be of highest interest?

The fourth question were tackled by a geographical analyse comparing the catchment areas of existing terminals with locations of forest resources in Sweden. The amount of logging residues and stumps that could potentially be available within 75 km of existing forest fuel terminals was calculated in order to identify areas for establishing new terminals. The calculation was based on the amount of logging residues and stumps falling out as a result of regeneration felling carried out in the reference (Business as usual) scenario in SKA -VB 08 for the period 2010 - 2019. The potentials used are after deductions for ecological, technical and economic restrictions (Skogsstyrelsen 2008; Athanassiadis et al. 2009).

A separate availability-analysis were made for terminals with access to railroad.

The demonstration of results were organized as an open exhibition at the terminal in Stockaryd parallel to the World Bioenergy conference, held by Svebio (the Swedish Bioenergy Association) in Jönköping June 3-5 2014. At the exhibition on the terminal posters presenting results from the project, Infres as well as hand outs could be found. On the 3rd of June a bus-tour from the World Bioenergy conference was organised together with Svebio and oral presentations of the results was made at the terminal. The demo in Stockaryd was advertised on the Stockaryd terminals webpages and the bus tour was advertised in the programme of the World Bioenergy conference.

Results & Discussion

Location was clearly chosen as the most important success factor by all respondents and also by literature (Anon. 2006; Bergqvist et al., 2007). It is closely related to the volume passing through the terminal. A larger forest fuel terminal for seasonal storage holds around 50 000 – 100 000 m^3 of chipped material, but a railroad terminal with big investments must revenue that volume many times per year. Still, seasonal storage are often requested by the terminals customers (normally forest companies). At Stockarydsterminalen this contradiction between high revenue and long time storage has been solved by offering customers a long time storage space nearby the loading terminal. This area is also suitable for chipping operations.

The criterions for a good location can vary depending on the purpose of the terminal and the view of different respondent groups (figure 2). Locations close to forest resources create value by making onward transport and comminution more efficient, while location close to industry allows joint utilization of resources and possibly return transports. For the energy companies, control and proximity to their own furnaces is most important. Therefore a location close to the energy plant is preferred by this group. For some logistic companies, access to railroad remained the base of their entire business model, but also forest companies that didn't have present use for railroad valued railroad access as strategically important. The aspect of strategic localization between forestry resources and customers were mentioned, since terminals lengthen road transports if they are not optimally located in the supply chain. Figure 2 describes the different strategies for localization conceptually.

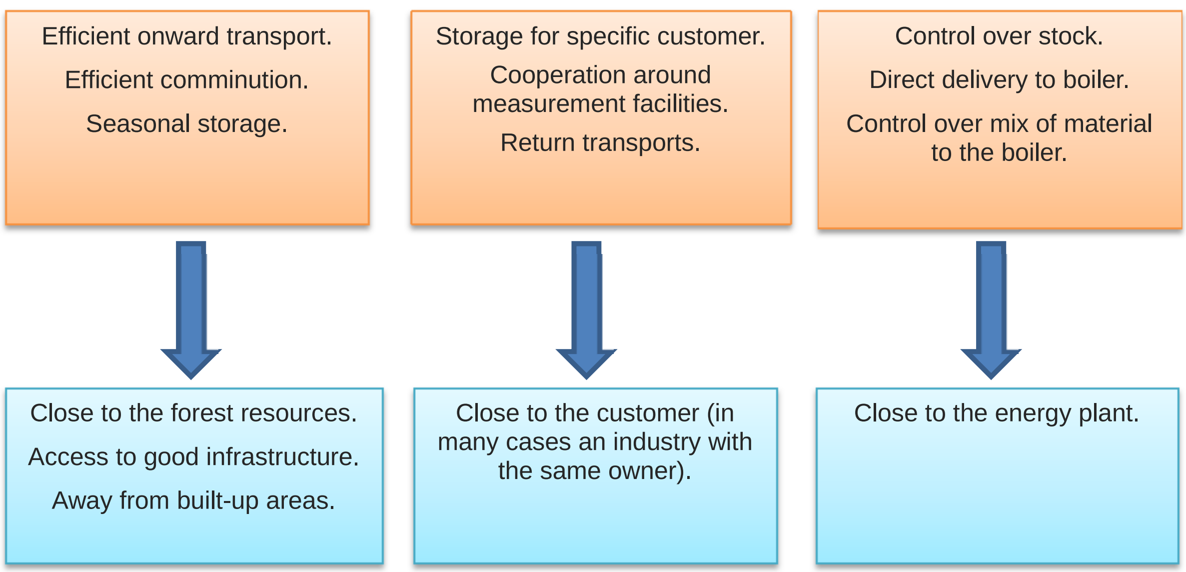

Figure 2. The orange boxes at the top describe different purposes for a terminal and the blue boxes below describe the different strategies for localization. The left column represents the view of ether a logistic company or a forest company. The middle column represents the view of a forest company with an own industry to supply. The right column represents a common view of an energy company.

Four additional success factors are listed below. The comparative importance between them could not be determined from the study.

- Facilities for measurements, such as scale for trucks, a measuring bridge or a drying oven. New requirements for measuring chipped material necessitates new technology, collaboration or merging of smaller terminals.
- Asphalt surface for chips handling is an important factor for ensuring quality by avoiding contaminants such as stones or gravel. However, chipped material is sometimes handled on gravel surfaces since end-customers rarely demanding or paying extra for chips stored on asphalt.
- Skilled, flexible and customer-oriented personnel is an aspect frequently mentioned by the logistic companies running open terminals where forest companies are customers.

- Good internal logistics and order on the terminal is important for many reasons. Old material should not be locked in by new, drivers should easily find their way to the right location on the terminal, cautions against fires should be taken and rail road loading should be organized in order to minimize loading time with available resources. This was also mentioned by Enström & Winberg (2009). Some of the open terminals used signs and marked up spaces very effectively to help the drivers and avoid mixing of materials.

All forest companies described terminal use in general as a necessary evil. But railroad terminals enabling new possibilities for business were exceptions from this opinion. Several forest companies mentioned that they want to stop using smaller terminals, especially in regions far from costumers and instead deliver more material directly to customer. In worst case, they had terminals located in the wrong direction with respect to the customer which cause unnecessary transport of the biomass. Such terminals were naturally the least wanted.

The map analysis showed that approximately 95 % of the Swedish forest fuel were to be found within the catchment areas of existing terminals. It also showed that 65 % of the fuel resources were found within the catchment area of a railroad terminal, although there are no guaranties that the listed terminals have suitable conditions for chips handling.

3. General evaluation

Both the interviews and the map analysis indicate that forestry companies often use too many terminals. The map analysis showed that approximately 95 % of the Swedish forest fuel were to be found within the catchment areas of existing terminals. It should be noted that many of the terminals are owned by a specific forest company and they may not grant other companies access to it. Hence the real coverage might be lower if we consider actual accessibility to a terminal. But since most of the raw material are not passing through a terminal at all, it is likely to believe that there are actually too many terminals, at least in some regions. This conclusion is also supported by the interviews.

Consequently, new initiatives would primarily involve mergers of terminals to strategically important places (often with railroad connection) to create sufficient volumes for investments.

Railroad terminals are rarely built for fuel handling alone. In most cases timber is the main product and forest fuel may be stored where there is capacity. But in order to create an efficient internal logistic one should be aware that moving chips is costly and that a good plan when material arrives could minimize the total driving distance and increase the total profit of the terminal (Enström & Winberg 2009, cf. figure 3). The configuration of tracks at the terminal also effects the shunting cost (cf. Frosch & Thorén 2010). The terminal in Stockaryd has a triangular connection to the main track that enables trains that come from any direction to leave in any chosen direction as well (figure 4). Trains can easily turn around there. The loading track is 550 m which is normally long enough for a full train to be loaded. The electrification goes all the way to the loading track. These factors are important for the terminals attraction of customers. They also prioritize service and try to offer more than just train-loading services

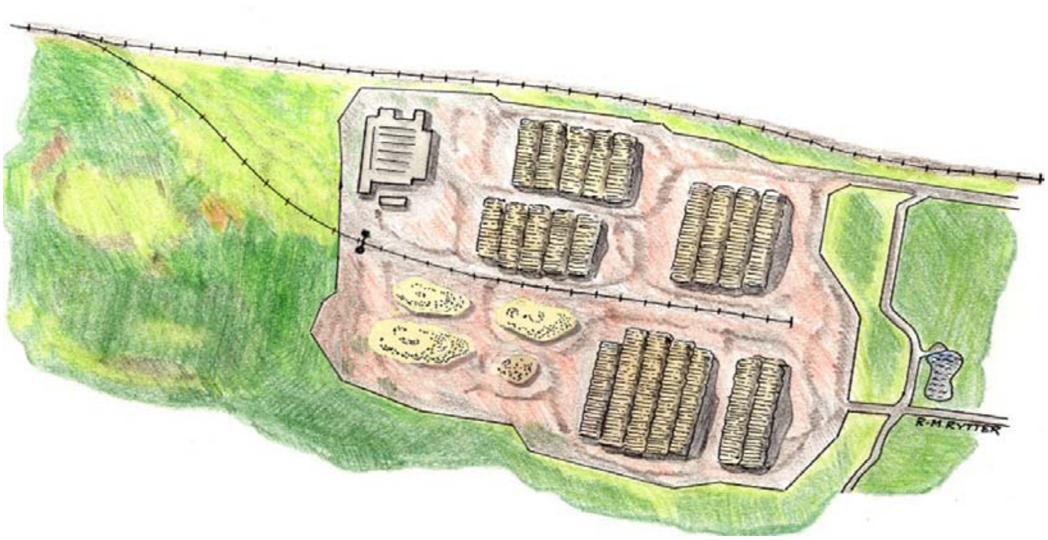

Figure 3. General sketch over a combined terminal for forest products. There are loading space on both sides of the track which enables short driving distances. Electrification goes all the way to the terminal and ends by the two dots in the sketch so the train (with electric engine) can reverse onto the loading track without the need for a diesel engine.

Figure 4. A triangular track connects the terminal in Stockaryd with the main track (named Södra stambanan). The picture is taken from the terminal looking in the direction of Södra stambanan. PHOTO: Stockarydsterminalen

4. Demo results

The poster exhibition were shown at the terminal in Stockaryd June 3rd to5th, and during this time there was 95-100 visitors according to the staff at the terminal. In addition to the poster exhibition several manufacturers of equipment demonstrated products aimed at terminal handling and biomass comminution at the terminal (figure 5). The visitors at the World Bioenergy conference were fewer than expected and even tough the bus tour were well announced it was competing with 3 other tours and several indoor sessions. Thus, only one person showed up for the bus-tour from World Bioenergy to Stockarydsterminalen. The participant were a Finnish researcher with a high interest in terminals.

Figure 5. Several manufacturers of equipment demonstrated there products at Stockaryd. Here a chipper-truck, built by OP System, chipping into the trailer.

5. Acknowledgements

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6. References

Anon. (2006). *Inland container terminal analysis. Final report*. British Columbia. IBI Group. Electronic version available: http://www.th.gov.bc.ca/PacificGateway/documents/061215_Inland_Container_Terminal_Analysis.pdf (2013-04-26)

Athanassiadis, D., Melin, Y., Nordfjell, T & Lundström, A. (2009). *Harvesting potential and procurement costs of logging residues in Sweden*. In M. Savolainen (Ed.), 4th International Bioenergy conference, Bioenergy 2009 - Sustainable Bioenergy Business (pp 293-300). Jyväskylä: FINBIO publication 44. ISBN 978-952-5135-43-5.

Bergqvist, R, Falkemark, G & Woxenius, J. (2007). *Etablering av kombiterminaler [Establishing intermodal terminals*] Göteborg: Division of Logistics and Transportation, Chalmers University of Technology. (In Swedish)

Enström, J & Winberg, P (2009). *Systemtransporter av skogsbränsle på järnväg [Systems for transporting forest fuel on rail]* Uppsala: Skogforsk (Arbetsrapport 2009:678). (In Swedish)

Eriksson, U. (2012). Inventering bränsleterminaler 2011. [Inventory of forest fuel terminals 2011] Electronic version available: http://ny.sdc.se/admin/Filer/Inventering%20br%C3%A4nsleterminaler%202011.pdf (In Swedish)

Frosch, M. & Thorén, P. (2010). Järnvägstransport av biobränslen [Rail transportation of bio fuel.] Värmeforsk report 1138. Electronic version available: http://www.varmeforsk.se/rapporter?action=show&id=2541 (In Swedish)

Skogsstyrelsen. 2008. *Skogliga konsekvensanalyser och virkesbalanser, SKA-VB 08*. Rapport nr 25. Jönköping, Sverige (In Swedish)

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INFRES – Innovative and effective technology and logistics for forest residual biomass supply in the EU (311881)

Johanna Enström, Henrik von Hofsten (Skogforsk)

Demo Report 11 – Demonstration of a High Capacity Vehicle for chips transport at Political week in Almedalen – D4.5

Uppsala, September 12, 2014

Dissemination Level	
Public	X
Restricted to other programme participants (including the Commission Services)	
Restricted to a group specified by the consortium (including the Commission Services)	
Confidential, only for members of the consortium (including the Commission Services)	

1. Introduction

Background to the objective

Forest products offers a rich source of renewable energy and is an important part of the Swedish and Finish energy budgets. Most of this is based on forest biomass, mainly in the form of industrial residues and by-products from the forest industry. These sources are almost fully utilised today, and therefore also primary forest fuels are used, mainly in the form of tops and branches from final felling, a.k.a. logging residues (Björheden 2011).

The economical margins for forest fuel is lower than for any other forest product and the product-value concentrated on a single truck-load is among the lowest compared to all other transports. This brings an enormous challenge to cut the logistic costs in order to enable long distance transport and use of forest fuel as an energy source. Efficiency in transport plays an important role in tackling that challenge.

Since studies of High Capacity Transport vehicles (further on mentioned as HCT-vehicles) has shown great potential in lowering transport costs along with emissions of CO_2, the aim of this demonstration was to inform decision-makers but also the general public about these possibilities and to meet questions and concerns that many people have about heavy vehicles.

High capacity vehicles in forestry -the current situation

Swedish legislation today allows vehicle combinations of maximum 25.25 m and a maximum gross vehicle weight (GVW) of 60 tonnes. However, research on heavier and in some cases longer vehicles is going on in Sweden since 2006. This is made possible by exemptions from the weight and length regulations given to test vehicles by the traffic authorities. The project ETT (*En Trave Till* in English *One More Pile*) is a research project lead by Skogforsk, which goal is to collect knowledge around High Capacity Transports (HCT) within the forestry sector in order to facilitate a broad implementation of HCT vehicles in Sweden. The research project is following the long term performance of 20 test vehicles used in different parts of the country. Two of these vehicles are longer vehicle combinations of 30 m length and 90 tonne GVW, the other 18 vehicles stays within the current length limit but has a maximum GVW of 74 tonne. There are also 33 other HCT vehicles being tested within different transport segments in Sweden in other research projects.

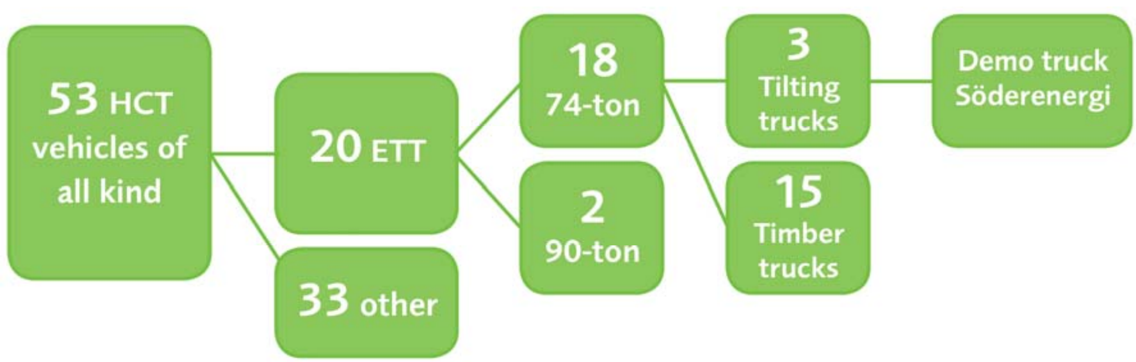


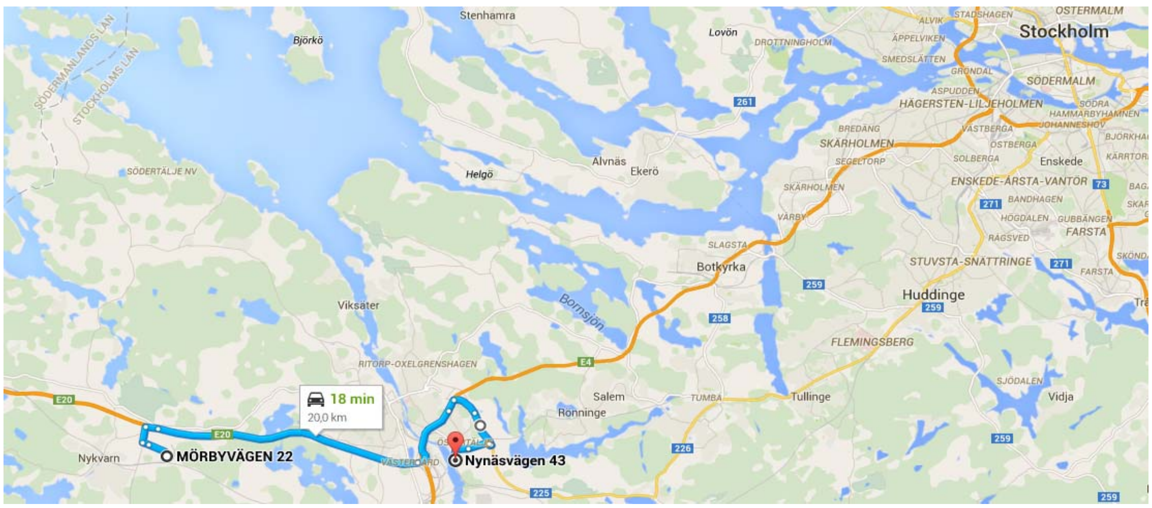
Figure 1. The figure shows the active HCT vehicles in Sweden and within the ETT project 09-09-2014. The subject for the demonstration was a tilting truck working for the energy company Söderenergi in Södertälje.

In Finland 76 ton GVW is generally allowed since October 2013. In Sweden, the possibility to allow 74-ton on part of the road-network is currently debated. The research that has been going on since 2006 has shown that a raise of total weight would be economically profitable as well as for beneficial to the environment since fuel consumption per transported tonne of goods decreases. Safety aspects have been evaluated as well and no increased risks, compared to vehicles within the current regulation, has been noted.

13.2.2015

The vehicle demonstrated in Almedalen was a 74-ton chip truck transporting forest chips for the energy company Söderenergi in Södertälje (photo on front page). Söderenergi produces heat and electricity at their CHP plant Igelstaverket located south of Stockholm. Igelstaverket is connected to the Stockholm network of district heating and provides heat for around 300 000 citizens, as well as for offices and industries. Söderenergi also provide electricity for 100 000 households. In their production Igelstaverket use around 1.7 TWh of fuel yearly, i.e. approximately 2 million m^3 of forest chips. The main sources are bioenergy from forest, forest industries and recycled wood. (www.soderenergi.se)

Södertälje is a densely populated city and most of the 1.7 TWh fuel must be found outside the closest region. The company has a harbour where they receive around 50 % of the material. For the other half Söderenergi uses trucks and trains on a fairly equal basis. They have a receiving train terminal located at Nykvarn, 20 km west of Igelstaverket. The terminal was built in 2009 for storage, comminution and reloading from train to truck. The terminals location was chosen since no closer location that could fulfil all requirements. Three tilting chip trucks are shuttling chipped fuel from the train terminal to the plant. The trucks are owned by Ove



Lindkvist Åkeri, who recently invested in the new 74-ton truck for chips.

Figure 2. The rout between the terminal in Nykvarn (Mörbyvägen) and the CHP-plant (Nynäsvägen).

Almedalen

Every summer in Sweden, a political-week is arranged in the medieval town Visby, on the Island of Gotland. It is often mentioned as Sweden´s biggest political meeting place, as this year was an election year it was more than 30 000 visitors. The eight political parties in the Swedish parliament have at their disposal one day each containing speeches by the party leader and intense media coverage. Skogforsk together with Söderenergi were one of 1459 organisations participating in the event and seeking the attention of visitors in general and decision makers in particular. For the demo, Söderenergi's 74 ton chip-truck were transported to Visby were Skogforsk and Söderenergi demonstrated it during 4 days of the political week (Sunday till Wednesday). Representatives from Skogforsk and Söderenergi held presentations every day about the ETT and Infres-projects and were available for meeting visitors. Seminars were also arranged (in the open trailer) where politicians and representatives from a number of organizations were invited as speakers. See the attached program with speakers in appendix 1.

2. Materials and Methods

At the time of the demonstration, the first 74-ton truck for chips had just been built, so naturally, the presented results had had to be based on the extensive research material gathered during 8 years of studies of 74-tonne timber trucks. A second demo of the 74 tonne chip truck is planned for 2015, where results from the current fuel measurements on the chip trucks will be presented.

Data on comparisons of 60 and 74 ton vehicles under equal conditions has been taken from Skogforsk's report *Focus Weeks 2013 – Monitoring fuel consumption of two rigs in the ETT demo project, ST-crane and ST-group* (Edlund et.al. 2013). The ABba-method was used for the comparison, which means that the trucks drive loaded one way and unloaded the other way back, hence fuel consumption is an average of the loaded and unloaded transport. The monitoring of fuel consumption was made through the trucks built in computer (Scania's Fleet management system). The manufacturer and hauler companies have given the researcher group access to this information. The loaded weights were provided by the driver for each load. Here, a summary of the results of the 74 ton vehicle without crane (ST-group) will be presented, since that is the most similar concept to the chip-truck.

Data for ST-group and the reference vehicle is shown in table 1. The truck called Reference, is the actual ST-group vehicle loaded to only 60 ton and with one axle lifted (lifting 2 axles were not possible). Compensation in fuel consumption has been made for the extra axel and 2.8 ton of the vehicle weight have been counted as load to compensate that the unloaded weight of the ST-group vehicle is that much higher than that of a normal 60-ton vehicle. The truck was a Volvo with a 16 litre engine (Euro 5, 700 hp).

	ST-group	Reference
Max GVW (ton)	74	60
Number of axels	9	8
Vehicle weight (ton)	19.0	16.2*

*Table 1. Data of ST-group and the reference vehicles. (*after compensation)*

The measurement ml/ton*km (*millilitre per tonne*kilometre)* is used to compare the fuel efficiency per transported unit between vehicles with different capacities. Hence tonne refers to the actual weight of the transported timber, here maximum 55 tonnes without breaking the law.

3. Results & Discussion

The studies have shown that a 74 tonne roundwood vehicle, without crane, significantly reduces fuel consumption per tonne transported goods by around 13% compared to if a 60-ton vehicle was used (Edlund et.al. 2013). This figure should be seen as a potential since it is only measured on one truck under one set of circumstances, but the study do use the same driver for both trucks. Control vehicles were used to assess the influence of external factors between replications.

	Average fuel consumption	ST-group savings
ST-group	19.6 ml/ton*km	13.2 %
Reference	22.6 ml/ton*km	

Table 2. Fuel consumptions and fuel savings according to (Edlund et.al. 2013).

A similar comparison study for the 90 ton truck have been published earlier in the synthesis report *ETT – Modular System for Timber Transport (Löfroth & Svenson 2011).* It shows that a 90 tonne truck saves 20 % in fuel consumption and around 20 % in costs per transported unit. This report also include technical descriptions of the vehicles and results from road wear studies, performance and safety studies in addition to the fuel consumption and effectivity studies. The cost savings per transported unit lies around 10% (Löfroth & Svenson 2011). The increased load capacity is between 20-25 % compared to a traditional timber truck without crane. The manoeuvrability, and safety aspects in general, are comparable to a conventional 60-tonne vehicle (Hjort & Sandin 2012).

13.2.2015
The Swedish National Road and Transport Research Institute (VTI) has been responsible for studies of safety aspects and has given out the reports Traffic safety effects due to an introduction of longer and heavier vehicles – a literature overview, (Hjort & Sandin 2012) and The effects of long and heavy trucks on the transport system - Report on a government assignment, (Vierth et.al. 2008). Vierth include analysis of the competition between road and rail transportation and the economic assessment of present-day vehicle regulations in Sweden compared to the EU-standard. The safety aspect has also been studied by Wåhlberg 2008. The report is a quantitative analysis of the international research of the effects of increased vehicle size on traffic safety. It concludes that a shift towards heavier vehicles would at worst have no safety impact at all, and in the best case a clear positive effect on traffic safety. Although, there might still be road types and environments less appropriate for heavier vehicles.

Skogforsk is currently monitoring fuel consumption and load weights for all vehicles within the ETT-project, currently 18 vehicles of which 8 have been studied long enough to be included in the latest report *Continual monitoring of fuel consumption and load utilization*, (*Widinghoff 2014)*. The average consumption for vehicles without crane (three vehicles) were 25.03 ml/ton*km. This figure is not comparable with the 19.6 ml/tonne*km in (Edlund et.al. 2013) since that study was performed only on public roads (on asphalt) in a special region. In (Widinghoff 2014) two of the three trucks had problems in reaching the maximum load weight because the volume were limiting. After what is known about the density of the material transported to Söderenergi, this is not expected to be a problem for the chip-truck.

The results from studies of roundwood vehicles are assumed to be well applicable also on chip trucks. The same kind of monitoring and studies of fuel consumption and loaded weight are currently being carried out for them and the results will be presented during 2015.

4. General evaluation

The presented results had to be based on earlier studies of 74-ton timber trucks. However given the weights and measurements of the new chip trucks, the increase in efficiency should be slightly higher compared to the timber trucks so there is reason to believe that the environmental benefits would be larger. The short driving distances (20 km) on the other hand holds a challenge on the economic side since loading time will have a high percentage of the total time. Economic gain is still expected but further studies will show in which range. The reduction in the number of loads needed to transport a given volume of fuel will probably be beneficial to other road users as the roads between the terminal and the CHP-plant are heavily trafficked. Hence, the project has a great potential for both environmental and economic benefits.

Even though we had to lean on the timber trucks results, this was the best possible time for a demonstration with decision makers in focus since a political decision were to be expected very soon based on current knowledge. It was especially important to point out the central role that efficient transport have in order to increase the use of biofuel. The cooperation with Svebio (Swedish bioenergy association) strengthened this message. Another point was to show that road and rail transport are not contrary. Both are needed in the transportation chain and should be performed as efficient as possible.

5. Demo results

A reflection from participation in Almedalsveckan is that it was difficult to find people who were not representing an organization there. Hence "general public" were mainly addressed through media. Our demonstration managed to be published three times in media: The papers *Svensk Åkeritidning (Swedish haulers magazine)* http://www.akeritidning.se/svensk-akeritidning/nyheter/2014/06/29/almedalsveckan-2014-tyngst-i-almedalen, the magazine *Trailer* http://www.trailer.se/news.php?id=10172 and a web-interview in the ATL (Agricultural Business Paper) http://www.atl.nu/atl-play/se-s-derenergis-nya-74-tonsbil .

A number of decision makers and opinion makers were invited as speakers, others showed up to get some information on HCT vehicles. Among the speakers (appendix 1) were Karin Svensson Smith, the current chairman of the parliamentary committee on transportation. We also met a representative from Swedish Association of Local Authorities and Regions, which are one of the referral organizations for the government in questions about new traffic legislation.

The political week in Almedalen had over 30 000 visitors. Around 55 persons participated in the events around the truck. Söderenergi and Skogforsk are pleased with the results.

6. Acknowledgements

The authors wish to thank the following organizations for making this demonstration possible: Söderenergi for their huge engagement in both preparations for and performance in Almedalen, Owe Lindkvist Åkeri for providing the truck and for personal engagement, Svebio for their cooperation with the program which attracted more people to the demonstration. We also thank all of our speakers during the four days in Almedalen.

The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2012-2015] under grant agreement n°311881. The sole responsibility for the content of this report lies with the authors. It does not necessarily reflect the opinion of the European Communities. The European Commission is not responsible for any use that may be made of the information contained therein.

7. References

Björheden, R. 2011. Growing Energy – the development of forest energy in Sweden. In: Efficient forest fuel supply systems. Composite report from a four year R&D programme 2007-2010. Skogforsk, Uppsala. ISBN: 978-91-977649-4-0.

Edlund J., Asmoarp V., Jonsson R., 2013. Focus *Weeks 2013 – Monitoring fuel consumption of two rigs in the ETT demo project, ST-crane and ST-group*. Skogforsk Arbetsrapport 803 -2013.

Hjort M. & Sandin J. 2012. Traffic safety effects due to an introduction of longer and heavier vehicles – a literature overview. VTI (National Road and Transport Research Institute), Linköping, Sweden

Löfroth C. & Svenson G. 2012. *ETT – Modular system for timber transport – One More Stack (ETT) and Bigger Stacks (ST)*. Skogforsk Arbetsrapport nr. 758 2012. Available in English at: http://www.skogforsk.se/english/projects/ettdemo---en-vag-till-ett-biobaserat-samhalle/ (2014-11-24)

Vierth I., Berell H., McDaniel J., Harldsson M., Hammarström U., Yahya M., Lindberg G., Carlsson A., Ögren M., Björketun U. 2008. The effects of long and heavy trucks on the transport system. Report on a government assignment. VTI (Swedish National Road and Transport Research Institute).

Widinghoff J. 2014. Continual monitoring of fuel consumption and load utilization of ETT- and ST-vehicles. Skogforsk Arbetsrapport nr. 831-2014.

af Wåhlberg, A. E. 2008. Meta-analysis of the difference in accident risk between long and short truck configurations. Journal of Risk Research, 11:3, 315 - 333

Webpage:
http://www.soderenergi.se/web/Foretaget.aspx (2014-11-24)

Appendix 1.

Kliv in i en av Sveriges första 74-tons flisbilar!

Demonstration och seminarium i Almedalen, 30 juni - 2 juli

Vi demonstrerar bilen och håller seminarier kring energieffektiva och klimat-smarta bränsletransporter.

Söderenergi
El och värme för ett hållbart samhälle

SKOGFORSK

Moderator, där inget annat anges:
Madeleine Engfeldt-Julin, kommunikationschef, Söderenergi

PROGRAM

Söndag 29 juni

14.00	Forskningsresultat kring effektivare transporter samt flisbilens roll i logistikkedjan **Johanna Enström**, projektledare Skogforsk och **Olle Ankarling**, logistikansvarig Söderenergi. Passa också på att kliva in i bilen!
16.00-17.30	Biobränslescenarier – hur mycket biobränsle kan vi använda i det svenska energisystemet år 2030? **Gustav Melin**, vd Svebio föredrar en ny rapport av Håkan Sköldberg och Mårten Haraldsson, PROFU. Kommentarer från **Maria Sunér Flemming**, Svenskt Näringsliv, **Per Kågesson**, debattör och författare, **Karin Medin**, vd Söderenergi, **Ann-Marie Lindell**, strategichef Göteborg Energi. Flera politiker förväntas medverka. Moderator: Lena Bruce, vvd Svebio
18.00	bilen stänger.

Måndag 30 juni

09.00	öppnar lastbilen.
11.30-14.00	Energieffektiva och trafiksäkra transporter av förnyelsebara bränslen *Effektivare transporter av biobränslen.* **Johanna Enström**, projektledare Skogforsk och **Karin Medin**, vd Söderenergi. *Bioenergi Sveriges största energislag. Hur utvecklar vi potentialen?* **Gustav Melin**, vd Svebio.
12.15	Mingel – Vi bjuder på lunchmacka och dryck.
13.00	Släpp bromsen och skapa mer trafiksäkra, energieffektiva och hållbara transporter nu **Karin Svensson Smith** (mp), **Göran Lindell**, (c), **Gustav Melin**, Vd Svebio, **Olle Ankarling**, logistikansvarig Söderenergi, **Johanna Enström**, projektledare Skogforsk och **Henrik von Hofsten**, forskare Skogforsk.
15.00	Forskningsresultat kring effektivare transporter samt flisbilens roll i logistikkedjan **Johanna Enström**, projektledare Skogforsk och **Olle Ankarling**, logistikansvarig Söderenergi Passa också på att kliva in i bilen!
17.00	bilen stänger.

forts. n.s.

13.2.2015

Kliv in i en av Sveriges första 74-tons flisbilar!

Demonstration och seminarium i Almedalen, 30 juni - 2 juli

Vi demonstrerar bilen och håller seminarier kring energieffektiva och klimat-smarta bränsletransporter.

Söderenergi
El och värme för ett hållbart samhälle

SKOGFORSK

forts. PROGRAM

Tisdag 1 juli

09.00	öppnar lastbilen.
10.00-12.00	Effektivare transporter av biobränslen samt större lastbilars roll bland flera trafikslag
	Bioenergi – Sveriges största energislag. Hur utvecklar vi potentialen? **Lena Bruce**, vvd Svebio
	Forskningsresultat kring effektivare transporter samt flisbilens roll i logistikkedjan. **Johanna Enström**, projektledare Skogforsk och **Karin Medin**, vd Söderenergi.
10.30	*Vad betyder större lastbilar för godstransporter på järnväg?* **Jan Kilström**, vd Green Cargo.
11.00	*Vad betyder större lastbilar för åkeriföretagen?* **Rikard Gegö**, vd Sveriges Åkeriföretag.
	Energieffektivisering av skogsbrukets transporter. **Anders Örtendahl**, operativ transportchef Stora Enso.
	Diskussion
12.00	Mingel – Vi bjuder på lunchmacka och dryck.
12.30	Energieffektiva transporter för Skogsindustrins konkurrenskraft **Karolina Boholm**, Skogsindustrierna **Anders Örtendahl**, operativ transportchef Stora Enso, **Olle Ankarling**, logistikansvarig Söderenergi och **Johanna Enström**, projektledare Skogforsk.
15.00	Forskningsresultat kring effektivare transporter samt flisbilens roll i logistikkedjan **Johanna Enström**, projektledare Skogforsk och **Olle Ankarling**, logistikansvarig Söderenergi.
	Passa också på att kliva in i bilen!
17.00	bilen stänger.

Onsdag 2 juli

09.00	öppnar lastbilen.
10.00-10.30 samt 13.00-13.30	Forskningsresultat kring effektivare transporter samt flisbilens roll i logistikkedjan **Johanna Enström**, projektledare Skogforsk och **Olle Ankarling**, logistikansvarig Söderenergi.
	Passa också på att kliva in i bilen!
14.00	bilen stänger.

Personal bl.a. Ove Lindkvist, åkeriägare, kommer att finnas på plats under bilens öppettider för att berätta mer om forskningsprojektet, demonstrera bilen samt om bränsleförsörjning till Sveriges största bioeldade kraftvärmeverk, Igelstaverket i Södertälje.

INFRES PROJECT CONTACTS

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INFRES – Innovative and effective technology and logistics for forest residual biomass supply in the EU (311881)

Jyrki Raitila, VTT

DEMO REPORT 12 – Drying of wood chips in a warm air dryer

Dissemination Level	
Public	X
Restricted to other programme participants (including the Commission Services)	
Restricted to a group specified by the consortium (including the Commission Services)	
Confidential, only for members of the consortium (including the Commission Services)	

Jyväskylä, Finland, 20 January 2015

Content

Preface

Natural Resources Institute Finland(Luke) is coordinating a research and development project 'Innovative and effective technology and logistics for forest residual biomass supply in the EU –INFRES'. The project is funded from the EU's 7th framework programme. INFRES aims at high efficiency and precise deliveries of woody feedstock to heat, power and biorefining industries.

INFRES concentrates to develop concrete machines for logging and processing of energy biomass together with transportation solutions and ICT systems to manage the entire supply chain. The aim is to improve the competitiveness of forest energy by reducing the fossil energy consumption and the material loss during the supply chains. New hybrid technology is demonstrated in machines and new improved cargo-space solutions are tested in chip trucks. Flexible fleet management systems are developed to run the harvesting, chipping and transport operations. In addition, the functionality and environmental effects of developed technologies are evaluated as a part of whole forest energy supply chain.

Moisture is the most important quality factor of fuelwood. It affects both, profitability of supplying wood chips and economy of running a heating plant. Most fuelwood is seasoned outdoors. Although this method is cheap, it depends on the weather and therefore a desired moisture level of wood cannot always be reached.

To get rid of weather dependency, wood chips can easily be dried in driers connected to a heating plant. Investment and running costs of a dryer determine how feasible such a drying method is as part of the wood fuel supply chain. This report contains a simple feasibility analysis of drying chips at a small or medium scale heating plant. Drying was also demonstrated in practise and the main principles of artificial drying were explained in a seminar.

This publication is a part of the INFRES project. The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2012-2015] under grant agreement n°311881.

Jyrki Raitila

Jyväskylä, 20/1/2015

1 Introduction

The most important quality factor of fuelwood is moisture. In order to increase the calorific value of fuelwood, regardless the form, wood has to be dried. Besides, most boilers and combustion devices cannot combust wet wood efficiently. Traditionally fuelwood is seasoned in outdoor storages until the desired moisture level has been reached. These storages, often simple stockpiles at a landing, serve also as a buffer for high fuel demand in winter. The moisture content of fresh wood varies from 45% to 55%, depending on the species and the logging time (Erber et al. 2014). In average drying conditions moisture can decrease to 30% at the end of the first drying period (Apr-Sep) in the Nordic countries. However, after that the average moisture of stacked fuelwood tends to increase in the fall and winter by 5-10% (Nurmi & Hillebrand 2007).

Most fuelwood supply chains follow the same principles. First trees are felled, delimbed and forwarded to a landing where they are stacked for storage or transported to a specific storage site such as a wood yard or terminal (Routa et al. 2013). Then they are seasoned long enough to ensure moisture has decreased to a desired level. Finally after six to twelve months storage periods wood stacks are chipped and wood chips are transported to a heating or power plant for energy generation. Some suppliers may chip semi-dried logs and store these chips at the plant. Naturally variations of these supply chains and methods occur depending on harvesting circumstances such as the terrain and machines as well as types of fuelwood to be harvested. For example, in Nordic countries logging residues and wholes trees are used much more extensively than in Central and Southern Europe (Routa et al. 2013).

Although the most common contemporary supply methods of fuelwood originate from experience and good practices, they all have some significant weaknesses with regard to quality management. Outdoor seasoning is always very weather dependent and therefore only estimates can be provided for moisture. Because of constantly changing drying conditions, moisture of delivered wood chips inevitably fluctuates. In a rainy year wood fuel may never reach a desired moisture level and the end-user has to therefore combust wet wood (Heiskanen et al. 2014). If too wet wood is used, the efficiency of a boiler decreases, malfunctions increase and the highest output cannot be reached. Besides, much more wood is needed to produce the needed amount of energy. Small heating plants and boilers require much dryer wood chips (<30% moisture) compared to large power plants that can combust wood chips containing water as much as 50% (Otepka et al. 2014). In any case, it is always more economical to use dryer wood chips.

Another challenge of seasoning wood outdoors is related to general storage management and costs. The larger the end-user, the more wood has to be stored in advance in order to meet high demand in winter. This may make storage management complicated if wood stacks are distributed at many landings around the end-user. In any case, keeping large amounts of wood in storages for a long time is costly and involves a risk of losing some value of stored wood because of a decreased quality or material losses for example by natural biodegrading (Heinek et al. 2012).

One possibility of drying wood chips is to do it in a warm air dryer built next to a heating plant. Small- and medium-sized heating plants have significant excess heating capacity most of the year. Their utilization rate is less than 50% on average. Only during a couple of winter months do they work close to their full capacity. Therefore, fuel wood dryers could use this excess capacity to dry wood chips to be used in these heating plants. (Raitila & Heiskanen 2014)

2 Aim

This drying study and demo aimed to show possibilities and benefits of drying wood chips in warm air dryers as part of a fuel supply chain. It also aimed to provide calculation tools and practical examples for entrepreneurs and other fuelwood suppliers for understanding the basics of warm air drying. This understanding is needed for either building or buying such a dryer.

3 Materials and methods

3.1 Drying model

In order to understand some of the physics of drying and how to size a fuelwood dryer, an Excel based calculation model was created. Using such a calculator is simple. The user fills in certain basic values according to which the model calculates corresponding parameters. Variations of the result parameters can be tested by inserting different basic values. A sample calculation is provided in Annex 1.

3.2 Seminar

A full day drying seminar was organized in connection with a dryer demonstration at Bioeconomy Institute of JAMK (Jyväskylä University of Applied Sciences) in Saarijärvi, Central Finland. This seminar was conducted by Metsäkeskus (Forestry Centre), JAMK, POKE (Vocational Institute of Northern Central Finland) and VTT. The seminar was attended by 35 people, of which most were entrepreneurs. Some students and researchers participated part of the day. The following topics were discussed:

- Drying of wood – delimbed stems and wood chips (VTT)
- Drying wood chips and firewood on asphalt (SeAMK)
- Basics of warm air drying (VTT)
- Introduction to JAMK's dryers
- Study on market potential of high quality wood chips (JAMK)
- Enhancing economy of firewood business (JAMK)
- Combustion study of wood chips with different moisture contents (JAMK)

3.3 Drying demonstration

After the seminar it was possible to visit two dryers and biomass combustion laboratory at Bioeconomy Institute. One of the dryers was built in an old freight container and another in a barn type storage. The institute has a wood chip firing boiler (250 kW) that can be used as a heating source for both dryers as well. It is also possible to use a separate boiler (80 kW) to heat drying air used in the dryers. For testing and in summer it is more economical to use the small boiler.

Building a biomass dryer is reasonably easy but several aspects should be considered carefully:

- Annual drying volumes, amount of wood chips
- Volume of the dryer, size of one batch
- Initial moisture of wood
- Target moisture of wood
- Source of heat, available output
- Temperature of heating air
- Ambient conditions
- Size and amount of blowers
- Circulation of drying air
- Heat exchangers and heat recovery

In simple and inexpensive dryers drying air is blown into the dryer from one end and led out from the opposite side. Without circulating warm air in the drying chamber and without controlling temperature and moisture levels of outgoing air the dryer works inefficiently, however. When wood chips are being dried, it is important to use a reasonable amount of wood chips in the drying batch, the thickness of the wood chip layer corresponding to the size and output of the air blower. The back pressure of one meter thick wood chip layer and how to choose a corresponding blower are illustrated in Figure 1.

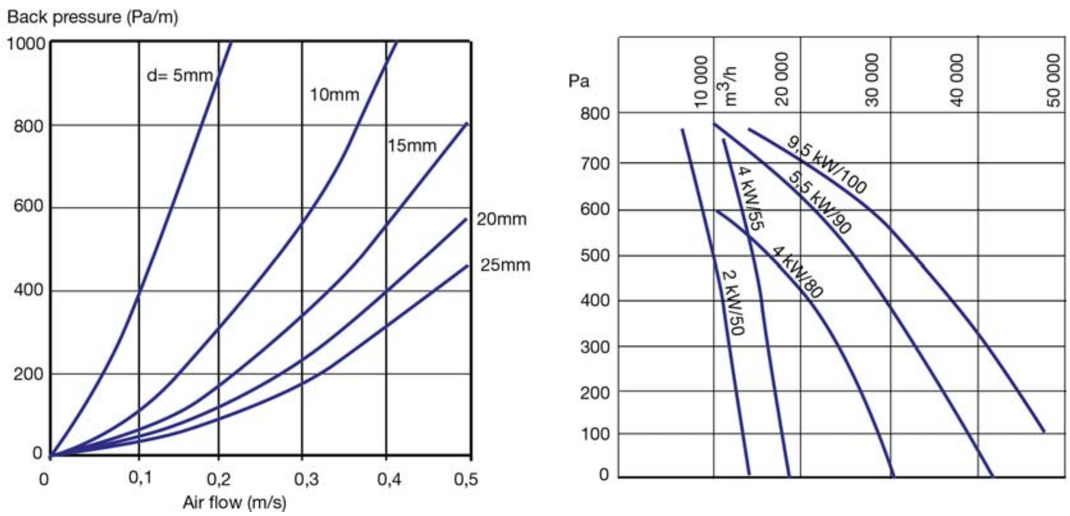

Figure 1. Left: Back pressure (Pa) caused by the wood chip layer as a function of air flow and chip size (d). Right: The required blower output and diameter of the blower as a function of back pressure and air volume flow.

In the container used for the demonstration (Figure 2), warm air is led into the chamber through a heat exchanger placed on top of the container. In such a small dryer one 2.5 kW blower provides more than enough drying air for wood chip batches of 15 to 20 loose-m^3. Warm air is blown through wood chips and led out into a discharge tunnel from the bottom through a perforated floor. Before going out warm wet air is circulated through the walls of the dryer to heat the container. It is also possible to circulate some of this warm air back into the chamber if so desired, for example when air is not fully saturated with water and still has drying capacity left.

Figure 2. The demonstrated warm air dryer was built into an old freight container (left). A separate 80 kW boiler and control system were placed in another container (right).

For a short drying demonstration the drying chamber was divided into two boxes where wood chips made from pine whole trees and stem wood were put. This way it was possible to compare whether whole tree chips would dry differently from stem wood chips. For the drying model, two different chip layer depths, 0.5 and 1 m, were tested (Figure 3).

Figure 3. The drying chamber was divided in two boxes so that it was possible to test and demonstrate the drying of two different wood chip types.

4 Results and discussion

4.1 Drying demonstration

Because all chip batches were relatively small (3.2 m^3) compared to the capacity of the dryer (15-20 m^3), all wood chips dried very fast and evenly. The main measurements and results are summarized in Table 1. Usually wood chips made from whole trees contain more fines and therefore require more output from the air blower to ensure sufficient air flow through wet wood chips. In this demo, however, particle sizes of both wood chip types did not differ very much from each other, and therefore air flow through both chip layers was very similar (see air pressure differences). In general, this demo showed that this kind of inexpensive freight container dryer is suitable for drying both types of wood chips. It has also proved to work nicely for log wood in previous tests.

Table 1. Main measurements of the drying demo in which 3.2 m^3 of both whole tree and stem wood chips were dried. The wood chip layer was 1 m thick.

	Whole tree chips	**Stem wood chips**
Initial moisture	38.2%	43.5%
Average wood chip size	8-16 mm (P16)	8-16 mm (P16)
Moisture after drying, top	1.9%	2.4%
Moisture after drying, bottom	5.5%	7.7%
Average air flow	3.4 m/s = 1,000 m^3/h	3.4 m/s = 1,000 m^3/h
Demonstration time	120 h	120 h
Air pressure difference between top and bottom	28 Pa	30 Pa

Drying was monitored with several data loggers measuring the temperature of incoming and outgoing air, water content of incoming and outgoing air and relative humidity of drying air. As seen in relative air humidity curves (Figure 4 & 5), whole tree chips dried faster because their initial moisture was lower than that of stem wood chips. In this demonstration wood chip were dried ‘too dry’ in order to get enough data from the whole drying period. In fact, wood chips were bone dry already half way the demo period. For more energy efficient drying, part of drying air should be circulated back into the drying chamber or the process should be stopped when the humidity of outgoing air begins to decrease rapidly.

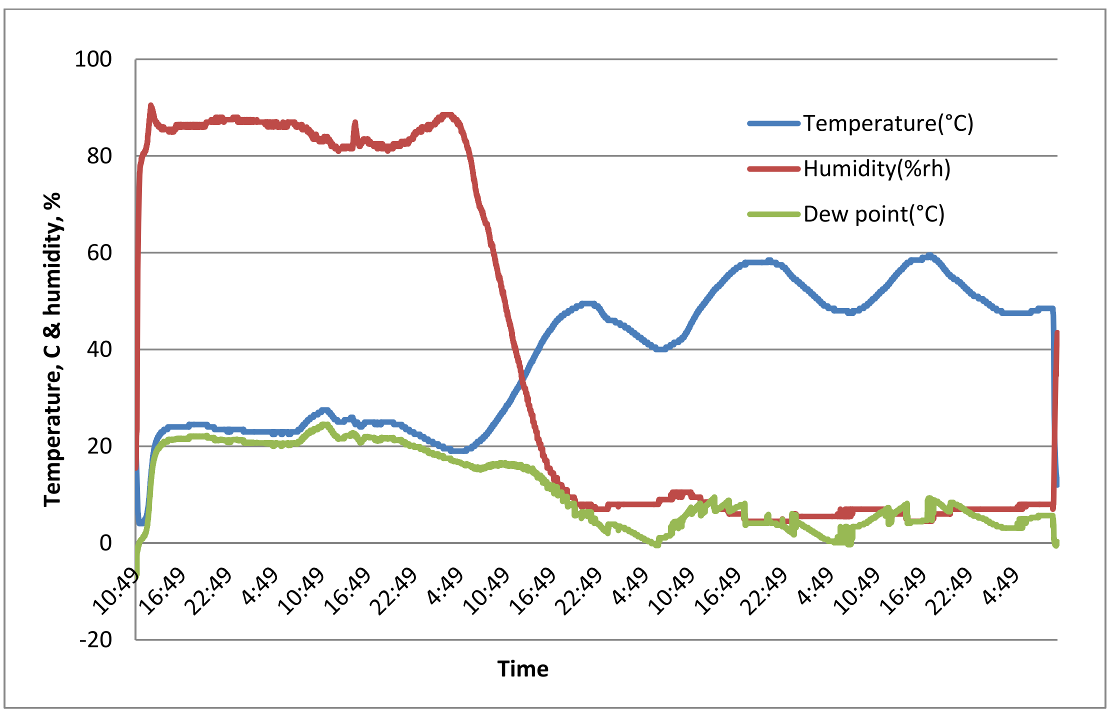

Figure 4. The temperature (°C), relative air humidity (% rh) and corresponding dew point (°C) of the outgoing drying air measured while drying whole tree chips.

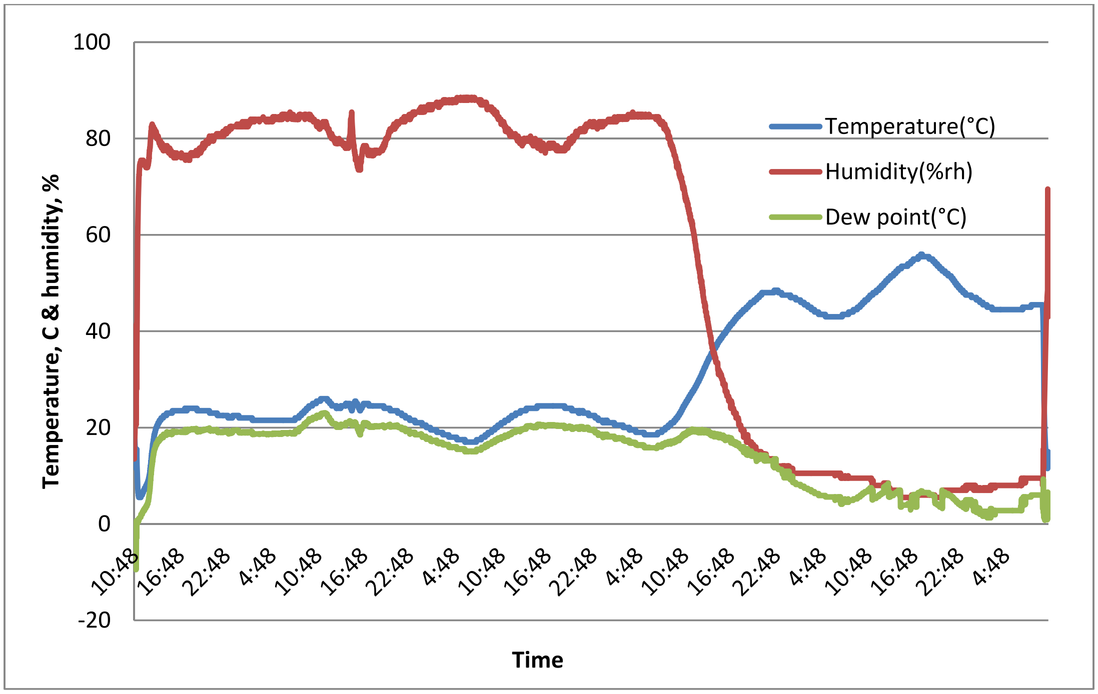

Figure 5. The temperature (°C), relative air humidity (% rh) and corresponding dew point (°C) of the outgoing drying air measured while drying stem wood chips.

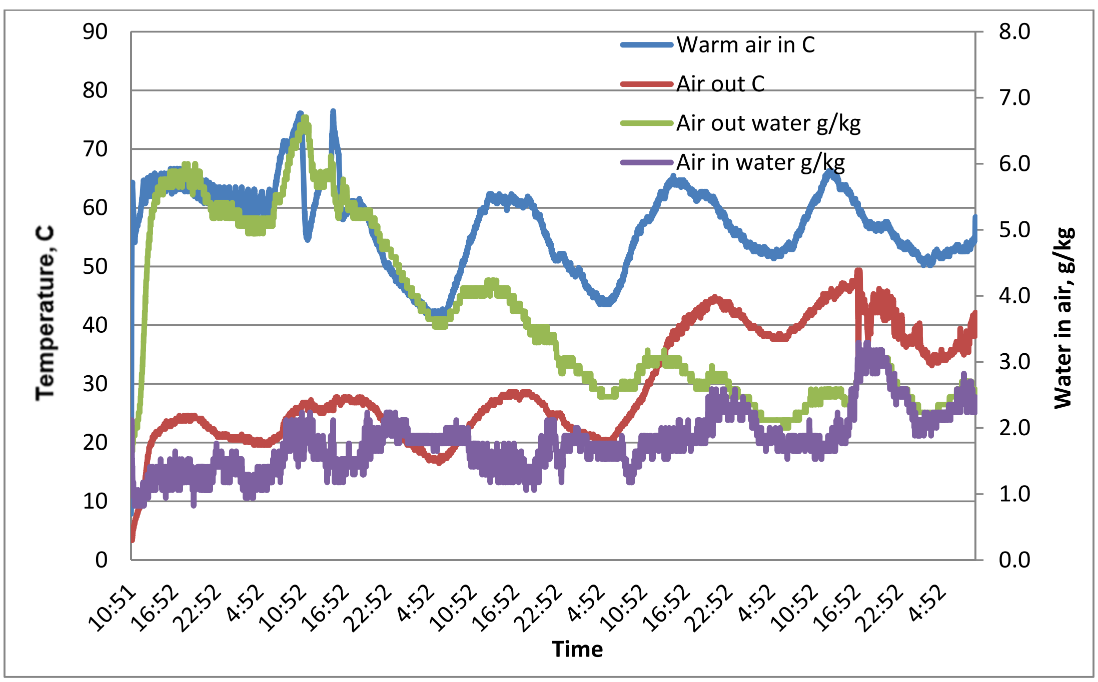

Figure 6. Temperatures (°C, blue & red) and water (vapor) content (g of water/kg of air) of incoming (purple) and outgoing (green) air. No more drying takes place when purple and green curves cross because then the water content is about the same in both air flows.

4.2 Calculation model

As mentioned before a calculation model was created to provide some basic parameters for designing or testing a warm air dryer (an example in Annex 1). Fifteen different basic values are needed for the calculation, such as:

- Initial moisture and desired moisture of fuelwood after drying
- Temperature and relative humidity of drying air before heating it
- Efficiency of dryer
- Desired drying time

Having inserted these basic values for which some defaults are provided, the calculator renders parameters such as:

- Temperature and relative humidity of drying air after heating
- Temperature and relative humidity of drying air after drying
- Amount of water to be evaporated
- Amount of energy and output needed for drying

This calculation model was verified with parameters measured during the drying demonstration. The model will be given to regional bioenergy advisors and key stakeholders to help them consider drying of wood chips as part of an alternative supply chain to produce high quality chips.

4.3 Comparison with conventional supply chains

In order to evaluate benefits of drying wood chips for the whole supply chain of fuelwood in a relatively small warm air dryer, costs of wood supply and possible drying costs were calculated.

4.3.1 How moisture affect supply costs of wood chips in biomass heat production

Pricing of different phases of supply chains can be done in many ways, depending on contracts. Often the first parts of the chain such as logging, forwarding, chipping and transportation are priced based on volumes or weight. On the other hand, sometimes the end user may only want to pay for delivered wood chips based on their heating value. In practice, there are many pricing combinations, depending on each case.

To make comparison easier, the supply costs of wood chip per produced energy (€/MWh) are calculated based predominantly on volumes or calorific value of delivered wood chips. Costs used in this exercise are from recent studies (Laitila et al. 2012) and from entrepreneur interviews. Two typical supply chains typically used in rural areas in Finland were chosen. In the first supply chain fuelwood would be bought at road side storages. The end user would then use subcontractors to do the chipping and transportation (**contractor model**). In the other supply chain one supplier would take care of the whole supply chain and deliver wood chips directly to the plant (**one supplier model**). In both cases wood chips would be made from whole trees, either for a heating plant producing annually 5,000 MWh or 1,500 MWh of heating energy.

<u>Plant 1 (energy production 5,000 MWh/a)</u>

The following assumptions and costs were used in supply chain calculations for the **contractor model**:

- Chipping with a mobile truck mounted chipper
- Road transportation with 120 m^3 chip truck
- Road side price of whole trees; 12 €/MWh (3.3 €/GJ)
- Chipping costs; 3.6 €/loose-m^3
- Transportation costs; 3.6 €/km

- Combustion efficiency of boiler; 78-88% depending on wood chip moisture (55-20%)
- Costs caused by heating system malfunction; 120 € each maintenance visit
- Costs caused by extra heating oil used for heating; 14,000-0 €/a depending on wood chip moisture (55-20%)

Bigger plants usually pay for the heating value of wood chips which is measured at the plant. Therefore euros per heating value (€/MWh) was used for costs of wood chip raw materials. Moisture of wood chips directly affects combustion efficiency and wood chip volumes needed for energy production through chipping and transportation costs.

In the **one supplier model** cost calculation is simpler because the supplier is paid for delivered wood chips for their heating value (€/MWh). Therefore the following costs were used:

- Delivered wood chips; 20 €/MWh (5.6 €/GJ)
- Combustion efficiency of boiler; 78-88% depending on wood chip moisture (55-20%)
- Costs caused by heating system malfunction; 120 € each maintenance visit
- Costs caused by extra heating oil used for heating; 14,000-0 €/a depending on wood chip moisture (55-20%)

Figure 7 illustrates costs of both wood chip supply chains for produced heating energy in relation to moisture of delivered wood chips.

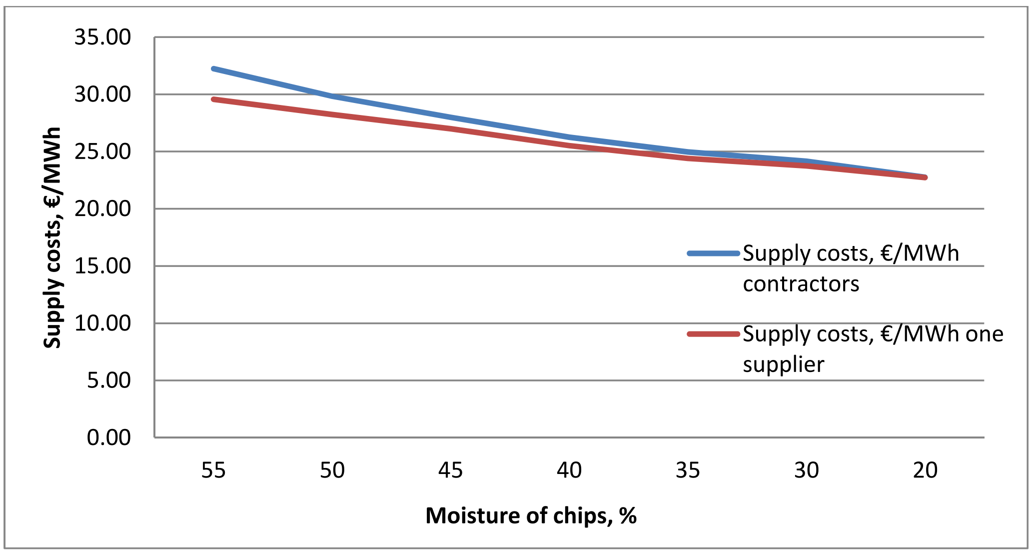

Figure 7. Supply costs of wood chips for 5,000 MWh annual energy production in the one supplier and contractor models.

<u>Plant 2 (energy production 1,500 MWh/a)</u>

The following assumptions and costs were used in supply chain calculations for the **contractor model**:

- Chipping with a tractor powered chipper
- Road transportation by tractor with 20 m^3 trailer
- Road side price of whole trees; 25 €/solid-m^3
- Chipping costs; 4.5 €/ loose-m^3
- Transportation costs; 2 €/loose-m^3
- Combustion efficiency of boiler; 78-88% depending on wood chip moisture (55-20%)
- Costs caused by heating system malfunction; 120 € each maintenance visit

- Costs caused by extra heating oil used for heating; 5,200-0 €/a depending on wood chip moisture (55-20%)

In the **one supplier model** the corresponding costs were:

- Delivered wood chips; 20 €/MWh (5.6 €/GJ)
- Combustion efficiency of boiler; 78-88% depending on wood chip moisture (55-20%)
- Costs caused by heating system malfunction; 120 € each maintenance visit
- Costs caused by extra heating oil used for heating; 5,200-0 €/a depending on wood chip moisture (55-20%)

It is important to notice that in the supply chain costs for wood, chipping and transportation are purposely based on volumes because smaller plants find it easier to have just one way to measure and pay for different costs. If different phases of the supply chain are paid for volumes, the cost difference for delivered wood chips between contractor and one supplier models becomes significantly higher, the wetter the raw material is (Figure 8). This is natural because for the same amount of wood less heating energy is delivered.

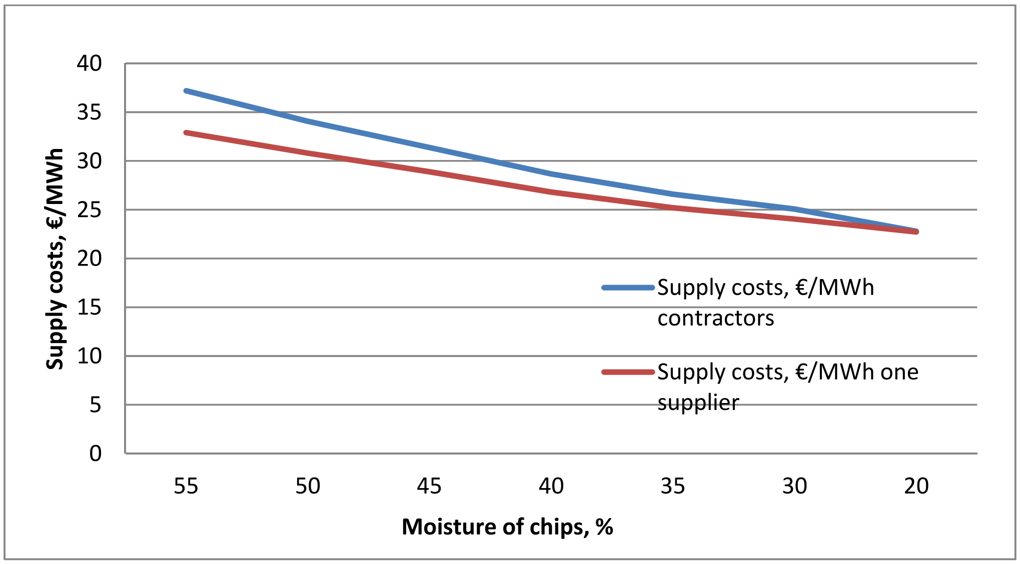

Figure 8. Supply costs of wood chips for 1,500 MWh annual energy production in the one supplier and contractor models.

These calculation examples show how moisture effects costs of supplying heating plants with wood chips. The cost difference is the bigger the more supply costs are based on volumes. The total cost difference also shows how much more the end user could pay for dryer wood chips for the same amount of produced heating energy. In other words, the cost difference could be used for drying, either natural or artificial.

4.3.2 Profitability of drying wood chips at a heating plant

One possibility to dry wood chips with warm air is to do it in a dryer built next to a heating plant. Small and medium sized heating plants have significant excess heating capacity most of the year. Their utilization rate is less than 50% on average. Only during a couple of winter months they work close to their full capacity. Therefore fuelwood dryers could use this excess capacity to dry wood chips to be used in these heating plants. Benefits of combusting dry wood chips (20-30%) are undisputable: boilers would work more efficiently, there would be fewer malfunctions of the system, boiler output would be higher, less additional fuels are needed and less wood chips are needed.

Profitability of drying wood chips at Plant 2 was evaluated by calculating costs of drying and comparing them with benefits from more economical heat production with wood chips containing water only 20%. A drying example was calculated for a 25 m^3 fuelwood dryer for 55% and 45% wood chips with the following parameters:

- Annual volume of dried wood chips; 2,100 loose-m^3
- Annual heating energy used for drying, calculated with the drying model; 445 MWh (55% moisture) and 268 MWh (45% moisture)
- Heating costs for drying; 40 €/MWh including capital and running costs of the heating plant or 24 €/MWh without any other but fuel costs
- Investment costs of dryer; 35,000 € according to a Finnish manufacturer
- Electricity and maintenance costs; 1,300 €/a
- Pay-off period; 10 a
- Interest rate; 5%

With these parameters drying costs were 9.3 €/loose-m^3 for 55% wood chips if drying heat was 40 €/MWh and 6.5 €/loose-m^3 if drying heat was 24 €/MWh. The corresponding costs for 45% wood chips were 7.0 €/loose-m^3 and 4.8 €/loose-m^3.

When drying costs were compared with lower heating energy production costs the following benefits were taken into consideration: less wood chips are needed, transportation and chipping costs are lower, boiler efficiency increases, fewer malfunctions occur, and less additional fuels are needed.

Profitability of drying and drying investment was evaluated by using the net present value method. Net present values of costs and benefits for a ten year pay-off period were calculated for both contractor and one supplier supply chains, using Plant 2 as the end user. Because dry wood chips cannot be stored outdoors, an additional storage investment (35,000 €) was included in calculations too.

Table 2. Profitability of the dryer investment in chosen supply cases. Figures indicate the annual difference between costs and benefits in net present values (€).

	Drying heat 40 €/MWh		**Drying heat 24 €/MWh**		**Drying heat 40 €/MWh + storage**		**Drying heat 24 €/MWh + storage**	
Initial moisture of wood chips	Contractor model	One supplier	Contractor model	One supplier	Contractor model	One supplier	Contractor model	One supplier
55%	14 792	-36 170	60 196	9 234	-775	-51 738	46 683	-6 334
45%	-8 159	-37 222	19 407	-9 655	-23 727	-52 789	5 894	-25 223

In the one supplier model investments would only be profitable when using a lower price for drying energy (24 €/MWh) and fresh wood is dried without any pre-seasoning. On the other hand, drying investments would be profitable in most contractor cases. This is evident because in the contractor model most supply costs of wood chips were based on volumes, and therefore drying decreases supply costs of fuelwood more than in supply chains that charge for work units mainly based on the heating value of wood.

In the previous comparisons it is assumed that the annual heat sales remain unchanged despite increased heat production capacity due to better fuel. Profitability of drying increases remarkably if the heating enterprise can increase its sales because of a higher boiler output.

Let us assume Plant 2 dries annually the drier's maximum capacity of 2,500 loose-m^3 of wood chips instead of 2,100 loose-m^3 needed to provide energy for annual heat sales of 1,500 MWh. Then the plant could sell 300 MWh more heating energy. This would increase annual gross revenues 18,000 € if customers pay 60 €/MWh. This annual increase in revenues makes the drying investment profitable in all options (Table 3).

Table 3. Profitability of the dryer investment in chosen supply cases if 300 MWh extra energy can be sold. Figures indicate the annual difference between costs and benefits in net present values (€).

	Drying heat 40 €/MWh		**Drying heat 24 €/MWh**		**Drying heat 40 €/MWh + storage**		**Drying heat 24 €/MWh + storage**	
Initial moisture of wood chips	Contractor model	One supplier	Contractor model	One supplier	Contractor model	One supplier	Contracto r model	One supplier
55%	162 462	101 792	216 514	155 845	146 894	63 779	203 001	140 277
45%	135 139	100 541	167 956	133 358	119 571	61 724	154 443	117 790

In the least profitable option (one supplier, 40 €/MWh for drying heat and storage) gross revenues should annually increase by 9,000 € to make the drying investment profitable. In practise this requires drying 200 loose-m^3 more wood chips and using half of the increased boiler output. Correspondingly, in the contractor model drying only 50 loose-m^3 of chips, and thus increasing revenues by 3,000 € would guarantee profitability of the investment.

The calculated examples show that drying of wood chips in a warm air dryer can very well be a feasible option for small and medium scale heating enterprises. Particularly, if such a heating plant can increase annual heat sales because the increased heating output of the system.

5 Acknowledgements

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References

Erber, G., Routa, J., Wilhelmsson, L., Raitila, J., Toiviainen, M., Riekkinen, J. and Sikanen, L. 2014. A prediction model prototype for estimating optimal storage duration and sorting. Metla working papers 297. P.76.

Heinek, S., Mair, G., Huber, M.B., Hofmann, A., Monthaler, G., Fuchs, H.P., Larch, C., Giovannini, A. 2012. Biomass conditioning: Minimization of the storage related loss of biomass. 20th European Biomass Conference and Exhibition, 18-22 June, Milan, Italy. Conference paper. Proceedings, pp. 116-121.

Heiskanen, V-P., Raitila, J. and Hillebrand, K. 2014. Varastokasassa olevan energiapuun kosteuden muutoksen mallintaminen (Modelling of moisture changes of stacked fuelwood). VTT Research Reports VTT-R-08637-13. (in Finnish). 26 p.

Laitila, J. 2008. Harvesting technology and the cost of fuel chips from early thinnings. Silva Fennica 42(2), s. 267–283.

Laitila, J., Leinonen, A., Flyktman, M., Virkkunen, M. & Asikainen, A. 2011. Metsähakkeen hankinta- ja toimituslogistiikan haasteet ja kehittämistarpeet (The Challenges and Development Needs for Forest Chips Procurement and Delivery Logistics). VTT Tiedotteita 2564. 143 pp. (In Finnish)

Nurmi, J. and Hillebrand, K. 2007. The characteristics of whole tree fuel stocks from silvicultural cleanings and thinnings. Biomass and Bioenergy 31(6). pp. 381-391.

Otepka, P. (ed.). 2014. Guidebook on Local Bioenergy Supply Based on Woody Biomass. Scientific & Academic Publishing, USA. ISBN: 987-1-938681-99-8. 147 p.

Raitila, J. & Heiskanen, V-P. 2014. Profitability of supplying wood chips dried at small or medium scale heating plants. International Journal of Engineering Research and Management. 1/9. pp. 21-27. http://www.ijerm.com/index.php?page=issues&id=44

Raitila, J., Virkkunen, M & Heiskanen, V-P. 2014. Metsäpolttoaineiden varastoitavuus runkoina ja hakkeena sekä lämmöntuotantoon integroitu metsäpolttoaineiden kuivaus. (Storing fuelwood in stems and wood chips and drying wood fuel in connection with heat entrepreneurship). VTT-R-78266-14. 55 p.

Routa, J., Asikainen, A., Björheden, R., Laitila, J. & Röser, D. 2013. Forest Energy Procurement – State of the Art in Finland and Sweden. Energy & Environment 2(6): 602-613.

Röser, D., Erkkilä, A., Mola-Yudego, B., Sikanen, L., Prinz, R., Heikkinen, A., Kaipainen, H., Oravainen, H., Hillebrand, K., Emer, B. & Väätainen, K. 2010. Natural drying methods to promote fuel quality enhancement of small energywood stems. Metlan työraportteja / Working Papers of the Finnish Forest Research Institute 186. 60 s. ISBN 978-951-40-2279-1 (PDF). Saatavissa: http://www.metla.fi/julkaisut/workingpapers/2010/mwp186.htm

Annexes

Annex 1. An example of the developed calculation model for dimensioning a warm air dryer for fuelwood.

Insert values in green cells. Calculated values appear in blue cells.

Starting values

Amount of fuel wood to be dried	V_f	25	loose-m^3		
Bulk density of fuel wood	ρ	347	kg/loose-m^3		
Initial moisture of wood	w_{f1}	55	%		
Target moisture of wood	w_{f2}	25	%		
Initial temperature of wood before drying	T_{f1}	-5	C		
Temperature of wood after drying	T_{f2}	15	C		
Temperature of incoming air	T_{a1}	-5	C		
Relative humidity of drying air before heating	φ_1	80	%		
Water vapor in air before heating ($T = T_a1$)	x_{a1}	2,96	g/m^3		
Length of dryer		4,9	m		
Height of dryer		2,3	m		
Width of dryer		2,3	m		
Volume of dryer		25,9	m^3		
Cross sectional area of dryer		11,27	m^2		
Developed area of dryer		55,66	m^2		
Thermal transmittance		0,0002	kW/m^{2}C		
Flow rate of drying air (temperature T_a1)		3000	m^3/h		
Efficiency of dryer		70	%		
Desired drying time	days	2		=	48 h

Calculated values

Page 2

Specific heat of wood	kJ/kgC	1,13		
Heat of vaporization	kJ/kg	2490		
Average specific heat of drying heat	kJ/kgC	1,01		
Weight of wet wood	kg	8675,0	(Moisture	55 %)
Weight of dried wood	kg	5205,0	(Moisture	25 %)
Weight of water in wood before drying	kg	4771,3		
Weight of waterin wood after drying	kg	1301,3		
Weight of evaporated water	kg	3470,0		
Heat is needed for:				
1. Heating ice in wood	kWh	13,8		
2. Melting ice in wood	kWh	441,3		
3. Heating water in wood	kWh	83,3		
4. Heating dry wood to final drying temperature	kWh	24,4		
5. Vaporization of water	kWh	2376,4		
6. Transmittance losses	kWh	10,7		
TOTAL (without transmittance losses)	kWh	**2939,3**		
Heating of drying air:				
Flow rate of water vapor in drying air	kg/h	8,88		
Flow rate of dry air in drying air	kg/h	3868,5		
Energy needed for heating drying air	**kWh**	**4199,0**	(Efficiency of dryer:	
Output needed for heating drying air	**kW**	**87,5**		70 %)
Temperature of drying air after heating T_a2	C	75,3		
Temperature of heating air after drying T_a3	C	16,1		
Speed of drying air on the bottom of fuel wood layer	m/s	0,10		
Water vapor in drying air after heating ($T=T_a2$)	x_a2	2,28 g/m^3		
Relative humidity of drying air after heating	φ2	0,9 %		

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INFRES – Innovative and effective technology and logistics for forest residual biomass supply in the EU (311881)

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Demo report 13 – Lipe Multipurpose Chip Truck and Semi-trailer Equipped with Electronic Trailer Steering System – D4.5

Dissemination Level	
Public	X
Restricted to other programme participants (including the Commission Services)	
Restricted to a group specified by the consortium (including the Commission Services)	
Confidential, only for members of the consortium (including the Commission Services)	

Joensuu, Finland, January 2015

Content

1 Introduction

European-wide political decisions and attempts to decrease the use of fossil fuels and to increase the use of renewables in energy production have significant effects on the demand of woody biomass (European Commission 2008). In the northern countries the small diameter wood and the logging residues with low commercial value are economically the most cost competitive sources of bioenergy. The importance of the wood chips will rise in the future in the situation where the European Union tries to increase its self-sufficiency in energy (Asikainen et al. 2008, Mantau et al. 2010).

The establishment of the new heat and power plants using the wood as a fuel will increase the competition of the wood chips which will lead to the rising purchasing prices. The Competition of the wood chips will increase the size of the raw material procurement area for the power plants. The larger procurement areas will lead to longer transportation distances as well. The longer transportation distances, increasing prices of the transportation fuel and higher consumption of time of the transportation will increase the costs of the wood chips (Asikainen et al. 2002). In Finland, in 2013, the total domestic land based wood transportation performance was 7294 milj.m^3km of which 57 % was made by trucks, 37 % by railroads and 6 % by water (Metsätehon katsaus 50, 2014) .

One solution to reduce the transportation costs is to increase the dimensions and compaction of the transportation vehicles. The European regulation restricts the maximum lengths and masses of the loaded vehicles (Directive 96/53/EC). In Finland, in the late 2013, was accepted an act which permits larger and heavier trucks in the road transportation (Valtioneuvoston asetus 407/2013). The new act can be justified by the long transportation distances in Finland. The Conventional chip truck consists of a 3-axle pulling vehicle and 4-axle trailer. The new regulations raised the maximum mass of the pulling vehicle and the trailer from 60 tonnes to 64 tonnes. Respectively, If the number of axles of the unit is increased to 9 within the maximum length of 25.25 meters, the combined mass of the transportation units is 76 tonnes: in other words the maximum mass of the whole unit is based on the axel masses (Korpilahti & Koskinen 2012).

Recently, the manufactures started to offer truck – trailer concepts of 8- or 9-axles. The maximum mass of the 9-axle concept has been raised from 60 to 69 tonnes. The Entrepreneurs offering transportation services for the power plants have been interested these bigger trucks in reducing long distance transportation costs.

The launched truck - trailer concepts with increased length and weight may cause problems for the chip transportation in forest roads with limited turning space and bearing capacity. The small diameter whole-trees and delimbed stems, stumps and logging residues are stored for drying in the forest roadside landing close to the actual harvesting site. Often the turn-around places of the forest roads are too small for the long 9-axle transportation units. Also, they can be too narrow and windy for turning and the road structure can be too weak for the heavy vehicle. The long wheelbase between the front and rear axles of newest concepts require wider turning areas than the traditional trucks. The tight turn with heavy load is possible but not recommended. The heavy load will strain the rear axles with massive forces and therefore the risk for axle or wheel breakdowns increases and the total life span of the trailer decreases.

Konepaja Antti Ranta constructed a vehicle concept for transportation chips. The studied concept consists of long semi-trailer equipped with ETS (Electronic Trailer Steering) system manufactured by Vehicle Systems Engineering (Figure 1). The system enables hydraulic steering of the trailer's rearmost axles. ETS is designed to improve maneuverability and mobility of the concept in small forest roads. This study is an overview of the studied transportation solution. Also the contractor's and drivers' feedback is described.

Figure 1. The nine axle multipurpose chip truck constructed by Konepaja Antti Ranta, here loaded directly with a chipper from the rear. Picture: Sami Lamminen, Luke

2 Material and methods

2.1 Technical specifications

The studied chip transportation concept is the 9 axle multipurpose chip truck constructed by Konepaja Antti Ranta (http://www.anttiranta.com/en/front+page/). The truck is Volvo FH12 installed with a load space. The trailer is a 3-axle semi-trailer with 2-axle dolly. The trailer is equipped with ETS system supplied by Vehicle Systems Engineering. The load spaces of the truck and trailer are equipped with hydraulic side tipping-based unloading and embedded fixing points for cargo. The total length of the concept unit is 25.25 meters and the maximum allowed mass is 69 tons. The detailed dimensions and turning calculations are presented in the Figures 2, 3 and 4.

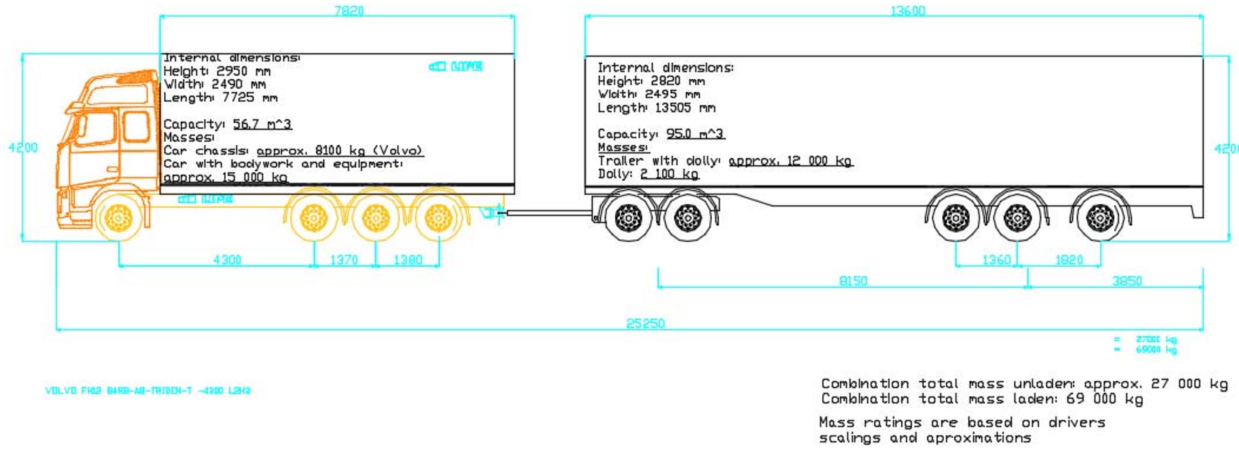
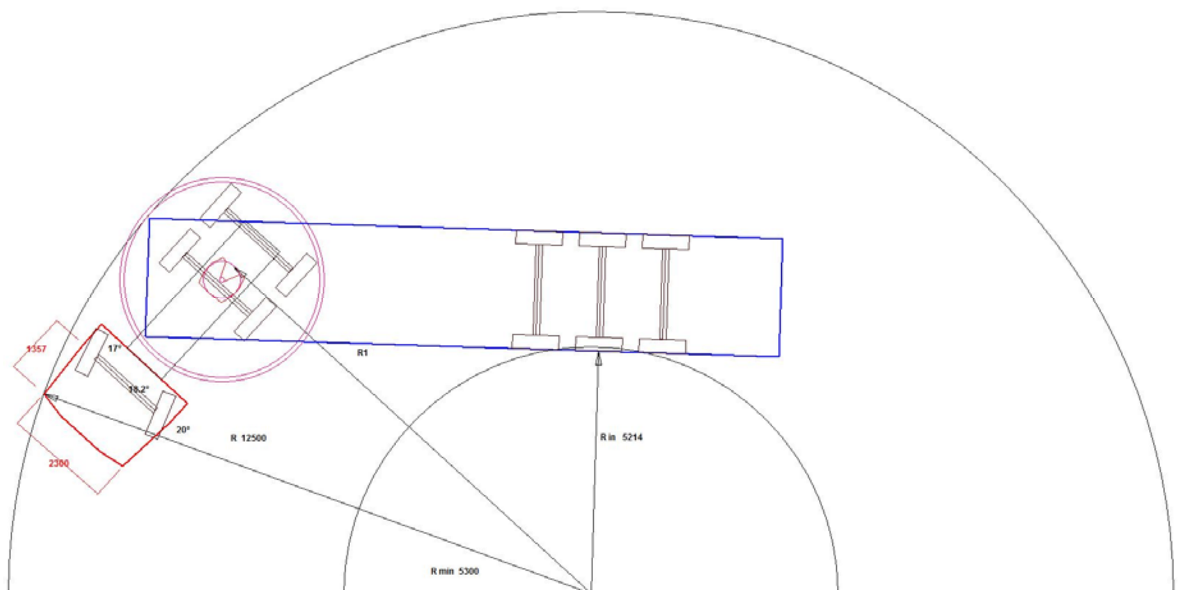


Figure 2. Dimensions of the chip truck (Source:Janne Immonen, Konepaja Antti Ranta Oy).



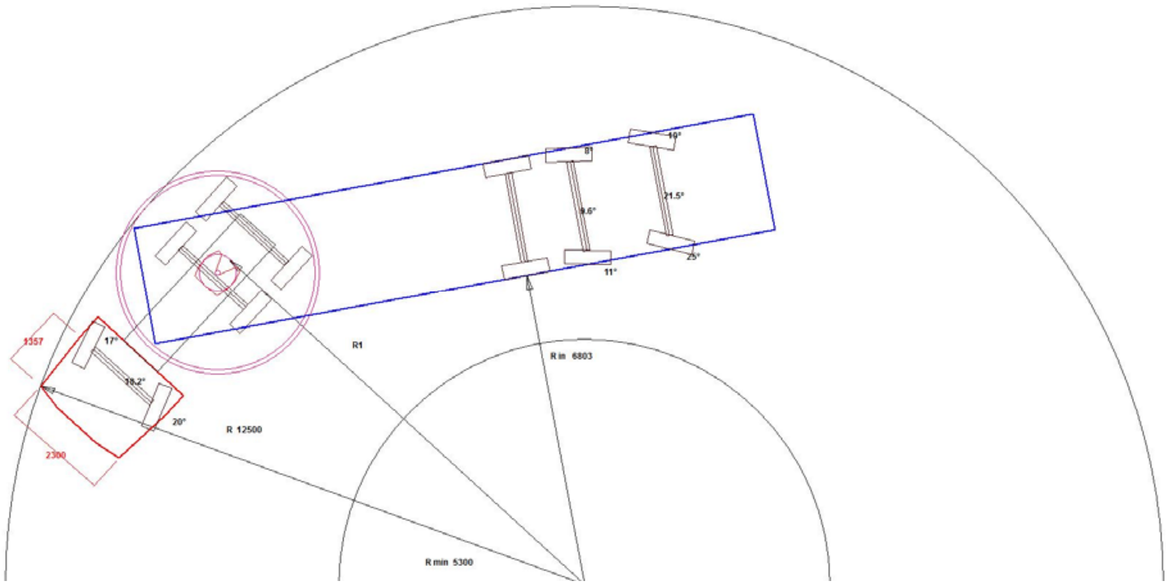


Figure 3. Outer and inner turning radius for a standard 13.6 m semi-trailer with rigid axles (above) and for a 13.6 m semi-trailer with two steerable axles (below). (Source: Janne Immonen, Konepaja Antti Ranta Oy)

The ETS system enables the steering the two rearmost axles of trailer (Figure 4). The axles can be steered automatically or manually. The major advantage of the ETS systems is smaller turning circle of the vehicle unit. The automatic steering is based on the movements of pulling vehicle. The required steering angle for rear axles is calculated by the information derived from the angle of the dolly and the trailer. The electronics are able to compensate the off-tracking caused by the long wheel base of the trailer by turning the axles. This leads to the situations where the truck unit is able to perform tighter turns, turn-a rounds and reversing around tighter corners than with rigid axles. The automatic steering is operational during the speed less than 60 km/h. When the speed is faster than 60 km/h the rearmost axles must be set in fixed position, this restriction is based on the Finnish national transportation regulations (Valtioneuvoston asetus 407/2013).

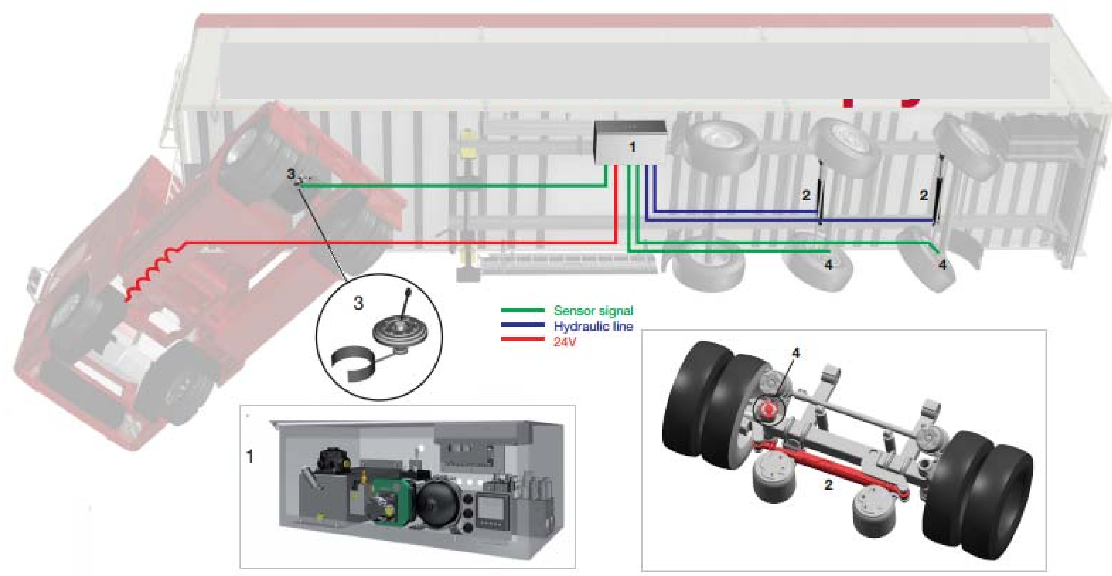


Figure 4. The overview of the Electronic Trailer Steering (ETS) system. (1) The system locker contains the hydraulic installation for controlling the cylinders on the axles and the Electronic Control Unit (ECU). Every knuckle-steered axle is fitted with an ETS steering cylinder (2), connected to the system locker (1). An angle sensor (4) is mounted on the steering knuckle at one end of each steered axle. The kingpin of the trailer is fitted with an angle sensor (3) that measures the angle between the truck (or dolly) and trailer. (Source: Vehicle Systems Engineering, modified by Sami Lamminen)

The driver has a possibility to switch off the automatic steering and control the trailer's rear axles manually, wherein adjusting of the steering angle of the rearmost axles is performed using the portable remote control (Figure 5).

Figure 5. Manual remote control of the ETS: It is possible to control manually the angles of the rearmost axles of the trailer. The mobile remote control enables second person to steer the rear of the trailer around a blind corner.

Figure 6. Axle load monitoring device.

The vehicle and the trailer were equipped with air-suspension which is rarely used in low level road network and on forest roads in Finland. For drivers, driving the vehicle is much smoother with air-suspension compared to conventional steel leaf springs. The other advantage of the air-suspension system is embedded weight scaling solution: the driver can monitor the weight of the load in real time. This ensures the possibility to maximize the load size during the chipping operation and which reduces the transportation costs. The driver can observe the individual axle loads of the vehicle and the trailer by using the separate monitoring device (Figure 6).

The field demonstrations of the LIPE chip truck with long semi-trailer equipped ETS system were carried out in October 2014. The demonstrations were organized as a follow up observing of the normal chipping and transportation operations. The operations were organized with two separate companies. Company *Oulun Bioenergia* was the main contractor and the official fuel supplier for the *Oulun Energia* heat and power company. *Oulun Bioenergia* was responsible for the fuel supply to the power plants. Furthermore, *Oulun Bioenergia* was responsible for the chipping operations and managing the chipping machines and related equipment. The transportation company *Muhoksen Biokuljetus* was responsible of transportation the chips to the power plant. *Muhoksen Biokuljetus* had in total four trucks for the transportation of wood chips. Two of them were equipped with ETS system assembled by under the brand LIPE.

The normal chipping - transportation chain included two transportations trucks and one chipping truck. During the demonstrations, the chain included two transportation trucks both equipped with ETS system. It was not possible to demonstrate or study the differences in maneuverability between the ETS system and rigid axle systems. During the four day demonstrations one researcher was observing operations in one of the two transportation trucks. Since there was no possibility to compare two different axle systems the results of the demonstrations are users' experiences based on the the transportation truck drivers' interviews during the operations.

3 Results and discussion

Demonstrations were organized in the region of Oulu in Northern Finland. In the demonstrations were two chip trucks equipped with ETS trailers and one chipper unit. Also the raw material storage areas were in the Oulu region and they were located relatively close to each other. Each of the storage areas consisted of several smaller piles of logging residues or whole trees. The total number of the storage areas was four and the transportation distance to the power plant was 140 km on average. Due to the rather long transportation distance, the trucks were able to deliver on two loads per day.

Three demonstration landings lied by narrow forest road and their main raw material was logging residues. The payload for logging residue chips based on weight was low due to significant proportion of fines. Therefore the maximum legal mass of the transportation concept is not exceeded when increasing the volume of load space. During the chipping it was crucial to fill the load spaces of the truck and the trailer at same time in order to minimize the transportation costs. However, it was not possible to place the chipper and the truck side by side on the narrow forest road. Therefor the chipping operations had to be performed in several series of actions. Firstly the chipper and the truck or the trailer had to be one after the other along the forest road in order to get close enough to the pile. Secondly the long trailer needed to be filled both from the front and from the rear to maximize the volume of the chips in load. Thirdly to maximize the payload of the trailer it was occasionally disconnected from the truck and connected to the chipping truck during the chipping. However, these actions lowered the productivity of the chipping but ensured the possibility to transport full loads of chips to power plant.

The storage areas in general were classified as easy working locations. Furthermore the chipping operations would have been possible to conduct in all storage areas using the conventional rigid axle trailers as well. According to the truck drivers the trailer without ETS presented in the demonstrations would have been slower to operate in narrow forest roads. The driver switched the ETS of into manual control only three times during the demonstrations. This occurred every time when turning the vehicle unit by reversing it around a corner through a narrow forest road junction. Two times the chipper operator was using the remote control (Figure 7) and in one case the researcher of the demonstrations had possibility to try the remote control while truck driver was reversing the truck. The manual control was easy and straight to use. The steering angle was adjusted only by pressing two large buttons showed in the Figure 6 (labeled as "L" and "R"). Instructions from the truck driver were also simple: "Keep it in the middle of the road"!

Figure 7. The truck is reversing and the chipper operator is manually steering the rear axles of the trailer by using the remote control (Figure 6). The communication between the truck driver and chipper operator was performed by mobile phone.

After using one year the ETS system in chipping operations the chipper operator's and truck driver's opinion was that in narrow forest roads the system enables to use larger transportation units also in challenging terrains. Usually the truck driver has to operate in four control points of the truck and the trailer (Figure 8). While driving forward and turning with rigid axle trailer the driver requires a wide space for front of the truck (green dot on Figure 8) to compensate the long wheelbase of the trailer. However, the ETS system reduces the space needed for turning by *increasing the turning circle of the rearmost axles of the trailer* (blue dot on Figure 8). For example, when driver is turning tight turn to the right the ETS system steers the rear axles of the trailer to the left.

Reversing the truck-trailer concept around a corner is more complex. With rigid axle trailer the driver manipulates in front of the truck (green dot) the positions of the three control points (red and blue dots) (Figure 8). Respectively the ETS system steers the rear control point of the trailer (blue dot) automatically or manually wherein the driver has only two control points (red dots) to manipulate in front of the truck (green dot). This reduces the space and movements needed in front of the truck (green dot) significantly. Also, it reduces the time needed for the operation. In forest roads, for the long trailers the space needed for the front of the truck (green dot) limits often the turning radius and therefore the space required (Figure 8).

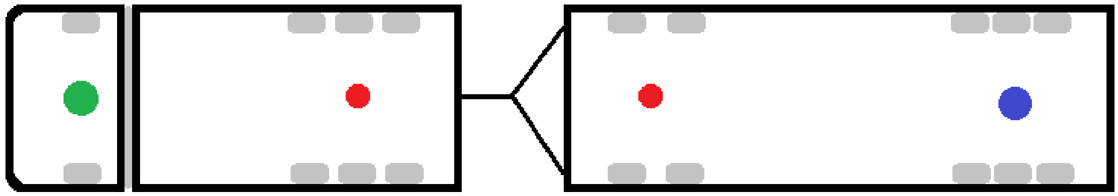


Figure 8. The four control points of the truck and the trailer.

The ETS system eases also the operations in small chip terminals. During unloading the driver can manually steer the rear axles of the trailer away from the chip pile and in that way prevent driving over the chips (Figure 9).

Figure 9. During the unloading the driver steers the rear axles of the trailer away from the chips.

During the summer 2014 on high demand construction season these trucks were used for transporting prefabricated elements of the small detached houses from the factories to the construction sites. In the construction sites, the steering conditions for the truck-trailer concepts can be even more challenging than on forest roads and the lack of open space sets up high demands. The transportation distances for building elements were even longer than normal distances for transportation of wood chips. Therefore to reduce costs the trucks were used also for transportation of mail on the return trip.

The VSE system has functioned well during one year. Only one bigger service was required. VSE systems´ control unit and the EBS-unit (Electronic Braking System) malfunctioned, everything but the batteries and the wiring had to be replaced for the VSE control unit. It was unclear what caused the malfunctioning. System manufacturers´ warranty covered for all the damage in this case. The VSE system locks the axles as rigid axles if the system is in failure mode. So the trailer is still usable.

4 Conclusions

The demonstrations and user feedbacks that were gathered during the demonstration revealed a potential of the long trailers equipped with ETS system for the transportation of wood chips. However, it was not possible to determine actual differences between the rigid axles and ETS system. To get the answer for that, a controlled test should be conducted. Also, for the future studies, the vehicle features for the wood chip roadside landings should be taken into account.

Other possible wood chip transportation could be chipper truck, short truck without load space and two long semi-trailers equipped with ETS systems. For this transportation chain, the chipper truck must to be equipped with additional axle and a fifth wheel for coupling the semi-trailer to the chipper truck.

5 Demonstration

In total 73 people from international COST Action FP0902 Final Conference participated the demonstration in Joensuu harbour terminal area at 29.08.2013. There, Antti Ranta`s new innovative truck prototype was introduced to the international Researchers group (Figure 11).

Figure 10. Demonstration in Joensuu harbour terminal.

References

Asikainen, A., Björheden R. and Nousiainen I. 2002. Costs of wood energy. In: Richardson J., Björheden, R., Hakkila P., Lowe A.T., Smith C.T. (Eds). Bioenergy from Sustainable Forestry – Guiding Principles and Practice. Kluwer Academic Publishers, Dordrecht, Boston, London. p. 125–155.

Asikainen, A., Liiri H., Peltola S., Karjalainen T. and Laitila J. 2008. Forest energy potential in Europe (EU 27). Working Papers of the Finnish Forest Research Institute 69. 33 p.

Directive 96/53/EC. Road weights and dimensions. [Internet site]. Available at: http://ec.europa.eu/transport/modes/road/weights-and-dimensions_en.htm/. [Citied on Feb. 2015].

European Commission 2008. Combating climate change The EU leads the way. Europe on the move series 2008. European Commission. Brussels, Belgium. 24 p.

Korpilahti, A. & Koskinen, OH. 2012. Puutavaran autokuljetus tehokkaammaksi. Metsäteho tuloskalvosarja 1/2012. Available: http://www.metsateho.fi/files/metsateho/Tuloskalvosarja/Tuloskalvosarja_2012_01_Puutavaran_autokuljetus_tehokkaammaksi_ak.pdf. (In Finnish).

Mantau H., Saal, U., Prins, K., Steierer, F., Lindner, M., Verkerk, H., Eggers, J., Leek, N., Oldenburger, J., Asikainen, A., Anttila P. 2010. EUwood – real potential for changes in growth and use of EU forests. Final report. University of Hamburg. Centre of Wood Science. Hamburg, Germany. 160 p.

Metsätehon katsaus nro 50. 2014. Puunkorjuu ja kaukokuljetus vuonna 2013 [Harvesting and long-distance transportation 2013]. 4 p. (In Finnish with summary in English).

Valtioneuvoston asetus 407/2013 ajoneuvojen käytöstä tiellä [The Finnish government regulation for road vehicles]. Available at: http://www.finlex.fi/fi/laki/alkup/2013/20130407#Pidm1799696/. [Citied on Feb. 2015].

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INFRES – Innovative and effective technology and logistics for forest residual biomass supply in the EU (311881)

Gernot Erber & Franz Holzleitner (BOKU

Demo Report 14: Harvesting operations in hard wood dominated stands using the energy wood felling head Naarva EF28

Dissemination Level	
Public	x
Restricted to other programme participants (including the Commission Services)	
Restricted to a group specified by the consortium (including the Commission Services)	
Confidential, only for members of the consortium (including the Commission Services)	

Vienna, 14.04.2015

Content

Preface

Natural Resources Institute Finland (Luke) is coordinating a research and development project 'Innovative and effective technology and logistics for forest residual biomass supply in the EU – INFRES'. The project is funded from the EU's 7th framework programme. INFRES aims at high efficiency and precise deliveries of woody feedstock to heat, power and biorefining industries.

INFRES concentrates to develop concrete machines for logging and processing of energy biomass together with transportation solutions and ICT systems to manage the entire supply chain. The aim is to improve the competitiveness of forest energy by reducing the fossil energy consumption and the material loss during the supply chains. New hybrid technology is demonstrated in machines and new improved cargo-space solutions are tested in chip trucks. Flexible fleet management systems are developed to run the harvesting, chipping and transport operations. In addition, the functionality and environmental effects of developed technologies are evaluated as a part of whole forest energy supply chain.

This publication is a part of the INFRES project. The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2012-2015] under grant agreement n°311881.

In this demo report, the execution and the results of Naarva EF28 felling head test, which took place in October and November 2014 in Austria, are documented. For the first time the felling head was employed in hardwood dominated stands. Additionally, a demo of the felling head was organized for professional audience on November 7th 2014. Impressions of the demo are included in the report.

Gernot Erber & Franz Holzleitner, Vienna, April 2015

Title	**Harvesting operations in hard wood dominated stands using the energy wood felling head Naarva EF28**
Author(s)	Gernot Erber & Franz Holzleitner
Abstract	The objectives of this study were to test the Naarva EF28 energy wood felling head in hardwood dominated stands and to show the capabilities of the head to a professional audience within a demonstration. The Naarva EF28 is an accumulating harvester head having a cutting guillotine instead of a saw bar, delimbing knives, feeding rollers and offering length measurement. Three mature stands separated by younger stands and composed of broadleaved (Fagus sylvatica, Quercus ssp., Carpinus betulus, Tilia ordata and Castanea sativa) and coniferous (Pinus sylvestris, Larix decidua and Picea abies) species, were the area of operation. Study sites silvicultural target was to establish natural regeneration. Therefore the thick undergrowth had to be removed. The dominating species in the undergrowth was hornbeam (Carpinus betulus L.). The head was attached to on a Komatsu 911 harvester and the time studies took place on four days and at three different sites between 18.11.2014 and 04.12.2014. Nineteen time study plots measuring 20 m x 20 m were situated in the stand. In total 598 work cycles were recorded with an average cycle time of 0.7 min. Most time of the operation was spent cutting and processing. A wide variation in harvesting conditions between the plot areas in terms of trees to cut, mean plot diameter and therefore consumed harvesting time, was observed. Overall mean productivity on cycle data basis was 2.40 tonnes dry matter/PSH_0 (2.93 m^3/ PSH_0), maximum productivity was 6.84 tonnes dry matter/PSH_0 (8.34 m^3/PSH_0) and minimum productivity was 0.53 tonnes dry matter/PSH_0 (0.65 m^3/PSH_0). A productivity model was developed from time study data with the mean DBH as explanatory variable for use within the valid range of 3.2 cm to 15 cm mean DBH. Employing multi tree operations (cutting and handling) improved the overall productivity and can therefore be recommended when carrying out small diameter operations. The smaller the mean diameter of the trees per grapple, the more could be accumulated and processed at once. As the driver was able to handle many trees at the same time for trees below 7 cm, productivity did not decline significantly. Harvesting in hardwood dominated stand proved to work well, as long as the cutting diameter did not exceed 20 cm. It is expected that the overall harvesting operation productivity will improve significantly due to the cut to length-capability of the EF28 head and therefore much easier forwarding operation. Concluding, the EF28 can be considered a feasible option in hardwood dominated stands. There's still room for improvements concerning resistance and solidity of the frame and moving parts, as well as blade wear in hardwood cutting. The demonstration was executed on November 7th 2014 with about 100 participants from all fields of forest business including small scale farmers, forest owners, harvesting entrepreneurs, machine manufacturers, interest representatives, researchers and students. Early thinning operations in hardwood dominated were demonstrated and extensively discussed.
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1 Introduction

Fully mechanized harvesting of small diameter trees with harvester and forwarder for energy purposes has been documented in detail throughout the last decade, especially in the Nordic countries, where this technology originates. The number of available machinery and equipment, employing different approaches is growing. Innovative improvements and further developments pushed these specially constructed heads into Central Europe too.

Currently, the market offers a wide range of energy wood felling heads for variable use. Cutting elements range from special designed saw bars to guillotines, which enable different solutions for felling and cross cutting. Feed rollers included sensors offer the possibility to produce high quality logs through an integrated length measurement system. Some heads are equipped with alternating fingers at the top of the head for multi-tree handling.

Steady supply of bioenergy plants with regional material for combustion purposes cost effectively is of major interest. Cascade use of raw material from forestry is a topic more and more discussed. Therefore material coming from first thinning operations with low quality or otherwise not marketable specifications offers an opportunity to satisfy both energetic utilization and pulp and paper production without negative mutual impact. Furthermore, these types of heads offer an opportunity to counteract reduced and postponed pre-commercial thinnings, if it is possible to produce energy wood (Hakkila 2005, Heikkilä et al. 2007).

Recent international studies show the potential of special developed machinery, especially in first thinning operations (Karhä 2006, Laitila & Asikainen 2006, Ovaskaenen et al. 2008, Belbo 2010, Fulvio et al. 2012, Laitila & Väätäinen 2013, Fulvio & Bergström 2013 and 2014). Austrian entrepreneurs and forest owners were pushing this new harvesting technology, using specially designed heads for their purpose and started to introduce them in recent years. They were mainly interested in the performance of the machinery under varying conditions and in different stands. Recent Austrian studies on energy wood heads by Affenzeller (2007), Rottensteiner (2008) and Elmer (2011) covered tractor and forwarder mounted heads. The tractor mounted, non multi stem handling head (Naarva Grip 1500-25) was employed in a thinning operation in a stand composed of pine, oak and larch. The material was directly loaded on and forwarded with a tractor trailer. An average productivity of 1.33 m^3/PSH_{15} for felling and extracting was achieved. In the first forwarder (head Moipu 400E) operation, conducted in a pine-oak-broadleaf thinning operation, trees on the strip road were cut and piled along the strip road. After finalizing the strip road, they were forwarded to the storage area. Then both sides of the strip road were thinned. Full length trees exceeded forwarders storage length, thus backwards driving was out of question. An average productivity of 3.30 m^3/PSH_{15} for felling and extracting was achieved. The second forwarder based thinning operation (head Moipu 300ES) was conducted in a pine-oak stand. In the first scenario only energy wood was harvested, in the second both energy wood and pulp wood were harvested. Again, first the strip road was cleared and then thinning was conducted on both sides. In the first case, the productivity for harvesting and extracting was 3.94 m^3/PSH_{15}. By additional harvesting of pulp wood the productivity rose to 4.05 m^3/PSH_{15} due to the higher load volume. An overview on both Nordic and central European studies on multi tree handling energy wood heads since 2000 is provided Table 1.

Within INFRES project, one task is to test new, innovative solutions for energy wood supply. The felling head Naarva EF28 was tested at a demonstration in a hard wood dominated stand, mounted on a standard Komatsu harvester. A major advantage of this head is the cutting blade instead of a cross cut saw as it is used in standard harvester heads. It allows easier cutting of low diameter stems and also cutting of more than one stem at the same time. Alternating fingers allow easy multi-tree handling which is extremely useful in small diameter stands. A length measurement system controlled by the feed rollers is an additional benefit and also offers the possibility to produce high quality logs. The head has been tested before under Nordic conditions by Laitila & Väätäinen (2013), mounted on an excavator in a thinning operation. In this operation, both energy wood and pulp wood were produced. An average multi stem productivity of 12.8 m³ per E_0h was achieved. Extensively use was made of the heads multi stem handling capacity.

The aim of this study was to assess the heads performance under central European hardwood conditions and to determine the heads capability to form a feasible alternative for replacing non cost effective manual pre-commercial thinning operations. A special focus was placed on the impact of multi tree operations in small diameter stands.

Table 1 –Overview on detailed studies of multi tree handling energy wood felling heads from 2000 onwards published in Europe.

Manufacturer	Head type	Cutting device	Bunching capability	Feed rollers	Delimbing capability	Length Measurement	Base machine	Treatment	Tree species	Productivity	Reference
Allan Bruks	Abab Klippen 250	elliptical shear blade	x				Logman 801 Forwarder	thinning	birch, alder, poplar	2.0-5.5 m^3/E_0h (felling)	Kärhä, 2006
Bracke Forest AB	C16	disk saw with chain	x				Ecolog 560 D	thinning	pine, spruce, birch	8.2 m^3/PMH_{15} (harvesting) 19.2 $m^3/$ PMH_{15} (forwarding)	Bergström & Fulvio, 2014
Bracke Forest AB	C16	disk saw with chain	x				Valmet 911.1	thinning	willow	3.5 ODt /PMH_{15} (harvesting) 7.2 ODt /PMH_{15} (forwarding)	Fulvio et al., 2012
Bracke Forest AB	MAMA	disk saw with chain	x	x		x	Ecolog 560 D	thinning	pine, spruce, birch	9.5 m^3/PMH_{15} (harvesting) 13.2 $m^3/$ PMH_{15} (forwarding)	Bergström & Fulvio, 2014
Moisio-forest	Moipu 300ES	2 blades	x	x	x	x	HSM 208f Harvester	thinning	pine, oak	3.94 m^3/PSH_{15} (felling & extracting)	Elmer, 2011
Moisio-forest	Moipu 400E	2 blades	x				John Deere 1110D Forwarder	thinning	pine, oak, beech	3.16 m^3/PSH_{15} (felling & extracting) 3.30 m^3/PSH_0 (felling & extracting)	Laitila & Asikainen, 2006 Rottensteiner et al., 2008
Nisula Forest	Nisula 280E	2 blades	x				Valmet XM Tractor	thinning	spruce, birch	3.0 m^3/E_0h (felling & extracting)	Belbo, 2010
Pentin Paja Oy	Naarva EF28	guillotine-blade	x	x	x	x	New Holland Kobelco E 135 B SR LC D Excavator	thinning	pine dominated	12.8 m^3/E_0h (harvesting)	Laitila & Väätäinen, 2013
Pentin Paja Oy	Naarva 1500-40	guillotine-blade	x				Farm tractor	clear-cut	platanus	3.8 t/hour gross productivity (felling)	Spinelli et al., 2006
Pentin Paja Oy	Naarva Grip 1600-40	guillotine-blade	x				Pro Silva Ässä 810 Harvester	thinning	spruce	4.7-8.5 m^3/h (felling)	Ovaskaenen et al., 2008
Pentin Paja Oy	Naarva Grip 1500-25	guillotine-blade					Valtra 8050 Tractor	thinning	pine, oak, larch	1.33 m^3/PSH_{15} (felling & extracting)	Affenzeller & Stampfer, 2007
Pentin Paja Oy	Naarva Grip 1500-25e	guillotine-blade	x				Valtra 120e Tractor	thinning	spruce	3.9 m^3/PSH_{15} (felling & extracting)	Eberhardinger, 2007

Manufacturer	Head type	Cutting device	Bunching capability	Feed rollers	Delimbing capability	Length Measurement	Base machine	Treatment	Tree species	Productivity	Reference
Ponsse	Ponsse EH 25	elliptical shear blade	x				Ponsse HS16 Ergo Forwarder	thinning	birch, alder, poplar	2.0-5.5 m³/ E_0h (felling)	Kärhä, 2006
Ponsse	Ponsse EH 25	elliptical shear blade	x				Ponsse Buffalo Dual	thinning	pine, spruce, birch	4.1-5.0 m³/PMH (felling & extracting)	Fulvio & Bergström, 2013
Ponsse	Ponsse H 53e	saw bar	x	x	x	x	Ponsse Buffalo Dual	thinning	pine, spruce, birch	4.1-5.0 m³/PMH (felling & extracting)	Fulvio & Bergström, 2013
Timberjack	TJ720	elliptical shear blade	x				Timberjack 870A Harvester	thinning/ clear-cut	various stands	2.9-4.4 green tonnes/h gross productivity (felling)	Spinelli et al., 2007
Timberjack	TJ730	elliptical shear blade	x				Timberjack 870A Harvester	thinning/ clear-cut	various stands	3.8 green tonnes/h gross productivity (felling)	Spinelli et al., 2007

2 Materials and Methods

Employed Machinery

The Naarva EF28 produced by Pentin Paja Oy is an accumulating harvester head having a cutting guillotine instead of a saw bar, delimbing knives and feeding rollers. Length measurement for producing assortments is solved via a sensor in the feeding rollers. Weight of the head is 700kg and could be handled via the harvester´s own control system or using the Naarva-automatic radio control system. The maximum cutting diameter of 28 cm is approximately 30 % lower for hard wood species. Further technical details are displayed in Table 2 and Figure 1.

Table 2 – Technical specification of the multi-tree handling energy wood felling head EF28. Picture: Holzleitner, F.

Factory code	EF28
Weight	700 kg
Height in felling position	116 cm
Grapple opening	83 cm
Delimbing diameter	4-42 cm
Feeding speed	4 m/s
Feeding force	13 kN
Feeding diameter	2-39 cm
Cutting diameter force and time	Max cutting diameter: 28 cm Cutting force: 240 kN Cutting time (200 l/min oil flow): 0.7 s
Cutting device	Shear for felling and bucking
Required pressure	240 bar
Required oil flow	170 l/min
Control system	Harvesters own control system or Naarva-automatic with radio control
Voltage	12V or 24V

The base machine was a standard 2003-model Komatsu (former Valmet) harvester 911. Maximum boom reach was 10m and machine weight was 18,000 kg. Due to the terrain conditions no chains or tracks had to be attached (Figure 2).

Figure 1: EF 28 head main parts.

Figure 2 – The energy wood harvesting head EF28 (left) and the base machine Komatsu 911 harvester (right). Picture: Holzleitner, F.

Study site description

The study site was located at Moschendorf (47° 2'53.12"N, 16°27'8.88"E), in the south of the Burgenland province and owned by the Austrian Federal Forests. Terrain was flat and without obstacles. Due to the stagnogley soil wet spots occurred here and there but did not hinder soil trafficability. Three mature stands separated by younger stands and composed of both broad leaf (Fagus sylvatica, Quercus ssp., Carpinus betulus, Tilia ordata and Castanea sativa) and coniferous (Pinus sylvestris, Larix decidua and Picea abies) species. The dominating species in the undergrowth was hornbeam (Carpinus betulus L.). Basal area weighted DBH in undergrowth at the tree stands ranged from a mean of 1.8 cm to a mean of 6.4 cm. Minimum diameter was 1 cm, maximum diameter 23 cm and the respective heights were 3.8 m and 25.9 m (Figure 3). Undergrowth basal area ranged from 27.8 m² to 67.9 m².

Figure 3 – Study site with remaining mature stand before (left) and after harvest (right) of undergrowth. Picture: Holzleitner, F.

Silvicultural objective

Study sites silvicultural objective was to establish natural regeneration. Therefore the thick undergrowth had to be removed fully, whereas all the mature trees, except manually cut mature hornbeam trees, remained standing.

Harvesting procedure

Undergrowth was harvested from strips along both sides of skid trails defined by the driver, with an approximate width 20 m. Trees were cut with the shear, collected and moved to the skid for processing. Then the packed trees were delimbed and cut to length with the shear blade. Along the skid trail, four to five meters long stems were piled with each pile of a two to three forwarder grapples volume. Tops were left on the skid trail for soil protection.

Time study description

The time studies took place on four days and three different sites between 18.11.2014 and 04.12.2014. Nineteen time study plots measuring 20 m x 20 m (400 m²) were situated in the stand. Plot boundaries were marked by colored ribbons strapped around the peripheral trees (Figure 4).

Within each plot tree DBHs were recorded and marked on the stem using a pre-defined color and number code (1 cm steps; code for below 10 cm, figures for lager diameters), facing the estimated location of the strip road. Thus the diameter could be allocated exactly during the time study. The employed harvester operator is used to run harvesters and forwarders and had more than one month of work experience with the EF28 head under different conditions. Parallel to the manual time study on a hand held computer, the whole time study was recorded with an onboard video documentation device (Figure 5). Thus accurate repeatability of all time study activities afterwards, especially detailed post-processing of all recorded data is guaranteed. Video data was used for error correction and at site B, plot 6 to 9, the time study was carried out wholly based on the captured video material.

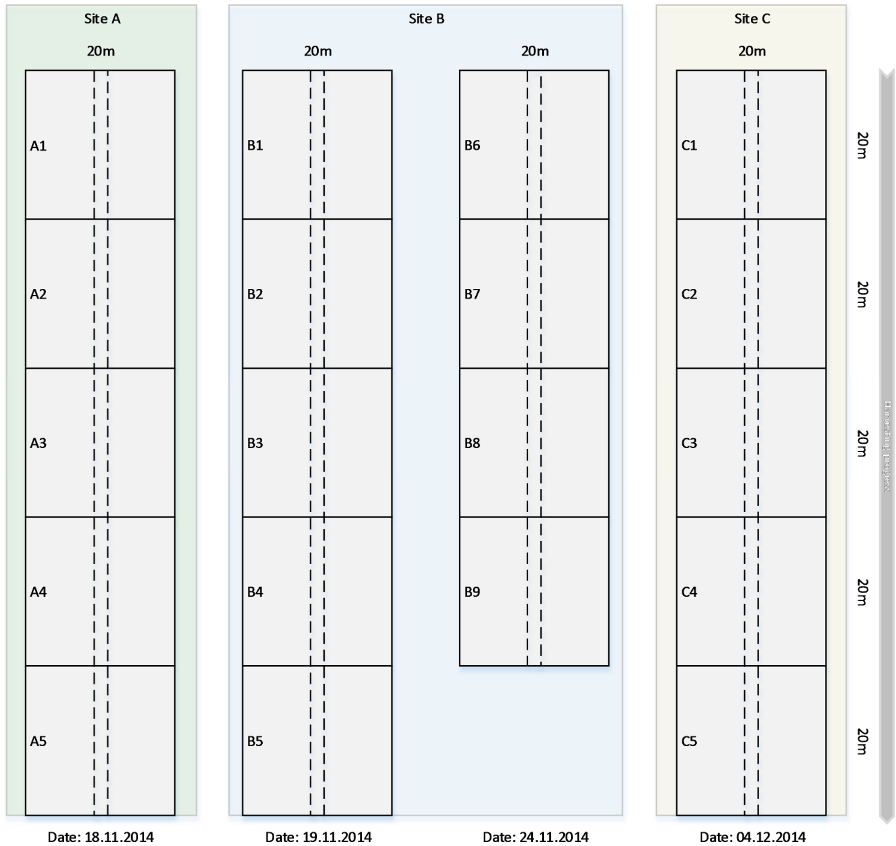

Figure 4 – Time study layout at three different sites.

Figure 5 – The time studies were recorded using video equipment for error correction in post-processing and partly for replacing classic field studies. Picture: Holzleitner, F.

The time study was carried out manually with ALGIZ 7 handheld computer. Working time was recorded employing continuous timing method. Effective working time phases were defined and recorded (Table 3).

Table 3 – Defined working time phases and respective starting and end points.

Work element	Starting point	Ending point	Priority
moving	machine moving forward or backward	wheels stopped turning	2
cutting	head is tilt into upright position and starts cutting	head is tilt into horizontal position	1
processing	head is tilt into horizontal position	head is tilt back into upright position	1
delay	neither moving, cutting or processing		3

Estimating dry mass per tree was done according to the Sterba and Nachtmann (2006) method for coppice species in eastern Austria. Moisture content was assessed for 12 wood disks in accordance with the European standard CEN/TS 14774-2.

Multi tree operations

Employing of the multi tree capacity of the head was recorded twice. First, whenever there was more than one tree handled per cycle, multi tree handling was marked positive. Secondly, whenever more than one tree was cut with one cut (due to the physical neighborhood), this action was recorded. The effect of these operations on the overall productivity was analyzed.

3 Study results and discussion

In total 598 cycles were recorded with an average cycle time of 0.7 min. The average moisture content of the material was 41.5 % ± 3.2 %. The recorded data was aggregated by plot (Table 4). Removal of trees per ha ranged from 1900 to 3725 with an average DBH between 3.7 cm and 9.6 cm. The number of trees per grapple varied between 1.6 cm and 6.4 cm. A mean of 0.8 t of dry matter per plot was harvested with a productivity of 2.30 t dry matter per PSH_0 (equivalent to E_0h). Most working time was spent on cutting (49.7 %] and processing (42.9 %). Less time was spent on driving and delays (Figure 6).

Table 4 –Harvest parameters aggregated by plot.

plot	cycles captured	removed trees per ha	harvested dry matter tonne	mean DBH	trees per grapple	min per plot	tonne dry matter per PSH_0
A_1	31	2575	0.8	5.4	3.3	21.6	2.22
A_2	41	2625	0.9	5.9	2.5	24.6	2.20
A_3	36	2475	0.8	6.1	2.6	22.6	2.12
A_4	28	2400	0.7	6.3	2.9	19.4	2.16
A_5	33	1900	0.8	7.6	2.1	22.2	2.16
B_1	47	2750	1.1	7.2	2.1	29.5	2.24
B_2	34	3225	0.8	5.2	3.2	22.3	2.15
B_3	33	2700	0.7	5.6	2.9	19.5	2.15
B_4	23	2825	0.7	4.7	4.7	18.9	2.22
B_5	28	3725	0.8	4.8	4.6	21.9	2.19
B_6	22	2300	0.6	4.6	4.2	13.8	2.61
B_7	18	2900	0.6	3.7	6.4	16.5	2.18
B_8	24	2925	0.7	4.5	4.9	20.3	2.07
B_9	25	3375	0.9	4.7	5.2	20.9	2.58
C_1	19	1900	0.5	5.4	3.6	13.4	2.24
C_2	28	2000	0.7	7.0	2.5	19.5	2.15
C_3	51	2225	1.3	9.6	1.6	30.7	2.54
C_4	48	2875	1.3	8.0	2.3	30.0	2.60
C_5	29	3075	1.0	5.4	4.2	23.9	2.51
Mean	**31.5 ± 9.6**	**2672 ± 492**	**0.8 ± 0.2**	**5.9 ± 1.5**	**3.5 ± 1.3**	**21.7 ± 4.77**	**2.30 ± 0.18**

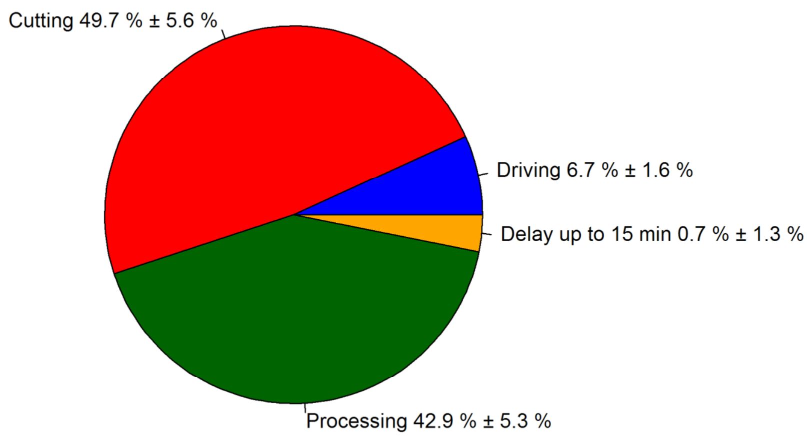

Figure 6 – Distribution of working phases.

Multi tree handling (more than one tree per grapple and cycle) and multi tree cutting (more than one tree cut at once) were analysed concerning their effect on the system productivity. It showed that, the smaller the trees in a cycle, the more likely were multi tree operations. From a mean diameter of 8 cm per cycle upward, a decline in the share of multi tree operations showed. From a diameter of 14 cm upwards, the share of multi tree operations was zero, which corresponds with the maximum cutting diameter of the EF28 (Table 4). A higher productivity was observed when multi tree operations were carried out. If more than one tree was cut with one move of the shear blade, mean productivity rose by 0.22 tonnes dry matter/PSH_0, whereas a rise of 0.12 tonnes dry matter/PSH_0 was observed for handling more than one tree per cycle.

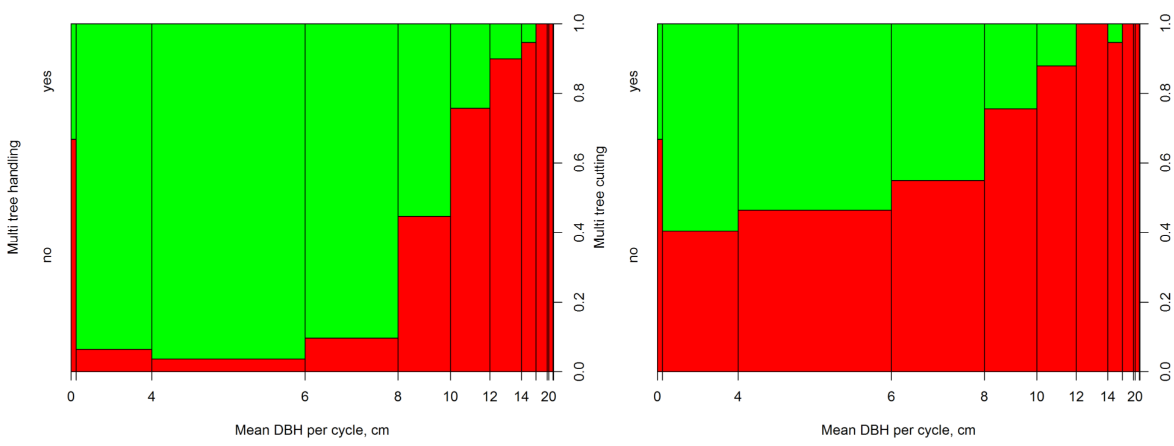

Figure 7 – The share of multi tree handling and multi tree cutting depends on the mean diameter per grapple. If diameters are small a large number of multi tree operations is carried out ("yes"; green). For diameters above 14 cm almost never a multi tree operation is carried out ("no"; red).

A curved borderline was observed for the relation of mean cycle DBH to number of trees harvested per cycle. For a mean DBH of 2 cm, up to 13 trees were accumulated in the grapple, whereas from a mean cycle DBH of 16 cm upward not more than one tree fit into the grapple (Figure 8).

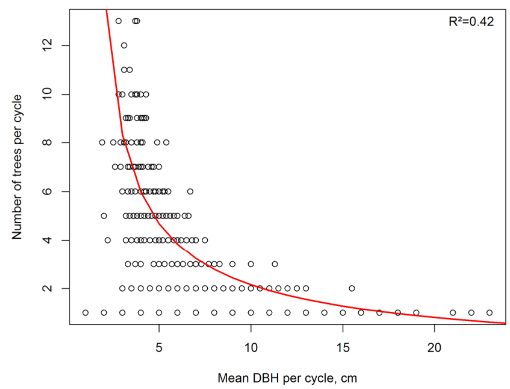

Figure 8 – The number of trees handled per cycle depends on the mean DBH per cycle.

Overall mean productivity on cycle data basis was 2.40 tonnes dry matter/PSH_0, the maximum productivity was 6.84 tonnes dry matter/PSH_0 and minimum productivity was 0.53 tonnes dry matter/PSH_0. For comparison reasons a volume productivity can be calculated. With an average dry density of hornbeam (820 kg/m³), the mean volume productivity is 2.93 m³/ PSH_0 (maximum productivity was 8.34 m³/PSH_0 and minimum productivity was 0.65 m³/PSH_0).

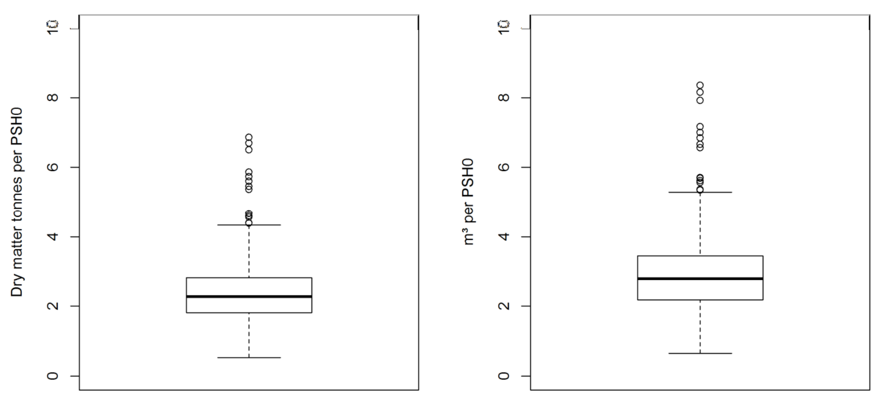

Figure 9 – Boxplots of EF28 productivity. Dry matter tonnes per PSH_0 (left) and converted m³ per PSH_0 (right).Thick black bar shows median, box 25th and 75th quartile, whiskers on top and bottom represent data in 1.5 x interquartile range, whereas the points represent outliers.

An efficiency model was developed from time study data with the mean DBH as explanatory variable (Table 5 and **Figure 10**) shall be used within its valid range, defined by the 5th and 95th quantile.

Table 5 – Parameters of the developed efficiency model for the EF28*.*

Target variable	**Explanatory variable**	**R^2 adj**	**Standard Error**	**Valid range 5th quantile**	**Valid range 95th quantile**
time consumption [min/tonne dry matter]	DBH mean [cm]	0.14	12.5 [min]	3.2 [cm]	15 [cm]

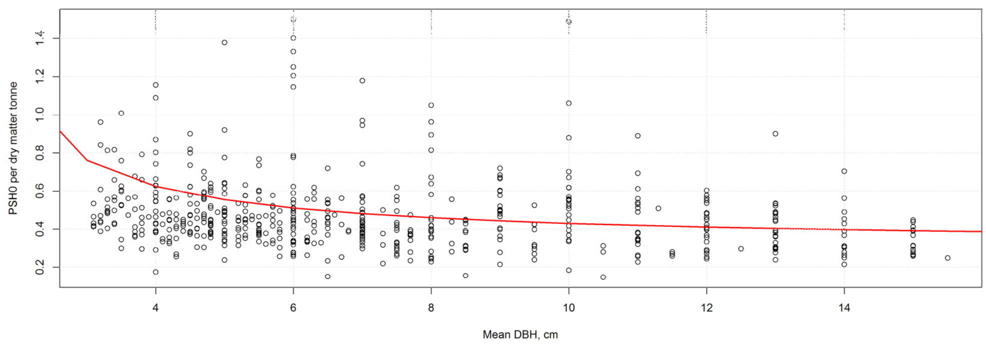

Figure 10 – Developed model for the time consumption per tonne harvested dry matter with the EF28 depending on the mean diameter per cycle.

From this model, a productivity model was derived (Model 1 and

Figure *11*).

Model (1) - Developed productivity model for the EF28.

$$Productivity\left[\frac{tonne\ dry\ matter}{PSH_0}\right] = \frac{60}{18.819 + 50.193\ \times\ DBH_{mean}{}^{-0.9}}$$

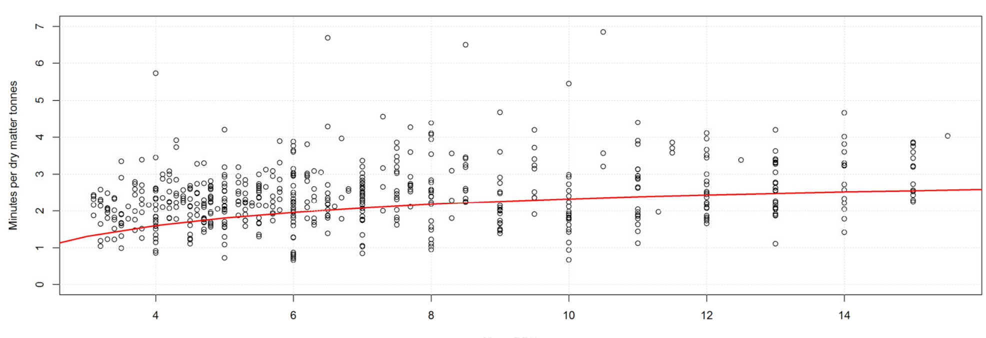

Figure 11 – Developed model for the productivity in tonnes of dry matter per PSH_0 with the EF28 depending on the mean diameter per cycle.

Most time of the operation was spent cutting and processing. Driving without any simultaneous harvesting or processing activities only accounted for about 7 % of the recorded time.

A wide variation in harvesting conditions between the plot areas in terms of trees to cut, mean plot diameter and therefore consumed harvesting time, was observed. Productivity in tonne dry matter/PSH_0 varied from 2.12 to 2.61 for the plots. Compared to other studies, a unique feature is the small average tree volume of 10 dm³ (Laitila and Asikainen 2013: 57 dm³, Fulvio and Bergström 2013: 30-40 dm³, Affenzeller 2007: 46 dm³, Elmer 2011: 77 dm³), which explains the low productivity. Other, similar equipped heads showed higher productivities, but also under better conditions concerning tree volume.

Employing multi tree operations (cutting and handling) improved the overall productivity and can therefore be recommended when carrying out small diameter operations. Here the multi tree handling and aggregation capacity shows its potential. After all that's what the EF28 head has been designed for.

Harvesting in hardwood dominated stand proved to work well, as long as the cutting diameter did not exceed 20 cm. Therefore the manufacturer's estimation, a reduction of the maximum cutting diameter of 28 cm by one third, proved to be accurate.

An interesting fact is the curved borderline that was found for the number of trees per grapple. It showed that for a mean diameter above 15 cm, only one tree could be handled at a time. The smaller the mean diameter of the trees per grapple, the more could be accumulated and processed at once.

It showed that there's a wide variation in the productivity of the EF28 head on cycle level, where productivity largely depends on the mean diameter per cycle. Contrary, if taking a look at the productivity on plot level, there's only a very small variation. Finally, this is what matters. As the driver was able to handle many trees at the same time for trees below 7 cm, productivity did not decline significantly.

If the EF28 is employed in small diameter hardwood stands, from a practical point of view, the developed model can be considered sufficient enough to estimate productivity and harvesting costs beforehand.

It is expected, as pointed out in Bergström and Fulvio (2014) that the overall harvesting operation productivity will improve significantly due to the cut to length-capability of the EF28 head and therefore much easier forwarding operation.

Concluding, the EF28 can be considered a feasible option in hardwood dominated stands. There's still room for improvements concerning resistance and solidity of the frame and moving parts, as well as blade wear under hardwood conditions. It can be expected that, as observed at the demo site, a significantly higher productivity can be achieved in a stand with larger diameters.

4 Demo impressions – 7th November 2014

The demo with more than 100 participants was executed on November 7th 2014 near Lockenhaus, province of Burgenland, Austria. Participants from all fields of forest business including small scale farmers, forest owners, harvesting entrepreneurs, machine manufacturers, interest representatives, researchers and students. Early thinning operations in hardwood dominated were demonstrated and extensively discussed.

The harvesting site was a slightly sloped (20 %) and north-east-east exposed. The operation carried out was the first thinning at an age of 30 to 40 years. Total volume at the stand was about 250 m³ per ha.

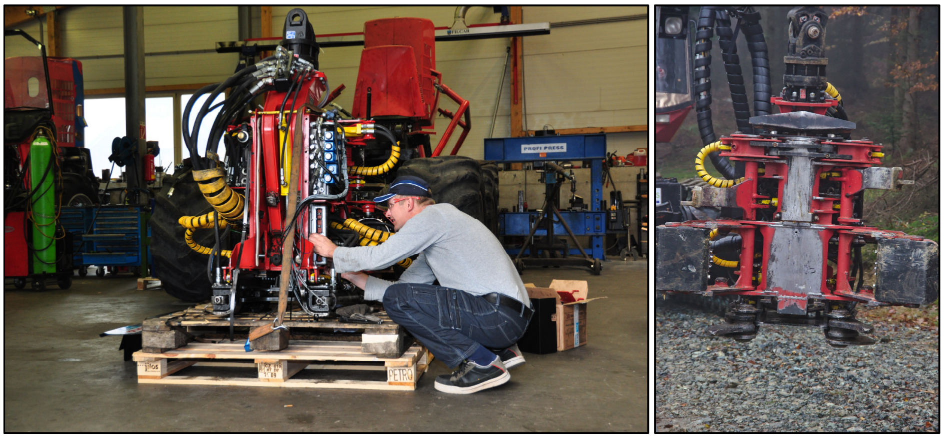

Figure 12 – Assembling and mounting the head at Komatsu Austria by Juha Korhonen (left) and head mounted on the Komatsu 911 at the demo site. Picture: Holzleitner, F., Kanzian C.

Figure 13 –The hardwood dominated stands at the demo site before (left) and after treatment (right) Picture: Kanzian, C.

Figure 14 – Visitors at the demo day, Friday, 7/11/2014 – Walking to the site (left) and examining the treated stand (right). Picture: Kanzian, C.

Figure 15 – Visitors at the demo day discussing and receiving detailed information on the machine and site. Picture: Kanzian, C.

<u>Additional impressions from the whole Demo-Day are available under the following links:</u>

<u>Demo Day English Version</u>!

<u>Demo Day German Version</u>!

References

Affenzeller, G., Energieholzbereitstellung mit Traktor und Krananhänger mit Fallbeilklingenaggregat, Project report - Institut für Forsttechnik (FT), BOKU-Universität für Bodenkultur, 2007, 33 p.

Belbo, H., Comparison of two working methods for small tree harvesting with a multi tree felling head mounted on farm tractor, Silva Fennica 44(3), 2010, 453-464.

Bergström, D. & Di Fulvio, F., Comparison of the cost and energy efficiencies of present and future biomass supply systems for young dense forests, Scandinavian Journal of Forest Research 29(8), 2014, 793-812.

Eberhardinger, A., Schwarze Zahlen in der Schwachholzernte?, Forst & Technik, 5/2007: 2-6

Elmer, G., Evaluierung des Fäller-Sammlers Moipu 300ES, Master thesis - Institut für Forsttechnik (FT), BOKU-Universität für Bodenkultur, 2011, 51 p.

Fulvio, Di F. & Bergström, D., Analyses of a single-machine system for harvesting pulpwood and/or energy-wood in early thinnings, International Journal of Forest Engineering 24(1), 2013, 2-15.

Fulvio, Di F., Bergström, D., Kons, K. and Nordfjell, T., Productivity and Profitability of Forest Machines in the Harvesting of Normal and Overgrown Willow Plantations, Croatian Journal of Forest Engineering 33(1), 2012, 25-37.

Hakkila, P., Fuel from early thinnings, International Journal of Forest Engineering 16(1), 2005, 11-14.

Heikkilä, J., Siren, M. and Ärjälä, J. O., Management alternatives of energywood thinning stands, Biomass and Bioenergy 31(5), 2007, 255-266.

Kärhä, K., Whole-tree harvesting in young stands in Finland, Forestry Studies 45, 2006, 118-134.

Laitila, J. and Asikainen, A., Energy Wood Logging from Early Thinnings by Harwarder Method, Baltic Forestry, 12 (1), 2006, 94-102

Laitila, J. & Väätäinen, K., The cutting productivity of the excavator-based harvester in integrated harvesting of pulpwood and energy wood, Baltic Forestry 19(2), 2013, 289-300.

Ovaskaenen, H.; Palander, T.; Jauhlaenen, M.; Lehtemäki, J.; Tekkanen, L. & Nurmi, J., Productivity of energywood harvesting chain in different stand conditions of early thinnings, Baltic Forestry 14(2), 2008, 149-154+225.

Rottensteiner, C.; Affenzeller, G. & Stampfer, K., Evaluation of the feller-buncher moipu 400E for energy wood harvesting, Croatian Journal of Forest Engineering 29(2), 2008, 117-128.

Spinelli, R.; Cuchet, E. & Roux, P., A new feller-buncher for harvesting energy wood: Results from a European test programme, Biomass and Bioenergy 31(4), 2007, 205-210.

Spinelli, R.; Nati, C. & Magagnotti, N., Biomass harvesting from buffer strips in Italy: Three options compared, Agroforestry Systems 68(2), 2006, 113-121.

Sterba, H., Nachtmann, G., Biomassefunktionen für Ausschlagwaldbaumarten im Osten Österreichs, In: Nagel, J.: Sektion Ertragskunde: Beiträge zur Jahrestagung 2006, 29.-

31.05.2006, Staufen, Deutscher Verband forstlicher Forschungsanstalten, Göttingen; ISSN 1432-2609, 2006, 184-189.

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INFRES – Innovative and effective technology and logistics for forest residual biomass supply in the EU (311881)

Dan Bergström (SLU), Fulvio Di Fulvio (SLU/IIASA),

Yrjö Nuutinen (LUKE),

Lena Jonnson (Swedish Forest Technology Cluster)

Demo Report 15: Studies and demonstration on the use of a bundle-harvester system in early fuel wood thinnings

Dissemination Level

Public	x
Restricted to other programme participants (including the Commission Services)	
Restricted to a group specified by the consortium (including the Commission Services)	
Confidential, only for members of the consortium (including the Commission Services)	

Umeå, April 24th, 2015

SEVENTH FRAMEWORK PROGRAMME

1. Introduction

In order to reach high cost efficiency in forest fuel supplies high payloads in terrain and road transportations are crucial. Therefore the biomass could be compressed into ca 2.5-3.5 m long bundles with densities of 270-780 kg/m^3 already in the stand or at roadside before being further handled and transported (Nordfjell & Liss 2000). Such systems has been analyzed in the past and it was concluded that if the bundles can be made in such way that they can be transported on conventional roundwood trucks, the logistical advantages are severe throughout the supply chain (Johansson et al. 2006). The bundles are easy to handle when being re-loaded, dry out during storage, and the comminution can effectively be done using large scale systems. However, the technologies studied for bundling are costly and new technologies with higher cost efficiency are required. Bergström and Di Fulvio (2014) show that if bundle-harvester systems for young dense thinnings are developed further, their cost efficiencies when including transportations to the end users will be significantly lower than for conventional tree-parts systems.

A first prototype of whole tree bundler for small trees was tested in Finland in 2007 (Jylhä & Laitila 2007), the early study shown that the bundling productivity was limited by the fact that simultaneous harvesting and bundling phases were only 8–18% of effective working time in the study. Therefore, it was concluded that the studied concept was not competitive with the conventional harvesting systems, however having a great potential for future development. A second prototype was studied in 2009 (Kärhä et al. 2009, Nuutinen et al. 2011), the productivity increased by 38-77% compared to the first prototype, and the improvement was due to a higher cutting-accumulation capacity and the improved bundling hydraulics, which increased the possibility to perform simultaneous harvesting and bundling.

A third version of the “Fixteri” bundling system was launched in 2013 and its efficiency (time/bundle) when implemented in a bundle-harvester concept has been further increased by 90-160% in comparison to previous versions (Björheden & Nuutinen 2014). The systems productivity has however not been extensively studied in stands with an average tree size harvested below 30 dm^3. In these stands, the share of disturbing under-growth trees can be significantly and might decrease cutting productivities (cf. Kärhä 2006).

Objectives

The objective was to study the effect of harvested tree size and density of undergrowth on the operational efficiency of a whole tree bundle-harvester in early fuel wood thinnings in the North of Sweden.

2. Materials and Methods

A stand containing patches dominated by broad leaves and conifers of various characteristics was selected. The study area was located in Holmsund (N 63°43’, E 20°25’) in the costal area of north of Sweden. The forest was 30-35 years old and contained mostly of Scots pine, Norway spruce and birch. The ground had in generally a good bearing capacity, the surface had no obstacles and the slope was slight. In total 26 units were marked out for harvesting with an average surface of 1215 m^2, and a total surface of 3.2 ha (Table 1). In 10 of the 26 units a pre-cleaning was carried out, meaning that trees with a DBH ≤2.5 cm (i.e. undergrowth trees) were cut with a cleaning saw and left on the ground prior to the thinning with the bundler-harvester.

Table 1. Characteristics of the 26 harvesting units after pre-clearance (in 10 of the units) and before thinning.

	DBH[1]	**DBH basal**[2]	**Stem volume**	**Density**[3]	**Height**	**Stem volume**	**Biomass**	**Undergrowth density**
Stats	***(cm)***	***(cm)***	***(dm^3)***	***(trees/ha)***	***(cm)***	***(m^3/ha)***	***(OD t/ha)***	***(n/ha)***
Mean	7.1	8.0	26.5	5406	8.2	133.9	92.3	4523
Min	5.5	6.3	15.0	2765	7.0	91.0	54.0	134
Max	8.5	9.9	43.0	9302	9.7	206.0	148.0	11951
Median	7.0	8.0	24.5	5200	8.1	131.0	91.0	3648
SD	0.9	1.0	8.1	1583	0.7	28.9	24.9	3509

[1]Arithmetic DBH for tree-sizes ≥ 2.5 cm DBH; [2]DBH weighed by basal area; [3]Including all tree sizes.

The machine system studied was a harwarder equipped with a bundling unit able to cut the trees and bundle them into 2.6-m long cylinders with a diameter of ca 60-70 cm (**Figure 1**). The base machine was a 8-wheeled Logman 811FC (Logman, Oy) with engine power of 125 kW, a mass of 15 t, a width of 2.8 m and ground clearance of 65 cm. It was equipped with a 10 m reach Logfit FT100 crane (Logfit AB) integrated on a rotating cabin with endless turning. The crane was equipped with a Nisula 280E+ (Nisula Forest Oy) accumulating felling head with a mass of 0.33 t and a maximum cutting diameter of 28 cm.

Figure 1. The Fixteri FX15 bundle-harvester system

The bundling unit was a Fixteri FX15 with a mass of about 6.5 t, a width of 240 cm, a length of 410 cm, and height 280 cm. The systems total mass was 23.5 t. The bundling unit it featured with two feed rollers, a cut-to length guillotine and a compression and bundling compartment. The bundling chamber has a fixed length of 260 cm and is featured with three sets of chains used for compression and a vertically sliding frame. On the right side of the compression chamber are two plastic net rolls mounted, each roll containing 4000 m of wrapping net. On the opposite side of the chamber are two mobile arms mounted for integrating scaling and dropping-off of bundles. The bundling unit is powered by the base machine´s electrical and hydraulic system (Fixteri Ltd 2014).

Whole trees were cut, accumulated and fed to the bundling unit for processing (Figure 2). The guillotine installed at the chamber gate bucks the stems in the feeding chamber into 260 cm lengths. Once the compartment contained sufficient material for producing one bundle (i.e. 450-500 kg of fresh mass), the bunch of trees was lifted up to a compaction chamber where the bundle was compressed by revolving chains and tied up by means of a plastic net, at the same time the lower compartment could be fed with other trees. Once the bundle reached a sufficient density it was automatically unloaded from the compaction chamber to two side arms, the bundle was automatically scaled and information on time of production and mass were recorded on the base machine computer. Then the bundle was dropped on the ground from the arms and a new bundling cycle started. The bundling process is completely automated and the operator can use the crane for cutting and feeding trees to the bundling unit while the bundle compaction is continuously performed. No residual biomass excesses the bundling process, i.e. the whole trees feed to it are bundled.

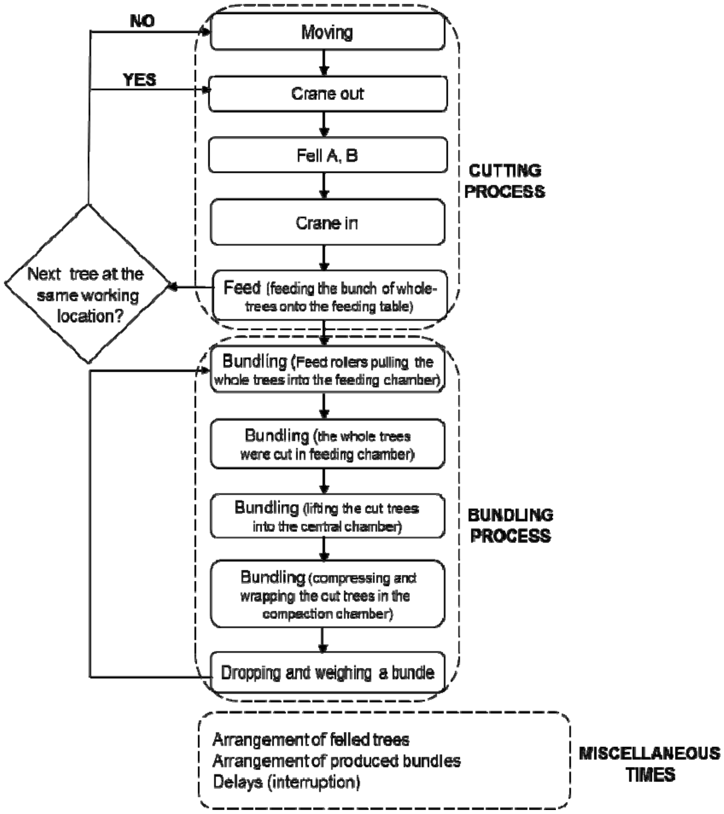

Figure 2. Flow chart of the work processes for the studied bundle-harvester. Notations A and B indicates that the several trees can be cut in one crane-cycle before delivered to the bundling unit.

The thinning was carried out selectively from below on a strip road pattern with a 20 m spacing between the roads. Removing priority was given to broadleaved species and the target was to leave at least 1200-1500 future crop trees/ha (i.e. trees with DBH > 6-7 cm).

The time study was conducted between 5th and 14th of May 2014, and the total duration of the study was 29.4 hours. The productive work time (PMH_0) consumption was continuously recorded and delays were recorded apart. The highest priority in the recording of time elements was given to the crane work, i.e. if the crane work and bundling were performed at the same time, the crane was prioritized and recorded. During the harvesting the number of felled trees per crane cycle (DBH > 2.5 cm) was also recorded (the threshold was visually estimated). At the same time, the machine computer created a dataset for each harvesting unit which contained the time (hour: minute: second) when each bundle was expelled from the bundler and its fresh mass (kg), as acquired from the integrated scale.

After the time study, the remaining stand's characteristics were inventoried again by using permanent transects used for the inventory of the stand characteristics prior to the thinning.

The oven-dry (OD) biomass content of stems, branches and needles was calculated using Marklund's (1987) functions. For conversion to solid volume, Hakkila's (1978) basic density values for crown biomass were used. The bundle mass was acquired directly from the machine database as a fresh mass and was converted to oven dry (OD) mass by using the moisture content (MC) recorded in each harvesting unit. Immediately after harvesting, in each of the harvesting units, one bundle was randomly sampled from which a 10 cm thick slide was cut off (in the middle of its length) by using a chainsaw for MC determination. The average MC for the pine, spruce and birch dominated harvesting units were 53.4 (SD =2.5), 58.7 (SD =1.3) and 52.6% (SD =3.0), respectively.

3. Study result

There were no differences between treatments (pre-clearance vs. no pre-clearance of undergrowth) on the remaining stands' properties (i.e. stand density, damage, strip road spacing). The remaining stands had in average 1852 trees/ha and consisting of of 39% pine, 20% spruce and 41% birch, by number. The strip-road width was in average 4.5 m and the distance between strip-roads 19.8 m. The bundles had in average a fresh weight of 439 kg (SD 24.1 kg) with a minimum and maximum value of 391 and 493 kg, respectively. The corresponding dry mass was 203.4 OD kg (SD 17.3).

The number of undergrowth trees had no significant effect on the harvester and bundling work time consumption. The felling crane was standing idle 7.4% of the effective work time, mostly due to feeding large trees and moving droppedbundles . In average 4.1 trees/crane cycle were harvested and there were no statistically significant differences between treatments. In average each crane cycle took 44.6 seconds and in average 5.5 crane cycles were required to produce a bundle. Hence, in average 4.1 min of work time were required per bundle.

The productivity reached in average 3.1 OD t/PMH_0 (SD 0.6 t/PMH_0) (6.6 fresh t/PMH_0 (SD 1.2 t/PMH_0)) .The independent variable, harvested tree size (stem volume), explained most of the variability in the productivity (67%) and was used as single variable for modeling the harvester-bundler productivity (OD t/PMH_0), since all other combinations of independent variables gave lower prediction values and/or were biased with multicollinearity (Figure 3).

In average 15.1 bundles/PMH_0 (SD 2.7) were produced with a minimum and maximum production rate of 10.8 and 20.3, respectively. The productivity in terms of bundles/PMH0 was also mostly explained by the harvested stem volume, and in this case it explained a slightly higher degree of variability compared the productivity in term of mass (74% vs. 67%).

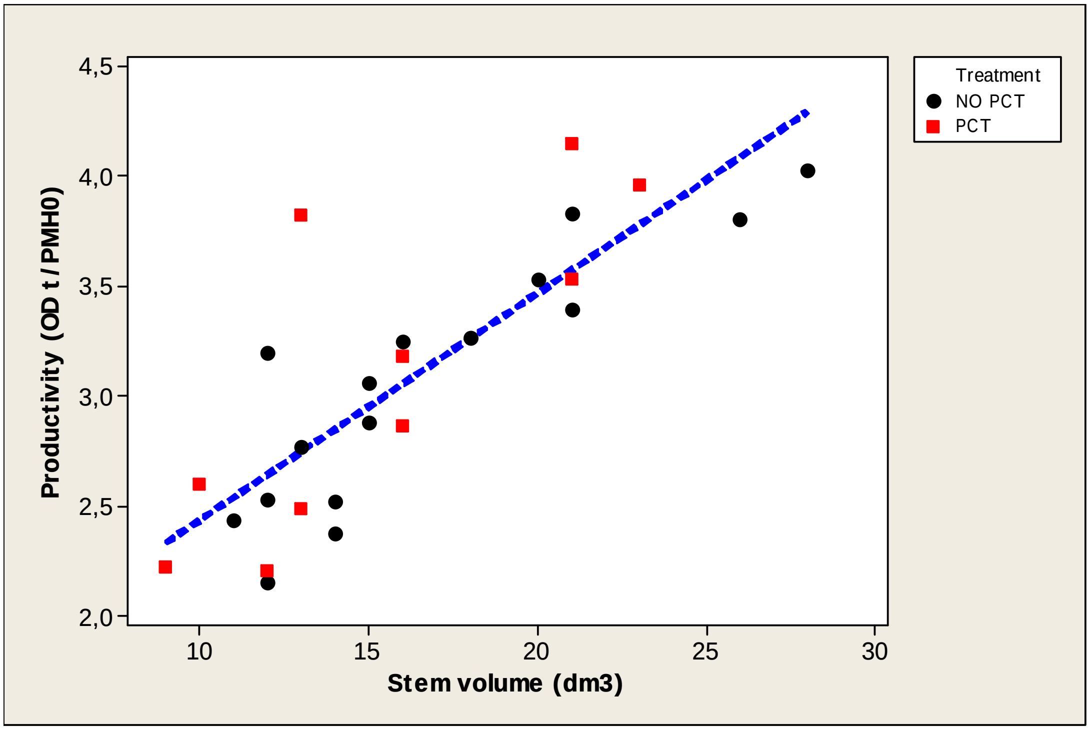

Figure 3. Productivity of the bundle-harvester system as a function of average harvested stem volume and treatments, PCT=pre-cleaned, NO PCT=not pre cleaned.

4. Chain level comparison with conventional supply chains

The cutting efficiency of the system is in line with previous studies (Björheden & Nuutinen 2014) and in line with conventional loose tree-parts harvesters. In average 4.1 trees/crane cycle were cut. Iwarsson Wide (2010) stated that the number of handled trees per crane cycle is a critical parameter for multi-tree handling in small diameter stands. Belbo (2011) showed through a simulation that the optimal number of accumulated trees in multi-tree cutting is from 4 to 5 trees per crane cycle. Thus, it seems that the cutting capacity was highly utilized in present study. As bundles achieve higher payloads than loads of loose tree parts the overall productivity of bundle supply systems are therefore higher. However, the operational cost of the bundle harvester is higher than for conventional harvesters, therefore the systems suitability is dependent on tree size harvested and transportation distances. Bergström and Di Fulvio (2014) show that bundle-harvester systems, similar to the studied one, are competitive compared to conventional tree pert systems in early fuel wood thinnings where the average stem volume harvested is greater than ca 30 dm^3. One obvious drawback with the bundle-harvester system is its high mass, which limits the machines usability on weak grounds.

5. General evaluation

The following conclusions can be drawn from the field study:

- The system efficiently produces high density bundles with high durability from whole trees.
- The efficiency of the system is limited by the cutting work speed, i.e. the efficiency of the bundler exceeds the efficiency of which trees can be feed to the bundler.
- The machine is relative heavy and its center of gravity is relatively high from the ground which gives high ground pressure and limits its maneuverability in side slopes.

In order to optimize the efficiency and potential of the bundle-harvester system, the following technical improvements/changes and future studies are suggested:

- The system can reach higher efficiency if featured with an accumulating head able to achieve higher cutting efficiency.
- A reduction of the bundler-harvester mass would render higher utilization (more type of stands could be harvested).

6. Demo results

In May 16th 2015, 80 persons gathered in Holmsund (10 km from Umeå) in north of Sweden for a field demonstration. The participants were researchers, machine manufacturers, machine developers, representatives from refining industries, forest companies and forest owners associations. The in-field demonstration included the entire supply system for small tree bundles (**Figures 4-9**): 4 & 5) cutting and production of bundles; 6) forwarding of bundles; 7) building of a storage pile; 8) truck transportation of bundles; 8) chipping of bundles. The main event was the demonstration of the “Fixteri FX15” bundling system which was attached to a Logman811FC equipped with a Nisula Forest 285 head (Figure 4). This system has previously been studied in Finland by the Metla (i.e. currently “Luke”), the Swedish Forest Research Institute (Skogforsk), Metsäteho and Pöyry Management Consulting. The Finnish study results show that the system is effective and competitive in comparison to conventional systems, and therefore it was interesting to study and demonstrate also in the Swedish conditions. The system was demonstrated while thinning a young dense stand. During the demonstrations, the audience had the possibility to ask questions both to the machine operators and machine owners/manufacturers.

Figure 4. The Bundle harvester system demonstrated.

Figure 5. Strip road with produced bundles.

Figure 6. Forwarding of bundles with a Komatsu Forest 865 forwarder equipped with a slash grapple (E36) and a crane-scale system (Intelweigh XW 50PS).

Figure 7. Building of a storage pile. Bundles are laid in cross sections for higher wind penetration.

Figure 8. Bundles are loaded on a conventional timber truck.

Figure 9. Chipping of bundles with a Doppstadt DH-910 drum chipper.

7. Acknowledgements

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8. References

Belbo, H. 2011. Efficiency of Accumulating Felling Heads and Harvesting Heads in Mechanized Thinning of Small Diameter Trees. Doctoral thesis. Linnaeus University Dissertations No. 66/2011. 42 p.

Bergström, D. & Di Fulvio, D. 2014. Comparison of the cost and energy efficiencies of present and future biomass supply systems for young dense forests. Scandinavian Journal of Forest Research, DOI:10.1080/02827581.2014.976590.

Björheden, R. & Nuutinen, Y. 2014. Study of Fixteri FX15a small-tree bundling unit. Swedish Forest Research Institute, Report no. 819–2014.

Hakkila, P. 1978. Harvesting small-sized trees for fuel. Folia Forestalia, 342, 38 p. (In Finnish with English abstract).

Iwarsson Wide, M. 2010. Technology and Methods for Logging in Young Stands. In: Efficient forest fuels supply systems (Thorsén, Å., Björheden, R. & Eliasson, L. Eds.) Skogforsk, 2010.

Jylhä, P. & Laitila, J. 2007. Energy wood and pulpwood harvesting from young stands using a prototype whole-tree bundler. Silva Fennica 41(4): 763–779.

Jirjis, R. 1995. Storage and drying of wood fuel. Biomass and Bioenergy, 9 (1-5): 181-190.

Johansson, J., Liss, J.-E., Gullberg, T. & Björheden, R. 2006. Transport and handling of forest energy bundles—advantages and problems. Biomass and Bioenergy 30 (4): 334–341.

Kärhä, K., 2006. Effect of undergrowth on the harvesting of first-thinning wood. Forestry Studies 45:101-117.

Kärhä K, Laitila J, Jylhä P, Nuutinen Y. & Keskinen S. 2009. Kokopuun paalaus -tuotantoketjun tuottavuus ja kustannukset [Productivity and costs of the whole-tree bundling supply chain]. Metsäteho Report 211. ISSN 1459-773X. (In Finnish)

Marklund L.G. 1987. Biomassafunktioner för tall, gran och björk i Sverige. Biomass functions for pine, spruce and birch in Sweden. Sveriges lantbruksuniversitet, Institutionen för skogstaxering, Rapport 45, 79p (in Swedish with English Summary).

Nordfjell, T., & Liss, J.-E., 2000. Compressing and Drying of Bunched Trees from a Commercial Thinning. Scandinavian Journal of Forest Research, 15(2):284-290.

Nuutinen Y., Kärhä, K., Laitila, J., Jylhä, P. & Keskinen S. 2011. Productivity of whole tree bundler in energy wood and pulpwood harvesting from early thinnings, Scandinavian Journal of Forest Research, 26:4, 329-338.

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INFRES – Innovative and effective technology and logistics for forest residual biomass supply in the EU (311881)

Franz Holzleitner and Gernot Erber
BOKU

Demo report 16 - Semi-Automated Process Analysis of Wood Chip Supply using a Fleet Management System – D4.5

Dissemination Level	
Public	x
Restricted to other programme participants (including the Commission Services)	
Restricted to a group specified by the consortium (including the Commission Services)	
Confidential, only for members of the consortium (including the Commission Services)	

Vienna, 30.04.2015

Content

Preface

Finnish Forest Research Institute (Metla) is coordinating a research and development project 'Innovative and effective technology and logistics for forest residual biomass supply in the EU – INFRES'. The project is funded from the EU's 7th framework programme. INFRES aims at high efficiency and precise deliveries of woody feedstock to heat, power and biorefining industries.

INFRES concentrates to develop concrete machines for logging and processing of energy biomass together with transportation solutions and ICT systems to manage the entire supply chain. The aim is to improve the competitiveness of forest energy by reducing the fossil energy consumption and the material loss during the supply chains. New hybrid technology is demonstrated in machines and new improved cargo-space solutions are tested in chip trucks. Flexible fleet management systems are developed to run the harvesting, chipping and transport operations. In addition, the functionality and environmental effects of developed technologies are evaluated as a part of whole forest energy supply chain.

This publication is a part of the INFRES project. The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2012-2015] under grant agreement n°311881.

A fleet management system, operation in trucks and chippers was investigated in this study. Further, entrepreneur's business processes were mapped and starting points for the implementation of semi-automated reporting and controlling system were identified.

Franz Holzleitner and Gernot Erber, Vienna, April 2015

Title	**Semi-Automated Process Analysis of Wood Chip Supply using a Fleet Management System**
Author(s)	Franz Holzleitner, Gernot Erber
Abstract	Fleet management systems offering online process controlling have been used in other business fields such as e.g. transportation of food or package shipment before, always seeking to optimize delivery both in terms of customer satisfaction and cost efficiency. Supporting supply-chain processes from the forest to the energy plant by on-board monitoring equipment has become more essential, especially in wood chip supply. Data collection was carried out using a predefined process flowchart including also a detailed process mapping covering all business activities along the whole wood chip supply chain at Holz Schwarz GmbH. Additionally the main drivers regarding management of delivery notes from the start of a job until delivery and cash flow where mapped, identified and analyzed. All together 1,119 transport jobs were sent via the user frontend to the transport systems with installed fleet management system from February 2014 to April 2015. After plausibility check 792 truckloads remained for further statistical analysis. Two transport systems both consisting of truck and trailer transported 52,522 m³ loose over a distance of 55,186 km. In average a tour took 3.1 hours from driving empty to the chipping site until finishing unloading at the plant, having a tour length of 70 km and consuming 36.3 liters diesel. Average loading/chipping productivity was 100.5 m³ loose per hour. As a benefit for the entrepreneur, an automated, browser based reporting system was implemented based on pre-processed fleet management data. By selecting a date from the calendar with delivery note, a daily statistic of transport or chipping was generated. Furthermore details on time consumption and fuel use on process level are displayed. Thus efficiency in job administration could be increased significantly.
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Name of the project	INFRES - INFRES – Innovative and effective technology and logistics for forest residual biomass supply in the EU (311881)
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Keywords	fleet manager, process analysis, chipping, transport, process mapping
Publisher	

1 Introduction

Effectively running and organizing wood chip supply for energy purposes is a complex task under constant cost pressure. Detailed analysis and optimization of the main business processes and trip times requires knowledge of every process and its attributes, such as time and fuel consumption, within the work flow. Based on recorded and analyzed process data, productivity and utilization of each machinery and transport systems can be investigated easily (Holzleitner, 2013). Detailed business process mapping and analysis offer the possibility to identify main cost drivers and starting points for re-engineering of a defined wood chip supply system (c.f. Windisch 2013). Decision support systems and strategic planning activities in forestry strongly depend on high-quality data (Holzleitner, 2013).

Fleet management systems offering online process controlling have been used in other business fields such as e.g. transportation of food or package shipment before, always seeking to optimize delivery both in terms of customer satisfaction and cost efficiency. Supporting supply-chain processes from the forest to the plant by on-board monitoring equipment has become more essential, especially in wood chip supply. The use of mobile devices in combination with GPS for controlling the transport of wood chips was analyzed by Sikanen et al. (2005). It showed that state of the art information technology is capable of fulfilling basic requirements in controlling within the wood chip supply chain. However, there's still a need for improvements in terms of user-friendly hardware and software as well as in data exchange systems (Holzleitner, 2013).

Fleet management systems support the entrepreneur through combined analysis of delivery notes, engine and location data. Data from transport activities can be recorded automatically over a long period, without detaining the driver from work. Data storing and reporting for managing delivery notes or controlling the fuel efficiency is then done automatically by database procedures without any further effort by users (Holzleitner, 2013)

On-demand and automatically derived process data can support the strategic and operational decision making processes within a company. In particular, accurate costing for new investments and post calculations for reengineering purposes can easily be done. Development of multicriteria decision support tools for supporting the process of selecting the most efficient timber harvesting system depends on data like these (c.f. Kühmaier and Stampfer 2010 and 2012).

There's still plenty of room for improvement in existing supply chains for wood chips. Cost management, organizational effort and adaptability under varying conditions thus demand technical improvements based on these data. Until now, data recording and analyzing are normally done manually in infield time studies, which cover only a certain, short time frame, and are therefore of limited significance compared to long-term studies (Holzleitner, 2013)

This demo aims to analyze the main processes of wood chip supply based on long-term machine data. Starting with a focus on all business processes needed for delivering wood chips from the forest road side storage to the plant. Delivery note based reporting will be set up for supporting entrepreneur's decisions in a second step. Further, the existing data base on biomass supply processes will be improved for future research activities.

2 Material and Methods

2.1 Business process mapping

Using predefined process schemes, the entrepreneur's business processes from getting in contact with the forest owner until wood chips are delivered and accounted were mapped. The main processes were identified in interviews with the responsible persons and subsequently mapped in a chronological and thematic manner.

2.2 Data recording concept for wood chip transport

Data collection was carried out between February 2014 and April 2015 using a predefined process flowchart, as presented in Holzleitner et al. (2013). The transport cycle for wood chips was divided into several work phases. Cut-off point between two loads was the start of a new cycle starting with the process of driving empty to the chipper. Details on the vehicles involved in the supply chain are displayed in Table 1.In total, three chipper systems (one truck-, two tractor-based) and three transport systems, (two truck-, one tractor-based) were employed.

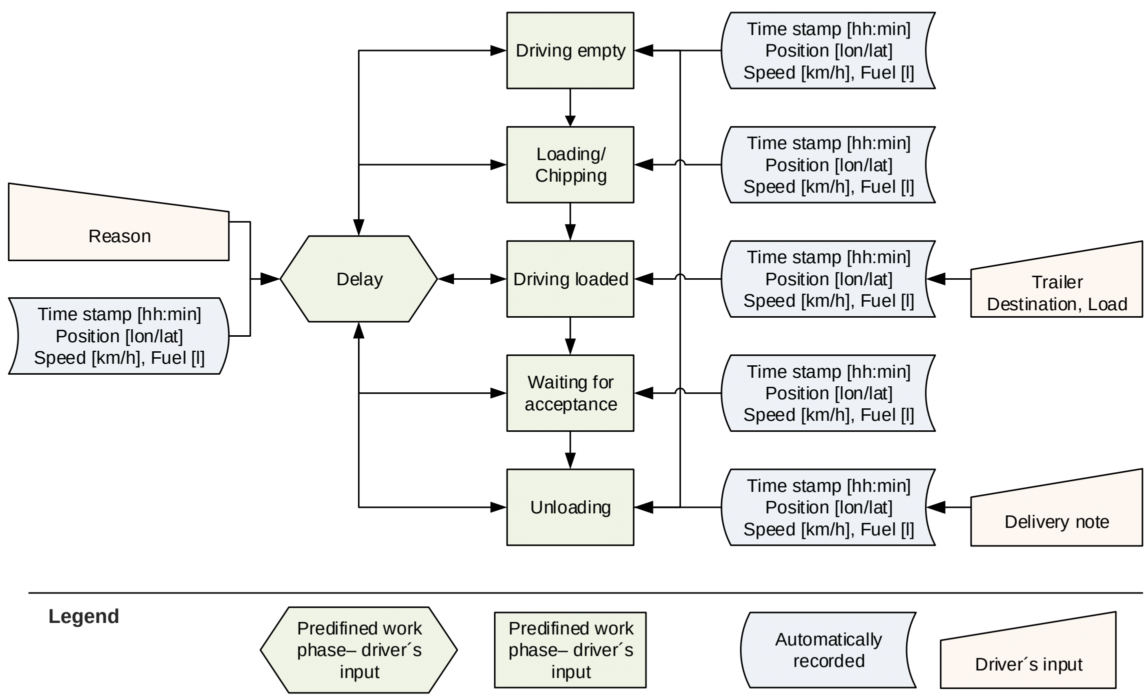

Figure 1 – Data recording concept example for wood chip transport using a fleet management system at Holz Schwarz GmbH. Data recorded either automatically or based on input by the driver (either pre-defined work phases or additional information).

Table 1: Holz Schwarz GmbH's vehicles equipped with a fleet manager device.

Nr.	Vehicle	Type	Year of construction	Power [kW]	Purpose	Transport capacity
1	IVECO truck	IVECO Trakker	2009	truck: 320	transport	75 m^3 loose with trailer
2	IVECO truck	IVECO Trakker	2009	truck: 320	transport	75 m^3 loose with trailer
3	IVECO truck Rudnick & Enners chipper	IVECO Trakker & RE-MTH 600*1000/10	2009	truck: 320; Chipper: 420	chipping	no transport
4	Steyr tractor & Mus-Max	Steyr 6230 & WOOD-TERMINATOR 9 XL	tractor:2013 chipper: 2012	tractor: 170	chipping	no transport
5	Case tractor & Mus-Max chipper	Case 370 & WOOD-TERMINATOR 11	tractor: 2015 chipper: 2014	tractor: 260	chipping	no transport
6	Steyr tractor & trailer	Steyr 6215 & miscellaneous	tractor: 2013	tractor: 160	transport	40 m^3loose

Hardware and software used for recording data within this demonstration were obtained from Funkwerk eurotelematik GmbH, a German manufacturer specialized in fleet management applications. The used version included an installed database with already pre-configured reporting and data management tools. Core of the data management system is a database that runs on a server at the Institute of Forest Engineering, Vienna, where all collected raw data is stored, prepared and merged for further analyses (Holzleitner, 2013).

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Figure 2 – Hardware (touch display) of the fleet management system used at the entrepreneur Holz Schwarz GmbH. Drivers use this to document working processes and additional information (Poier & Holzleitner).

Hardware installed in the driver's cabin consists of a terminal for handling navigation, documenting the progress of the delivery notes and additional driver input (Figure 2). Positioning is done by an integrated GPS antenna. Data transmission to the server is conducted via a GSM network module (Figure 3). Engine related data were directly recorded from the Fleet Management Systems Interface (FMS) of each vehicle. The interval for capturing data is flexible and was set to one minute for the study. Datasets contain following information: time stamp, vehicle ID, position and additional engine related data, which depend on the FMS version and data availability. The costs per oven dry ton before taxes for the fleet management amount to 0.72 € (Holzleitner, 2013)

Due to different vehicles types such as trucks and farm tractors, not all engine data types were available via FMS from every vehicle. Therefore, fuel consumption was analyzed only for the transport trucks with trailer and, in case the truck mounted chipper had an extra engine, for the trucks engine only. Information on transported volumes was gained from a digital delivery note database of the entrepreneur, which was linked to the rest of the data for the analysis period February 2014 to July 2014.

Creation and processing of delivery notes, as well as the progress controlling were conducted at the Institute of Forest Engineering. GSM network connection allowed adjustment of settings on the institute's desktop.

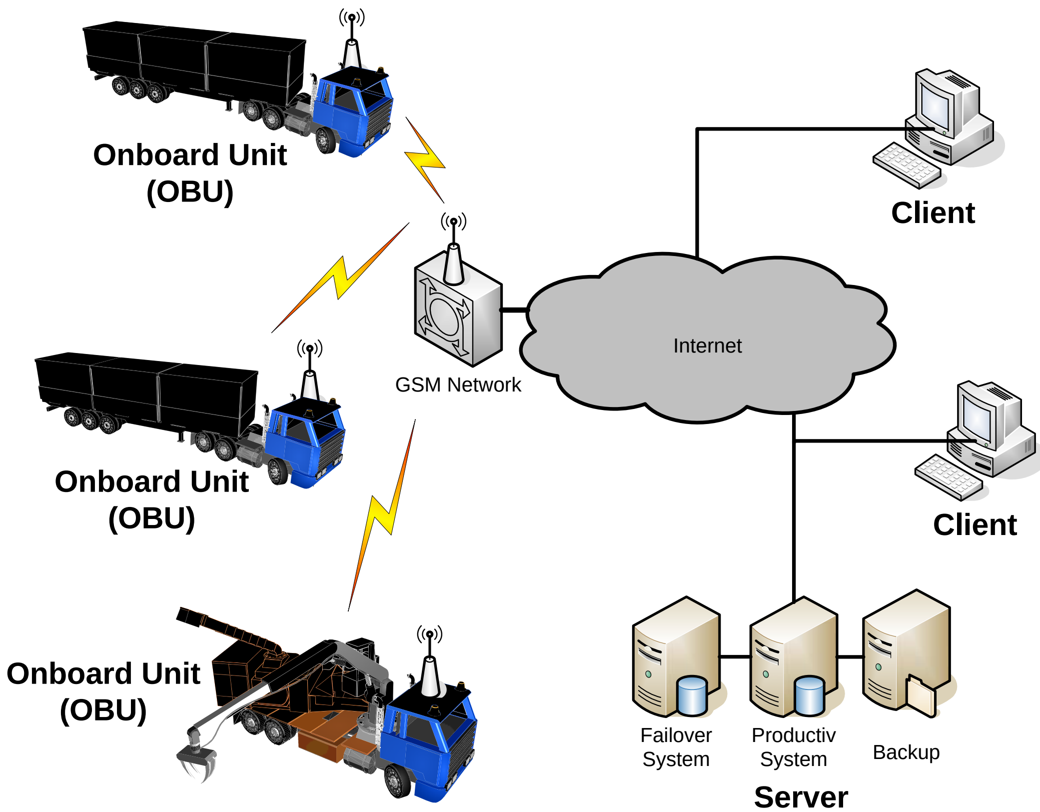


Figure 3 – Data recording principle example for wood chip transport using a fleet management system at Holz Schwarz GmbH. Data from the onboard units (OBU) is transferred via GSM-network to a server, where data is stored, processed and available for clients.

3 Results

The main processes from getting in contact with the forest owner until wood chips are delivered and accounted were identified and mapped (Figure 4 and Figure 5). All processes were then arranged in a chronological and thematic manner to provide an overview on responsibilities, information and material flow.

Core of the whole process flow is a hand written control slip. The driver of the chipper counts the number of truck loads going from the chipping site to the customer and documents it on the control slip. The slip further contains information about the transport vehicle´s license plate, their driving distance, date and customer information. If chipping is finished, the control slip is handed over to the office for accounting and controlling activities. Based on this information a spreadsheet data base is set up for adding additional information about scaling data from the customer. Based on the developed process map, potential starting points for software based solution integration were sketched. The fleet management system could provide important data for delivery note management and abbreviate administrational processes. Especially an up-to-date controlling of finished orders is impossible in the current situation. Another issue is the rudimental state of development in data management. All accounting and controlling activities are done in a self-developed spread sheet, linked to external data. Altogether, from February 2014 to April 2015, 1,119 transport jobs were sent to the transport systems via the user frontend with the installed fleet management system (Table 2). After a plausibility check 792 truckloads remained for further statistical analysis. Two transport systems, both consisting of truck and trailer, transported 52,500 m³ loose over a distance of 55,200 km. An average tour took 3.1 hours from driving empty to the chipping site till finishing unloading at the plant, covering a distance of 70 km and consumed 38.3 liters diesel. Average loading and thus chipping productivity was 100.5 m³ loose per hour.

Table 2: Overview of main transport parameters for wood chip supply covering the whole recording period and all loads.

	Tour length	**Tour length**	**Fuel consumption per tour**	**Fuel consumption per 100 km**	**Fuel consumption per m³ loose**	**Loading / chipping time**	**Loading / chipping productivity**
	[km]	***[h]***	***[liters]***	***[liters]***	***[liters]***	***[h]***	***[m³/h]***
n	792	792	792	792	792	792	792
mean	69.7	3.1	38.3	57.1	1.0	0.8	100.5
std.dev	53.8	1.2	24.8	15.1	0.6	0.4	55.0
min	3.0	0.5	2.0	5.6	0.1	0.3	15.0
max	381.0	9.0	165.0	150.0	6.0	4.8	750.0
sum	55,186	2,436.8	28,756	-	-	650.8	-
median	57.5	3.0	32.0	54.5	0.8	0.8	80

For process based analysis of transport and chipping activities 73 truckloads were selected within period from February 2014 to July 2014. These were those loads which were covered by scaling data and delivery notes. Due to the availability of this information, load weight and moisture content of these truckloads were known. Thus wet tonne could be used as reference unit. Though representing only 10% of the total recorded data, it showed that these data did not differ significantly from the whole data set (*Table 3*). When transporting broad leaf wood chips with a mean moisture content of 35 % (3.613 MJ per m^3 of wet material), 0.29 litres of diesel are consumed per GJ of delivered energy content.

Table 3: Overview of main transport parameters for wood chip supply for the period February 2014 to July 2014.

	Tour length	Tour length	Fuel consumption per tour	Fuel consumption per 100 km	Fuel consumption per wet tonne	Fuel consumption per m^3 loose	Loading / chipping time	Loading / chipping time per wet tonne	Loading / chipping productivity
	[km]	***[h]***	***[liters]***	***[liters]***	***[liters]***	***[liters]***	***[h]***	***[h]***	***[m³/h]***
n	73.0	73.0	73.0	73.0	73.0	73.0	73.0	73.0	73.0
mean	85.4	3.3	41.3	51.6	2.6	0.8	0.9	0.1	93.6
std.dev	54.1	1.1	23.5	10.6	0.9	0.2	0.4	0.1	49.2
min	7.0	1.5	5.0	29.4	1.2	0.4	0.3	0.1	33.3
max	280.0	7.0	119.0	90.0	5.9	1.2	2.3	100.4	300.0
sum	6,233.0	240.8	3,017.0	-	-	-	67.8	-	-
median	81.0	3.3	42.0	50.0	2.2	0.7	0.8	25.5	75.0

Additionally, based on preprocessed fleet management data, an automated, browser based reporting system was implemented. By selecting a date from the calendar with a delivery note a daily statistic of transport or chipping was generated. Furthermore, details on time consumption and fuel use on process level are displayed (*Figure 6*).

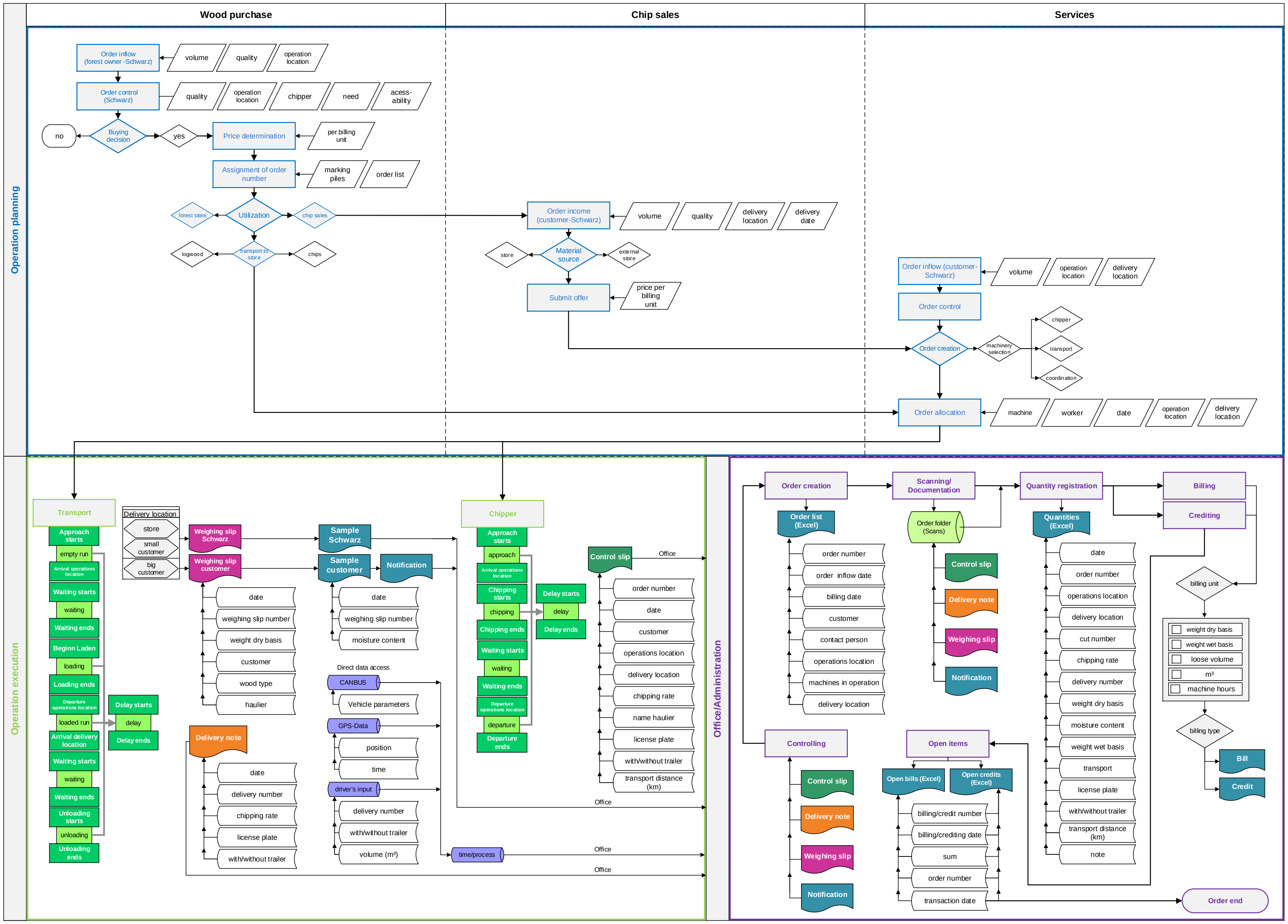


Figure 4 – Business process map for wood chip supply of the entrepreneur Holz Schwarz GmbH, (Poier & Holzleitner).

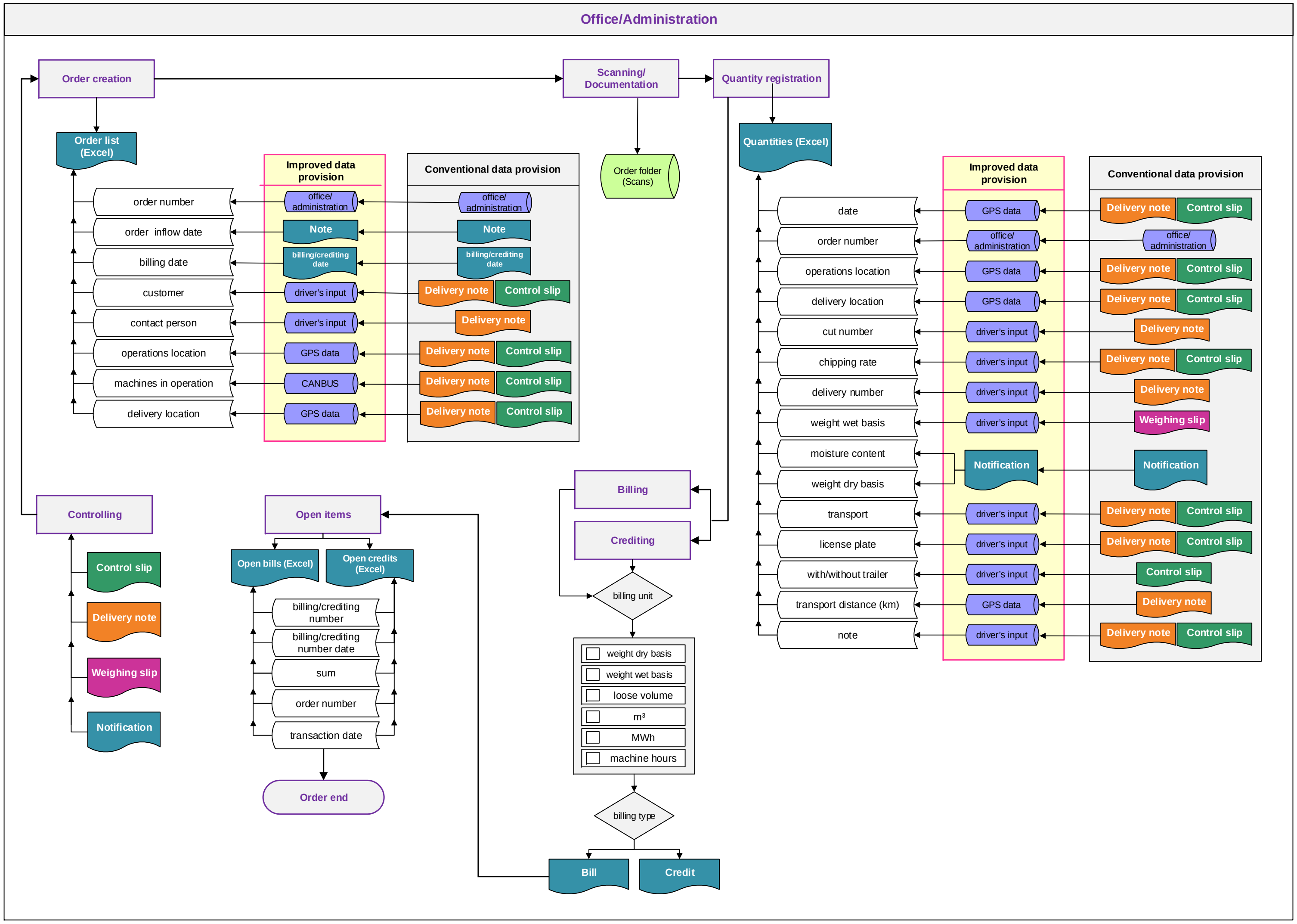
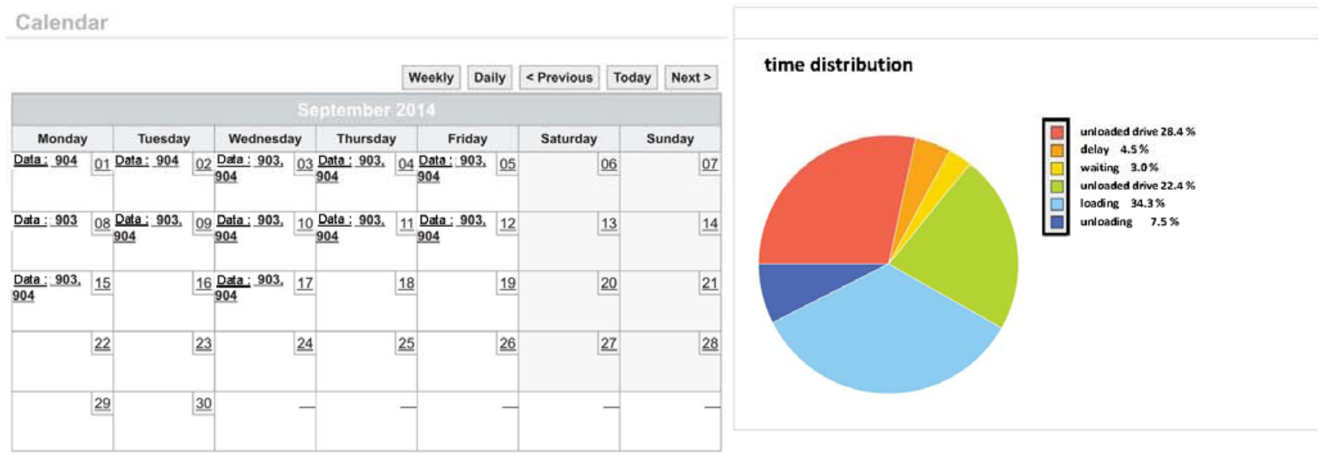


Figure 5 – Business process map for wood chip supply of the entrepreneur Holz Schwarz GmbH, focusing on administration and the support potential of automated data recording via fleet management system (Poier & Holzleitner).



truck tours

truck	info	tour start	tour end	km unloaded	km loaded	km sum	fuel unloaded	fuel loaded	fuel sum	m³	trailer	time unloaded	time loading	time loaded	time unloading	time waiting	time delay	time sum	info delay	info waiting	order Nr.
OP 903 BF	8513	Thu 11.09.2014 07:01	Thu 11.09.2014 09:29	17	34	51	10	9	26	75	yes	00:30	01:15	00:30	00:15	00:00	00:00	02:30	-	-	20021828
	8515	Thu 11.09.2014 09:29	Thu 11.09.2014 13:04	32	35	67	17	14	37	75	yes	00:45	01:15	01:15	00:15	00:00	00:45	02:45	break	-	20021829
	8517	Thu 11.09.2014 13:05	Thu 11.09.2014 16:03	27	30	57	14	9	27	75	yes	00:30	01:30	00:30	00:15	00:30	00:00	03:00	-	chipper delay	20021830
Truck total:				**76**	**99**	**175**	**41**	**32**	**90**	**225**		**1.75**	**4**	**2.25**	**.75**	**.5**	**.75**	**8.25**			
OP 904 BF	8514	Thu 11.09.2014 08:36	Thu 11.09.2014 11:19	0	0	0	0	0	0	75	yes	00:45	01:00	00:45	00:15	00:00	00:00	02:45	-	-	20021801
	8516	Thu 11.09.2014 11:21	Thu 11.09.2014 15:13	123	28	151	65	11	79	75	yes	02:15	00:45	00:45	00:15	00:00	00:00	03:45	-	-	20021803
Truck total:				**123**	**28**	**151**	**65**	**11**	**79**	**150**		**3**	**1.75**	**1.5**	**.5**	**0**	**0**	**6.5**			
report total:				**199**	**127**	**326**	**106**	**43**	**169**	**375**		**4.75**	**5.75**	**3.75**	**1.25**	**.5**	**.75**	**14.75**			

Figure 6 – Automated, process based reporting based on fleet management data for wood chip supply of the entrepreneur Holz Schwarz GmbH (Höller & Holzleitner).

Additionally, the main drivers regarding management of delivery notes from the start of a job till delivery and cash flow were mapped, identified and analyzed. Altogether administration takes more than 4.6 hours per chipping site. Driving, phone calls and inspection account for most of the required time (Figure 7). Documenting and accounting in the office represent almost 50 % of the required time per chipping operation (Figure 8).

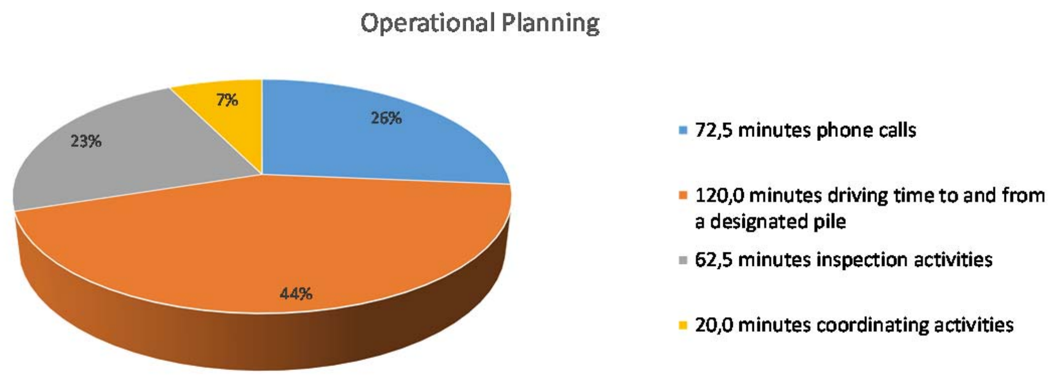


Figure 7: Business processes needed for operational planning activities for wood chip supply by the entrepreneur Holz Schwarz GmbH. (Poier & Holzleitner).

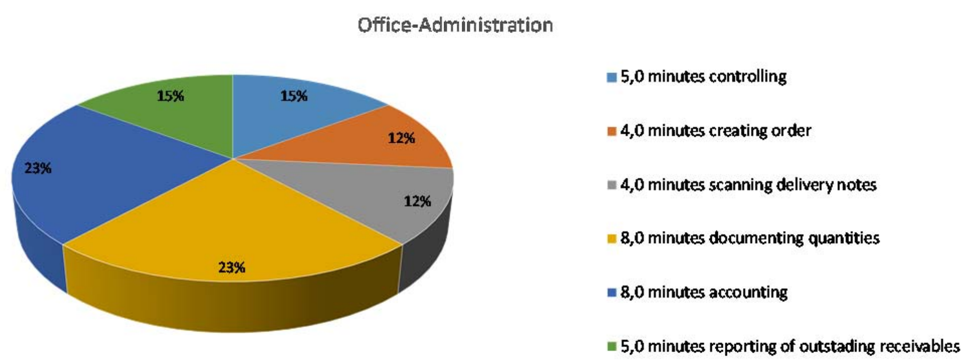


Figure 8: Business processes needed for administration activities for wood chip supply by the entrepreneur Holz Schwarz GmbH (Poier & Holzleitner).

Discussion

The demo of semi-automated process analysis clearly showed the need for active and on-demand controlling in an entrepreneurs daily business. From a technical point of view the employed equipment proved to work flawlessly.

In a first step, together with the entrepreneur, a detailed pre-study process analysis was conducted. It showed that the fleet management system is not able to cover all processes but could strongly support daily business activities on the operational level, especially chipping and transport activities. Other detected processes can benefit from data provided by the fleet management system.
Further, process mapping provided the entrepreneur with enlarged knowledge on his needs when it comes to decide which commercial management system to introduce in the future. Such a system should be capable of handling all detected processes and provide detailed reports, like those, then custom-made, within the demo. Such a system could increase the efficiency in job administration significantly. Especially switching from a paper-based to an electronic control slip would be an important step.
Based on the long term study data the entrepreneur is now able to redesign organisation and recalculate pricing scheme. On a tactical level this data base will support him in determining the geographical limits of operation in terms of cost efficiency.

From a scientific point of view the gained data and results are of priceless value for further research activities and identifying the most important starting points for reengineering and redesign of wood chip supply on both, organisational and technological level. Naturally, this report is only able to offer a small glimpse of the whole data volume and its potential for different additional analyses.

Concluding, semi-automated fleet management data recording can be considered a more than able approach in process analysis and a handy tool, both in terms of daily business and research activities.

4 Demo impressions – 7th November 2014

The demo with more than 100 participants was conducted on November 7th 2014 after the demo of the felling head near the entrepreneur´s headquarter at Pilgersdorf, province of Burgenland, Austria. Participants from all fields of forest business including small scale farmers, forest owners, harvesting entrepreneurs, machine manufacturers, interest representatives, researchers and students attended the demo. Chipping operations including transport activities together with the fleet management system and the framework of INFRES were demonstrated and extensively discussed.

Figure 9 – Visitors at the demo day – Discussing and receiving detailed information on the fleet management system used for semi-automated process analysis. Pictures: Lorenz, R.

Figure 10 –Participating vehicles equipped with the fleet management system. Pictures: Holzleitner, F.

References

Holzleitner, F., Analyzing time and fuel consumption of timber harvesting and transport processes based on long-term machine data, Dissertation, Institute of Forest Engineering, University of Natural Resources and Life Sciences Vienna, 2013, 60 p.

Kühmaier, M. and K. Stampfer, Development of a multi-attribute spatial decision support system in selecting timber harvesting systems, Croatian Journal of Forest Engineering 32 (2), 2010, 13 p.

Kühmaier, M. and K. Stampfer, Development of a multi-criteria decision support tool for energy wood supply management, Croatian Journal of Forest Engineering 33 (2), 2012, 17 p.

Poier, A., Geschäftsprozessanalyse bei der Waldhackgutbereitstellung am Beispiel der Holz Schwarz GmbH, Master Thesis, Institute of Forest Engineering, University of Natural Resources and Life Sciences Vienna, 2015, 42 p.

Sikanen, L., A. Asikainen, and M. Lehikoinen, Transport control of forest fuels by fleet manager, mobile terminals and gps, Biomass and Bioenergy 28(2), 2005, 8 p.

Windisch, J., Röser, D., Mola-Yudego, B., Sikanen, L. and Asikainen, A., Business process mapping and discrete-event simulation of two forest biomass supply chains, 2013, Biomass and Bioenergy 56, 12 p.

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INFRES – Innovative and effective technology and logistics for forest residual biomass supply in the EU (311881)

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Petri Kaksonen, Kari Kokko and Jussi Suutarinen, Kesla Oyj

Demoreport 17 - JOINT DEMONSTRATION OF THE LARGE NINE AXLE CHIP TRUCK-TRAILER UNIT AND THE HYBRID CHIPPER– D4.5

Dissemination Level	
Public	x
Restricted to other programme participants (including the Commission Services)	
Restricted to a group specified by the consortium (including the Commission Services)	
Confidential, only for members of the consortium (including the Commission Services)	

Joensuu, July 2015

Content

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Natural Resources Institute Finland (Luke) is coordinating a research and development project 'Innovative and effective technology and logistics for forest residual biomass supply in the EU – INFRES'. The project is funded from the EU's 7th framework programme. INFRES aims at high efficiency and precise deliveries of woody feedstock to heat, power and biorefining industries.

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This report describes the performance of the nine axle truck-trailer unit constructed by Konepaja Antti Ranta Oy and Kesla C 860 H hybrid chipper in the supply systems based on chipping at the terminal or the roadside landing. The study defined the fuel consumption and productivity levels of the Kesla C 860 H hybrid chipper for processing large sized roundwood and logging residues as well as the payloads, unloading times and fuel consumptions of the nine axle truck-trailer unit for transporting fuel chips from the chipping place to the CHP plant. In addition, the quality and bulk density of the chips produced from roundwood and logging residues were analysed. In the follow up study were recorded the payloads and fuel consumption of the nine axle truck-trailer unit when transporting wood chips from plywood mill and sawmill to the BCTMP and sulphate pulp mill.

Juha Laitila, Jukka Antikainen, Antti Asikainen, Janne Immonen, Esa Mononen, Petri Kaksonen, Kari Kokko and Jussi Suutarinen, Joensuu, July 2015

This publication is a part of the INFRES project. The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2012-2015] under grant agreement n°311881.

Title	**PROTOTYPE OF HYBRID TECHNOLOGY CHIPPER– D4.5**
Author(s)	Juha Laitila, Jukka Antikainen, Antti Asikainen, Petri Kaksonen, Kari Kokko and Jussi Suutarinen.
Abstract	This report describes the performance of the nine axle truck-trailer unit constructed by Konepaja Antti Ranta Oy and Kesla C 860 H hybrid chipper in the supply systems based on chipping at the terminal or the roadside landing. The objectives of this study were to test the new hybrid technology chipper, Kesla C 860 H, with large sized roundwood and logging residues and define payloads, unloading times and fuel consumptions of the nine axle truck-trailer unit when transporting fuel chips from the chipping place to the CHP plant. Chipping productivity, fuel consumption, quality and bulk density of the produced chips was analysed. In the follow up study were recorded the payloads and fuel consumption of the nine axle truck-trailer unit when transporting wood chips from plywood and sawmill to the BCTMP and sulphate pulp mill. During the time studies, both the chipper and hybrid system were working well and truck mounted chipper was also capable of operating in constricted roadside landings. The large nine axle truck-trailer unit was at its best when transporting fuel chips from the terminal. The results of this study must be considered to be preliminary because the amount of chipped and transported wood assortments was rather small. The chipper and especially the hybrid system are under continuous development, and follow up-study is needed for the precise determination of the productivity, fuel consumption and operating costs. The bulk density of dry wood chips is rather low and thus the payload is usually limited by the frame volume rather than the mass capacity of the modern truck-trailer unit. The average chipping productivity of Kesla C 860 H hybrid chipper unit was 11 936 kg (dry mass) per effective hour (E_0h), when chipping roundwood. The average chipping productivity with logging residues was 11 830 kg E_0h^{-1}. Fuel consumption of Kesla C 860 H hybrid chipper was 2.7 litres per chipped 1000 kg (dry mass) when chipping roundwood and 3.1 litres for logging residues. Bulk density was 317−330 kg/loose-m^3 for logging residue chips and 255−271 kg/loose-m^3 for roundwood chips, when the moisture was 48−53 % and 33−44 % respectively. During the time studies the average fuel consumption of the truck-trailer unit was 52.7 litres per 100 km. According to follow up study, the average fuel consumption of the truck-trailer unit was 38.8 litres when driving with empty load and 54.5 litres with full load. Kesla C 860 H chipper has been introduced to the audience in first time at FinnMetko forest machinery exhibition on August 2014 in Central Finland, and second time in Hakevuori Forest Energy Day at Askola in Southern Finland in March 2015. The nine axle Lipe truck-trailer unit constructed by Konepaja Antti Ranta were introduced to the audience first time on 11– 13 June 2015 at Logistics - Transport 2015 fair in Helsinki.
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1 Introduction

1.1 Wood flows from forests

Truck-trailer units dominate the wood transportation of forest and energy industries in Finland (Karttunen et al. 2013, Strandström 2015b). The transport is unavoidable due to the distance between the resource and the end-users and truck transportation is used since there are no alternatives for the transport wood material from the forest landings (Wolfsmayr & Rauch 2014, Strandström 2015b). Railway or waterway based transportation modes are limited to long distance transports from terminals to the end-users (Wolfsmayr & Rauch 2014, Strandström 2015b). In last year 75% of the industrial roundwood transported was brought to the mill directly by road (Strandström 2015b). Railway transportation accounted for 22% of the industrial roundwood volume, and waterway transportation (by floating and barge combined) accounted for 3% (Strandström 2015b). In 2014 Finnish forest industries consumed 64.5 million m^3 of roundwood (Ylitalo 2015a). Moreover, 9.24 million m^3 of sawmill chips and dust, were utilized by the pulp and paper industries in the secondary wood consumption (Ylitalo 2015a).

Forest chips are transported by trucks to the power and heating plants and at the present time there are only a few large CHP installations that can even use railway or waterway transportation in Finland (Hakkila 2004, Tahvanainen & Anttila 2011, Karttunen et al. 2012a, Karttunen et al. 2013). A solid frame ordinary truck-trailer system is also the most commonly used vehicle for peat and forest industry by-product transport logistics (Hakkila2004, Karttunen et al. 2012b, Karttunen et al. 2013). Forest industry by-products consist of assortments such as bark, sawdust, shavings, cut off and recycled wood (Hakkila 2004, Kons et al. 2014, Ylitalo 2015b). The raw material of forest chips consist of logging residues, tree parts, non-merchantable roundwood and stumps from timber harvesting operations and pre-commercial thinnings (Hakkila 2004, Kons et al. 2014, Ylitalo 2015b).

1.2 Transport efficiency of wood biomass

Comminuting increases the density and homogeneity of forest residues (Eriksson et al. 2013), which justifies its application early in the supply chain (Björheden 2008). Transport efficiency is increased since each truck can carry more biomass as a result of higher solid content of volume which has positive impact in terms of cost, CO_2 emissions, need of manpower and traffic on the roads (Routa et al. 2012, Eriksson et al. 2014). Different wood biomass types have different characteristics that impact efficiency and economics of transporting logistics (Uusvaara 1978, Uusvaara & Verkasalo 1987, Talbot & Suadicani 2006, Ranta & Rinne 2006, Wolfsmayr & Rauch 2014, Cambero et al. 2015). For dry or loose material, the maximum load is limited by the volume of material, whereas the weight limits the maximum load for wet or artificially compacted chips (Talbot & Suadicani 2006, Ranta & Rinne 2006, Wolfsmayr & Rauch 2014).

The bulk density depends on the wood species basic density, particle size distribution, moisture content as well as the loading method and applied pressure when loaded (Uusvaara 1978, Uusvaara & Verkasalo 1987, Lindblad & Verkasalo 2001, Talbot & Suadicani 2006, Eriksson et al. 2013, Wolfsmayr & Rauch 2014). The solid volume to comminuted volume is affected by a number of factors which include the size and shape of comminuted material and the heterogeneity of the particle sizes, where larger heterogeneity will usually result in higher bulk density, as airspaces are less regular and filled by smaller particles (Uusvaara 1978, Uusvaara & Verkasalo 1987, Talbot & Suadicani 2006, Eriksson et al. 2013, Wolfsmayr & Rauch 2014). In many cases forest chips and forest industry by-products are rather light and volume demanding and could benefit of bigger load spaces when transported by road (Korpilahti 2015). Utilizing modern vehicle designs such as a moveable axle group or liftable axles or steering axles at the rear end of trailer, even a maximum dimensioned truck-trailer unit can be well maneuverable on forest roads and turnarounds (Korpilahti 2015).

Permissible payloads are governed by the legal gross mass and the allowable axle mass. Measures and weight limits for heavy vehicles were changed by the statute that came into force the 1st of October 2013 in Finland (Valtioneuvoston asetus 407/2013, Karttunen et al. 2013, Korpilahti 2015). New legislation enables higher gross weights as well as 20 cm higher vehicles which means bigger load spaces (Karttunen et al. 2013, Korpilahti 2015). The changes in legislation have been motivated by reductions in logistical costs and greenhouse gas emissions.

According to the new statute two new vehicle types such as 8-axle truck-trailer unit with maximum gross weight of 68 tonnes and 9-axle truck-trailer unit up to 76 tonnes are accepted (Valtioneuvoston asetus 407/2013, Korpilahti 2015). Prerequisite is that 65% of trailer axles having twin tyres, otherwise maximum weights are 64 and 69 tonnes (Valtioneuvoston asetus 407/2013, Korpilahti 2015). Current legislation on the physical dimensions of the truck-trailer combination limits total length to 25.25 m, width to 2.55 m and height to 4.4 m (Valtioneuvoston asetus 407/2013, Karttunen et al. 2013, Korpilahti 2015). Maximum load spaces are for truck about 60 m^3 and for a trailer 100 m^3 (Korpilahti 2015). Earlier the chip truck-trailer unit consists of a 3-axle truck and 4-axle trailer resulting in 60 tonne legal gross weight (Karttunen et al. 2012b, Karttunen et al. 2013). Typical frame capacities for conventional truck-trailer units range between 120 m^3 and 140 m^3 and tare weights between 20 and 25 tonnes (Karttunen et al. 2012b, Karttunen et al. 2013). Semitrailers are not common in Finland (Karttunen et al. 2012b).

1.3 Production of forest chips

Chipping is a central part of forest energy supply chain and it may take place on the logging site, at the road side landing, at a terminal, or at the plant. Machines operating at terminals, road side landings or logging sites are run using diesel engines while grinders and chippers operating at industrial sites can be powered with electric engines (Di Fulvio et al. 2015). A third option is to use hybrid systems, which store excess energy from the diesel engine during low periods of loading for use during peak loading times (Sun et al. 2010, Einola 2013, Eriksson et al. 2013, Di Fulvio et al. 2015). Fuel costs are 30-33% of total comminuting costs (Laitila et al. 2015a) and fuel prices have been rising remarkably (Einola 2013). Therefore more and more interest to novel solutions reducing the fuel consumption is brought to discussion and hybrid systems capable of evening out the power peaks of the work cycle are of great interest among machine manufactures.

In the year 2014, Finnish heating and power plants consumed 18.7 million m^3 solid wood fuels, of which 10.2 m^3 million were forest industry by-products and 7.6 million m^3 comprised forest chips (Ylitalo 2015b). About 49% of forest chips were made of small diameter thinning wood produced in the tending of young stands and 36% was produced from logging residues of final fellings (Ylitalo 2015b). The share of the stump and root wood was 11%, while 6% of forest chips were produced from large non-merchantable roundwood (Ylitalo 2015b). Majority of delivered forest chips were chipped at roadside landings (Strandström 2015a). About 29 % of the forest chips were produced at the terminals and 14 % were comminuted at the end-use-facilities (Strandström 2015a). Roadside chipping is the predominant supply system for logging residue and thinning wood chips (Strandström 2015a). Comminuting at the terminal is the leading method for producing fuel chips from stumps or non-merchantable roundwood (Strandström 2015a). Comminuting in the terrain is a seldom-used harvesting method in Finland (Kärhä 2011, Strandström 2015a).

1.4 Aim and implementation of the study

This report describes the performance of the large nine axle truck-trailer unit optimized for transportation of chips and other biomaterials between terminals and large end use facilities constructed by Konepaja Antti Ranta Oy and Kesla C 860 H hybrid chipper in the supply systems based on chipping at the terminal or the roadside landing. The study defined the fuel consumption and productivity levels of the Kesla C 860 H hybrid chipper for processing large sized roundwood and logging residues as well as the payloads, unloading times and fuel consumptions of the large truck-trailer unit for transporting fuel chips from the chipping place to the CHP plant. In the follow up study were recorded the payloads and fuel consumption of the nine axle truck-trailer unit when transporting wood chips from plywood mill and sawmills to the Joutseno BCTMP and sulphate pulp mill.

The quality and bulk density of the chips produced from roundwood and logging residues were analysed. The degree of filling is normally determined using a measurement stick or visual evaluation. In this study we tested a novel 3D-scanning device called Microsoft Kinect to obtain 3D-model of wood chip load from the truck container. In addition the fuel consumption and chipping productivity were compared to findings from previous study examining Kesla C 860 H hybrid chipper (Laitila et al. 2015b).

The field studies were conducted in cooperation with Kesla Oyj, Konepaja Antti Ranta Oy, Kuljetus Matti J. Salminen Oy, Konnekuljetus Oy, Vapo Oyj and Jyväskylän Energia Oy in June 2015 in the municipalities of Jyväskylä and Uurainen. The chipping study in Jyväskylä and Uurainen was hosted by Vapo Oyj. Kesla Oyj provided the chipper and Kuljetus Matti J. Salminen Oy an operator for chipping experiments. Konepaja Antti Ranta Oy provided the Lipe truck-trailer unit and Konnekuljetus Oy drivers for the chip transporting studies. Natural Resources Institute Finland was responsible for field studies and reporting of these. The produced chips of the chipping experiments were transported to the Keljonlahti power plant of Jyväskylän Energia Oy.

2 Material and Methods

2.1 Kesla C 860 hybrid chipper

The Kesla C 860 H hybrid chipper is mounted on a three-axle Volvo FM 440 truck chassis (Figure 1) and the raw material are fed into the chippers feeding table with Kesla 2112T timber loader. The width and height of intake opening are 800 mm x 600 mm. There are eight angled blades in a novel rotor that are positioned in a two rows of drum and a square mesh sieve is placed beneath the drum to avoid that oversized chips leave the drum casing. During the time study, the hybrid chipper was equipped with a 100 mm x 100 mm sieve. The Kesla C860 hybrid chipper weighs 8200 kg.

Figure 1 – Chipping non-merchantable roundwood (top) and logging residues (down) with the Kesla C 860 H hybrid chipper during time studies (Photos: Petri Kaksonen/Kesla).

The Kesla C 860 H hybrid chipper is powered by an inline four-cylinder Volvo Penta TAD572VE diesel engine powers in a hybrid arrangement with an electric motor. The engine provides 160 kW at 2300 r/min and a maximum torque of 910 Nm. It has a bore and stroke of 110 x 135 mm and displacement of 5.1 litres. The wet weight of the engine is 583 kg. The diesel engine only powers a generator providing electricity for the electric drivetrain (Figure 2). The electric generator and motors are from Visedo's PowerDRUM XSe and XXS frames. Visedo also provides the PowerMASTER M-frame inverter for the generator and motor control.

The electric drivetrain powers not only the wood chipper but all equipment needed for the chipping operation, including the Kesla 2112T crane used for feeding the wood into the chipper (Figure 2). The needed energy is generated by the diesel engine with the support of super capacitor energy storage (Figure 2). The motors driving the chipper and hydraulic pumps are permanent-magnet motors, and the total system minimizes loss of energy and provides high energy efficiency. There is no mechanical connection between diesel engine and chipper. In future there is an option to connect the hybrid chipper to the power network, which enables it to run on electricity alone (Figure 2)

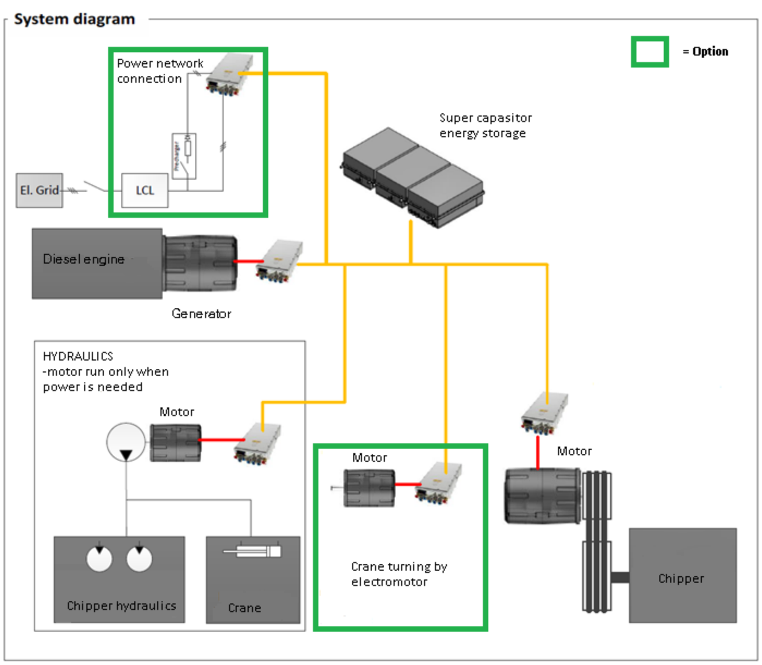

Figure 2 – The system diagram of the the Kesla C 860 H hybrid chipper (Source: Petri Kaksonen/Kesla Oyj).

2.2 The nine axle Lipe truck-trailer unit

The studied nine axle truck-trailer unit, which brand name is Lipe, was constructed by Konepaja Antti Ranta Oy (Figure 3). The tractor of the Lipe truck-trailer unit was completely new Volvo FH16 HP 8*4 Rigid Tag Tridem having an engine power of 552 kW. The vehicle consisted of a 4-axle truck and 5-axle trailer. The truck-trailer unit was designed especially for transporting by-products of forest industries and wood chips from terminals, because the long wheelbase between the front and rear axles of novel vehicle concept require wider turning areas than traditional trucks. The detailed dimensions and turning radius are presented in the Figures 4 and 5.

The weight of the truck-trailer unit was 24 500 kg and the legal gross weight were 69 000 kg (for the truck 35 000 kg and for the trailer 34 000 kg). Total number of tyres were 22 (for the truck 12 tyres and for the trailer 10 tyres). The load space of the truck was 57.4 m^3 and the trailer 100 m^3. The floor and wall of the load spaces were thermo insulated and unloading was based on hydraulic side-tipping. In addition the load space was equipped with hydraulically opening and locking waterproof covers (Figure 3) and hydraulically raising sidewalls. The unloading and cover functions were controlled with the electric control system from the truck cabin. The versatile load space can be easily customized for use in different transportation tasks, which enables e.g. backhauling of baled pulp or sawn timber and thus minimizes vehicles driving distances with empty load.

Figure 3 – The nine axle Lipe truck-trailer unit at the Tikkakoski roundwood terminal during the chipping/loading experiment (Photos: Petri Kaksonen/Kesla).

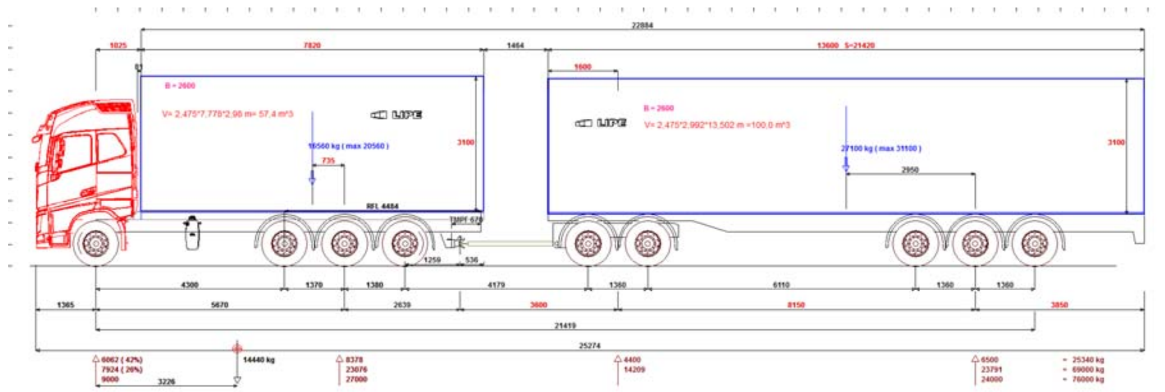

Figure 4 – Dimensions of the nine axle Lipe truck-trailer unit constructed by Konepaja Antti Ranta Oy (Source: Janne Immonen/Konepaja Antti Ranta Oy).

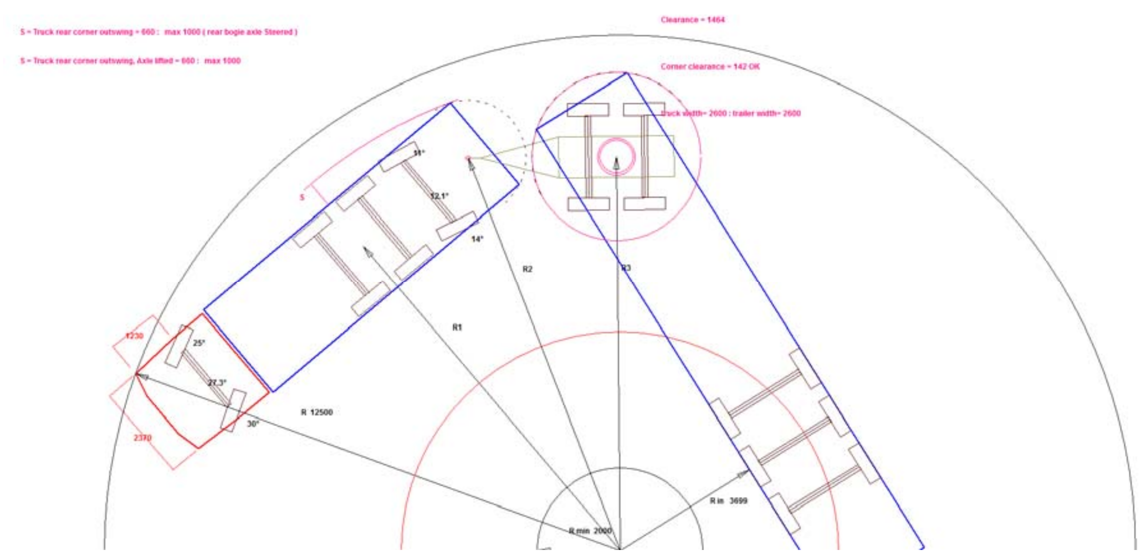

Figure 5 – Outer and inner turning radius for the nine axle Lipe truck-trailer unit (Source: Janne Immonen/Konepaja Antti Ranta Oy).

The truck and the trailer were equipped with air-suspension which is rarely used in low level road network and on forest roads in Finland. For drivers, driving the vehicle is much smoother with air-suspension compared to conventional steel leaf springs. The other advantage of the air-suspension system is embedded weight scaling solution: the driver can monitor the weight of the load in real time. This ensures the possibility to maximize the load size during the chipping/loading operation and which reduces the transportation costs. The driver can observe the individual axle loads of the vehicle and the trailer by using the separate monitoring device (Figure 6).

Figure 6 – The axle mass monitoring device (Photo: Antti Asikainen/Luke).

2.3 Time study of chipping

The chipping study of non-merchantable roundwood was carried out in 15th June 2015 at wood terminal in Tikkakoski, Central Finland. Logging residues were chipped in 16th June 2015 at roadside landing in Uurainen, Central Finland. Both the experiments were carried out under natural light during the daytime (8:00–19:00), with the same experienced chipper operator. The temperature was +10–16 °C during the study. The chipped material were non-merchantable Norway spruce (*Picea abies*), Scots pine (*Pinus sylvestris*) and Downy birch (*Betula pubescens*) roundwood from thinnings and final fellings (Figure 7), and Norway spruce (*Picea abies*) dominant logging residues (tops and branches) from final felling (Figure 7). The storing times of both materials were about one year.

Figure 7 – Chipping non-merchantable roundwood with the Kesla C 860 H hybrid chipper at the wood terminal in Tikkakoski (top) and logging residues (down) at the roadside landing in Uurainen (Photos: Petri Kaksonen/Kesla).

The length of roundwood logs was 3 m and they had a minimum top diameter of 6 cm and the diameters of the butt ends ranged from 10 to 60 cm. The observation unit for roundwood chips was the Lipe truck-trailer unit with a 157.4 m^3 gross cargo volumes. Due to restrictions of the road network, the observation unit for logging residue chips was a Lipe truck container unit with a 57.4 m^3 gross cargo volumes. Each load was measured with a certified weight scale at the plant, and both filled and empty weights of the containers/trucks were recorded. The effective hourly productivity (E_0h) of the chipping operation was presented per dry mass (kg) of the forest chips. The chipping machinery was positioned parallel to pile and during chipping, the chips were blown directly into container either from the side or from the rear (Figure 7). During the study 49.5 odt (80.4 green tonnes) of roundwood and 18.2 odt (36.9 green tonnes) of logging residues were chipped with Kesla C 860 H chipper.

The fuel consumption of the chipper units was measured at a local fuel station after chipping trial. Chipper units were parked in exactly same place in the beginning and at the end of the shift and tank were refilled to full. The accuracy of the fuel pump was 0.1 litres and the fuel consumption was presented per dry mass (1000 kg) of the produced forest chips.

The working time was recorded through the application of a continuous timing method wherein a clock ran continuously and the times for different elements were separated from each other under distinct numeric codes (e.g. Harstela 1991, Magagnotti et al. 2013). During the experiment the researcher observed the work performance outside the risk zone so that he was not disturbing the work of the operator (Figure 7). The operation time of the studied chippers was recorded manually with a Rufco-900 field computer, and working time was divided into work elements in order of priority:

Boom out: Boom movement from the chipper to the piled material

Grip: Gripping of material

Boom in: Boom movement from the pile to the feeding table

Feeding: Placing the material into the feed orifice and release of the grapple load

Adjustment: Possible adjustments of the material on the feeding table

Chipping: Chipping while the timber loader is idle

Moving and preparation: Repositioning of the chipper to next pile and preparing the chipper ready for chipping work

Delays: Time not related to chipping work, but for which the reason for the interruption was recorded.

The data analysis was conducted for direct chipping time only (E_0h), in order to avoid the confounding effect of delay and preparation time, which is typically erratic (e.g. Spinelli and Visser 2009, Eliasson et al. 2012, Holzleitner et al. 2013). The studies were also too short to record representative delay times. To the effective working time (E_0h) included the work phases of boom out, grip, boom in, feeding, adjustment and chipping. The number of grapple loads for each truck load was counted, in order to calculate the average weight of the grapple load in feeding.

The chip samples were taken directly from the arriving truck loads as part of the normal delivery process at the Keljonlahti power plant, after unloading chipped wood to the ground (Uusvaara 1978, Uusvaara and Verkasalo 1987). Samples were taken to define the moisture content, basic density, particle size distribution, ash content, and net calorific value of chipped wood, and samples were analysed in the laboratory of the Natural Resources Institute Finland according to the following standards: EN 14780, EN 14774-1, EN 14774-2, EN 14774-3, SCAN-CM 43:95, EN 15149-1, EN 14775, EN 14918.

Five samples were taken for each truck load, and wood samples were stored in plastic bags, which were carefully closed and marked. Moisture samples were packed in double bags in order to minimise the risk of bag outbreak or evaporation. The dimensions of the plastic bags were 35 x 35 cm (volume 8 litres), and the raw material, date, and time were written on the label. In addition, plastic bags were wrapped in a plastic sack, and each load was packed in a corrugated paperboard box of its own.

2.4 Time and follow up study of transporting

The transporting research was carried out as a combination of time study and follow-up study. The time study was integrated with the chipping experiments and during that were transported two truck-trailer loads of roundwood chips and two pure truckloads (truck without trailer) of logging residue chips to the Keljonlahti power plant via forest, asphalt and unpaved gravel roads. Due restrictions of the turn-around place, the logging residue chips were transported without trailer.

Two professional truck drivers participated to the time study and the time study analyst observed the transportation work while sitting in the truck’s cabin. The unloading times of the truck-trailer unit at the Keljonlahti power plant were recorded manually with a Rufco-900 field computer. Driving distances were measured using the truck’s odometer, with an accuracy of 100 m. The fuel consumptions loaded and unloaded were recorded with the on board computer of Volvo truck. Each load was measured with a certified weight scale at the plant, and both filled and empty weights of the containers/trucks were recorded.

To the follow-up study participated three professional truck drivers. Drivers were asked to independently complete a form, on which they recorded information about the driving distances loaded and unloaded, payloads and fuel consumption with empty and full load. The truck drivers worked in three-shift system and the follow up study took the time five days. The follow up study data compromised 13 full truck-trailer loads of wood chips transported via asphalted highway from Central Finland to Joutseno BCTMP and sulphate pulp mill located in South-East Finland.

2.5 Measuring degree of filling

The degree of filling (Figure 8) is normally determined using a measurement stick or visual evaluation. In this study we tested a novel 3D-scanning device called Microsoft Kinect (Figures 9 & 10) to obtain 3D-model of wood chip load from the truck container. The main goal was to determine the degree of filling more efficiently and accurately than with current methods. The Microsoft Kinect sensor (Figure 9) was originally developed for the gaming industry but when the Microsoft published the software developer packages (SDK) for the device the usage has rapidly expanded for different industrial fields as well.

Figure 8 – The loads were completely filled at the chipping place (Photo: Petri Kaksonen/Kesla).

The sensor includes several different components which are used at the measurement process (Figure 9). The most important parts are the IR emitter and IR depth sensor which are used in the depth map measurements. The depth map is calculated from known speckle pattern which is formed using a diffractive element and an infrared laser (IR Emitter). The laser beam is scattered to dense point cloud which is projected on the surface of the target.

The used laser is on an infrared region so it cannot be detected by an eye; therefore the projected image is captured using an infrared camera (IR Depth Sensor). The resolution of the IR depth sensor is 640 x 480 pixels with 11 bits dynamics which defines the scanning accuracy of the sensor. The final 3D object can be formed by registration of different depth maps using the iterative closest point (ICP) method.

The sensor was developed for indoors use and the power of the laser is relatively low which may cause a problem when the sensor is used outdoors. The intensity level of the direct sun light is much higher than the laser can produce which will saturate the measurements. Cloudy weather or some external shade will improve the measurement usability and accuracy.

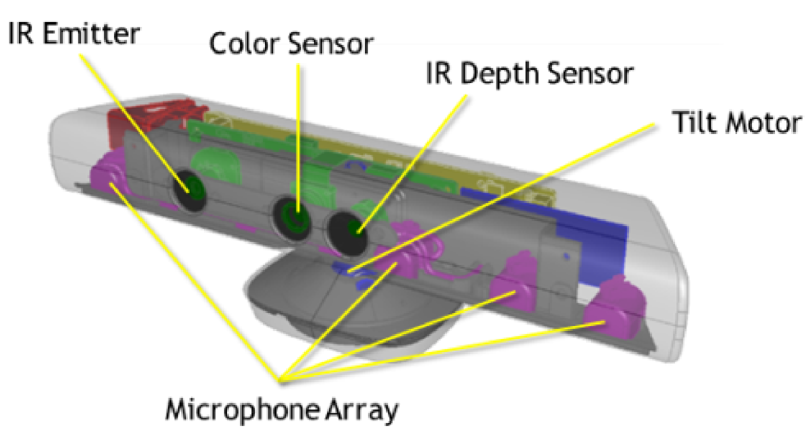

Figure 9 – The structure of the Microsoft Kinect sensor (Source: Microsoft)

The measurements were planned to do at the terminal site using a long rod. The sensor was installed at the end of the rod and it was moved manually over the container. However, the measurements were hard to complete because of handling problems of the long rod, but the most crucial limitations came from the weather conditions. The direct sunlight (measurements were saturated) and occasional rain (laptop wasn't a weather proof) disturbed the measurements. Therefore the measurement location was changed into the power plant where the rod can be adjusted more easily over the container (Figure 10). The measurements were done from 5 meter high stairs where the top of the container was easily seen and measured (Figure 11).

Figure 10 – The Microsoft Kinect sensor was installed at the end of the rod and it was moved manually over the container (Photo: Antti Asikainen/Luke).

Figure 11 – The 3D-scanning were done from 5 meter high stairs at the power plant (Photo: Antti Asikainen/Luke)

3 Study results

3.1 The chipping experiments

The average chipping productivity of Kesla C 860 H hybrid chipper unit was 11 936 kg (dry mass) per effective hour (E_0h) and standard deviation (SD) was 772 kg E_0h^{-1}, when chipping roundwood (Figure 12). The average chipping productivity with logging residues was 11 830 kg E_0h^{-1} (SD 989). The average chipping productivity (dry mass, kg) per maximum engine power (kW) was 75 kg kW^{-1} when chipping roundwood and 74 kg kW^{-1} with logging residues. The average weight of the grapple load was 150 kg (SD 9) for roundwood (dry mass) and 81 kg (SD 16) for logging residues (Figure 12). Compared to previous experiment (Laitila et al. 2015b), the productivity were at the same level (Figure 12).

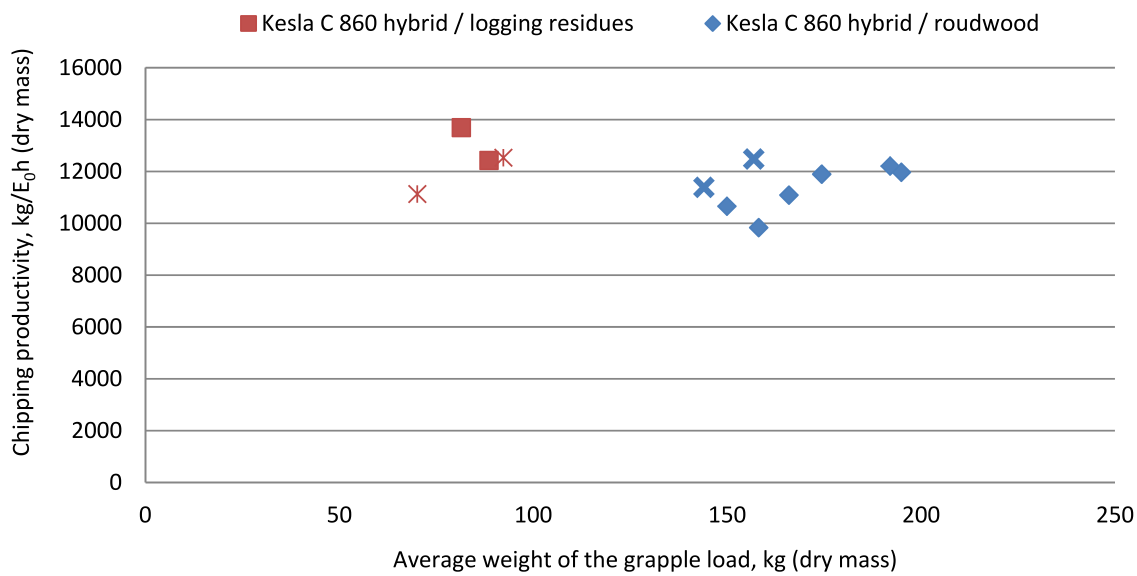

Figure 12 – Chipping productivity of Kesla C 860 H hybrid chipper with logging residues and roundwood. The results of the present study are marked with cross.

The average chipping time per 1000 kg (dry mass) was 304 seconds for roundwood and 301 seconds for logging residues (Figure 13). The study confirms that chipping time consumption is inversely proportional to engine power when chipping roundwood. Chipping, while the timber loader was idled, took 8–79 % of the effective working time. Loading (boom out, grip and boom in) accounted for 15–38 % and feeding (feeding and adjustment) 6–53 % of the effective working time when chipping roundwood and logging residues with Kesla C 860 H hybrid chipper (Figure 13). The fuel consumption of Kesla C 860 H hybrid chipper was 2.7 litres per chipped 1000 kg (dry mass) when chipping roundwood and 3.1 litres for logging residues. In the previous study, the fuel consumption of Kesla C 860 H hybrid chipper was 3.1 litres per chipped 1000 kg (dry mass) when chipping pulpwood and 2.9 litres for logging residues (Laitila et al. 2015b).

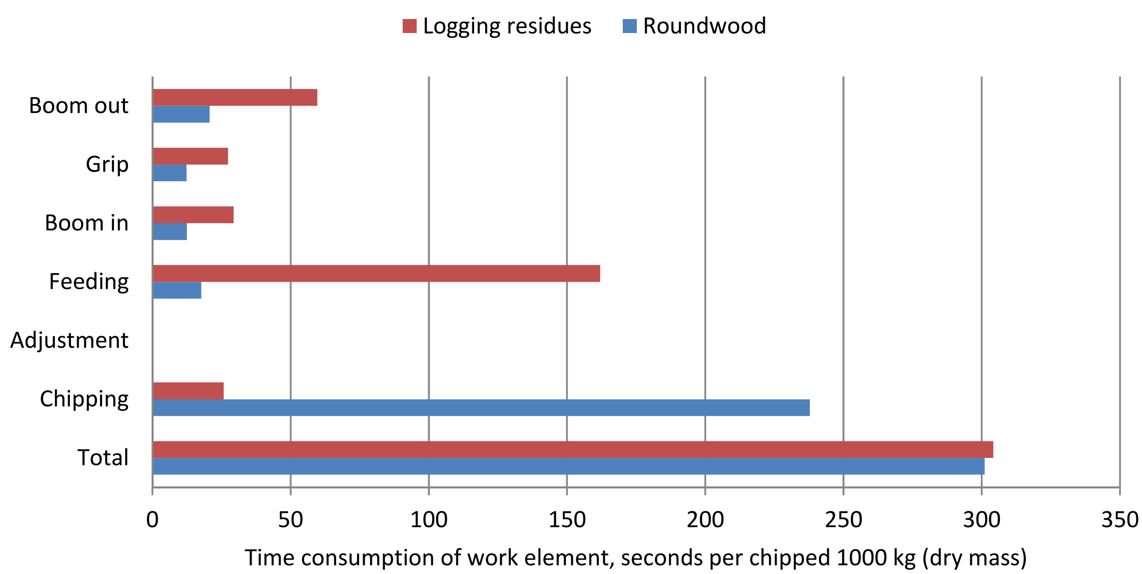

Figure 13 – Time consumption of work elements per chipped 1000 kg (dry mass) with Kesla C 860 H hybrid chipper when chipping roundwood and logging residues.

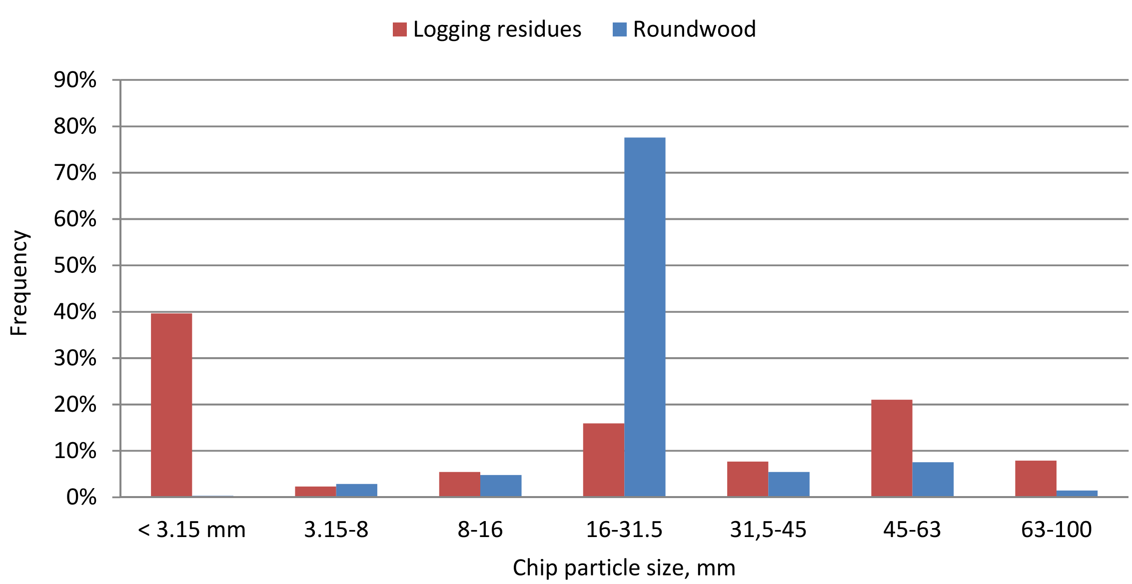

Figure 14 – Particle size distribution for logging residue and roundwood chips produced by the Kesla C 860 H hybrid chipper.

Bulk density was estimated to be 317–330 kg/loose-m^3 for logging residue chips and 255–271 kg/loose-m^3 for roundwood chips at the chipping place. Particle size class (Figure 14) was P31 for roundwood chips and P63 for logging residue chips (Alakangas and Impola 2014). The average basic density of roundwood and logging residues were 402 kg m^{-3} (SD 1.3) and 430 kg

m^{-3} (SD 14.3). The average moisture content of roundwood chips was 39.6% (SD 8.0) and for logging residues the average moisture content was 50.8% (SD 2.8). The average of net calorific value of roundwood chips was 20.1 MJ kg^{-1} (SD 0.11) and 20.9 MJ kg^{-1} (SD 0.02) for logging residue chips. The average ash content was 0.7 % (SD 0.11) for roundwood chips and 4.2% (SD 0.89) for logging residue chips.

3.2 The truck transporting experiments

During the time study the fuel consumption of the truck-trailer unit was 66.2 litres per 100 km with full load and 39.2 litres per 100 km with empty load. The driving distance was 37 km and the payload of roundwood chips were 40 000 kg. Total weight of the truck-trailer unit was 65 600 kg. The fuel consumption of the pure truck loads (truck without trailer) was 41.5 litres per 100 km and 37.4 litres per 100 km with empty load. The average payload of logging residue chips were 18 450 kg and the total weight of the truck was 33 720 kg on average.

The average unloading time of the truck-trailer unit was 4.4 minutes with the hydraulic side-tipping, when the roundwood chips were directly unloaded to the asphalted yard of the Keljonlahti power plant.

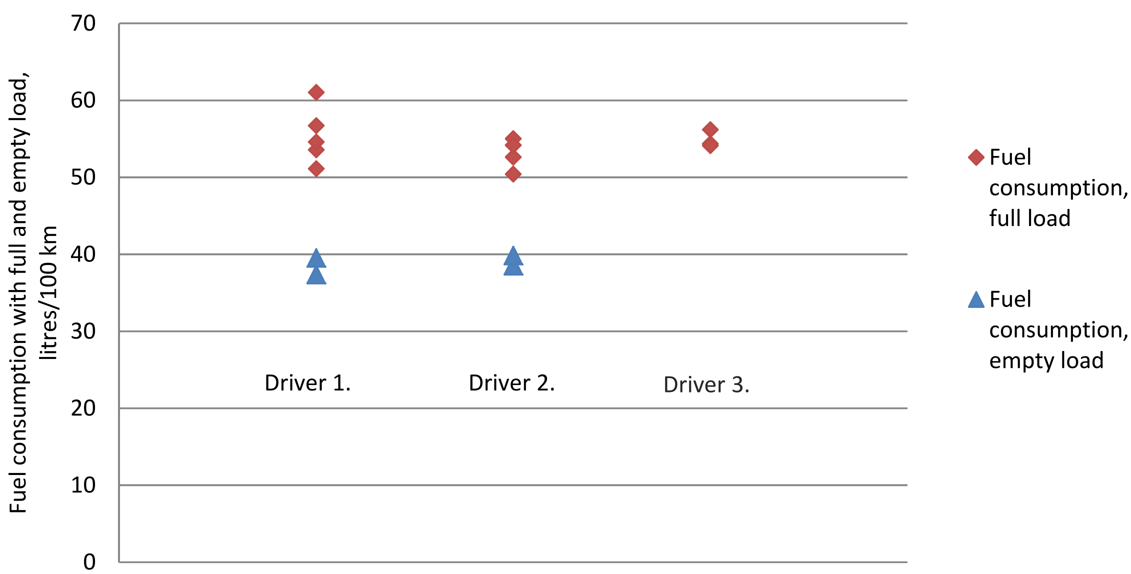

Figure 15 – Fuel consumption of the Lipe nine axle truck-trailer unit when transporting wood chips from plywood mill and sawmill to the BCTMP or sulphate pulp mill.

The average transporting distances in the follow-up study were 129 km (SD 32) with empty load and 265 km (SD 46) with full load. During the follow up study the average fuel consumption of the truck-trailer unit was 54.5 litres per 100 km (SD 1.1) with full load and 39.2 litres per 100 km (SD 1.1) with empty load (Figure 15). To the follow-up study participated three professional truck drivers. The driver 1 had the average fuel consumption with full load 55.4 litres per 100 km (SD 3.7). Correspondingly the driver 2 and the driver 3 had the fuel consumption 53.3 (SD

1.8) and 54.9 (SD 1.1) litres per 100 km (Figure 15). The payloads were in range of 31 700 – 48 154 kg (Figure 16) and the average payload were 39 774 kg (SD 5333). The two of the heaviest payloads (Figure 16) were recorded when transporting wood chips origin from sawmills. Fuel consumption of the nine axle truck-trailer unit increased slightly when the payload increased (Figure 16).

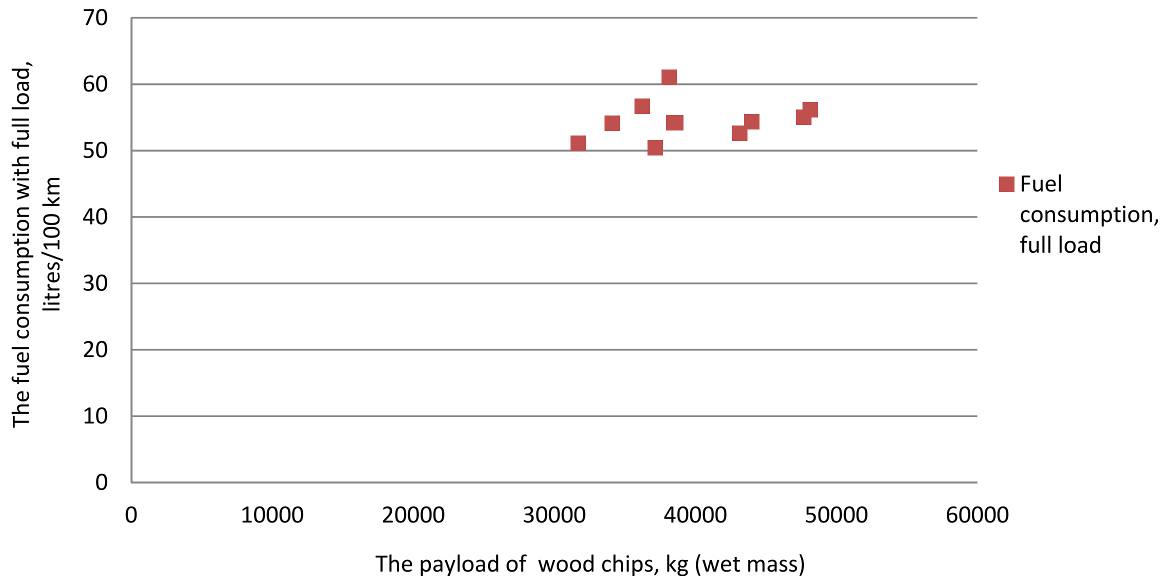

Figure 16 – Fuel consumption of the nine axle truck-trailer unit as a function of the payload when driving loaded.

3.3 The degree of filling experiment

Due the lack of the computation power of the used laptop machine the measurements were done in small pieces. These separate pieces were merged to one model (Figure 17) afterwards using the Meshlab and the volume analysis is done using the netfabb Studio software. Measurement experiments were done both for roundwood and logging residue chips. Degree of filling was determined by measuring the volume of the wood chip bed and compared that to total volume of the truck container. For wood chips made from roundwood the degree of filling was 82 % and for the logging residues 78 %.

It should be noticed that the determined degree of filling was obtained after the 30-40 km transportation so the wood chip level is compressed. In addition, the whole surface area of the wood chip load was not measured and evaluated because of the limited measurement conditions. Therefore, the surface area included into the analysis was only 60 – 80 % from the truck container area.

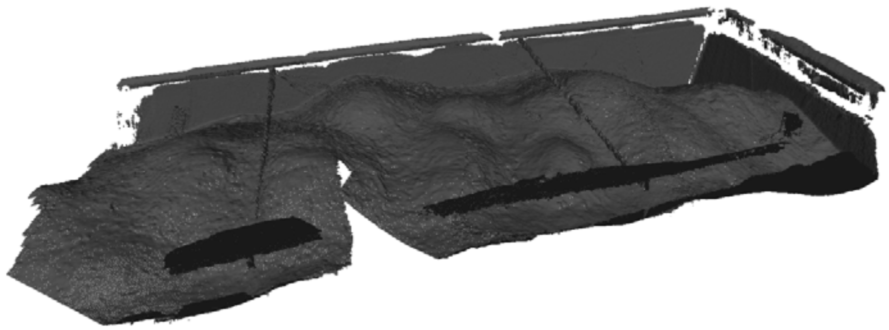

Figure 17 – Reconstructed model from the wood chip load. The model is formed from five separate scans.

The experiment shows that the measurement method works well for the determination of filling degree. However there are some limitations such as direct sunlight which will affect to the measurements. Method will work better if the ambient illumination can be limited which can be done by selecting the measurement location more carefully for example under covered hovel or similar.

4 General evaluation

During the time studies, the truck-trailer unit, the chipper and the hybrid system were working well. The truck mounted chipper was capable of operating in a constricted roadside landings and the large nine axle truck-trailer unit was at its best when transporting fuel chips from the terminal. The productivity results of the chipping experiment must be considered to be preliminary because the amount of chipped wood and assortments were rather small. The chipper and especially the hybrid system are under continuous development, and follow up-study is needed for a more accurate determination of long term productivity, fuel consumption and operating costs.

The versatile load space which enables e.eg. backhauling, is a clear benefit on long transporting distances, because larger procurement areas, increasing prices of transporting fuel and higher consumption of time of the transportation will increase the costs of the wood chips. The large monthly variation of energy wood demand poses a challenge for the transport economy: In winter demand of fuels and their transport is peaking and in early autumn, spring and summer there is much less transport work available (Windisch et al 2015). For instance, Jyväskylän Energia receives 190 loads/day of fuel in January and only 14 loads/day in August (Ryymin 2015). Versatility of transportation equipment represents also one way of achieving year-round employment and ensuring the availability and stability of a professional workforce. Unloading based on side-tipping is an efficient method, compared to methods based on walking floor or chain unloading, if chip delivery systems are designed compatible also for side-tippers.

Increased payload is a key economic factor in reducing transporting costs. The potential for artificial load densification is set by the initial bulk density of the chips and the volume capacity and legal payload of the truck-trailer units. The bulk density of dry wood chips is rather low and thus the payload is usually limited by the frame volume rather than the mass capacity of the modern large truck-trailer unit. Therefore the large nine axle truck-trailer unit having a 69 tonnes maximum gross weight is a smart choice optimizing the load space and weight ratio when transporting e.g. ground stumps or roundwood chips from terminals or veneer chips from plywood mills. With more heavy or wet materials (e.g. logging residues), the 76 tonnes nine axle truck-trailer unit equipped with twin tyres is the right choice.

The long wheelbase between the front and rear axles of newest concepts require wider turning areas than the traditional trucks (Figure 18). The tight turn with heavy load is possible but not recommended. The heavy load will strain the rear axles with massive forces and therefore the risk for axle or wheel breakdowns increases and the total life span of the trailer decreases. Utilizing modern vehicle designs such as a moveable axle group or liftable or steering axles at the rear end of a trailer this size vehicle can be well manoeuvrable also on forest roads and turnarounds.

Figure 18 – Benefits by using bigger trucks depend very much on the transported material and restrictions of the road network in its operation region (Photo: Petri Kaksonen/Kesla).

5 Demo results

The world first full hybrid wood chipper Kesla C 860 H were presented first time at the FinnMetko forest machinery exhibition on August 28–30th 2014 in Central Finland. The exhibition had over 32 000 visitors. In spring 2015 Kesla`s hybrid chipper was introduced to the audience, including high level policy makers and forest and energy professionals in Hakevuori Forest Energy Day at Askola (Figure 19). In total around 1000 people participated the demonstration at 19.3.2015 in Askola in South Finland.

The demonstrated nine axle Lipe truck-trailer unit constructed by Konepaja Antti Ranta were introduced to the audience first time on 11– 13 June 2015 at Logistics - Transport 2015 fair in Helsinki (Figure 20). The event had approximately 12 500 visitors and it is the biggest event for logistics and transport in Nordic countries.

To the joint demonstration of the nine axle chip truck-trailer unit and hybrid chipper in Tikkakoski and Uurainen participated total three people from Finland and Sweden.

Figure 19 – Kesla C 860 hybrid chipper demonstration in Hakevuori Forest Energy Day in South Finland (Photo: Kari Kokko/Kesla).

Figure 20 – Lipe truck-trailer unit demonstration at Logistics - Transport 2015 fair in Helsinki (Photo: Janne Jokela/ Metsäalan Ammattilehti).

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7 References

Alakangas, E., Impola, R. 2014. Puupolttoaineiden laatuohje [Quality norms for wood fuels]. VTT-M–07608–13 – päivitys 2014. Bioenergia ry, Energiateollisuus ry and Metsäteollisuus ry. 66 p. (In Finnish).

Björheden, R. 2008. Optimal point of comminution in the biomass supply chain. In publication Suadicani, K., Talbot, B. 2008 (Eds.): The Nordic-Baltic Conference on Forest Operations–Copenhagen September 23-25, 2008. Forest & Landscape Working Papers no. 30-2008. 92 p.

Cambero, C., Sowlati, T., Marinescu, M., Roser, D. 2015. Strategic optimization of a forest residues to bioenergy and biofuel supply chain. International Journal of Energy Research (39)4: 439–452. Published online of August 4, 2014. DOI: 10.1002/er.3233.

Di Fulvio, F., Eriksson, G., Bergström, D. 2015. Effects of wood properties and chipping length on the operational efficiency of a 30 kW electric disc chipper. Croatian Journal of Forest Engineering (36):1 85–100.

Einola, K. 2013. Prestudy on power management of a cut-to-length forest harvester with a hydraulic hybrid system. The 13th Scandinavian International Conference on Fluid Power, SICFP2013, June 3–5 2013, Linköping, Sweden: 71–83.

Eriksson A., Eliasson L., Jirjis R. 2014. Simulation-based evaluation of supply chains for stump fuel. International Journal of Forest Engineering 25(1): 23–36. http://dx.doi.org/10.1080/14 942119.2014.892293.

Eriksson, G., Bergström, D. & Nordfjell, T. 2013. The state of the art in woody biomass comminution and sorting in Northern Europe. International Journal of Forest Engineering 24(3):194–215.

Hakkila, P. 2004. Developing Technology for Large-Scale Production of Forest Chips. Wood Energy Technology Programme 1999–2003. Technology Programme Report 6/2004. National Technology Agency. 98 p.

Harstela, P. 1991. Work studies in forestry. University of Joensuu. Silva Carelica 18. 41 p.

Holzleitner F., Kanzian C., Höller N. 2013. Monitoring the chipping and transportation of wood fuels with a fleet management system. Silva Fennica vol. 47 no. 1 article id 899. 11 p.

Karttunen, K., Väätäinen, K., Asikainen, A. & Ranta, T. 2012a. The operational efficiency of waterway transport of forest chips on Finland's Lake Saimaa. Silva Fennica 46(3): 395–413.

Karttunen K., Föhr J., Ranta T., Palojärvi K., Korpilahti A. 2012b. Puupolttoaineiden ja polttoturpeen kuljetuskalusto 2010. [Transportation vehicles for wood fuels and peat in 2010]. Metsätehon tuloskalvosarja 2/2012. (In Finnish). 17 p.

Karttunen, K., Lättilä, L., Korpinen, O.-J., Ranta, T. 2013. Cost-efficiency of intermodal container supply chain for forest chips. Silva Fennica vol. 47 no. 4 article id 1047. 24 p.

Kons, K., Bergström, D., Eriksson, U., Athanassiadis, D., Nordfjell, T. 2014. Characteristics of Swedish forest biomass terminals for energy, International Journal of Forest Engineering, 25:3, 238-246, DOI:10.1080/14942119.2014.980494

Korpilahti, A. 2015. Bigger vehicles to improve forest energy transport. Metsätehon tuloskalvosarja 3/2015. 33 p.

Kärhä, K. 2011. Industrial supply chains and production machinery of forest chips in Finland. Biomass and Bioenergy 35(8):3404–3413.

Laitila, J., Ranta T., Asikainen A., Jäppinen E., Korpinen O.-J. 2015a. The cost competitiveness of conifer stumps in the procurement of forest chips for fuel in Southern and Northern Finland. Silva Fennica vol. 49 no. 2 article id 1280. 23 p.

Laitila, J., Prinz, R., Routa, J., Kokko, K., Kaksonen, P., Suutarinen, J., Eliasson, L. 2015b. Prototype of hybrid technology chipper. INFRES demo report D4.6.19 p.

Lindblad, J., Verkasalo, E. (2001). Teollisuus- ja kuitupuuhakkeen kuivatuoretiheys ja painomittauksen muuntokertoimet [Basic density and conversion factors for industrial and pulpwood chips]. Metsätieteen aikakauskirja 3/2001:411–431. (In Finnish).

Magagnotti, N., Kanzian, C., Schulmeyer, F., Spinelli, R. 2013. A new guide for work studies in forestry. International Journal of Forest Engineering (24)3: 249–253.

Ranta T., Rinne S. 2006. The profitability of transporting uncomminuted raw materials in Finland. Biomass and Bioenergy 30(3): 231–237. http://dx.doi.org/10.1016/j.biombioe.2005.11.012

Routa, J., Asikainen, A., Björheden, R., Laitila, J., Röser, D. 2013. Forest energy procurement - state of the art in Finland and Sweden. WIREs Energy and Environment 2(6): 602–613.

Ryymin, R. 2015. Opening address. General Assebly Meeting of INFRES, Consiglio Nazionale delle Ricerche, Piazzale Aldo Moro 7, Rome, Italy. 25 p.

Spinelli, R., Visser, R. 2009. Analyzing and estimating delays in wood chipping operations. Biomass and Bioenergy 33(3):429–433.

Strandström, M. 2015a. Metsähakkeen tuotantoketjut Suomessa vuonna 2014 [Production chains of forest chips in Finland in 2014]. Metsätehon tuloskalvosarja 8/2015. 20 p. (In Finnish).

Strandström, M. 2015b. Puunkorjuu ja kaukokuljetus vuonna 2014 [Harvesting and long-distance transportation in 2014]. Metsätehon tuloskalvosarja 7a/2015. (In Finnish). 33 p.

Sun, H., Yang, L., Jing, J. 2010. Hydraulic/electric synergy system (HESS) design for heavy hybrid vehicles. Energy 35(12):5328–5335.

Tahvanainen, T., Anttila, P. 2011. Supply chain cost analysis of long-distance transportation of energy wood in Finland. Biomass & Bioenergy 35(8): 3360-3375.

Talbot, B., Suadicani, K. 2006. Road transport of forest chips: containers vs. bulk trailers. Forestry Studies (45): 11-22.

Uusvaara, O. 1978. Teollisuushakkeen ja purun painomittaus [Estimation of industrial chip and sawdust weight]. Folia Forestalia 341. 18 p. (In Finnish with English summary).

Uusvaara, O., Verkasalo, E. 1987. Metsähakkeen tiiviys ja muita teknisiä ominaisuuksia [Solid content and other technical properties of forest chips]. Folia Forestalia 683. 53 p. (In Finnish with English summary).

Valtioneuvoston asetus 407/2013 ajoneuvojen käytöstä tiellä [The Finnish government regulation for road vehicles]. Available at: http://www.finlex.fi/fi/laki/alkup/2013/20130407#Pidm1799696/

Windisch, J., Väätäinen, K., Anttila, P., Nivala, M., Laitila, J., Asikainen, A., & Sikanen, L. 2015. Discrete-event simulation of and information-based raw material allocation process for increasing the efficiency of an energy wood supply chain. Applied energy, Volume 149: 315–325

Wolfsmayr, U.J., Rauch, P. 2014. The primary forest fuel supply chain: A literature review. Biomass and Bioenergy (60):203–221.

Ylitalo, E. 2015a. Puun käyttö 2014: Metsäteollisuus [Forest industries' wood consumption in 2014] Available at: http://stat.luke.fi/metsateollisuuden-puun-kaytto (In Finnish).

Ylitalo, E. 2015b. Puun energiakäyttö 2014 [Solid wood fuel consumption in heating and power plants 2014] Available at: http://stat.luke.fi/puun-energiakaytto (In Finnish).

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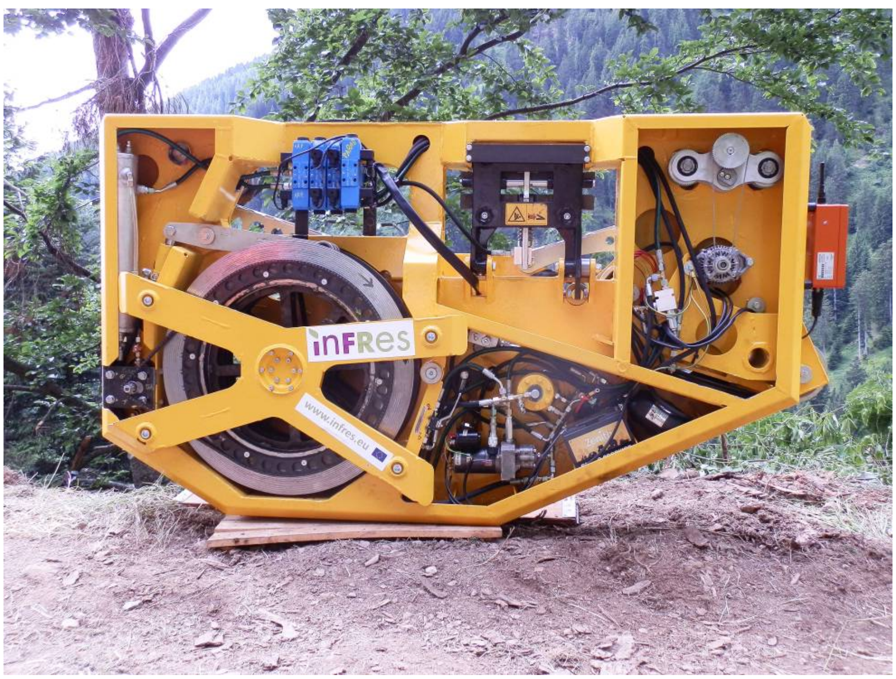
INFRES – Innovative and effective technology and logistics for forest residual biomass supply in the EU (311881)

Raffaele Spinelli & Natascia Magagnotti (CNR IVALSA)

Gernot Erber & Maximilian Kastner (BOKU)

Francesca Ziller & Daniele Valentini,Valentini (Valentini Teleferiche)

Demo report 18 – Un-motorized full suspension carriage for increasing cable yarding efficiency – D4.5



Dissemination Level	
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Confidential, only for members of the consortium (including the Commission Services)	

San Michele all'Adige, 23.06.2015

Preface

Finnish Natutal Resources Institute (Luke) is coordinating a research and development project 'Innovative and effective technology and logistics for forest residual biomass supply in the EU – INFRES'. The project is funded from the EU's 7th framework programme. INFRES aims at high efficiency and precise deliveries of woody feedstock to heat, power and biorefining industries.

INFRES concentrates to develop concrete machines for logging and processing of energy biomass together with transportation solutions and ICT systems to manage the entire supply chain. The aim is to improve the competitiveness of forest energy by reducing the fossil energy consumption and the material loss during the supply chains. New hybrid technology is demonstrated in machines and new improved cargo-space solutions are tested in chip trucks. Flexible fleet management systems are developed to run the harvesting, chipping and transport operations. In addition, the functionality and environmental effects of developed technologies are evaluated as a part of whole forest energy supply chain.

This publication is a part of the INFRES project. The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2012-2015] under grant agreement n°311881.

This report describes the new carriage designed and produced by Valentini Teleferiche within the scope of INFRES, and the demonstration jointly organized by Valentini, IVALSA and BOKU. The demonstration was held on June 19th and 20th 2015, in Rumo near Cles, in the Trento Province (Italian Alps).

Raffaele Spinelli, Natascia Magagnotti, Gernot Erber, Maximilian Kastner, Francesca Ziller and Daniele Valentini

San Michele all'Adige, Vienna and Cles, June 2015

This publication is a part of the INFRES project. The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2012-2015] under grant agreement n°311881.

Title	**Demo report 18- Un-motorized full suspension carriage**
Author(s)	Raffaele Spinelli, Natascia Magagnotti, Gernot Erber, Maximilian Kastner, Francesca Ziller and Daniele Valentini
Abstract	Current yarding technology is penalized when attempting whole-tree extraction on long distances. To compensate for distance one should increase yarding speed, which is too dangerous when a long load is dangling under the carriage. That may cause excessive solicitation of the cable set up, and result in an accident if the load hits one of the standing trees at the sides of the yarding corridor. The obvious solution consists in lifting trees horizontally under the carriage, suspended from two points. That requires a double carriage, composed of two separate elements working in tandem, each with its own lift line. Such carriages already exist, but they are all motorized. This means that one of the carriage elements contains a diesel engine, which is used for powering both lift lines through a hydrostatic or electric transmission. Installing a diesel engine on a carriage incurs several drawbacks, such as: a marked increase of tare weight, a high purchase cost, the risk of fuel spills along the line and the higher noise pollution. For this reason, Valentini developed a new carriage devised for full load suspension without the help of a diesel engine. The new carriage uses the power of the main winch for load lifting, like conventional self-clamping carriages, but it is designed for use in a tandem configuration, which is not possible with conventional carraiges. Compared to the motorized alternative, the new tandem carriage is 40% lighter and 33% cheaper to purchase. Furthermore, by removing the on-board diesel engine, overall fuel consumption is reduced 20%. This new technical solution is increasing the viability of biomass recovery, and in general the financial and environmental sustainability of wood harvesting from remote mountain forests. The carriage was demonstrated in Northern Italy on June 2015, in an event jointly managed by Valentini, CNR IVALSA and BOKU.
Date	June 2015
Language	English
Pages	15 p.
Name of the project	INFRES - INFRES – Innovative and effective technology and logistics for forest residual biomass supply in the EU (311881)
Financed by	European Commission – FP7 programme
Keywords	Yarding; Cable extraction; Biomass; Steep terrain; Mountain
Publisher	

1 Introduction

The Alps are one of the great mountain range systems of Central and Southern Europe, stretching 1200 km across 8 different Countries. Forest cover represents 40% of the Alpine landscape, and forests have always played an important role in supporting the alpine economy, which is especially true today with the boom of engineered wood products and energy biomass.

The need to balance cost-effective wood production with careful protection makes alpine forestry particularly complex. Continuous-cover forestry is popular, as it offers a good compromise between these two vital functions. However, continuous-cover forestry reduces harvest intensity and it may constrain operation profitability. Low harvest intensity and the typical access constraints of the Alpine territory hinder the introduction of modern mechanization, which is the only solution to cost containment in the face of increasing fuel and labor cost. Under these conditions, significant benefits can be obtained by modernizing cable yarding, which is the back-bone of steep slope harvesting worldwide.

On steep terrain, cable yarding is the cost-effective alternative to building an extensive network of skidding trails and results in a much lower site impact compared to ground-based logging (Fig. 1). On the other hand, cable yarding is inherently expensive because it is normally deployed on difficult sites. For this reason, cable yarding offers lower profit margins compared to ground-based logging. This justifies a stronger optimization effort, supported by a deeper knowledge of technical cost and market rates.

Figure 1: Modern cable yarding operation

Cable yarding is very popular in the Italian Alps. In 2012, there were over 350 cable yarding contractors in alpine Italy alone (Spinelli et al. 2013). North Italian loggers have a long tradition with cable yarding, and several yarder manufacturers operate their plants in northern Italy. One north-Italian logging company out of four has both the skills and the equipment for cable yarding. Thirty-five percent of the machines are modern tower yarders, while the rest are sled-mounted yarders. Tower yarders are increasingly popular and they are often paired with a processor. Tower yarders are the modern counterpart of the traditional sled-mounted yarders, and they are generally half as old. On the other hand, sled mounted yarders can work with longer skylines and are especially useful when no roads are available. In fact, new long-distance tower yarders are narrowing the gap between the two models.

In Northern Italy, companies equipped with a yarder harvest almost twice as much wood as the other companies (mean 4,059 vs. 2,340 m^3 $year^{-1}$; median 2,000 vs. 970 m^3 $year^{-1}$), and the difference is statistically significant ($p<0.0001$). They also target significantly larger lots (mean 678 vs. 565 m^3; median 428 vs. 300 m^3).

Figure 2: The yarding operation at the Demo site

Trentino could be used as an example, because it sticks out from the other Italian Regions. Companies in Trentino have opted for increased mechanization and specialization. They have the largest proportion of modern tower yarders and the largest processor fleet (Fig. 2). As a consequence, they achieve the highest productivity and confront less severe problems with labour recruitment, if the younger age of entrepreneurs and the lower incidence of immigrant workers can be taken as indicators. Trentino companies have also changed their business strategy in favour of subcontracting, which allows concentrating all efforts on the technical tasks rather than splitting forces between actual logging and wood trading. Furthermore, in

Trentino the process of mechanization has been widely supported with public subsidies, thus mitigating the strain on entrepreneurs. All of that explains why the mountain forest demonstration was organized in Trentino, rather than in any other Regions. There, any new ideas can have a stronger impact and spread quicker than they would do elsewhere.

2 Biomass recovery

Biomass recovery from yarding sites is only viable if whole trees are extracted (Fig. 3). In that case, trees are processed at the landing, where residual biomass accumulates, ready for recovery as wood fuel. That is already done in many countries, including Italy.

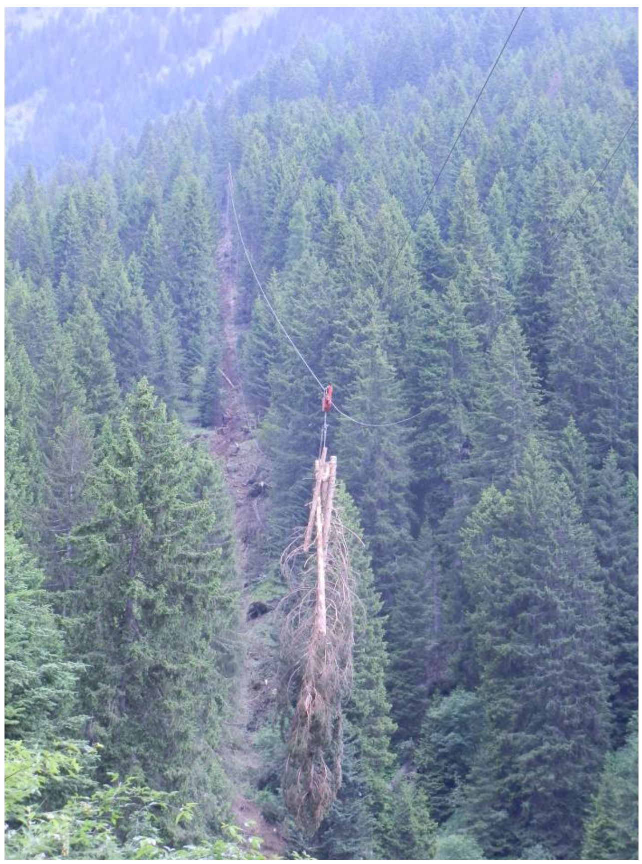

Figure 3: Long-distance yarding

However, whole tree yarding is viable on relatively short distances only (300-500 m). Therefore, biomass production is currently restricted to forest areas with a good forest road network and practically excluded from many forests in the less accessible areas of France and Italy, for instance.

In order to compensate for extraction distance one should increase yarding speed, which is too dangerous when a long load is dangling under the carriage. That may cause excessive solicitation of the cable set up, and result in an accident if the load hits one of the standing trees at the sides of the yarding corridor. Therefore, long-distance whole-tree extraction requires special technical solutions. Among them, the most logical consists in lifting trees horizontally under the carriage, suspended from two points. That requires a double carriage, composed of two separate elements working in tandem, each with its own lift line.

Figure 4: Full suspension achieved with a motorized twin-carriage

Such carriages already exist, but they are all motorized (Fig. 4). This means that one of the carriage elements contains a diesel engine, which is used for powering both lift lines through a hydrostatic or electric transmission. Installing a diesel engine on a carriage incurs several drawbacks, such as: a marked increase of tare weight, a high purchase cost, the risk of fuel spills along the line, and the higher noise pollution.

Furthermore, a motorized carriage is much more expensive and vulnerable than a carriage without a motor, which is going to result in a much more expensive repair bill in case of falling. Finally, a motorized carriage will need to be taken down daily (or more often) for refuel and maintenance.

To make an example, the strongest and most effective full-suspension carriage developed so far, the SEIK Skybull, has a weight of 2.8 tonnes and costs about 120,000 €, which are going to make an eventual fall very expensive.

These same drawbacks affect smaller-scale motorized carriages as well. Even if they are lighter (and less powerful) than top-of-the-range models, these carriages are still relatively heavy and expensive (Fig. 5). While they may simplify line set-up and make manoeuvring much smoother, they present the same vulnerability issues as any other motorized carriages.

Figure 5: One of the newest small-scale motorized carriage

3 The new carriage

For all these reasons, Valentini developed a new carriage devised for full load suspension without the help of a diesel engine. With the new carriage, the lift line is powered by the mainline, which wraps around a dedicated parabolic capstan co-axial with the lift line drum. The mainline then exits the capstan and connects to the haulback line, to form the classic closed loop. By reeling in the haulback line on the yarder winch, the lift line spools out. Conversely, when the mainline is reeled in on the yarder winch, then the lift line spools in, lifting the load. This system is not new, and has been adopted by several other manufacturers for their products. However, the novelty of Valentini's project is that the lift line drum can be disconnected from the capstan and braked, so that it is now possible to operate two identical carriages in tandem. By alternately braking and disconnecting the two lift line drums, one can use the lift lines independently, as required by effective work practice.

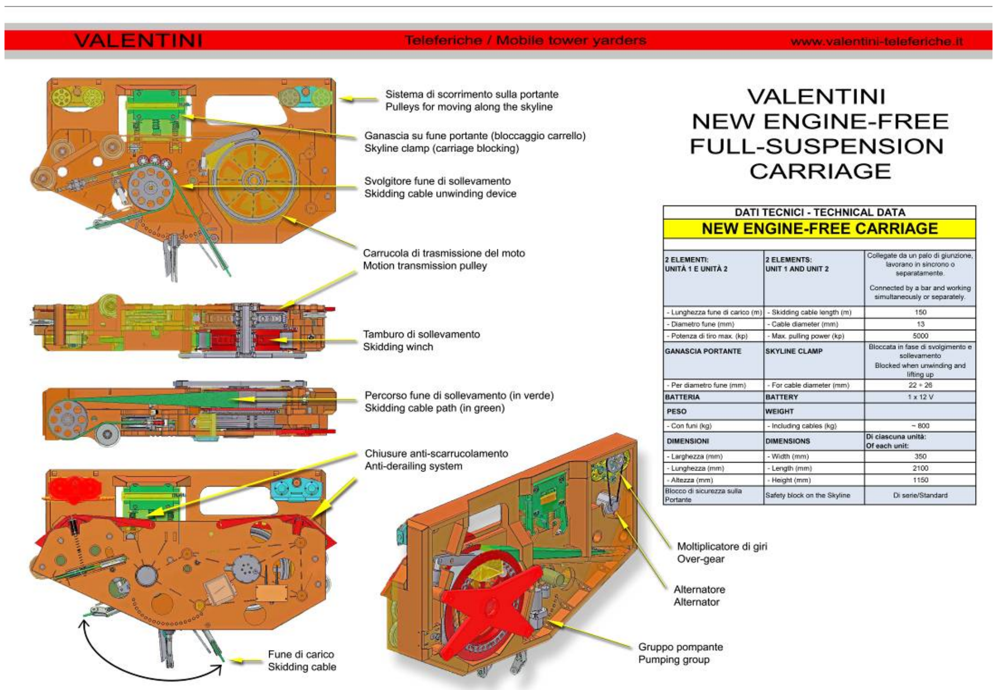

Figure 5: The un-motorized full-suspension carriage developed by Valentini (one element)

A schematic description of the new carriage is presented in figure 6, which depicts one of the two identical units designed to work in a tandem configuration. The carriage has 4 hydraulic valves, used to activate the following functions: swing in and out the hydraulic clamp mount; closing or opening the hydraulic clamp; connecting or disconnecting the lift line drum to the capstan; engaging or disengaging the lift line drum ratchet block. Hydraulic pressure is provided by a standard accumulator, which is kept charged by an electrically operated hydraulic pump. An alternator is applied to the skyline rollers through a gear reduction, so that the compact battery lodged into the carriage is kept charged. As the carriage travels on the skyline, the alternator accumulates energy into the battery, which keeps the hydraulic accumulator loaded. This way, one obtains a double energy accumulation, in the battery and in the hydraulic accumulator. That allows complex manoeuvring without running out of hydraulic pressure, even when the carriage is working on short distances, and provides energy for operating the radio-control system (transceiver on the carriage) .

All actual work – lifting and travelling – is done through the yarder winches, so that the power sources in the carriage are kept to the minimum necessary for the braking/releasing and connecting/disconnecting of the work gear (Fig. 7).

Figure 7: Power is sourced from the yarder winches, not from an on-board engine

Compared to the motorized alternative, the new tandem carriage is 40% lighter and 33% cheaper to purchase. Furthermore, by removing the on-board diesel engine, overall fuel consumption is reduced 20% (Table 1). These are dramatic improvements, which are likely to increase the viability of biomass recovery, and in general the financial and environmental sustainability of wood harvesting from remote mountain forests.

Furthermore, one can use the two carriage elements separately, just to replace a traditional self-clamping carriage. That would accrue a clear benefit in terms of reduced mainline wear. Standard self-clamping carriages use the mainline to lift their loads, which results in an accelerated wear of the lift end of the mainline. As a result, operators have to cut the worn end of the mainline at regular intervals, in the order of one or two weeks, depending on use intensity. By doing so, they end up making the mainline too short, which leads to premature replacement the moment they have to tackle a long distance job and they lack enough mainline length.

Table 1: Comparison between the innovative Valentini carriage and a motorized carriage with the same approximate lifting capacity

		Motorized	New Valentini	
Pull	kN	40	50	25%
Weight	t	2.8	1.7	-39%
Diesel consumption	l/h	15	12	-20%
Price	€	117000	80000	-32%

4 The demonstration

On June the 19th and the 20th the new carriage was demonstrated in a softwood forest near Rumo, in the Province of Trento, Northeastern Italy (Fig. 8). The demonstration was organized by Valentini, IVALSA and BOKU, with the support of a local entrepreneur, Paolo Vicenzi, who provided access to his operation for the event.

Figure 8: The new carriage being tuned at the Valentini factory right before the Demo

At the time of the demonstration, the Vicenzi crew were harvesting spruce and fir trees from a high-elevation mixed conifer forest. The lower anchor was located at an elevation of 1400 m asl, whereas the upper anchor was about 300 m higher. The yarder was the newest Valentini V600/1000 M3 B10 , the same model launched almost one year earlier on occasion of INFRES Demonstration n° 9.

This machine is mounted on a tracked undercarriage and features a larger new engine (245 Hp) and re-designed drums, which are now equipped with a store section, where unused cable is accumulated in order to reduce cable wear and maximize mainline pull. On most yarders, a store section is only available on the skyline drum, not on the mainline and haulback drums. In contrast, this new Valentini design offers store sections on all working drums, to the benefit of lower maintenance and stronger pulls. In its basic configuration, the new machine offers 1000 m skyline in the 22 mm swaged version, and a maximum mainline pull of 56 kN. The machine on show was rigged in the three cable configuration, for downhill extraction. It was operated by a 3-men crew, including the processor operator.

Figure 9: Taking the carriage to the demo site

The demo program was geared to attract primarily active loggers, forest owners and certified foresters, making sure that the focused remained on cost-effective forest biomass technology for mountain operations. For this reason, the event spanned over two days – Friday and Saturday – to make sure that loggers had an opportunity to visit the worksite over the festive day. The demo site was open from 09:00 to 18:00 on Friday, and from 09:00 to 17:00 on Saturday: the last visitor arrived at 16:15 (Fig. 9).

Total attendance numbered 63 registered participants, excluding those who did not sign the list for one reason or another. Participant came mostly from the Province, but also from other regions in Northern Italy.

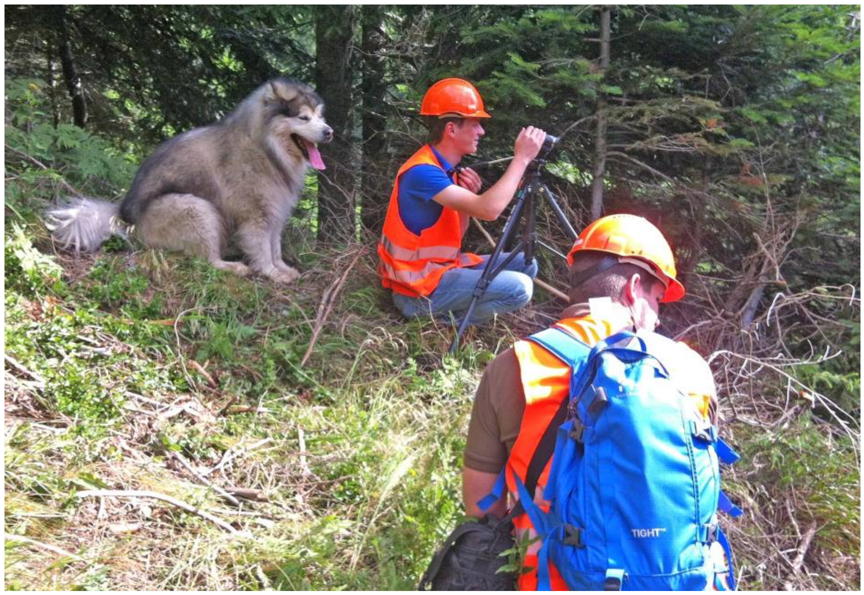

Figure 9: Acquiring video footage for the virtual demo

During the Demo days, BOKU researchers took video records of the operations. This was done concurrently from a standard video station on the ground, and from a new action video camera installed on the yarder carriage. Additional footage was shot the day before, during preparations. The video material will be cut and assembled into a short virtual demo for posting on the INFRES website, so that people who could not attend the live demonstrations in June will have the opportunity to get essential information about the new carriage. This video will integrate CAD animations provided by Valentini, for explaining the working principle of the innovative carriage, which is difficult to visualize from conventional video images.

5 Conclusions

The Alps offer different work conditions compared to most Nordic countries, especially with regards to terrain morphology and forest access. Forwarding can be applied to a relatively small proportion of the productive area, and processors are best teamed with yarders. Under these conditions, yarding capacity is crucial to effective harvesting, and represents a main asset of Alpine logging companies. Yarding skills are more difficult to acquire than yarding equipment, but the Alpine logging firms seem to possess these skills to a very high degree. The maintenance, improvement and expansion of the already pervasive Alpine yarding skill should be supported by all available means. Integrating timber production with wood fuel harvesting can provide a vital contribution in this area, and it has already become quite popular. High-speed full suspension yarding is crucial to extending wood fuel harvesting to remote areas. This Demonstration was instrumental in raising awareness of the new technical options available for full suspension yarding and that may help modernizing a sector that is strategic for the development of mountain regions.

6 Acknowledgements

The authors wish to thank the Fanti Legnami, Paolo Vicenzi and the operators at the Demo site for their support with the demonstration and the study.

The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2012-2015] under grant agreement n°311881. The sole responsibility for the content of this report lies with the authors. It does not necessarily reflect the opinion of the European Communities. The European Commission is not responsible for any use that maybe made of the information contained therein.

7 References

Spinelli R., Magagnotti N., Facchinetti D. 2013. A survey of logging enterprises in the Italian Alps: firm size and type, annual production, total workforce and machine fleet. *Int J For Eng* 24: 109-120.

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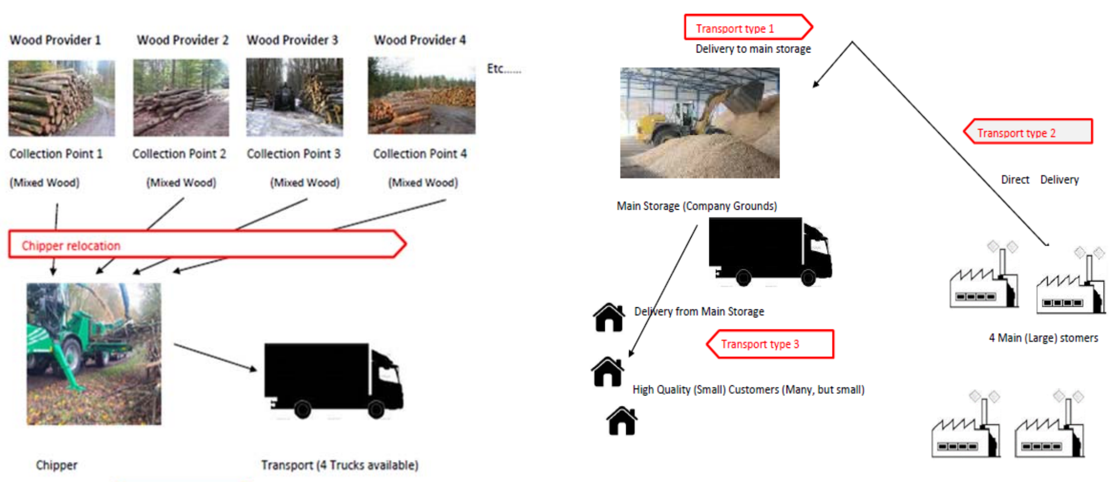
INFRES – Innovative and effective technology and logistics for forest residual biomass supply in the EU (311881)

Matti Tuukkanen (Ecomond)

Matthias Dees (ALU-FR)

Demo Report 19 – Transport logistic software for wood chip firms, demonstrated in Germany – D4.5



Dissemination Level	
Public	x
Restricted to other programme participants (including the Commission Services)	
Restricted to a group specified by the consortium (including the Commission Services)	
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Freiburg, June 25h, 2015

1. Introduction

There are numerous Transport Management Software's (TMS) as well as Optimisation software's on the market which are used in standard transport applications. These software's typically are designed for some industry and/or are very difficult to be converted into other industries. Developing a solution to bioenergy business would be extremely expensive and would not be suitable because of the business being run mainly by small companies. TCS product family, from INFRES partner Ecomond OY, is unique since it is non industry specific solution with very high level of parametrisation making it possible to be used in bio energy business too as well as in small companies. On this background the objective was to demonstrate and evaluate the solution in such a company.

This kind of software will help companies greatly to improve their efficiency in many ways from lowering the cost, improving service and also quality. Such software can contribute to reduction of transport cost and utilization of resources, which are essential cost factor but also offer a wide range of further optimization possibilities that lead to a reduction of costs and can thus contribute to a further mobilisation of biomass that is highly dependent on transport and production costs.

The INFRES partner Ecomond OY is a Finnish company that has develop a Transport Control System (TCS), a unique tool for managing, controlling and optimizing various operations from Waste Management to Services and Logistics to Security. TCS contains Office (ERP), Mobile and Optimisation modules in one server based system making it unique. TCS OPTI is a unique tool to optimise complex logistics since it is capable of not only optimise "milk round" cases, but also demand based non-stop routing.

In the course of the production of wood chips transport cost plays an important role. Wood chip companies are mainly small scale companies. The management of transport logistics is conventionally done using direct communication and exchange of information by mobile phones. Using advance transport management software can offer substantial cost savings that substantially exceed hardware and software cost, both in terms of saving of transport and labour costs.

On this background INFRES partner Ecomond OY adopted and developed the TCS Transport Control and Optimization software to the requirements of a wood chipping company.

The INFRES partner Fallert AG, a biomass wood chipping company was interested to test the software, explore its possible benefits in utilizing it in form of a demonstration to the company and to explore via that demonstration its scope for operational use within the company.

The INFRES partner University of Freiburg supported the demonstration by providing and preparing the street and forest road data, by translating software terms and by software testing of the demonstration version and by training of Fallert AG staff and for facilitating the communication to cope with translation issues.

2. Material and method

The demonstration uses the Fallert AG as an example. The Fallert AG is utilizing one chipper and 4 trucks for transport tasks. Both the chipper movements from chipping place to chipping place as well as the three transport tasks: (1) direct delivery of chips from the chipping location to large customers, (2) delivery of chips from the chipping location to the central storage place and (3) delivery to the large group of small scale customers from the central storage place (See Figure 1).

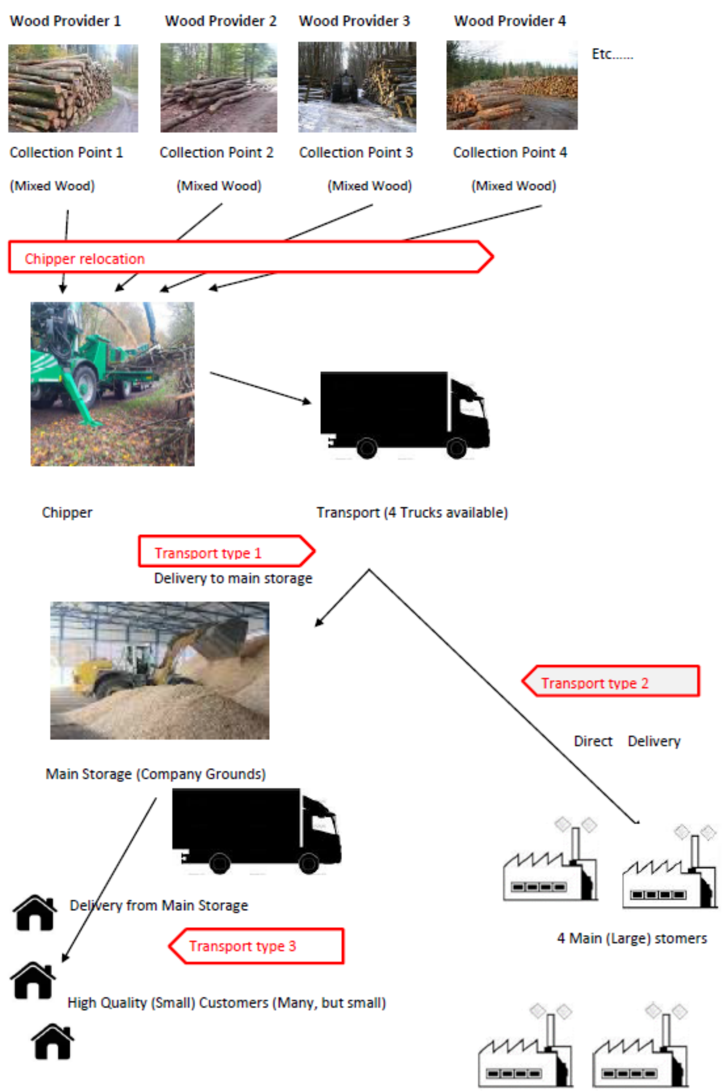

Figure 1. Transport and chipper movements at Fallert AG

The following challenges to organise a cost effective organisation of the transport aspect occur among many others. The chipper can chip at maximum 200 loose cubic meter wood per hour, the distances to the company ground range from 5 to 200 km. Around 60 forest storage places are chipped every month whereas the amount to be chipped per place varies from below 50 to 600 loose m³. Thus a large number of chipper relocations are necessary as well as of truck movements that have a transport capacity in the range of 70 loose cubic metres. During winter time 2 trucks focus on delivery to customers. The large scale customers need to be delivered in summer too. Thus the need to carefully coordinate and optimize the transport is a challenge that provides a huge scope for a software based task management and optimization.

Figure 2 and Figure 3 illustrate the chipper and one of the trucks in daily operations.

Figure 2. The chipper at the central storage place and chipping at a forest road

Figure 3. Delivery of chipps at the central storage place

Figure 4. Chipping at a storage place of a pellet factory

3. Features and functionalities and potentials benefits of the transport software

TCS is an end-to-end solution for managing logistics or almost any operations outside the offices. It is a modular server-based software which consists of three main modules:

- TCS Office is an ERP (Electronic Resource Planning)for managing operations in the field and is in almost always integrated to customer invoicing and/or other systems. TCS Office solution is managing all information related to operations like:
    - Customer address, type of services, frequencies, quantities etc.
    - Real time monitoring, tracking, and dispatching
    - Pricing based on actual services
    - Reporting, emailing, picturing etc.
    - Internal tasks
- TCS Mobile is a mobile solution being used by the field workers to get their tasks, and report all exceptions and work done to Office. It can be used in PC, Tablet or Windows Smart Phone
- TCS OPTI is state of art optimisation solution which can be used either as a part of TCS or as standalone tool. It is extremely highly parametrized allowing usage in various industries regardless of their business.

  It is used in various levels in operations:
    - Strategic level for management decisions, quotations, customer profitability calculation
    - Operational level to plan routes for foreseeable future like next day, week or month

- Dynamic-On Line optimisation on routes that have already been started, but some changes occurred

4. Software customisations

Forest based biomass has quite many challenges and industry specific demands that has been developed during INFRES project. Unlike normal logistics where trucks are starting and stopping at the same place driving same routes for long time forest based biomass is very unstable. The deviation in volume is varying heavily between winter and summer, collection points and volumes are changing all the time. The optimisation must be able to manage demand based logistics where the driving force is customer demand. There are typically constraints like:

- Pick up location (road side) with coordinates, volumes, assortments, pick up dates for not before and not after dates for drying and also quality issues
- Number of trucks, chippers, their working hours, capacities etc information which must be taken into account in optimisation
- Customers from single private customer to big power plants with monthly, weekly, daily and hourly volumes, time windows and number of trucks allowed per hour

All these kind of constraints have been developed during INFRES project to TCS.

5. The demonstration

The demonstration needed the following preparatory steps:

- Provision of street and forest road data to Ecomond by University of Freiburg.
- University of Freiburg characterized the biomass business to allow an adequate customization and tested the customized software.
- Translation of the menu text terms from English to German by University of Freiburg followed by integration into the software by Ecomond. **Virhe. Viitteen lähdettä ei löytynyt.** shows the TCS data entry module in the German version
- Training of University of Freiburg of using the software by Ecomond via internet based communication.
- Training of Fallert AG using the software by University of Freiburg at the Fallert AG premises.
- Utilization of the office component of the software by Fallert AG over 3 weeks.
- General demonstration of the mobile software component by University of Freiburg to Fallert AG staff. This was necessary, since there was only one mobile tablet available that could not well be fixed in the chipper. Due to these restrictions a test in full operation in everyday business was not feasible.

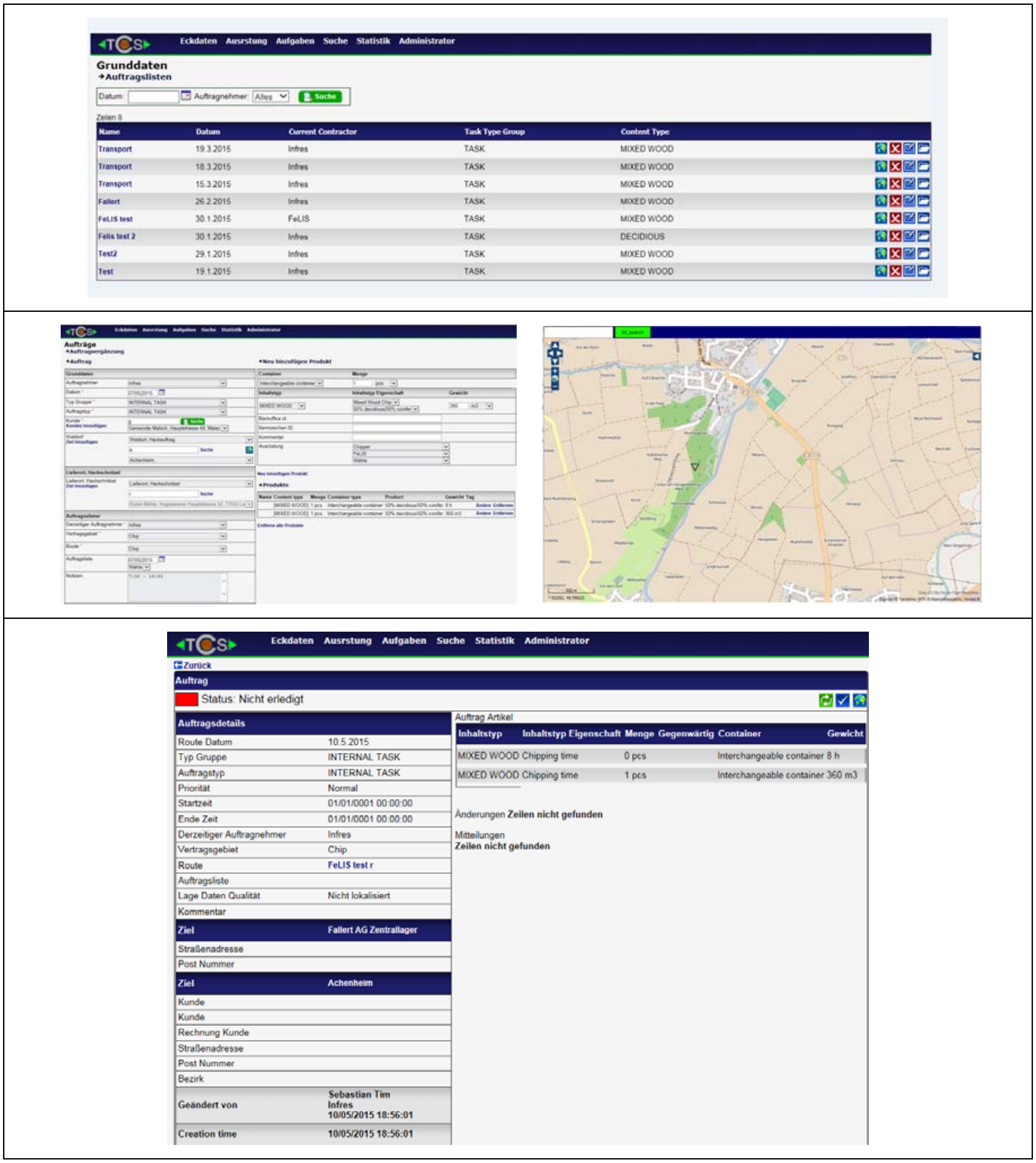

Figure 5 Customised German version of the task management software module

After the test and an on-site visit on 09.04.2015 the experiences and the scope for an operational utilisation have been discussed. Present in the discussion have been: Matti Tukkanen (Ecomond), Matthias Dees (University of Freiburg), Fallert (Sen,) and Jürgen Mergelsberg (Fallert AG) to discuss the experiences by the Fallert AG.

The Fallert AG has experienced the software and they have seen advantages in the material flow control to customers and in excellent recording of all transport activities. But they see as well see obstacles for an immediate introduction. The introduction of TCS would require a complete change of the communication on transport and chipping from traditional communication towards TCS. Given the moderate IT skills of the staff this is seen, besides cost for hardware and software as the major challenge for an immediate introduction.

Based on Ecomond calculations and previous experience the savings in overall operational costs should reach 20-30%. There is no single and simple savings, but they consist of the following points:

- Better planning with TCS OPTI
- Less time needed for planning and distributing the tasks for drivers
- Better information to drivers about locations and all other relevant information for them
- Less hassle in the office since things are done as planned
- Improvements in invoicing, salary payment and customer refunding
- Better control of the whole process

6. Summary evaluation

The Fallert AG showed, based on the demonstration, a high interest of introducing the software in the midterm. Fallert sees the advantages that occur in the material flow control to customers and in excellent recording of all transport activities. Both aspects would from their perspective facilitate cost savings. The introduction of TCS would require a complete change of the communication and information on transport and chipping flow via TCS. Given the moderate IT skills of the staff this is seen, besides cost for hardware and software as the major challenge for an introduction.

In Forest Based Bioenergy the biggest challenge is the scattered market where all players are small companies with 1-5 trucks and very limited IT-skills. All operations are manages as “good old way” and little time and money is spent on IT solutions like TCS.

To get TCS or any other similar solution widely used the companies should join their forces in acquiring a solution like this. This would not only help them in managing their operation, but also help their profitability both on purchase and also in sales. As long as the companies remain small it is extremely difficult to sell this kind of solution. We have seen some changes taking place on the market and remain optimistic.

7. Acknowledgements

The authors wish to thank the following people for their support with the study and demo: Mr. Fallert & son (Fallert Holzenergie) and Mr. Jurgen Mergelsberger (Fallert Holzenergie).

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INFRES – Innovative and effective technology and logistics for forest residual biomass supply in the EU (311881)

Juliana Walkiewicz, Eric Jessup, Matthias Dees (FELIS)

Raffaele Spinelli, Natascia Magagnotti (IVALSA)

Demo Report 20 – Wood chip drying using biogas heat in Germany

Dissemination Level	
Public	x
Restricted to other programme participants (including the Commission Services)	
Restricted to a group specified by the consortium (including the Commission Services)	
Confidential, only for members of the consortium (including the Commission Services)	

Freiburg, June 25h, 2015

Preface

Natural Resources Institute Finland (Luke) is coordinating a research and development project 'Innovative and effective technology and logistics for forest residual biomass supply in the EU –INFRES'. The project is funded from the EU's 7th framework programme. INFRES aims at high efficiency and precise deliveries of woody feedstock to heat, power and biorefining industries.

INFRES concentrates to develop concrete machines for logging and processing of energy biomass together with transportation solutions and ICT systems to manage the entire supply chain. The aim is to improve the competitiveness of forest energy by reducing the fossil energy consumption and the material loss during the supply chains. New hybrid technology is demonstrated in machines and new improved cargo-space solutions are tested in chip trucks. Flexible fleet management systems are developed to run the harvesting, chipping and transport operations. In addition, the functionality and environmental effects of developed technologies are evaluated as a part of whole forest energy supply chain.

This publication is a part of the INFRES project. The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2012-2015] under grant agreement n°311881.

This paper presents the results of a virtual demo (video) designed to extend the results of the German experience with active drying to the largest possible audience, through posting the video on the INFRES website and showing it to selected audiences at seminars, workshops etc. The paper describes both the contents of the virtual demo and the results of the first extension efforts.

Title	**Wood chip drying using biogas heat in Germany**
Author(s)	Juliana Walkiewicz, Eric Jessup, Matthias Dees, Raffaele Spinelli & Natascia Magagnotti
Abstract	Active drying of wood chips is the most effective way to reduce product immobilization and weather dependency, but it has always been too expensive for commercial use. However, the increased value of good quality chips and the larger availability of low-cost excess heat have changed the game and are making active drying a viable technique for rapid production of quality chips with guaranteed moisture content. Simple dryers can be obtained by modifying old freight containers or barns, and connecting them to a heating plant for absorbing excess heat. Investment and running costs of a dryer determine how feasible such a drying method is as part of the wood fuel supply chain. The operation is especially viable when using low-cost residual heat from biogas plants and when drying fresh chips that have not been pre-seasoned in the field, otherwise the immobilization cost is raising the overall cost. Given the proliferation of biogas facilities throughout central and southern Europe (more than 7500 facilities in Germany alone), active drying could be adopted and expanded, resulting in significantly lower costs of production and increased markets for wood chip energy throughout Europe. By forcing hot air with a blower into suitably modified containers, the moisture level of wood chips reduces from approximately 50% down to approximately 10% within 3 days in summer time, or 6 days in wintertime when the ambient temperature reaches values below freezing.
Date	June 2015
Language	English
Pages	12 p.
Name of the project	INFRES - INFRES – Innovative and effective technology and logistics for forest residual biomass supply in the EU (311881)
Financed by	European Commission – FP7 programme
Keywords	Drying; Heat; Quality;
Publisher	

1. Introduction

The wood chip energy market continues to evolve throughout Europe and future growth largely depends upon both customer markets (CHP-C and distributed heating), the trade-off associated with investment in alternative heating/electrical systems and the cost (economic, environmental, and ecological) of alternative energy supply systems relative to existing fossil fuel based systems. A significant economic cost component for energy wood chips is in drying freshly chipped material in order to target energy customers which have higher quality requirements and lower chip moisture needs.

In order to satisfy the growing demand for forest bioenergy in the residential and micro combined heat and power (CHP) markets, wood chip energy must satisfy relatively high quality requirements (cleanness) and low moisture levels and be cost competitive to alternative energy carriers (both renewable and fossil) and comply with requirements of the residential heat and CHP installations. Being a waste-product in the past, wood chips from residuals are now recognized as a product which - by standardization and conditioning - can enhance the value added. This perception is mainly driven through increased demand. Its diversity and therefore the differential use of wood chips is at best when the product is processed in a way it can be included into standardized industrial processes (Kuratorium für Waldarbeit und Forsttechnik e.V. 2013). This creates a challenge for the bioenergy firm in order to increase processing activities while also lowering costs of production.

Fallert Holzenergie is a small-medium size bioenergy firm (wood chips) that has developed a partnership with an area agriculture producer with an existing biogass facility. This partnership has allowed Fallert to develop a customized trailer drying system in order to utilize the excess heat from the biogass facility to dry wood chips in a very cost efficient manner. Given the dramatic increase in biogass facilities throughout Europe, especially in Germany (over 6,000 facilities) there exist a large potential for utilizing this excess heat to dry wood chips.

This opportunity will be presented in the form of a video. The video introduces to the topic and shows the practical implementation and ends with an explanation of the benefits of the approach.

This allows a presentation of the method at local events for wood chip companies and biogas producers. With this approach a greater audience can be reached all over Europe since the need for traveling is not given.

The video can be accompanied by presenting as an introduction and explanation the background and motivation for biogas based drying that is presented in the following chapter. This opportunity was used in Italy, where the virtual demo was held twice, on occasion of two sector events, and namely: FORLENER 2013 and EIMA 2014.

2. Background and material

The demonstration uses the Fallert AG as an example where the demonstration of the technological alternatives is subject to the video presentation.

Likewise the cost information presented here in the following refers to this one single medium wood chips producing enterprise in South-West Germany, but can be seen as exemplary for the structure of the wood chips producing industry of central Europe. Nonetheless, one should be aware, that variations over such a large geographical region and between enterprises do exist.

In order to produce high quality chips, the production process contains several steps (see Figure 1). After being chipped in the forest and transported to the terminal, the material needs to be dried to lower moisture content down to the degree needed by the customers. Usually small scale customers as private households or micro combined heat and power plants (CHP) need clean wood chips of low moisture content, due to their facility conditions and smaller boiler sizes, which are considerably less efficient burning high moisture chips.
After the drying process, chips are sieved in order to exclude non-wooden components that may cause damage to the facility and – if needed – separate wood chips by size in order to satisfy different customer needs.

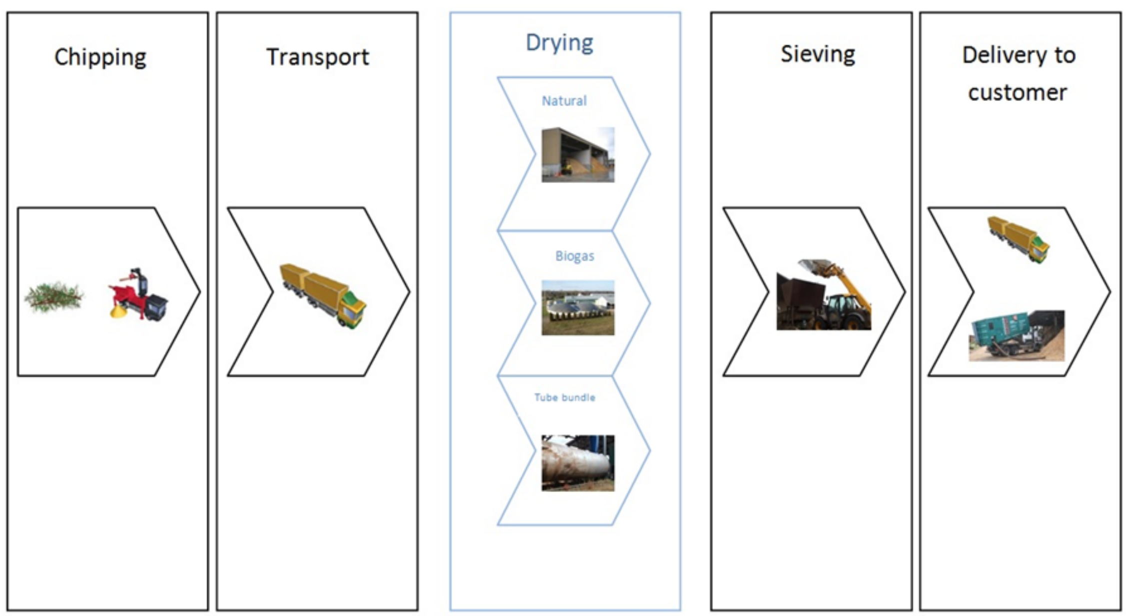


Figure 1: Supply chain for wood chips production

Drying the woodchips increases the energy that can be gained in the conversion process. Therefore for chips used to produce energy it is of great advantage to reduce the moisture content of wood that is in the range of 50-60% when they originate from freshly harvested wood.

Conventional drying methods

The conventional drying process in Germany is conducted mainly in two ways. Either wood chips are dried naturally or by a drying machine, i.e. a tube-bundle dryer or drying conveyor. Nonetheless other drying approach do exist (AEBIOM 2008).

In the natural air-drying process, chips are piled onto a clean – often concrete – ground and covered with a fleece or similar to protect the material against rain, snow, wind and pollution.

Hereby the moisture content is reduced from about 50% to 35% within 3 months in summer time. Because of the influence of the ambient temperature on the fermenting process inside the pile, the drying time significantly increases in winter. The cost of air-drying depends on different parameters as the choice of covering material, manpower, machines and space. In the case of our project partner, an approximate value of 0.50 Euro per bulk meter is applied.

In the case of the tube bundle dryer – as used by the Fallert AG – the heat exchanging device reaches a temperature up to 150°C and reduces the moisture content of one bulk meter of wood chips to 20% within an hour. According to given information the drying cost by this machine is approximately 3 to 3.5 Euro per bulk meter, depending on filling volume, energy cost, etc. Of course, with higher inlet temperatures more volume can be dried but at the expense of increased production costs due to the higher energy demand.

The major drawbacks of these two conventional drying techniques are the high dependency of seasonal ambient temperatures for natural drying and the low output per hour when chips are dried with the tube bundle dryer (approx. 1.5m³ per hour).

Biogas woodchip drying

The proposed drying concept requires a partnership between an agricultural producer that runs a biogas facility and a forest bioenergy firm, processing, storing and delivering wood chips in Southern Germany.

Given the proliferation of biogas facilities throughout central and southern Europe (more than 7500 facilities in Germany alone, see Figure 2), it could be adopted and expanded in other areas, resulting in significantly lower costs of production and increased markets for wood chip energy throughout Europe (Fachverband Biogas e.V.,2013).

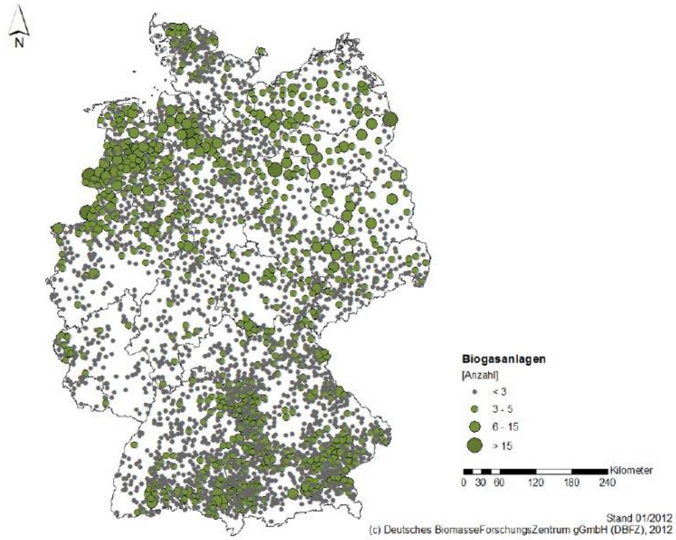


Figure 2: Biogas facilities in Germany

Due to the amendment to the "Renewable energy act" (EEG) from 2012 (BMWi, 2014), operators of biogas-facilities need to fulfill certain requirements if they wants to receive a premium on the combined heat and power production by using the excess-heat. In order to receive the premium, a minimum 60% capacity utilization of waste heat per year is required of which maximally 25% may be used for fermentation purposes. 35 to 60% of the remaining waste heat has to be used for ulterior functions as i.e. heating of buildings or drying of loose material.

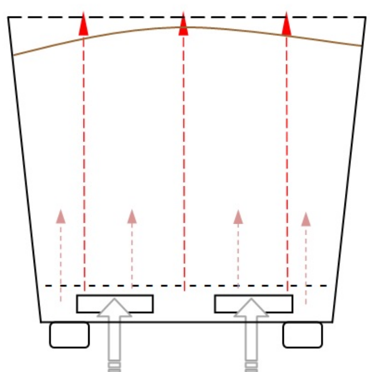
Since 1992 the number of biogas-facilities increased from 139 to 7515 in Germany alone (Fachverband Biogas e.V. 2013). Therefore it stands to reason that an alternative approach of drying wood chips refers to the usage of waste heat of biogas-facilities. During the process of producing biogas for electricity and heat, outside air is used to cool the system. This air in turn heats up and would be blown as excess heat into the atmosphere if not used for heating of buildings or drying of grain, digestates, split logs, wood chips, etc. (Thierer et al 2012).

Because of easy-handling and relatively low investment costs drying containers are commonly used for this purpose. Generally these are conventional containers with a capacity of 32-35m³ which are modified by inserting a false floor with small holes or grooves and connections for flexible tubes. By conducting the warm air with a blower through the tubes into the container, the wood chips dry from the bottom to the top. The moisture level of wood chips reduces from approximately 50% down to approximately 10% within 3 days in summer time, while output may decrease by 50% in wintertime when the ambient temperature reaches values below freezing.

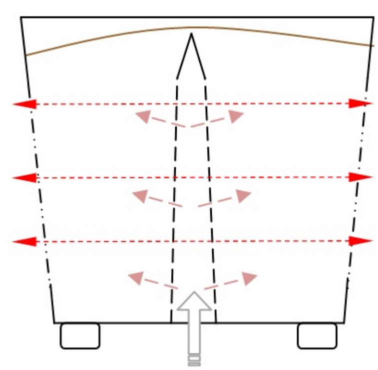
For the container solution with the false floor and a facility where 6 containers can be connected, a monthly drying volume of approximately 1400 m³ can be reached in summer time and 1000 m³ in winter time.

One disadvantage of this so-called vertical drying process is the unequal drying of chips from the bottom and chips on top. The warm ascending air cools down and condensates at the undried wood chips at the top. Since cool air absorbs less moisture, the container load must dry longer in order to reach a certain moisture level for all chips or the whole pile must be stirred. Both leads to higher production costs (Krämer 2013).

To reduce the drying time and lower generation of condensate, an alternative approach is, instead of a false floor, to insert a perforated air-supply duct in the middle of the container for that the wood chips drying is conducted horizontally from the middle of the pile to the outside. An additional advantage is the equal drying of chips from the bottom and chips from the top and the more energy-efficient drying since the drying distance is reduced by leading the warm air through the middle of the pile horizontally to the sides. Due to the openings at the side, the container can be covered at the top against rainfall (See Figure 3) (Krämer 2013).



Container with false floor and vertical drying



Container with centered air supply duct and horizontal drying

Figure 3: Vertical and horizontal drying systems (Source: Krämer 2013)

The biogas-drying option offers a viable alternative to conventional tube drying of conventional wood chips, depending on the circumstance of each firm, their proximity to bio-gas producers and the customer location and demand. To be able to compare the cost competitiveness of the alternative drying options, different factors have to be taken into account, as investment costs, machine life and usage, operating costs, economies of scale, etc., that differ from firm to firm . In the case of biogas-drying, also location enters the considerations as transportation costs increase with the distance between the biogas-producer and the wood chips-producer.

In addition to that it has to be taken into consideration that the premium for biogas-producers works as a subsidy to achieve the political goal of promoting and strengthening the competitiveness of renewable energy. Therefore it is ambiguous how future policy changes concerning the premium may favor or abate the competitiveness of this wood chips drying approach.

3. The video

The video material was produced in 2013. It includes a brief presentation on motivation for wood chip drying, presents conventional drying methods, air drying and tube bundle dying and the innovative alternative biogas facilities excess heat based drying in special containers. In includes a film sequences from wood chipping in the forest, transport and of the three mentioned drying methods. The film has a sequence of short and easy readable text passages that present the essence of the information of chapter 2. Examples are given in Figure 4. The video has a length of 9:15 minutes.

Figure 4: Scenes from the video

4. Presentations of the video

The video presenting the virtual demo was shown in Italy, at two separate occasions. The first presentation was held on September 28, 2013 in Vercelli, on occasion of the FORLENER 2013 forest energy fair. The second was held on November 13, 2014 in Bologna on occasion of the EIMA agricultural machinery fair. In both cases, the presentation was integrated into the seminar programme offered by the fair, in order to obtain widespread visibility for the INFRES initiative.

FORLENER is the most important wood energy fair in Italy and it matches the INFRES scope for covering the whole chain (FORLENER stands for Forest-Wood-Energy). On the other hand, it is attended by a relatively small number of visitors, which in 2013 numbered about 9000.

Giovedì 13 novembre 2014

Ore 11.30 – 12.15

LA RISORSA BIOMASSA: ELEMENTO CHIAVE PER LO SVILUPPO DELLA BIOECONOMIA E DELLA CHIMICA VERDE

Sofia Mannelli - Chimica Verde Bionet

La bioeconomia in agricoltura produce vantaggi reali solo quando genera filiere che interagiscono positivamente con il territorio, prevedendone un miglioramento sociale e ambientale attraverso modelli di gestione sostenibile caratterizzata da: input ridotti, mantenimento della fertilità dei suoli, conservazione della biodiversità, integrazione con l'agricoltura alimentare e valorizzazione di terreni marginali non adatti alla produzione di cibo.

Nel seminario si parlerà di come la Chimica Verde favorisca l'economia circolare attraverso la promozione dell'interazione e dell'integrazione tra le varie filiere che costituiscono il ciclo vitale dei beni: agricoltura, chimica di base, trasformazione industriale, distribuzione del prodotto finito, recupero, valorizzazione del rifiuto fino all'immissione in ambiente di materia capace di restituire quel nutrimento al suolo che è indispensabile per la vita del Pianeta.

Verranno portati esempi di bioraffinerie realizzate in Italia e riconosciute come migliori pratiche per l'uso sostenibile di materie prime ottenibili da colture dedicate, sottoprodotti e residui includendo in coda al ciclo produttivo una destinazione energetica delle materie di scarto.

Dibattito con il pubblico.

Ore 15.00 – 15.45

IL PROGETTI EUROPEI SULLA MECCANIZZAZIONE FORESTALE E LE BIOMASSE: INFRES E SLOPE

Raffaele Spinelli, Gianni Picchi - CNR IVALSA

Il seminario fornirà un'introduzione generale agli obiettivi e ai primi risultati dei progetti Europei del CNR-IVALSA. La presentazione del progetto INFRES (tecnologie e schemi logistici innovativi per l'approvvigionamento di residui forestali nell'Unione Europea) svilupperà in dettaglio il tema dell'essiccazione del cippato con il calore di risulta delle centrali elettriche a biogas, portando in evidenza l'esempio Tedesco. Il seminario includerà anche un breve video illustrativo del sistema containerizzato per la gestione del materiale da asciugare. Il progetto SLOPE (Integrated proceSsing and controL systems fOr sustainable forest Production in mountain arEas) approfondirà le soluzioni tecniche e gestionali concepite per rendere più competitive le utilizzazioni forestali in montagna.
Il seminario descriverà come le tecnologie più innovative (LiDAR, droni, sensori ed etichette elettroniche) verranno utilizzate per ottimizzare sia il lavoro in bosco che la gestione del prodotto legnoso.

Dibattito con il pubblico.

Figure 5: The BiomassEIMA poster listing the INFRES virtual Demo

EIMA is the largest agricultural machinery fair in Italy, which broke all attendance records in 2014 by totalizing over 235.000 visitors. This is one of the large European agricultural machinery fairs, in the same circuit as SIMA in Paris and Agritechnica in Hannover. Within EIMA, a smaller cluster of events is devoted to energy biomass, grouped under the BiomassEIMA umbrella. The virtual demo was included within the BiomassEIMA events, in order to reach a different audience (more agricultural and less forestry) than at FORLENER. That would make much sense, considering that the virtual demo deals exactly with the interface between agriculture (biogas production) and forestry (wood chip production) and therefore it can raise the interest of biogas producers, which were unlikely to visit FORLENER.

Figure 6: People attending the virtual Demo in Vercelli

At both events, the virtual demo consisted of a brief introduction by R. Spinelli, then the projection of the video, and finally a Questions and Answers sessions. Overall, the single virtual Demo lasted about 25 minutes.

5. Results of the demo

The 2013 virtual Demo at FORLENER was attended by 22 participants, whereas the Demo held in Bologna one year later attracted 18 participants. These numbers are similar to those registered by other seminars held on the same occasions and they may be taken to indicate that Fair visitors are probably more attracted by the stands than by seminars, in general. Nevertheless, the virtual demos were a good way to introduce entrepreneurs to the new perspectives offered by active drying with waste heat. In particular, the Bologna demo allowed touching a pool of potential users that is relatively difficult to reach for the classic forester, i.e. farmers and biogas producers.

Acknowledgements

The authors wish to thank the following people for their support with the study and demo: Mr. Fallert & son (Fallert Holzenergie) and Mr. Jurgen Mergelsberger (Fallert Holzenergie).

References

AEBIOM, 2008. Wood Fuels Handbook: Production - Quality Requirements – Trading. Italian Agriforestry Energy Association, Italy.

BMWi, Bundesministerium für Wirtschaft und Energie, 2014. Das Erneuerbare-Energien-Gesetz. http://www.erneuerbare-energien.de/EE/Redaktion/DE/Dossier/eeg.html?cms_docId=73930, last access 02.07.2014.

Fachverband Biogas e.V. German Biogas Association, 2013. Branchenzahlen – Prognose 2013/2014. http://www.biogas.org/edcom/webfvb.nsf/id/DE_Branchenzahlen/$file/13-11-11_Biogas%20Branchenzahlen_2013-2014.pdf, last access 02.07.2014.

Krämer, G, 2013. Mobiltrockner – Prüfergebnisse und Direktvergleich. IBT-Krämer, Institut für Brennholztechnik.

Kuratorium für Waldarbeit und Forsttechnik, 2013. Optimierte Stoffstromsteuerung und Aufbereitung von Holzhackschnitzeln. LIGNA, 06. – 10. May 2013, Hannover, Germany.

Thierer, M.,Eberhard, G., Wessbecher, M. & Bayer, B.. 2012. Abwärmenutzung bei Biogasanlagen. Länderspecial Bayern/ KWK-Bonus. http://www.energy20.net/pi/index.php?StoryID=1220&p=mJ3rC2nsGxWFBanjU.jGmQF3Ccl_ExJkccClnMfiMg3pRUO0SHWqEqIbac38SQ8.Cx8lac2daZO3AhCrER.9V9fgBb8pccYFCd-.TUeXpAOBf7WzQ_iqEhewO9jtW.TqquRvSfMwEC33, last access 02.07.2014.

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INFRES – Innovative and effective technology and logistics for forest residual biomass supply in the EU (311881)

Josep M. Tusell, Jordi Canals, Diego Almenar, Judit Rodríguez

Cooperativa Serveis Forestals, SCCL

Forest Sciences Centre of Catalonia

Demo Report 21 – Using synthetic cable for wood and biomass extraction in Catalonia (Spain)

Dissemination Level

Public	x
Restricted to other programme participants (including the Commission Services)	
Restricted to a group specified by the consortium (including the Commission Services)	
Confidential, only for members of the consortium (including the Commission Services)	

Santa Coloma de Farners, 25th of March of 2015

SEVENTH FRAMEWORK PROGRAMME

1. Introduction

The use of steel cable is well implemented in the work of wood and biomass extraction by yarding in Catalonia. While the use of forwarders begins to become evident, the use of a winch attached to adapted agricultural tractors and skidders are the main equipment of the harvesting crews. In first place, there are adapted agricultural tractors, and in second place there are the skidders. According to Lliró & López *(*2014) in Catalonia there are 24 skidders owned by 21 companies. Both tractors and skidders use steel cable for wood and biomass extraction, because steel is a durable material that can withstand the continuous friction and harsh conditions to which the yarding is subjected. This resistance, however, gives a higher weight to the cable, which makes more difficult the handling, lowering the yield of the extraction, and requiring considerable physical effort of those operators carrying out this operation.

Compared to the steel cable, a synthetic rope has these comparative advantages (Hamilton, 2008; Fanjul *et al.,* 2011; Magagnotti & Spinelli, 2012; Domenjó *et al*., 2014):

- Reducing environmental impact: being lighter, it makes the extraction easier, reducing friction and damage to the soil.
- Improving working conditions and ergonomics of operators: at same strength, the synthetic rope weighs much less (between eighth and tenth compared to a steel cable) and has a higher flexibility, which facilitates operations and can increase work rate. It also reduces the risk of injury in the hands due to broken wires.
- Despite the difference in price (14.9 €/m synthetic rope vs. 2.5 €/m steel cable) (Magagnotti & Spinelli, 2012), thanks to the increase in the productivity of work this difference can be paid off.
- They are little elastic and so less prone to backward movement when they break. Whiplash behaviour is minimized because the elasticity and weight of the rope are lower than traditional steel cables.
- Tensile strength equivalent to a steel cable (at the same diameter).
- For the same diameter, lighter weight (8 to 10 times lighter than steel wire)
- In case of breakage, it’s easy to repair on site through proper link.

However, there are also disadvantages (Magagnotti & Spinelli, 2012) such as:

- There may be problems with the movement of chokers by the string, since the junction of two rope ends increases the diameter of the rope. This is easily solved by putting also wider chokers.
- When going downhill with the synthetic rope, the winch drum is not easily unwind given the little weight of this cable.
- The synthetic cable tends to wrap, which can disrupt the normal movement of chokers through the rope.
- Problems of fire exposure.
- Increased sensitivity to friction with stones.

- Easy to cut with sharp objects
- High price: synthetic cable is priced between 3 and 4 times higher than the same diameter steel cable.

Table 1: Price of steel and synthetic cable according to the diameter

Diameter (mm)	Steel cable price (€/m)	Synthetic rope price (€/m)
8	1.58	4.80
10	2.73	6.90
12	2.94	10.70
14	3.57	14.00

The introduction of synthetic rope in the harvesting chain can mitigate the shortcomings of conventional wire cable, although it raises doubts about its strength. This is why it is necessary to evaluate the extraction with synthetic rope in order to get results on their performance and the positive consequences that can contribute to the safety of operators during the extraction phase.

Under the INFRES project the use of synthetic cable instead of steel cable for forest extraction operations of wood and biomass in Catalonia was tested. The resistance offered by the synthetic cable, along with ergonomic improvements for forest workers should be the necessary arguments to forest harvesting crews implement this equipment for their daily work.

In the test performed, the strength and ability to mobilize of the synthetic cable in ordinary conditions was assessed and also possible improvements in comfort and security that provides its daily use was evaluated.

2. Objectives

The aim of the experiment was to determine the productivity of the synthetic cable based on the volume of wood and biomass extracted (EUR/t) and to assess the ergonomic improvements and sensorial quality of work for workers.

3. Materials and Methods

The demonstration was organized by the Cooperative Forestry Services (CSF) in the region of Catalonia in collaboration with the Forest Technology Centre of Catalonia (CTFC). Arpana participated for the training of the crews that had to work with synthetic cable.

The demonstration was split into two days. The first demonstration (8-5-2014) was only addressed to forest companies and forest crews, and reached an attendance of 18 persons. The second day (9-05-2015) the demonstration was addressed to a wider group: forest companies, crews, forest owners, managers, technicians. This second day the attendance raised to 33 persons.

Figure 1: First demo day addressed to forest companies and forest workers with an explanation on how to use the synthetic rope

After the demonstration days, during February and March of 2015 the use of the synthetic cable was monitored in the area of Guilleries - Montseny, with a same forest crew and different forest types. The monitoring included forests with holm oak *(Quercus ilex),* beech *(Fagus sylvatica),* chestnut *(Castanea sativa)* or radiata pine *(Pinus radiata).* All forests are in the Arbúcies municipality, in the shire of La Selva, Girona province.

The synthetic cable was mounted in a Ventura winch with remote control attached to a Massey Ferguson tractor (MF 4255), with 95 HP power. A forestry Dyneema synthetic rope of 12 mm diameter and 100 m length manufactured by Cordelería Hercules was used in the tests. The crew that worked with synthetic cable consisted of four people: the tractor operator, the felling one, the delimbing one and the one that hooks the wood to the cable.

Before using the synthetic rope, the extraction with steel cable by the same extraction crew in the holm oak plot was monitored during one week. This work was monitored in order to allow a productivity comparison to the synthetic rope.

Regarding the ergonomic perception of operators, all members of the crew were separately surveyed in order to obtain a valuation of the perception of ergonomic improvements while using a synthetic rope compared to the steel cable.

Specifically workers were asked about:

- Improved comfort at work
- Reduced muscle fatigue / effort
- Ease to carry up / down the rope
- Ease to use rope
- Reduced injuries to hands
- Reduction in "whip" effect
- Improvement to wind up into the drum
- Reduced damage to standing trees
- Relevance of the material cost
- *What price would you be willing to pay?*

Being 1 No improvement/none/much less; 2. Little /few; 3. Same as steel cable; 4. Some improvement; 5. Greatly improved/much more.

Figure 2: Second day demonstration addressed to more general actors (forest managers, forest owners, etc.)

4. Study results

During the last January week and the first February week of 2015 the comparative extraction works took place: the first week, a steel cable was used; the second week, it was the synthetic rope.

Table 2: Production (tonnes) and time (work days) of one week works with steel cable and synthetic rope

One week work in a holm oak plot	Green tonnes	Work days	t/work days
Steel cable	104.34	19.5	5.351
Synthetic rope	132.87	26.5	5.014

According to these results, in this case there was no productivity increase due to the use of synthetic rope. The cost would be equivalent since productivities are similar, and the personnel, fuel and machinery expenses are the same.

Figure 3: Steel cable winch detail

The whole experience of extraction with synthetic rope lasted from the first day of February until the end of March 2015, which includes a total of 133.75 work days. During this period, the synthetic cable mobilized 694.5 tons of wood of different species.

Table 3: Production (tonnes) and time (work days) with synthetic rope in different plots

Species	Work-days	Extraction (fresh tones)
Holm oak	40.75	203.75
Holm oak	19.50	97.5
Chestnut	38	190
Beech	16	96
Pine	19.5	107.25
TOTAL	**133.75**	**694.5**

The length of the cable at the end of the experience was 55 meters. Therefore during the experience 45 meters of synthetic cable were used.

Therefore to mobilize 107.25 tonnes of wood biomass 45 meters of synthetic cable were spend, which represents a cost of 481.50 Euros. Therefore, the cost of using the synthetic cable is 0.69 Euros/t of wood and biomass.

5. Demo results

As previously mentioned, the demonstration took place in two days addressed to different actors. The total attendance was 51 persons and some of the conclusions have been:

- For proper operation of synthetic cable, operators must be trained with basic knowledge regarding maintenance and repair.
- Since wearing or overstrains could cause a decreased lifetime of synthetic cable, the execution of the extraction work has to be done paying attention to this constraint.
- Numerous studies show an increase in productivity using synthetic cable. It is interesting to further evaluate this tool in Catalan forests, analyzing the work of the cable in different conditions (slopes, forest type and accessibility) with forest crews more experienced in its use.
- It has been mentioned a certain complexity when using this cable downhill, but on the contrary it seems to be very interesting uphill. This could be avoided with a double drum winch, where synthetic rope can be used uphill and steel cable downhill.

6. General and perceptions evaluation

Regarding the performance and comparative data obtained along a week of using each type of cable there were no major differences regarding the productivity (wood and biomass mobilized). The small difference could be due to the lack of practice and confidence in the early days of working with synthetic rope. This reason have reduced the productivity significantly along these early days.

Figure 4: Whole stem yarding with synthetic cable

In a general sense, once passed the first days of little knowledge of synthetic rope, making trust its resistance, the operation with synthetic rope has been positive. Note that the cable breaks often, on average once a day, usually by the end of the cable about an average of 0.5 meters length and a maximum of 5 meters length. The higher risk of breakage at rope's choker end due to higher friction was not considered as a negative aspect, because repairing the rope only took 3-5 minutes.

Figure 5: Breakage at the end edge of the synthetic rope

Regarding the valuations by operators, the answers to the different questions are shown in table 4.

Table 4: Average rating of different improvements of the synthetic rope compared to the steel cable according to the workers perception (values 1-5 mean: 5 = great improvement, 1=is not significant).

Question	**Average valuation**
Improved comfort at work	5
Reduced muscle fatigue / effort	5
Ease to carry up / down the rope	5/3
Ease to use rope	4
Reduced injuries to hands	5
Reduction in "whip" effect	3*
Improvement to wind up into the drum	4
Reduced damage to standing trees	4
Relevance of the material cost	5
What price would you be willing to pay?	3

*: Although the assessment of *Reduction in "whip" effect* is in average *same* (3) as with steel cable, it was mentioned that being a different material (synthetic instead of steel) makes it less dangerous and no risky.

As conclusions of the experience, different positive and negative aspects can be mentioned (table 5)

Table 5: Positive and negative aspects of using synthetic rope for wood and biomass extraction

Positive aspects:	**Negative aspects:**
• Flexibility • Weight • Possibility to work without gloves • No danger of "whip" effect	• Price • Confidence • Not suitable for large trees • Not suitable for stony terrain • Minor durability

Finally, a possible increase in the productivity of the synthetic cable could be reached if some improvements were used in the procedure:

- Using a winch with remote control: in this case, the same operator has the winch control can walk with the hauled stems, and react more quickly to stop the cable if any of the logs gets stranded. This avoids additional efforts to the cable that can damage it excessively and may even cause it to break.

Figure 6: Hauling with synthetic cable, strain situation with risk of breakage

- Using a double drum winch: in this case the synthetic rope can be used in less stony terrain, and the steel cable can be used in can be used in stony terrain. This would extend the life of the synthetic cable.
- Improved results with adapted accessories (for instance chokers): the use of these elements avoids a possible clamping of synthetic cable, which can cause premature wear or even a rupture.

Figure 7: Chokers to be used with synthetic rope

7. Acknowledgements

We thank the collaboration of Forest Montseny SCP in the execution of the forest works and results monitoring.

8. References

Domenjó, I., Casals, S., López, I., Navarro, P.J. 2014. *Treballs forestals innovadors: el desembosc amb cable sintètic. Visita a la serradora Boix.* In XXXI Jornades Tècniques Silvícoles Emili Garolera: 33-39.

Fanjul, A., Sánchez, S., Alonso-Graña, M., Álvarez, E., Canga, E., Majada, J. 2011. *Sustitución del cable de acero por cable sintético en el desembosque de castaño en Asturias*. Progreso Forestal, 25 p. 16-20.

Hamilton, P.S. [ed.] 2008. *Life expectancy of synthetic fibre mainlines in cable skidding applications*. FP and Innovations. Vol. 10.

Lliró, O. I López, I. 2014. *La maquinària forestal a Catalunya: els tractors arrossegadors o skidders.* Catalunya Forestal, 119:25-26.

Magagnotti, N., Spinelli, R. 2012. *Replacing steel cable with synthetic rope to reduce operator workload during log winching operations*. Small-scale Forestry, 11, 2012 p. 223-236.

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Infres – Innovative and effective technology and logistics for forest residual biomass supply in the EU

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Jordi Canals & Josep Maria Tusell, SCCL

Demo Report 22 – Comparative study of a loading unit with compression and a conventional forwarder at transportation of bulky woody biomass

Dissemination Level	
Public	x
Restricted to other programme participants (including the Commission Services)	
Restricted to a group specified by the consortium (including the Commission Services)	
Confidential, only for members of the consortium (including the Commission Services)	

Solsona, 14th of August of 2015

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The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2012-2015) under grant agreement n°311881.

Introduction

The biomass market in Catalonia continues rising as more biomass boilers are installed. The uses of biomass for heating and power are not only with the aim to increase the offer of renewable energy is due to the necessity to reduce the fire risk in large areas in the countryside and increase the resilience of the forest. The sustainability forest management in high density conifers forests allows the growth of youngest trees which are covered by a medium age trees. These areas are the result of a policy of afforested the marginal agricultural lands between 1940 and 1993 (Tolosana et al 2014). These forests consisting of conifer plantations or directly afforested areas are on terraces, which were earlier full of olive trees and vineyards Usually these areas burn in the summer and after that and to avoid insect attacks the extraction of the majority of dead trees is necessary.

The Mediterranean forest has a low annual growth due to the high temperatures and low precipitation. This means that the extraction of biomass is less productive in contrast with northern forest. Other characteristics of the Mediterranean forest are high slopes which makes difficult the forest operations. In the past and with the aim of solve the high slopes the farmers constructed terraces to be able to work there, making forest operations difficult. These characteristics of the Mediterranean forest have slowed the development of biomass and other wood markets. Increase the yields of the operations of the supply chain in the forest is necessary to improve the market due to is needed to have better economic results in the harvesting works.

The aim of compare two systems of forwarders in this demo is to reduce the cost of the forest operations and test if the new technologies and development are really useful, as Spinelli (2014) said "*modernizations are still in progress*". In the thinning operations the objective is to reduce the mass helping the rest of the trees to have better growth in the future, therefore the result of the operation is to thin trees that do to meet the quality requirements of the wood industry. A good end use for this kind of trees is energy production but with a good economic result for the owner and the harvester, nowadays the economics of these operations is not good and efforts to reduce the prices of this operation are necessary. Bunch high quantity of trees in a forwarder is necessary to collect the highest amount of biomass by each transport and this with the least possible time for each sport where it is necessary stop to collect the piles done in the forest. By other hand the difficulty of some lands with terrace and also stoniness make the necessity to use forwarders when the slopes are not too high. The Press Collector is a forwarder able to compact and transport high amounts of biomass; moreover the biomass extracted is young tress with branches.

The aim of this demonstration is to study if the Press Collector is able to increase the yield of the harvesting operations by compacting the biomass compared with the use of a conventional forwarder.

1. Materials and methods

Two forwarders were used during in the demos, the Dutch Dragon Press Collector (PressC) with a capacity of 40-48 m³ bulk volume coupled in a John Deere 1710 eco III, and the John Deere 1510 (JD 1510) with a capacity of 15 metric tonnes which calculated with a density of 450kg/m³ are 33.34 m³, Figure 1.

Figure 1: John Deere 1510 on the left and Press Collector on John Deere 1710 on the right.

Data from works were collected in three test, the two firsts plots were test of a single forwarder every time and the last test were in the same place and in the plot where the demos with public took place, there both forwarders were working.

The first plots where the test took place were in Llers (PressC, Figure 2) and in Pla de l'Estany (JD 1510), both in Girona on 25/03/2014 and on 27/10/2014, respectively. The forest in Llers had burned in the last summer in the fire of Empordà. The forest had stones and terraces; moreover the terrain was wet due to the rain during the demo. In Pla de l'Estany there was mixed forest with *Pinus halepensis* and *Quercus ilex* without bush nor stones, the operation consisting of a thinning to improve the growth of the remaining trees.

Figure 2: Dutch Dragon Press Collector in Llers

The last test was organized in Santa Eulàlia de Ronçana in Vallès Occidental on 28/03/2015. The forest had an event of strong winds in January in the same year, therefore in some places in this forest the trees had fallen.

The times of operations were calculated noting the start for each operation, starting with loads, downloads, and travelling with and without the biomass. The periods without work were also noted. With the aim to get data for the tests, 16 completes series had taken for the JD 1510 and 13 completes series for the PressC. The distance driven by the forwarders was also calculated.

2. Study results

In the tree demos the amount of biomass extracted was 139 tonnes of young trees with branches.

Figure 3: Characterisation of biomass removed

The Figure 3 and Figure 4 show the characterization of the trees by diameter classes. The piles of biomass were done near the road, but in 3 trips of the PressC there were not enough biomass to full it.

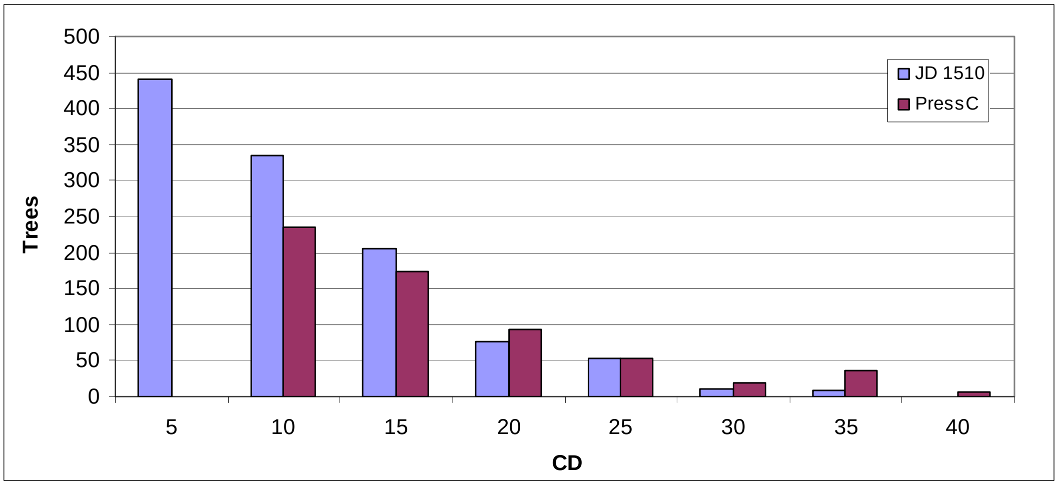

Figure 4: Diameter class of trees extracted with the forwarders

In the first plots the distances done by the forwarders were different due to the different places and conditions. The forest in Llers was with terraces, stones and the day before had been raining and the distance was 353 meters. However the forest in Pla de l'Estany had better accessibility conditions but the distance from the load and the download was 1589 meters. In the last test the distance average were 383 meters for JD 1510 and 480 for the PressC. The Table 1 show the speed of the forwarders in the different tests.

Table 1: Forwarders speed

Test	Meters / minute	
	JD 1510	PressC
Llers		89.70
Pla de l'Estany	275.01	
Santa Eulàlia de Rončana	70.22	80.43

The speed result obtained is different in the cases of the two first demos but is similar in Santa Eulàlia de Rončana. The forwarders obtained more similar results when the place and the conditions are the same. Otherwise is necessary to remark that the PressC is in a JD 1710 which have a higher power than the JD1510 but in the other hand the two panels of the PressC are heavier than the structure of the JD1510. This is an interesting aspect to consider also for the fuel consumption and prices of the machinery.

For each load of material the JD 1510 had done an average of 34.31 grapples meanwhile the PressC had done 29.11. In this average there are 3 series for the PressC was not take due to there was not enough material to fill the forwarder.

The total of biomass processed in the test is shown in the Table 2

Table 2: Biomass processed in the tests

Test	JD 1510			PressC		
	Biomass (t)	Loading (min)	Downloading (min)	Biomass (t)	Loading (min)	Downloading (min)
Llers	45	163	38			
Pla de l'Estany				50	148.15	57.56
Santa Eulàlia de Ronçana	27.6	136.5	31.5	16.4	97.5	18

The Figure 5 shows the yields of the operations.

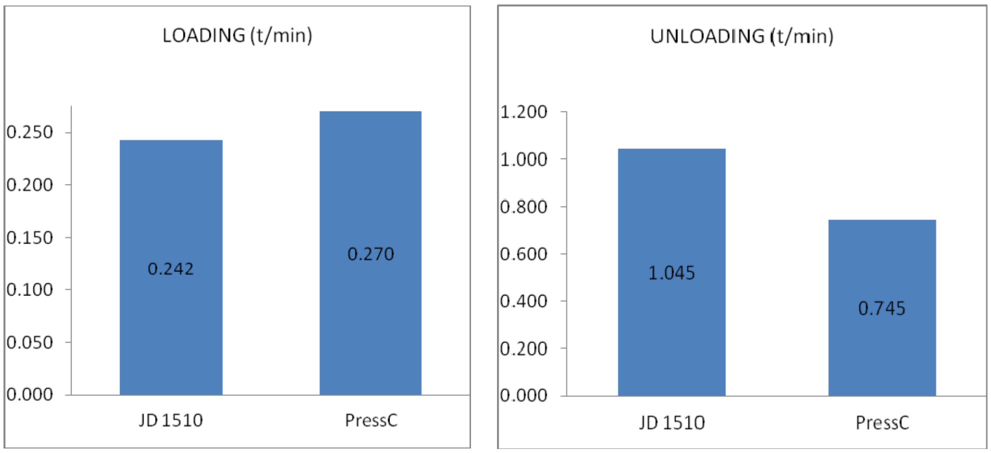

Figure 5: Time for loading and unloading by forwarder

As is it shown in the Figure 5 the load per minute in the PressC is higher than in the Jd 1510. This fact could be explained due to the diametric class, whereas in the PressC there were not tresses from diametric class 5, there were in the JD 1510. In contrast the download of the material were more quickly in the JD1510

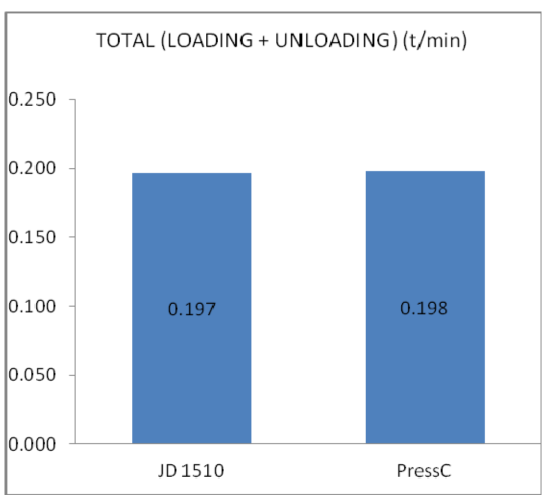

Figure 6: Loading plus unloading of biomass, tonnes per minute

Summarizing both results the PressC show a productivity higher than J1510 which represents a 0.81% of yield in the process of loading and unloading as it is shown in the Figure 6.

The last result is the number of cycles that each forwarder did in order to transport all the biomass. This is shown in the Table 3.

Table 3: Tonnes per cycle

Test	J1015		PressC	
	Biomass	Trips	Biomass	Trips
Llers	45	8		
Pla de l'Estany			50	9
Santa Eulàlia de Ronçana	27.6	8	16,4	4
Total	4.54 tones/cycle		5.11 tones/cycle	

One remarkable data is the average amount of biomass (5.11 t) transported per cycle by the PressC compared to a conventional forwarder (4.54 t).

It is also necessary to remark two aspects of these results, there are three trips of PressC without the total of biomass that the PressC is able to transport, and the second aspect is the moisture of the biomass in Pla de l'Estany. It is an important aspect due to the forest had been burned and the tresses ware dead. Considering that the dead wood have a moisture of 15% in wet basis, and the biomass recently harvested a moisture of 50% wb the results would be 7.8 tonnes by cycle.

Taking the real results of the demos the PressC is able to transport a 12.55% more biomass in each cycle.

3. General evaluation

Summarizing the results in the demonstrations indicate that either the PressC or JD15010 show similar results in the yields loading and downloading the biomass. The speed of the forwarders even having different power are quite similar, the higher power from the JD1710 of the PressC could be compensated by the weight of their panels.

The difference with both forwarders is the capacity of collect biomass, the PressC demonstrate a 12.55% of higher capacity which means that their need less cycles to load the same biomass than the JD 1510.

Considering the results obtained the conclusion is that both forwarders are similar in the yield aspect if the distances are little due to the trips are not very important, but if the distance increase then the time that the JD 1510 will use to travel implicate that the yield of all the process decrease.

The PressC are bigger than the JD1510 and this could be an impediment to drive into the typical Mediterranean forest where there is high density of tresses. Regarding this impression the engineer who manage the operations in the forest explain that is necessary open spaces in the forest due to the PressC is bigger than a normal forwarder, also he observed that the panels have a huge weigh and this could reduce the speed in the trips.

4. Demo results

The demo took place in Santa Eulàlia de Ronçana in the centre of Catalonia on 27^{th} of March on 2015. The 26 assistants mostly were forest workers, entrepreneurs and forest operators but also there are forest owners, technicians and people from administration too. The average of years of forest experience where 27 years.

Figure 7: Assistants in the demonstration

In the demos both machines were working continuously, so the assistants could see all the process of PressC and also the JD 1510, and the entire cycle, loading and unloading and the driving with and without biomass.

The forest where the demo took place had an event of strong winds two months before and in some places all the trees had fallen.

The assistants valorise the machinery with an 8.5 of 10, and valorise with a 7.5 of 10 the improvement that the machinery could provide to the harvesting works. The two aspects which they consider that where bottleneck were the price of the forwarder and the size. The assistants consider that it would be difficult to use the machine in the forest of Catalonia due to the slopes, the density of trees, and the social aspect related with machinery in the forest. The forwarder (both) needs a wide trail into the forest which means to extract stumps and the visual aspect of the forest after the works is considered a negative impact.

The last question posed to the attendance was if they would buy the PressC and a 45% of them answered “yes”. It is important to consider that the people who said yes were forest workers whereas the entrepreneurs said no or depend in a 75%. The doubt that they have were if the quantity of forest where use it were enough to compensate the price. Technicians and entrepreneurs answered in the same manner.

One consideration of the company who uses the PressC was that there is a lack of professionals who know how to use the forest machines properly.

5. Acknowledgements

First at all thanks to the company Forestal Soliva S.L. who was using the forwarders to allow take data of the demonstrations and also receive the assistants of the demos with public and explain their conclusions. Secondly thanks to the Infres project and the people working on it to make this study possible and finally thanks at all the people who were working directly taking the data, processing it and the workers who manage the forwarders.

6. References

Spinelli, R., Ebone, A.; Gianella, M. (2014) Biomass production from traditional coppice management in northern Italy. Biomass and Bioenergy. Volume 62. Pages 68-73.

Tolosana, E., Laína, R., Ambrosio, Y.; Martín, M. (2014). Residual biomass recovery from fully-mechanized delayed thinnings on Spanish Pinus spp. Plantations. Biomass and Bioenergy. Volume 71, Pages 98-105.

7. Web references

- www.deere.es

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INFRES – Innovative and effective technology and logistics for forest residual biomass supply in the EU (311881)

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Demo Report 23 – Demonstration of good terminal logistics and high capacity transports at Söderenergi's receiving biofuel terminal in Nykvarn, Sweden – D4.5

Dissemination Level	
Public	x
Restricted to other programme participants (including the Commission Services)	
Restricted to a group specified by the consortium (including the Commission Services)	
Confidential, only for members of the consortium (including the Commission Services)	

1. Introduction

Forest products offers a rich source of renewable energy and is an important part of both Swedish and Finish energy budgets. Most of this is based on forest biomass. However the economical margins for primary forest fuels is lower than for any other forest product and the product-value concentrated on a single truck-load is among the lowest of all product segments on our roads. As the large scale use of forest fuels in CHP plants are concentrated to the larger urban areas and the forests are spread throughout the countries, there is an enormous challenge to cut logistic costs in order to enable long distance transport and use of forest fuel as an energy source. Efficiency in transport plays an important role in handling that challenge.

With an increasing number of large customers in the biofuel market, more cost effective logistic solutions for truck and railway transportation as well as terminal handling and are needed. Both sending and receiving terminals play an important role in enabling businesses between regions and thereby more available forest fuel. In the Infres demo report "Success factors for forest fuel terminals" (Enström et al. 2014), we focused on the sending terminal, whereas this demonstration focuses on a receiving terminal and the logistic around it. A lot of research has been done in the field of terminal logistics within the Infres project. Therefore researchers within the field were invited to come and share their results during the demonstration, as a complement to the practical example given by Söderenergi.

Söderenergi, is a municipal owned production company that provides 300 000 citizens, offices and industries in Södertälje and Stockholm with heat and around 100 000 households with electricity. Their production site Igelstaverket use around 1.7 TWh of fuel yearly, i.e. approximately 2 million m^3 of chips. The main sources are biomass chips from forest, forest industries and recycled wood (www.soderenergi.se). Approximately one third of the chips arrives by train. Due to lack of storage space and railway tracks at Igelsta these chips are delivered to a receiving terminal in Nykvarn. Between the terminal and the CHP-plant, materials are transported by a chip-truck. Since May 2014, a High Capacity truck with 74-ton GVW performs this task. This truck was demonstrated in a previous Infres demo in Almedalen (Enström & von Hofsten 2014). The 74-ton truck was studied for a year when the demonstration were made and the first results were presented for the first time at the demonstration.

The aim of the demonstration was to show examples of good terminal logistics at a large receiving terminal for forest fuel. This was achieved through presentation of all the parts in the fuelwood supply chain around the terminal, which obviously included transportation with trains and big trucks but also biomass storage and safety aspects to avoid self-ignition of wood chips. This was complemented by analyses of the costs for internal biomass terminal operations from Finland.

2. Materials and Methods

The demonstration were held the afternoon May 26th, 2015, at Söderenergi's fuel terminal in Nykvarn (Sweden), 18 km from the CHP plant Igelsta in Södertälje. Researchers as well as operational public were invited. Host for the demonstration were Söderenergi, the owner of the terminal at Nykvarn. Olle Ankarling, head of logistic operations at Söderenergi, presented the companies fuel-logistics and the role of the terminal during a tour around it. Some topics of special interest were the train and truck logistic, the usage of building blocks at the terminal and cautions against fire. A summary of this presentation is presented in the result chapter.

A general overview of terminals of different types were given by VTT, which is presented in the results of this report. Skogforsk presented an ongoing project around 74-ton chip-trucks and the results from one year of fuel studies from three such trucks. One of them were shown during the demo with both the owner of the truck and one of the drivers present. The background of the project is described further in Demo report 11. Here we present the study of fuel consumption and technical experiences from the first year of operation. The study of fuel consumption is made by continuous monitoring of the consumption through Scandia's fleet management system along with weight data provided by the drivers of the trucks. The method is described in *Widinghoff 2014*.

Results from many different research projects were presented in the poster exhibition (figure 1).

Figure 1. Poster presentation at the terminal.

Poster presentations were held by eight researchers from Sweden, Finland and Holland. The posters are appended to this report. Presenters names are underlined.

- *Multi-functional biomass terminals*. <u>Dan Bergström</u>. Dept. of Forest Biomaterials and Technology, SLU
- *Effects of covering chips during long term storage*. <u>Erik Anerud</u>, Dept. of Energy and Technology, SLU
- *Supply of forest biomass to terminals/bioenergy combines in North Sweden.* <u>Dimitris Athanassiadis</u> and Martin Svanberg, Dept. of Forest Biomaterials and Technology, SLU.
- *Forest Biomass Terminal Properties and Activities.* Kalvis Kons, Dan Bergström, Dimitris Athanassiadis & <u>Tomas Nordfjell</u>. Department of Forest Biomaterials and Technology, SLU.
- *Biomass feedstock supply through terminals*. Jyrki Raitila and <u>Matti Virkkunen</u>, VTT
- *Costs of Satellite terminal*. <u>Jyrki Raitila</u> and Matti Virkkunen, VTT
- *Methods and applications for discrete-event simulations of biomass feedstock supply chains in Finland – three cases.* <u>Olli-Jussi Korpinen</u>[1], Kari Väätäinen[2], Robert Prinz[2], Lauri Sikanen[2] and Eero Jäppinen[1]. [1]Lappeenranta University of Technology (LUT). [2]Natural Resources Institute Finland (Luke).
- *Measurements at biomass terminals*. <u>Heikki Ovaskainen</u> and Timo Melkas, Metsäteho Oy.
- *Improving wood harvesting logistics by a dedicated GIS-based biomass module*. <u>Rik te Raa</u> and Patrick Reumerman, BTG Biomass technology Group BV.

3. Results & Discussion

The terminal in Nykvarn

The terminal in Nykvarn is Söderenergi's feeding terminal for the CHP-plant Igelstaverket in Södertälje. Around 170 000 ton biofuel are handled annually at the terminal and the storing capacity on the 9 hectare surface is approximately 40 000 ton. Wood fuel from Sundsvall in the north to Varberg in the south arrives to the terminal by train. The terminal receives approximately 125 trains per year. In addition some material also arrives with truck to the terminal and if the storage area in Igelsta becomes to full some material is transported to Nykvarn for long term storage. Each train replaces approximately 40 trucks (referring to a Swedish truck combination of 25.25 m and 60 ton).

The terminal is located in Nykvarn as there was no possibility of locating a terminal closer to the Igelsta plant since Södertälje is a densely populated region. The plant is located next to the water with an own port, which receives approximately a third of the fuel needed by the plant. Another third of the supply is being delivered by train to the terminal in Nykvarn and approximately a third directly by truck to the plant or in some cases the terminal. Storing opportunities at the plant are limited and thus material delivered by boat occasionally has to be transported to the terminal in Nykvarn for storage. The advantage of buying and receiving large quantities of biomass can outbalance the cost of extra handling. Ankarling describes the feeding terminal as a necessity for a smooth logistical operation. Being able to handle fluctuations and disturbances of different kinds is critical for a facility like Igelstaverket. This has been apparent at several occasions, e.g. if a boiler stops unplanned it is important to be able to redirect incoming material to the terminal – hence it shouldn't be full, but if the train accidently derails and stops the incoming flow (which has happened even though it theoretically couldn't) it shouldn't be empty either. Somewhere in between makes it perfect to balance the supply. The goal is to keep around 15 000 ton fuel at the terminal, which equals 4 weeks consumption in the plant.

A problem for the terminal over the last years has been fires caused by self-ignition of wood chips and the difficulty to extinguish the smouldering material. Several actions have been taken to avoid this hazard. Heat detecting cameras that measures the temperature of the surface material has been installed, but Söderenergi still needs to work out at which surface temperature (approximately) the material inside the stack starts to smoulder. A student project with this aim will soon be started. The possibility of digging down temperature measuring equipment in the asphalt has been rejected as to costly. Lessons have also been learned on how to separate the stored materials and in order to do so, building blocks (in concrete) has been stapled up at the terminal. These walls do not only separate material, they also reduce the materials exposure to wind, which is another important factor to reduce the fire hazard. Block walls are also built around the drainage ditch in the middle of the terminal, and this has considerably increased the storage capacity (se figure 2).

Figure 2. Building blocks separating material from a ditch increases the terminals storing capacity.

Since Söderenergi can't eliminate terminal handling, they are working to improve its efficiency. The efficiency in transport both to the terminal and from terminal to plant have been addressed by increasing the load capacity of the trucks and trains used.

Efficient trucks

Skogforsk is currently leading the ETT-project (One More Pile), which goal is to collect knowledge around High Capacity Transports (HCT) within the forestry sector in order to facilitate a broad implementation of HCT vehicles in Sweden. More about the ETT-project and earlier results can be found in Enström & von Hofsten (2014). An independent part of the project is a follow up study of the three first 74 ton chip-trucks, of which one, truck A, transport chips between Nykvarn and Igelsta. This truck was shown at the demonstration (see figure 3 and figure 9).

Figure 3. Demonstration of the 74-ton chip-truck shuttling material between the terminal and plant.

The three trucks are Scania trucks with dolly and trailer combinations of a similar construction. They are 25.25m long and have a loading capacity of 150 m^3 or 49 metric ton. They all mainly use RME (Rapeseed Oil Methyl Ester) as fuel, which in itself reduces emissions of fossil CO_2 with around 60 %. But the type of transport work performed varies a lot. Table 1 shows the average driving distance, fuel consumption and average percentage of weight filling for each of the trucks. The fact that truck A stands out in terms of fuel consumption is not surprising considered that the average transport distance is only 22 km, hence the share loading and unloading time is very high as well. Truck A has also the highest use of RME (100 %), RME cause a slightly increased consumption due to a slightly lower energy content than standard diesel fuel. The fact that the calculation only take account of the loaded distance also causes vehicles with a high share of loaded distance in relation to the total distance to look better in terms of fuel consumption per ton*km.

$$ml/tonkm = \frac{\Sigma\, fuel}{\Sigma\,(distance\ loaded \times\ \ load\ weight)} \times 1000$$

Table 1. Summary of production data for the three studied trucks.

	Fuel consumption ml/(ton*km)	Degree loaded distance	Loading and unloading time	Average speed
A	32.7	50.7 %	39.2 %	27.5 km/h
B	18.1	69.4 %	18.9 %	51.3 km/h
C	17.9	58.6 %	15.4 %	52.5 km/h

All three vehicles have proven to work very well in operation. The agility of the configuration is actually somewhat better than for regular 60-ton vehicles thanks to the axle-configuration. Even though the EMS-regulation (European Modular System) for distance between axes provides great agility it also causes a long overhang which increases the risk of overload on the last axle.

The construction with dolly and trailer (according to the EMS system) provides the opportunity to complement with a link between the dolly and trailer, i.e. a similar configuration as the 90 ton GvW ETT roundwood vehicle. A project to evaluate such a chip-truck has recently started, and awaits approval from the authorities. The test-vehicle, the current truck A, will then measure 33.7m in total length and have a maximum total weight of 98 ton.

Terminal functions

While the terminal in Nykvarn serves as a transport hub for deliveries of comminuted fuelwood, it is sometimes convenient and even necessary to process wood fuel raw materials at the terminal. This would often include chipping or grinding, screening and storage. In any case, material handling through such a terminal causes some extra costs compared to direct supply from forest to plant but can also lead to reduced costs for chipping operations.

In the study of Virkkunen et al. (2015) three different developing terminal types, satellite terminal, feed-in terminal fuel and upgrading terminal, were identified. Satellite terminals with a throughput of 1 TWh, 0.7 TWh, 0.3 TWh and 0.1 TWh of fuelwood were selected for a cost analysis, as satellite terminals have a complex structure that exhibits all required work phases and sources of terminal supply costs that must be considered, and also due to the satellite terminal's key role in long haul wood fuel supply chains. In this study the satellite terminal referred to a biomass fuel processing and storage terminal near the biomass resources and far away from the fuel users. It can also function as a transport hub of biomass fuels between large end-users and biomass resources (Raitila et al. 2015).

Figure 4 presents a breakdown (%) of the total terminal cost when delimbed stem are comminuted in 1 TWh and 0.1 TWh terminals and the material is fed directly to comminution. In the 1 TWh option the total terminal supply costs are 2.6 €/MWh and in the 0.1 TWh option 3.4 €/MWh. Measurement devices create additional costs for the 1 TWh terminal. However, the lower costs in terminal operations offset the additional cost and in total the fuel production costs are 31% lower in the 1 TWh terminal option (Virkkunen et al. 2015).

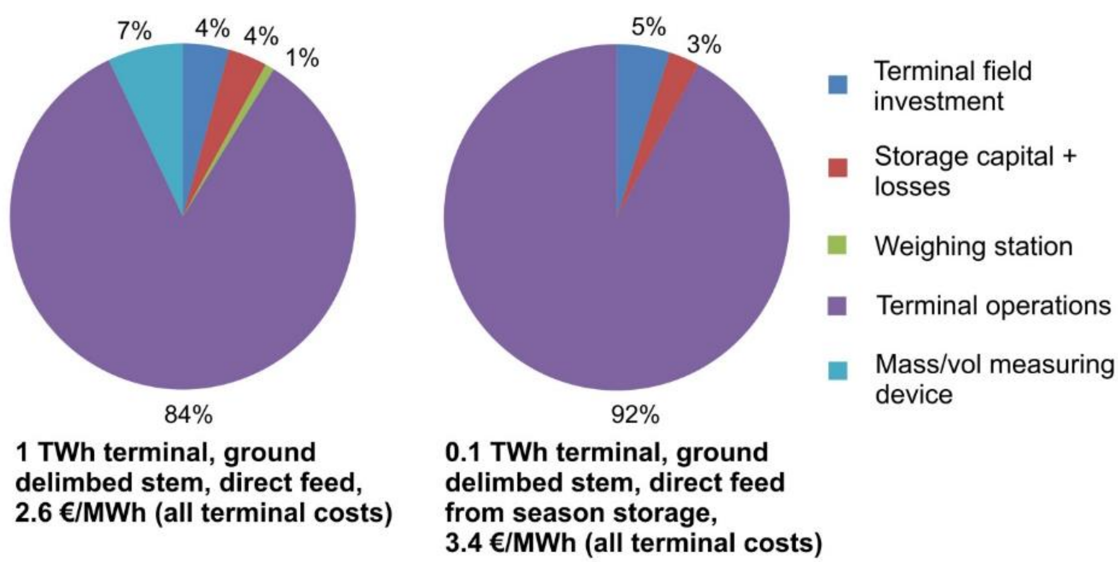

Figure 4. Terminal cost breakdown in percent for delimbed stems fed directly to comminution in 1 TWh and 0.1 TWh terminals (Virkkunen et al. 2015).

Figure 5. Grinding on a satellite terminal.

Figure 6 presents the distribution (%) of terminal operation costs for delimbed stem in 1 TWh and 0.1 TWh terminals in the direct feed option. The terminal operation costs are 2.2 €/MWh in 1 TWh terminals and 3.1 €/MWh in 0.1 TWh terminals (Virkkunen et al. 2015).

The grinder feeding costs are significantly higher in the 0.1 TWh terminal (0.25 to 0.4 €/MWh in the 1 TWh terminal compared to 0.45 to 0.95 €/MWh in the 0.1 TWh terminal). This is mainly explained by the use of trucks in grinder feeding in the smaller terminal and costs of moving the comminution machines within the terminal. Additional wheel loader operations are also more costly in the 0.1 TWh terminal. This is due to the fact that a greater terminal area has to be under maintenance per supplied unit of produced fuel. In total the terminal operation costs are 41% lower in the 1 TWh terminal. The main explanation for this is the lower comminution costs in the larger terminal: 1.8 €/MWh in the 1 TWh terminal versus the 2.3 €/MWh in the 0.1 TWh terminal (Virkkunen et al. 2015).

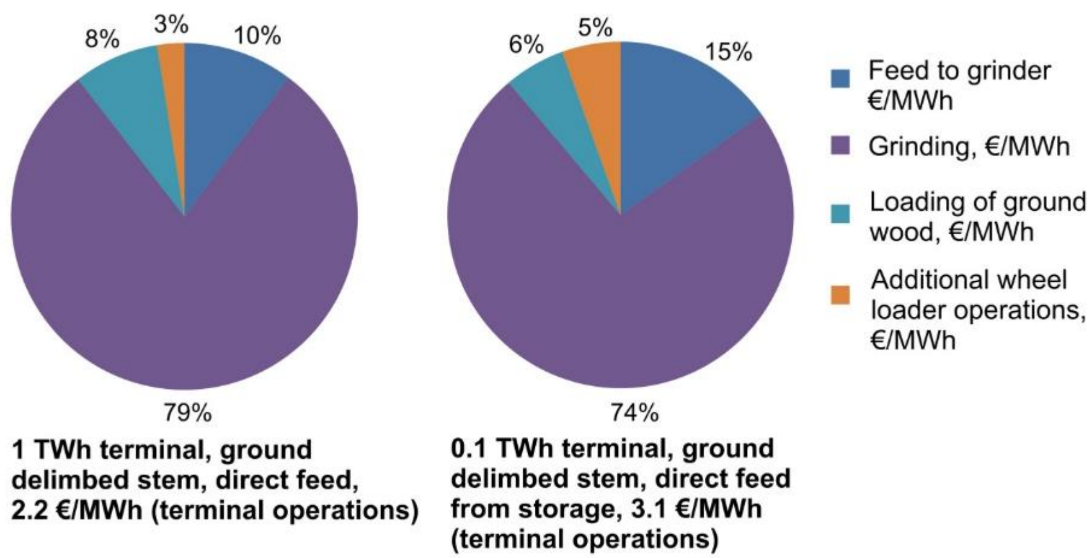

Figure 6. Cost breakdown of terminal operation costs in 1 TWh and 0.1 TWh terminals for delimbed stems, direct feed to comminution (Virkkunen et al. 2015).

Supply cost comparison: direct supply chain and terminal supply chain

Figure 7 summarizes an example of the total supply cost of chips from delimbed stems in a traditional supply chain and a terminal supply chain. The direct chain consists of the standing wood price, the cost of felling and forwarding, capital costs and costs of chipping and long distance transport (100 km by truck). The terminal chain consists of the roadside price of wood (similar to standing price + harvesting cost), transport cost to the terminal, terminal costs and long distance transport costs (>600 km by train) (Virkkunen et al. 2015).

The applied terminal costs are based on fuel supply through a 1 TWh terminal assuming a direct feed supply option (2.6 €/MWh) and season storage supply (3.4€/MWh) option. This represents the most economical terminal supply option for delimbed stem (Virkkunen et al. 2015). The presented cost at plant is 19.6 €/MWh in the direct supply chain and 21.8–22.6 in the terminal supply chain (direct feed/season storage options through a 1 TWh terminal). The figures indicate that fuel supply through a terminal is 12 to 15% more expensive compared to direct fuel supply and 5–9% more expensive compared to the current average price of forest fuel in Finland (20.7 €/MWh, Bioenergia-lehti 04/2014). However, the studied terminal supply case is dedicated to long haul (600km by railway) biomass supply from, for example North-Eastern Finland to a large cogeneration facility located in Finland's Metropolitan area, and thus large scale wood biomass supply can be expected. With a 50% shorter supply distance (300km) and with an estimated 45 % transport cost reduction (applied cost 3.41 €/MWh) the cost of fuel supplied through terminals would be 19–19.8 €/MWh, roughly equal to the supply costs of a direct supply chain (Virkkunen et al. 2015). It is important to note that for the smaller terminals, the terminal costs are significantly higher (up to 34% difference between the total supply costs in a 1 TWh and 0.1 TWh terminal) (Virkkunen et al. 2015).

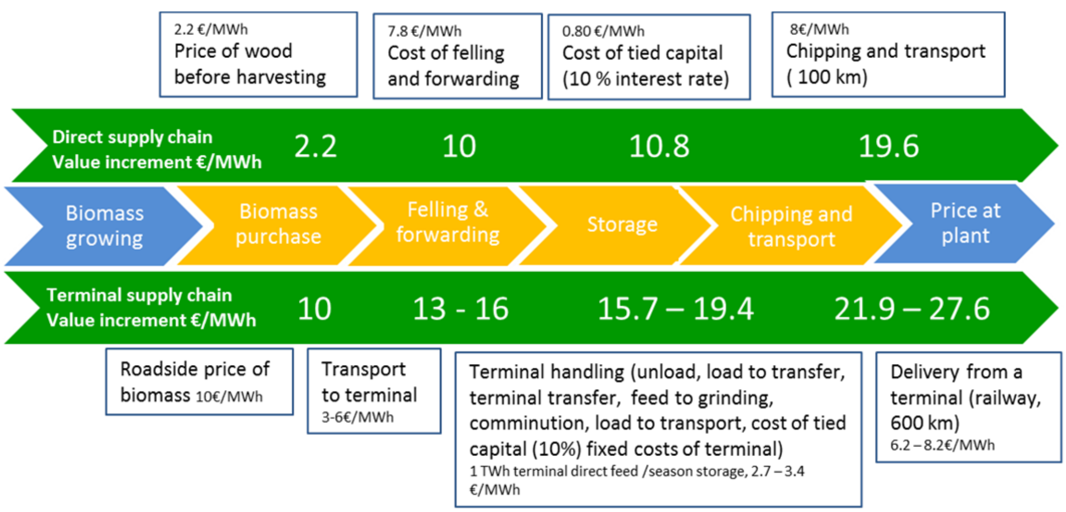

Figure 7. An examplar summary of the total supply cost of delimbed stem in a traditional supply chain and a terminal supply chain (Virkkunen et al. 2015).

4. General evaluation

It is worth considering the importance of a feeder terminal for a large CHP plant in a populated region. A new, even larger bio based CHP-plant are being built in the northern parts of Stockholm (Värtan) with an even smaller operational storage area. It is clear that the logistical challenges will remain an important issue for the biofuel market and that the use of terminals to facilitate long distance transportation will most likely increase.

To enable a cost efficient supply of biomass to the metropolitan areas from remote forest areas it is crucial that both the satellite (sending) and the feeder (receiving) terminals are operated in the best possible way. Satellite terminal often have better possibilities for efficient comminution, since they can operate 24/7, which in many cases not is possible in an urban environment due to noise regulations etc. Furthermore, for many biomass assortments, e.g. logging residues and small trees, comminution improves the transport economy since chips are less bulky than the loose materials. Truck transports are not an economically viable option for long distance transports (>250 km) and reloading to railroad or sea transports necessitates a sending terminal, as enough material to fill a train or ship has to be stored and available when the loading begins.

Opportunities of increasing efficiency in truck transportation by using High Capacity Vehicles is still debated in Sweden, as in many countries within the EU. It is of high importance to spread present knowledge and to continue to follow up the demonstrational vehicles, especially when new concepts such as a 98-ton vehicle is to be tested. There are not enough comparing studies between chip-trucks of 60 versus 74 ton to draw sharp conclusions of their comparative fuel consumption, but the potential of 13% reduction, as have been shown for timber trucks could be expected (Edlund et.al. 2013). The conclusion that all three vehicles are working well in daily operations, using RME as fuel, is an important result.

5. Demo results

27 persons participated in the demonstration (including the arranging companies) (see figure 8). The participants were a mixed group of researchers and practitioners working with forest fuel operations, mainly from Sweden and Finland, but also from Holland. The presentation of the terminal and the 74-ton truck were held in Swedish (with possibilities for questions in English) whereas the poster presentations were held in English (with possibilities for questions in Swedish). The arrangers are pleased that several new research results as well as practical experiences were presented during the event.

Figure 8. Presentation at the terminal.

6. Acknowledgements

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Figure 9. A truck leaving the scales at the terminal.

7. References

Edlund J., Asmoarp V., Jonsson R., 2013. Focus *Weeks 2013 – Monitoring fuel consumption of two rigs in the ETT demo project, ST-crane and ST-group*. Skogforsk Arbetsrapport 803 -2013.

Enström, J. & von Hofsten, H. 2014. Demonstration of a High Capacity Vehicle for chips transport at Political week in Almedalen. INFRES Demo Report 11 – D4.5

Enström, J., Grönlund, Ö., Athanassiadis, D., Öhman, M. 2014. Success factors for forest fuel terminals. INFRES demo report 10 – D4.5

Palmer, C-H. & Iwarsson Wide, M. Eds. 2015. Skogens energi – en källa till hållbar framtid. Sammanfattande rapport från Effektivare Skogsbränsle System 2011-2015. Skogforsk.

Raitila, J., Virkkunen, M & Korpinen, O-J. 2015. Cost analysis of a satellite terminal for forest fuel supply in Finland. Submitted to Scandinavian Journal of Forest Research.

Virkkunen, M., Kari, M., Hankalin, V. & Nummelin J. 2015. Solid biomass fuel terminal concepts and a cost analysis of a satellite terminal concept. VTT Technology 211. 69 p. ISSN 2242-122X.

Widinghoff J. 2014. Continual monitoring of fuel consumption and load utilization of ETT- and ST-vehicles. Skogforsk Arbetsrapport nr. 831-2014.

Webpage:
http://www.soderenergi.se/web/Foretaget.aspx (2014-11-24)

Appendix 1.

Posters

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