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

Dimitris Athanassiadis and Johanna Wallsten, SLU

Raffaele Spinelli, , IVALSA

Judit Rodriguez, CTFC

Jyrki Raitila, VTT

Rik te Raa and John Vos, BTG

Matthias Dees, Taner Turkmengil and Juliana Walkiewicz, University of Freiburg

Technological and economic barriers to introduce and apply innovations in forest energy sector – D6.1

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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.

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Innovation is a key factor for development and progress at a company, regional and national level. This publication explores different aspects of innovation activities and products in the forest technology sector and tries to answer to some important questions; What criteria are companies using to measure the success or failure of an innovation? What innovation barriers are the companies facing and how are they tackling them? Why some specific innovations have succeeded while other failed?

Dimitris Athanassiadis, Johanna Wallsten, Raffaele Spinelli, Judit Rodriguez, Jyrki Raitila, Rik te Raa, John Vos, Matthias Dees, Taner Turkmengil, Juliana Walkiewicz

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Authors	Dimitris Athanassiadis, Johanna Wallsten, Raffaele Spinelli, Judit Rodriguez, Jyrki Raitila, Rik te Raa, John Vos, Matthias Dees, Taner Turkmengil, Juliana Walkiewicz
Abstract	This report presents results from three studies done within the Work Package 6 (Technology foresight and barriers of innovation) of the EU FP7 project INFRES. The aims of the studies were to 1) identify and rank the criteria that forest machine manufacturing companies are using to measure the success/failure of an innovation, 2) identify barriers that forest machine manufacturing companies are facing and find out how these barriers are tackled and 3) identify and discuss innovations that have been successful in the forest energy sector and innovations that were not successful and the reasons for that. In the first study, different forest technology manufacturers were asked to rank a number of criteria that determine the success of an innovation. The second study also included forest technology manufacturers answering a questionnaire about barriers and drivers for innovation. In the third study forest technology experts from all of Europe were asked to comment on 10 important innovations and also suggest if these innovations were a success or a failure in their regions. The results from study 1 revealed that manufacturers point out criteria that are related to customer relations, i.e. customer satisfaction, product performance level and meeting quality guidelines as the most important. Company benefit measures (e.g. growth of demand of the products of the company) also seemed to be prioritized. However, the answers differed among companies and more studies will be needed in order to see if company size, number of products on the market and other factors may affect the answers here. In study 2, the most important barriers were lack of financing, especially for new high-risk projects. This is further supported by the fact that the forest technology sector is a small market and that development costs are high. Lack of skilled engineers was occasionally seen as a barrier as well. The answers regarding solutions to barriers suggest that the most important solution seem to be collaborations with customers, both to get a feel for what customers want, but also to better introduce new technology in a sometimes conservative market. Furthermore, collaborations with universities and research institutes will become more important as those will help unlock additional funding for development of innovations. However, drivers for innovations were often tied to competitiveness (to stay on top, offer the best products, being one step ahead of competitors), but there was also a few who felt rather passionate about innovation in general, so a genuine interest in product development seem to be an important driver as well. In study 3, some past innovations were evaluated and several issues were raised as key factors in the success: productivity, investment, flexibility, maintenance, suitable environment, competition, marketing or conservatism. Innovations that increased productivity of the operations, reduced the cost and were flexible (can work in most conditions) were identified as successful. On the other hand innovations that are poorly marketed, require complicated logistics, can only be used in specific conditions and have a low productivity were considered as a failure.
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1. Introduction

1.1 Innovation definition and types of innovation

Innovation is a continuous process in the industrial sector where changes to products and processes are constantly underway. It leads to growth of output and increased productivity (OECD 2005). According to Schumpeter (McCraw 2010) there are 5 types of innovation

(1) The introduction of a new product – or a new quality of a product.

(2) The introduction of a new method of production of a product.

(3) The creation of a new market for an existing product.

(4) The conquest of a new source of supply of raw-materials or half-manufactured goods.

(5) The finding of new ways (of a new organization) to carry out the production of a product.

In the above types of innovation, a product innovation includes both the introduction of new products and services as well as significant improvements in the functional or user characteristics of existing products and services.

According to the Oslo Manual (OECD 2005)"*an innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations"*. According to the same manual, *"innovation activities include all scientific, technological, organizational, financial and commercial steps which actually lead, or are intended to lead, to the implementation of innovations*." Some of these activities may be innovative in their own right, while others are not novel but are necessary to implementation.

Innovation activities vary greatly in their nature from company to company. Some companies engage in well-defined innovation projects, such as the development and introduction of new products, whereas others primarily make continuous improvements to their products, processes and operations. Both types of companies can be innovative. As previously defined an innovation can consist of the implementation of a single significant change, or of a series of smaller incremental changes that together constitute a significant change.

According to the Oslo manual four types of innovations are distinguished: product innovations, process innovations, marketing innovations and organizational innovations. As only product and process innovations will be dealt with in this report these are the only ones described here:

A product innovation is the introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses. This includes significant improvements in technical specifications, components and materials, incorporated software, user friendliness or other functional characteristics. Product innovations can utilize new knowledge or technologies, or can be based on new uses or combinations of existing knowledge or technologies. The development of a new use for a product with only minor changes to its technical specifications is also a product innovation. Product innovations in services can include significant improvements in how they are provided (for example, in terms of their efficiency or speed), the addition of new functions

or characteristics to existing services, or the introduction of entirely new services (OECD 2005).

A process innovation is the implementation of a new or significantly improved production or delivery method. This includes significant changes in techniques, equipment and/or software. Process innovations can be intended to decrease unit costs of production or delivery, to increase quality, or to produce or deliver new or significantly improved products (OECD 2005).

Both product and process innovations can improve the performance of the company, for example by increasing demand (e.g. product differentiation, targeting new markets or influencing demand for existing products) or reducing costs.

1.2 Innovation barriers

In a manufacturing company, there can be reasons that innovation activities and thus the production, introduction and implementation of innovative products and processes is hampered or not initiated at all. These include; a) economic factors, such as high costs, no public grants, difficulties in attracting private financing or lack of demand, b) factors specific to an enterprise, such as lack of skilled personnel or knowledge, and c) legal factors, such as regulations or tax rules (OECD 2005). The ability to appropriate the gains from the company's own innovation activities also affects innovation. If, for example, companies are unable to protect their innovations from imitation by competitors, they will have less incentive to innovate (OECD 2005). On the other hand, if an industry sector functions well without formal protection, promoting such protection can slow the flow of knowledge and technology and lead to higher prices for goods and services (OECD 2005). If the support technology for a cost-effective implementation of an innovative product or process idea does not exist then many great ideas cannot develop into a viable innovation e.g. at 70s and 80s we lacked the electronic technology (sensors, processors, actuators etc.) we have today.

1.3 Innovation characteristics

a) Innovation is associated with uncertainty over the outcome of innovation activities. It is not known beforehand what the result of the innovation activities will be, e.g. whether R&D will result in the successful development of a marketable product or how much time and resources will be needed to implement a new production process and how successful they will be (OECD 2005).

b) Innovation involves investment. Relevant investment can include acquisition of fixed and intangible assets as well as other activities (such as salaries, or purchase of material or services) that may yield potential returns in the future (OECD 2005).

c) Innovation is subject to spill-overs. The benefits of creative innovation are rarely fully appropriated by the inventing company. Companies that innovate can benefit from knowledge spill-overs or from the use of the original innovation. For some innovation activities, imitation costs are substantially lower than development costs, so that an effective appropriation mechanism to provide an incentive to innovate may be required (OECD 2005).

d) Innovation involves the utilization of new knowledge or a new use or combination of existing knowledge. New knowledge may either be generated by the innovating company in the course of its innovation activities (i.e. through intramural R&D) or acquired externally through various channels (e.g. purchase of new technology). The use of new knowledge or the combination of existing knowledge requires innovative efforts that can be distinguished from standardized routines (OECD 2005).

e) Innovation aims at improving a company's performance by gaining a competitive advantage (or simply maintaining competitiveness) by shifting the demand curve of the company's products (e.g. increasing product quality, offering new products or opening up new markets or groups of customers) or a company's cost curve (e.g. reducing unit costs of production, purchasing, distribution or transaction), or by improving the company's ability to innovate (e.g. increasing the ability to develop new products or processes or to gain and create new knowledge) (OECD 2005).

1.4 Measurement of new product success

A New (radical innovation) or Improved (incremental innovation) Product (hereon abbreviated to NoIP) is an important element for the success of a manufacturing company. A radical innovation activity is applying major changes in a product while an incremental innovation activity changes a product in a minor way. Measurement of the success/failure of a NoIP seems to be a process that is quite complex. If the factors that are associated with the measurement of the success or failure of a NoIP are not well defined/understood and relevant then results cannot be trusted. Banyté and Salickaité (2008) report that the scientific literature claims that losses experienced by enterprises because of failure of an innovation introduced into the market are a lot greater than losses experienced when innovation fails during creation.

In order to identify the success factors for an innovation, a number of criteria (indicators) must be defined by which an innovation´s success can be measured and which can be used to make an objective distinction between successful and less successful or failed innovations. For example the value (economic, social or environmental) that the product has created through its use is an important indicator on the success/failure of a NoIP.

Griffin and Page (1996) report 16 metrics/factors that can be used to measure the performance of a new product after its launch (Table 1) from the manufacturing company's perspective. In Huang et al. (2004) Australian manufacturing small and medium size companies (SMEs) were asked to select their most recent new product and to indicate whether they had measured the success of that project. If they had, they were asked about the success measures used to make such an assessment and how well they thought the new product had performed on the 16 measures, using a five-point scale that ranged from ''well below average'' to ''well above average''. The most frequently used criteria were customer acceptance (70%), customer satisfaction (68%), achieving product performance goal (62%), and meeting quality guidelines (60%). Among the most identified success/failure in the market factors of innovation are market analysis and recognition of consumer wishes and needs, design and quality (Banyté and Salickaité 2008).

1.5 Forest machine manufacturing

European forest operations are conducted in a non-homogenous environment and have to be done at a low cost and with a minimal environmental impact in order to maintain profitability for the forest contractors and sustainability of the forest resources. The theoretical biomass potential from the European forests in 2010 was estimated to be nearly 1.3 billion m^3 including bark. Approximately half of the potential is made up of stemwood and the rest consists of logging residues, stumps and woody biomass from early thinnings in young forests. The potential is, however, reduced to about 750 million m^3 due to various environmental, technical and social constraints. The constraints affect especially residues, stumps and biomass from early thinnings (Verkerk et al. 2010).

The forest biomass procurement chain from the forest site to the heat and/or power plant or (in the future) to a biorefinery facility involves a series of machinery e.g. harvesters, forwarders, chippers etc. Forest machinery is characterised by production in limited numbers, very advanced technique and a high degree of customer adjustments. New product development and technical advancements within the forest machine manufacturing sector focuses on improving the productivity of the machines, reducing machine purchase cost, lowering energy consumption, pursuing non-fossil fuel options (e.g. DME, hybrids), improving of the technical availability, improving the working environment of the operator and improving environmental performance (lower soil compaction, lower emissions). Some of those development measures are driven by market pressure while others are driven by legislation and European regulation.

Barriers and drivers that influence the diffusion of new products/innovations in the forest technology sector have been little studied. The performance of individual NoIPs, on the other hand, has been studied through case studies where the performance of a NoIP is evaluated mainly through productivity studies in some specific region with some specific forest properties.

Companies in the forest machine manufacturing sector are mostly SMEs, but typically provide their products on the world market. Their activities include production of machine parts and even whole machines. Typically these SMEs are located in rural areas and have a not negligible contribution to the local labour market and the local economy and development. Innovative SMEs are a very important factor for the European Union. Although many SMEs are similar in size they may utilise different processes for new product development. O'Shea & McBain (1999) found that the 5 SMEs included in their study were similar in size, age, number of large customers and turnover but each used its own process for product development.

In Sweden clustering of companies within the forest technology sector is common both in the north and south parts of Sweden; "Cluster of Forest technology" and "Tunga Fordon" respectively. The cluster constellations are usually between companies that have similarities, but are not direct competitors, and the benefits are e.g. a shared experience for innovation strategies and an administrative structure for finding funding from outside the companies.

According to experience from Sweden a) forest machine manufacturers have very limited resources for building test benches and prototypes for demonstration; b) forest contractors have no monetary resources and even no incentives to actively drive forward the development of the forest technique; and c) the innovators have big difficulties in achieving early stage financing (Thor 2012).

1.6 Aim of the report

The aim of the report is threefold.

a) Identify and rank in matter of importance the factors that forest machine manufacturing companies are using to measure the success or failure of an innovation.

b) Identify and elaborate on the barriers that forest machine manufacturing companies are facing.

c) Identify and discuss innovations that have been successful (induced major improvements in the productivity and performance of the existing forest energy supply chains) and innovations that were not successful (despite the fact that they could have been important for the development of the supply chains).

2. Method

This report is structured in three phases, each one corresponding to one of the aims. The data for the three phases were collected by researchers from the different countries involved in the Work Package 6 of the INFRES project. The participating forest machine manufacturing companies (both SMEs and larger companies) were all producing forest machinery and forest machine parts (hereafter we use the term “company” to refer to the companies that participated in the survey). Data collection occurred in March-June 2014.

In phase 1 different criteria and sub-criteria that can affect the success of an innovation were ranked by companies from different parts of Europe. The process in phase 1 is based on the Analytic Hierarchy Process (AHP; Saaty 2008, Dodson Coulter et al. 2006, Crawford and Williams 1985). In Phase 2 information was collected with relevance to the barriers and drivers of innovations. In Phase 3 selected innovations were judged by a group of experts according to their market successfulness or unsuccessfulness.

2.1 Phase 1

A number of main criteria and sub-criteria measuring the success of a new product, from a company point of view, were subjected to pairwise comparisons by the participating companies according to the AHP. A total of 4 main criteria (MC) were compared with each other and within each main criterion 3-6 sub-criteria (SC) were compared (Table 1 and Appendix 1).

Table 1. New product success measurement main criteria and sub-criteria 1, 2, 3 and 4 (modified from Griffin and Page (1996).

Main Criteria (MC)	Sub-Criteria (SC)
Customer related measures (MC1)	SC group 1
	Customer acceptance (SC1.1)
	Customer satisfaction(SC1.2)
	Meet revenues goals (SC1.3)
	Meet revenue growth (SC1.4)
	Meet market sales goals (SC1.5)
	Meet unit sales goals (SC1.6)
Financial performance measures (MC2)	SC group 2
	Break even time, payback period (SC2.1)
	Attains margin goals (SC2.2)
	Attains profitability goals relative to investment. (SC2.3)
	Internal rate of return/Return on Investment (SC2.4)
Product-development process (MC3)	SC group 3
	Development cost (SC3.1)
	Launched on time (SC3.2)
	Product performance level (SC3.3)
	Meet quality guidelines (SC3.4)
	Speed to market (SC3.5)
	Duration of demand (SC3.6)
Company benefit measures (MC4)	SC group 4
	Proportion of the total sales by the new products (SC4.1)
	Influence on the overall profit of the company(SC4.2)
	Growth of demand for the company products (SC4.3)

For example, pairwise comparisons of the main criteria MC1, MC2, MC3 and MC4 provided the relative importance of each of the criteria for each of the manufacturing companies that

were included in phase 1. The Saaty rating scale (Saaty 2008) was used to weight the different pairs (Table 2).

Table 2. The Saaty Rating Scale

Intensity of Importance	Definition	Explanation
1	Equal importance	Two criteria or sub-criteria have the same relative importance
3	Weak importance of one over another	Experience and judgment slightly favour one criterion or sub-criterion over another
5	Essential or strong importance	Experience and judgment strongly favour one criterion or sub-criterion over another
7	Demonstrated importance	A criterion or sub-criterion is strongly favoured and its dominance demonstrated in practice
9	Absolute importance	The evidence favouring one criterion or sub-criterion over another is of the highest possible order of affirmation

The pairwise comparisons were done during interviews led by researchers participating in the INFRES project. Before each interview the interviewed person from each company had a chance to look at the criteria and any questions they had about the criteria and the procedure were answered by the researcher before the ranking. The companies providing the comparisons were both partners in the INFRES project and other companies of relevance from different regions in Europe (Table 3).

Table 3. Descriptions of the companies that participated in Phase 1 from Sweden (SE), the Netherlands (NL), Finland (FI) and Italy (ITA).

Country	Company main product	Innovations/year	Turnover (M€/year)
SE-1.1	Tracks for forest machines	2	32
SE-1.2	Small harvesters and forwarders	1	5.5
SE-1.3	Forest regeneration products	0.5	5.2
SE-1.4	Rotators	1-5	210
SE-1.5	Forestry attachments (grapples, etc.)	1	12
NL-1.1	Small wood chippers	1-2	3
NL-1.2	Larger wood chippers and forwarders	-	-
NL-1.3	Large stationary wood chippers	1	-
FI-1.1	Large harvesters and forwarders	3-4	400
FI-1.2	Large wood chippers	0.3	1
FI-1.3	Hydraulic trailers	1	2.6
FI-1.4	Forestry attachments (harvesting heads, etc.)	5-8	45
ITA-1.1	Attachment for stump harvesting	15	5
ITA-1.2	Large wood chippers	26	6.5
ITA-1.3	Mobile skyline-yarders	14	3

Analysis of criteria weight

The collected criteria weight from the different companies was analysed statistically with mixed model procedure in SAS software (v 9.3). The model was:

Y = criteria (Cri) + country × criteria (Co*Cri)

Country (n=4) was added as a class variable, but was not included in the model since the sum of all criteria always adds up to one and therefore cannot differ. The main factor Cri (n=3-6) would show if there were statistical differences among the weights of the criteria and the interaction factor Co*Cri (n=12-24) would show if weighing was statistically different among countries. Both Cri and Co*Cri were fixed factors. In the case of a P-value < 0.05 for any of the two factors the differences were considered significant and pairwise comparisons using Tukey's adjustment were done. The main criteria group (MC) and each sub-criteria group (1.1-1.6; 2.1-2.4; 3.1-3.6; and 4.1-4.3) (Table 1) were analysed separately.

Analysis of consistency ratio

The consistency ratio (CR) is a value between 0-1 and is important because it identifies how logic the ranking is within each criteria group. The CR should preferably be below 0.1 and all values larger than that were further analysed to identify the reason for the high CR. In some cases the values were re-checked with respective company. The CR was evaluated with the following scale

0 = Excellent
<0-0.05 = Very good
<0.05-0.10 = Good
<0.10-0.20 = Acceptable
<0.20- = High

When CR was above 0.10 the order of the ranking within each row of each criterion was compared. If the CR was 0, then the ranking was exactly the same in each row within each criterion. If the ranking changed a lot between rows inconsistency was high, hence the CR increased.

2.2 Phase 2

Phase 2 was conducted as a questionnaire (Appendix 2) addressed to 18 participating companies from 4 countries (Table 4) on the barriers the companies face on developing and introducing a NoIP. The companies varied greatly in size, and also on which market they were active in.

Table 4. Description of the companies that participated in Phase 2.

Country	Company main products	Company main market	Employees	Turnover (M €/year)	Innovations/year
SE-2.1	Forest regeneration products	Global	20	4.9	0.5
SE-2.2	Small harvesters and forwarders	50% Sweden 50% export	17	5.5	1
SE-2.3	Harvesters and forwarders	Global	1500	400	6
SE-2.4	Rotators	Global	135	21	1-5
NL-2.1	Small wood chippers	Netherlands, Germany Belgium	14	3	1-2
NL-2.3	Large stationary wood chippers	Global	6	NI*	1
FI-2.1	Hydraulic trailers	Fennoscandia	18	2.6	1
FI-2.2	Forestry attachments (harvesting heads, etc.)	Global	300-310	45-50	5-8
IT-2.1	Hydraulic loaders for forestry	Europe	15	5	2
IT-2.2	Mulchers for the recovery of agroforestry residues	Global	26	6.5	2-3
IT-2.3	Cable yarders (both sled and tower types)	Global	14	3	3-4
IT-2.4	Chippers and Grinders	Europe	15	4	0.5
IT-2.5	Mulchers for the recovery of agroforestry residues	Global	52	18	1-2
IT-2.6	Dedicated heavy-duty forestry mulchers	Global	102	30	1-2
IT-2.7	Loaders, lifting equipment and Truck fitting	Italy	95	16	1
IT-2.8	Excavator attachments, namely: buckets, hammers, log grapples and feller-buncher shears	Global	67	14.5	NI*
IT-2.9	Forestry trailers to farm tractors and forwarders	Europe, South America	12	2	1
IT-2.10	Mulchers for the recovery of agroforestry residues	Global	40	6	1

* No Information

2.3 Phase 3

Phase 3 was conducted as a questionnaire addressed to INFRES experts as well as other European researchers of the personal network of the participants in WP6. Firstly, 10 important innovations were identified by the WP6 participants and then experts were asked to have an opinion on if the innovations were successful or not and also explain their success (or lack of success) (Appendix 3). The ten innovations that were identified by the group and addressed by the experts are:

 # 1 Cone-screw chipper

A wood chipper equipped with a spinning conical screw (in contrast to drum or disc) with sharpened outer edges.

 # 2 Crane with a pivoting outer boom

Harvester crane that has an extra pivot point on the outer boom which makes it possible for the crane to reach around remaining trees especially in thinning operations in dense stands.

 # 3 Harvester head with multi-tree handling by means of accumulating arms

Felling head that can perform consecutive felling cuts in one crane cycle and accumulate the felled trees within the head.

 # 4 Mini feller forwarder for use in thinning operations

Small size, low capital cost machines adapted to thinning operations of small size trees.

 # 5 Bundler

Machine that collects, compacts, and wraps the logging residues into bundles.

 # 6 Truck mounted chippers and grinders

A truck mounted with a chipper/grinder

 # 7 Solutions for compressing logging residues on the forwarder

Solutions for compressing of logging residues on the forwarder in order to increase its load capacity.

 # 8 Terrain chippers

A chipper built on a forwarder chassis equipped with a container wherein the chips are blown.

 # 9 Loaders equipped with a scale for measuring how much material loaded on a e.g. forwarder or truck

A loader equipped with a scale in order for the driver to be able to monitor the amount of material loaded on the forwarder or truck

 # 10 Harvester head that can rapidly switch from harvester to log-grapple and back

Harvester heads that can be used both for felling, processing and loading.

3. Results and Discussion

3.1 Phase 1

The standard deviation (SD) for some criteria was rather large, as is evident from the raw data numbers in Table 5. The SD varied from 4% to 108% of the mean and only in four cases (Sweden MC1; Netherlands SC2.2 and SC4.3 and Italy SC3.4) it was below 10% of the mean. For the global average the SD was more than 50% of the mean in 16 out of 23 cases. As a result large numerical differences were often required to find significant differences in the statistical analysis. This large SD is a result of differences among companies within each country. However, the data set was not large enough to take into account company differences such as company size, number of innovations, or financial situation, all which may affect the weight of the criteria.

When looking at the average numbers, there was a consensus across companies in the Netherlands and Sweden that the customer related main criterion (MC1, Table 1) has the highest value relative to the other criteria when coming to assess successfulness in the introduction of a NoIP (Table 5). This shows that these companies are interested in building a long term relationship with their customers, which may generate some profit also in the future. In Finland and Italy, MC4 (company benefit measures) was the most important criterion i.e. ranked higher than all other main criteria. Main criterion MC2, financial performance, was ranked last in all countries except Finland. The statistical analysis for the whole set supported this to some extent, as MC1 was significantly higher than MC2 and MC3, but not MC4 (Table 6). There was also a significant interaction between criterion and country which supports the above mentioned differences (Table 7). It is interesting that customer related measures were considered so important by companies in Sweden whereas companies in Finland, geographically very close, considered company benefit measures to be more important.

The main factor Cri was significant for all SC groups except SC2. The SC4 also had a significant interaction effect between country and criteria, indicating that companies in different countries weighted this criterion differently (Table 6).

Sub-criteria SC1.1 (customer acceptance) and SC1.2 (customer satisfaction), both within main criterion MC1, were ranked highest except in Italy where SC1.1 was ranked last (Table 5). The SC1.2 was significantly higher than SC1.3, SC1.4, SC1.5 and SC1.6 (Table 6). Even though the difference between SC1.1 and SC1.2 was not significant (P=0.070) it is worth noting that customer satisfaction was considered more important than customer acceptance, once again showing that a good relationship with customers is very important in the long run.

Attaining margin goals (SC2.2) was ranked highest concerning financial performance of a NoIP in Sweden and the Netherlands (Table 5). The length of break-even time (SC2.1) was judged to have the least importance in Sweden, the Netherlands and Italy while in Finland it was ranked first. In Italy, the attainment of profitability goals relative to investment (SC2.3) judged to be the most important criterion followed very closely by SC2.4, the attainment of margin goals. However, there was no significant difference among the sub-criteria within the financial performance measures (Table 6).

Table 5. Mean for main and sub-criteria (standard deviation (SD)) local and global weights for new product success measurement criteria† by 5 companies in Sweden, 4 companies in Finland, 3 companies in the Netherlands and 3 companies in Italy. For each country and within each main and sub-criteria the means sum to 1 (subject to rounding error).

	Sweden		Finland		Netherlands		Italy		Global	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
MC1	0.60	0.03	0.27	0.21	0.39	0.10	0.23	0.16	0.40	0.20
MC2	0.15	0.10	0.21	0.08	0.11	0.05	0.14	0.08	0.16	0.08
MC3	0.13	0.09	0.14	0.10	0.27	0.15	0.25	0.28	0.19	0.15
MC4	0.11	0.07	0.38	0.23	0.24	0.20	0.37	0.30	0.26	0.21
SC1.1	0.22	0.09	0.21	0.16	0.22	0.13	0.10	0.08	0.19	0.12
SC1.2	0.35	0.17	0.22	0.17	0.37	0.05	0.24	0.20	0.30	0.16
SC1.3	0.15	0.06	0.14	0.11	0.14	0.05	0.15	0.04	0.15	0.07
SC1.4	0.13	0.10	0.20	0.11	0.10	0.05	0.18	0.10	0.15	0.09
SC1.5	0.08	0.05	0.14	0.07	0.07	0.03	0.18	0.08	0.11	0.07
SC1.6	0.06	0.03	0.09	0.03	0.11	0.03	0.15	0.09	0.10	0.05
SC2.1	0.13	0.13	0.30	0.14	0.20	0.11	0.11	0.05	0.19	0.13
SC2.2	0.36	0.22	0.21	0.03	0.31	0.01	0.32	0.17	0.30	0.15
SC2.3	0.23	0.13	0.28	0.08	0.24	0.06	0.34	0.15	0.27	0.11
SC2.4	0.28	0.14	0.21	0.08	0.24	0.06	0.23	0.14	0.25	0.11
SC3.1	0.08	0.04	0.12	0.11	0.14	0.10	0.08	0.05	0.10	0.08
SC3.2	0.09	0.04	0.12	0.08	0.15	0.11	0.06	0.04	0.10	0.07
SC3.3	0.23	0.16	0.21	0.12	0.26	0.07	0.21	0.15	0.23	0.12
SC3.4	0.25	0.08	0.24	0.14	0.23	0.05	0.30	0.02	0.25	0.08
SC3.5	0.07	0.03	0.17	0.16	0.08	0.03	0.06	0.04	0.10	0.09
SC3.6	0.28	0.20	0.14	0.11	0.14	0.08	0.30	0.12	0.22	0.15
SC4.1	0.17	0.15	0.34	0.23	0.12	0.03	0.32	0.13	0.24	0.17
SC4.2	0.51	0.19	0.46	0.20	0.35	0.08	0.21	0.22	0.41	0.20
SC4.3	0.32	0.10	0.20	0.09	0.53	0.05	0.47	0.26	0.36	0.18

† For explanations of the different criteria see Appendix 1.

In the product development process group (MC3) there were 3 criteria that had a lower weight (SC3.1, SC3.2, SC3.5) and 3 (SC3.3, SC3.4, SC3.6) that had a higher weight (Table 5 and 6). The lower weight group all concerned the company's costs and process for the innovation, whereas the SC3.3 (product performance level) and SC3.4 (meet quality guidelines) both can be related to customer issues, once again showing the importance of a satisfied customer. The SC3.6 criterion duration of demand could be considered an effect of the other two. If the quality and performance level is good, more people will buy the product and hence the duration of demand increases. There were significant differences between all lower weight criteria and all higher weight criteria (*P=0.002-0.034*), except for SC3.6, which only tended to be significantly higher than SC3.1 (*P=0.065*) and SC3.2 (*P=0.076*).

Table 6. Least square means for the different criteria† and P-values for main factor Criteria and interaction factor Country*Criteria (Co*Cri).

							P-value	
Group	1	2	3	4	5	6	Criteria	Co*Cri
MC	0.37^{b}	0.15^{a}	0.2^{a}	0.28^{ab}			0.0017	0.02
SC1	0.19^{ab}	0.29^{b}	0.14^{a}	0.15^{a}	0.12^{a}	0.10^{a}	<0.0001	0.6
SC2	0.19	0.3	0.27	0.24			0.103	0.558
SC3	0.10^{ab}	0.11^{ab}	0.23^{c}	0.25^{c}	0.09^{a}	0.21^{b}	<0.0001	0.708
SC4	0.24	0.38	0.38				0.031	0.034

† For explanations of the different criteria see Appendix 1.
$^{a-c}$ Numbers within rows with different superscripts differ significantly (*P*<0.05)

The last SC group (company benefit measures) is one where it might be expected that size of the company matters. For a large company with many innovations each innovation would have a lower influence than for a small company that only has a few products at the market at the same time. It is possibly this is the reason that the SD in general was high for this group. In general, the SC4.2 (influence on the overall profit of the company) and SC4.3 (growth demand for the company products) was considered more important than SC4.1 (proportion of sales by the new products). This would mean that it's more important to add to the overall goodwill of the brand and that the entire company makes a profit, rather than a single innovation. Even though Cri was significant, no differences among sub-criteria was significant (P<0.05) when using Tukey's adjustment (Table 6). This is due to a large variation among the answers from the different companies.

Table 7. Least square means for Country*Criteria interaction for criteria groups† where the interaction was significant

	Sweden	Finland	Netherlands	Italy
	Main Criteria (MC) group			
MC1	0.60[b]	0.27	0.39	0.23
MC2	0.15[a]	0.21	0.11	0.14
MC3	0.13[a]	0.14	0.27	0.25
MC4	0.11[a]	0.38	0.24	0.37
	Sub-Criteria (SC) 4 group			
SC4.1	0.17	0.34	0.12	0.32
SC4.2	0.51	0.46	0.35	0.21
SC4.3	0.32	0.20	0.53	0.47

† For explanations of the different criteria see Appendix 1.

a-b Numbers within columns and criteria group with different superscripts differ significantly (*P<0.05*)

Table 8 shows the consistency ration for all groups and companies. In general too many comparisons had a high consistency ratio. The reasons for this are probably several; as the number of the pairwise comparisons increases the consistency ratio becomes larger. It is also possible that the interviewed person may not have understood the criteria correctly or are unfamiliar with some of them.

Table 8. Consistency ratios for all companies for new product success measurement Main Criteria† (MC, n=4) and Sub-Criteria (SC) groups 1 (n=6), 2 (n=4), 3 (n=6) and 4 (n=3).

Company number	MC	SC1	SC2	SC3	SC4
SE-1.1	0.17	0.10	0.03	0.09	0.00
SE-1.2	0.02	0.05	0.04	0.20	0.00
SE-1.3	0.29	0.13	0.08	0.62	0.16
SE-1.4	0.21	0.10	0.06	0.05	0.00
SE-1.5	0.25	0.25	0.28	0.23	0.25
NL-1.1	0.02	0.07	0.00	0.00	0.00
NL-1.2	0.02	0.06	0.05	0.04	0.01
NL-1.3	0.18	0.10	0.23	0.15	0.01
FI-1.1	0.21	0.12	0.14	0.09	0.05
FI-1.2	0.03	0.14	0.00	0.45	0.40
FI-1.3	0.24	0.08	0.27	0.09	0.01
FI-1.4	0.01	0.07	0.06	0.04	0.12
ITA-1.1	0.04	0.07	0.00	0.08	0.48
ITA-1.2	0.24	0.41	0.11	0.15	0.00
ITA-1.3	0.08	0.16	0.01	0.09	0.06

† For explanations of the different criteria see Table 1.

A lot of things may affect the answers for these comparisons. It could be size of the company, the financial situation of the company, the position of the person interviewed, tradition of the region/country, etc. These factors are hard to take into account when doing the analysis of the data, especially since the data set was rather small, and the only one that we could use here was country. However, one thing that was obvious from all comparisons was that measures that somehow related to customer relationship are more important than measures that mainly affect the company. In a small market, which this is, it makes sense to cultivate your customer pool, since you don't have that many alternatives. That doesn't necessarily mean that the profit of the company or the innovation is not important, but in the long run the customers are prioritized.

3.2 Phase 2

The questionnaire was answered by a very wide range of companies (Table 4), from relatively small (6 employees) to very large (300 to 1500 employees) . Turnover varied from 2 to 400 M€, with a mean of 35 M€. There was a strong Italian bias among the companies (10 respondents out of 18). All respondents operate on international markets, often on the global arena. Respondents generally market between 0.5 to 6 innovations per year, with the average number of innovations being 2 per year. Two out of 18 companies (6%) declared they face no barriers to innovation. The rest pointed at a number of different barriers, especially financial (44% of responses) e.g. when developing a completely new innovation and lack of capacity (19%) in terms of personnel and time. There were many aspects of the financial situation that was mentioned as a barrier. One is the lack of external funding for new ideas and high-risk projects. Another is high development costs in combination with a rather small market, occasionally in combination with difficulties to charge a high enough price for a product. Patent costs were also mentioned as a financial barrier. A few companies mentioned the problem of finding skilled engineers. This can be due to both competition with e.g. the mining or the car industry and to a general lack of educated engineers. Smaller companies may not have enough staff to both develop new products and to maintain the production of the current ones. Finally, a few companies also mentioned lack of good quality components, regulations and problems with testing the products as barriers. In some cases, the time elapsed between conception and marketing is seen as a main barrier. This list of barriers agrees well to the list presented in OECD/Eurostat (1997). As a comparison, concerning barriers to product innovation in the Swedish and Finnish sawmilling industry Stendahl et al. (2007) found that resource constraints (such as lack of time, financing and knowledge), process uncertainties (such as raw-material supply, product yield, and market development) weaknesses of the wood material, and structural shortcomings of supply chains to some market segments were the most important ones.

In the present study barriers are encountered about evenly in all stages, from conception to marketing. Testing of the prototype and servicing of the new models seem somewhat less problematic than the rest. Most popular solutions are to establish close cooperation with customers and suppliers (27%) in order to make the introduction of new innovations easier and to increase understanding for the costs of developing new products. Cooperation with research institutions and universities is considered a lower priority (8%) and occasionally functional to obtaining subsidies and research funds for the development of a new innovation. Subsidies (15%) and generic better planning (15%) are considered important solutions as well

The most common drivers to innovation, regardless of country or size, are the wish to stay competitive or surpass competitors and to react to satisfy customer demands (the two being closely related). It is also worth noticing the non-insignificant role of a somewhat more abstract interest in technology and the desire to excel. These ultimately lead to the same results as above (overcome competitors) but the character of these answers is somewhat more emotional, showing that innovation is often internalized within the company's mission and exceeds the pure need of surviving in a competitive environment.

3.3 Phase 3

In the following section the opinions of the experts on the ten innovations are summarised.

#1 Cone-screw chipper

The innovation is either considered a failure or is unknown to the experts, which could be seen as a failure as well. The most common reasons were poor flexibility (29%), presence of stronger competitors (17%), low productivity (13%), difficult maintenance (13%) and lack of a suitable environment (13%). The opportunities of the innovation are energy efficiency and final product quality.

It must be considered whether the second most common reason for failure, i.e. stronger competitors, is really a reason or merely the result of low productivity or poor flexibility.

 # 2 Crane with a pivoting outer boom

The innovation is either considered a failure or is unknown to the experts, which could be seen as a failure as well. More precisely, it is generally known (and so far not widespread or penetrated to markets) in the Nordic countries and unknown elsewhere. Except for 1 expert, all agree on this. The most common reasons were poor marketing (23%) and conservatism (23%), which both belong to the same family of non-technical causes. Besides, the innovation addresses a less dynamic sector, i.e. early thinnings, which has a secondary priority compared to final cut, due to its lower profitability. The opportunities of the innovation are excellent suitability to the environment offered by early thinning and productivity advantage.

Due to the fact that failure is largely dependent on poor marketing, this innovation may assert itself in the future, if better marketing is implemented. Moreover, an increase in use of forest biomaterials for biorefinery and bioenergy purposes would open a larger market for innovations such as these. On the other hand, this innovation could be surrogated for by the skilful use of the boom-tilt facility.

 # 3 Harvester heads with multi-tree handling accumulating arms

The innovation is generally considered a success, especially in the Nordic countries, where it turned out to be a best-seller. The success was less in countries where labour cost is relatively low (esp. Eastern Europe).The most common reasons for success were productivity (54%), suitability to specific work environments - e.g. early thinning (23%) and flexibility (8%). Main limits are in the specific targeting of less profitable operations (36%), together with limited flexibility (21%) and poor product quality (14%). For this reasons success outside Nordic countries seems specifically tied to new biomass plantations. In Eastern Europe success is limited by cheap labour and limited investment capacity, which makes motor-manual felling and processing still less expensive than mechanized multi-tree harvesting. Success in Nordic countries may also depend on the presence of a very large harvester fleet, whereas harvester fleets in Eastern and Southern Europe are still comparably small.

 # 4 Mini feller forwarders for use in thinning operations

Almost half of the experts (43%) clearly found this kind of equipment as a failure rather than a success. The remaining ones (57%) didn't know it or didn't give a clear answer about the success of this equipment. Therefore, it seems to be not very well known and proven equipment, yet. The main reasons for the failure are; the need for a suitable environment (29%), low flexibility (25%) and low productivity (18%). Also small equipment has a reputation for low mechanical reliability, short service life and low productivity. In many cases larger equipment (second hand or new) is preferred since results are better and it has much higher overall competitiveness. The main advantages (mentioned by 5 experts) were good productivity and good performance in a suitable environment. As some experts noticed, this is a specialist machine with low versatility and flexibility that works well in stands with small trees, easy terrain and short extraction distance.

Opportunities: It seems that small equipment have –and will have- their own small market in specific situations, a critical mass of suitable operations for one contractor in the same area.

 # 5 Bundlers

About 90% of the experts gave an opinion about success or failure of bundlers. Bundlers are mainly considered unsuccessful (66% of the total; 74% of the ones that made an assessment) by the experts. Only one quarter of the experts considered bundlers as a successful innovation (23% of the total; 26% of the ones that made an assessment).The main disadvantage (21%) of this equipment is that an additional costly step is introduced to the chain, which is not fully offset by the expected advantages (i.e. easier transport). Other negative factors are: high initial investment (11%), lack of flexibility (13%), and existing logistic chains (11%) together with competition with other systems - e.g. chipping (9%).The main advantages of the bundlers are the high demand for their product (logging residues and/or bundles) (29%), existing logistic chains (24%) that allow easy introduction of bundling into the supply chain (Poland, Portugal, Ireland), favourable terrain conditions (18%) and competition (or lack of) with roadside chipping (18%).

Only specific situations (external factors) allow the success of this equipment. For instance in Ireland: roadside chipping is not well known, there have been some contracts to supply bundles, etc.; Northern Spain: small ownerships make it difficult to organize chipping logistics.

Opportunities: This equipment seems suitable for big areas of clear cuts, when there is a large demand for logging residues in combination with long transportation distance.

 # 6 Truck mounted chippers and grinders

A 68% of the consulted experts gave a success/failure opinion about truck mounted chippers/grinders. They mainly estimated this equipment to be successful (84% of answers; 57% of all). Negative opinions are only found among the Central-Eastern experts (half of them). All South, Central-West and Finnish experts rated this innovation as a success. The main advantages are flexibility (26%), high productivity (20%), and fast/easy mobility (17%). Also a suitable environment and competition with other equipment give an advantage to

this equipment (14%). Sometimes, success is associated with contractors focused on chipping. It is considered as a competitive equipment when the biomass is scattered around a large territory (where it is necessary to relocate the chipper quite frequently), although its high productivity makes it suitable to different situations.

The main disadvantages (only 9 quotations) are a lack of favourable terrain conditions (33%), high costs, and lack of flexibility compared with other equipment (competition) (22%). These few mentions come mainly from Eastern-Central Europe (Czech Republic, Poland and Romania), where it seems that the road network is not always suitable for trucks (forest roads in poor condition, lower accessibility than tractors/forwarders, excessive gauge for some roads), and so tractor-towed or forwarded-mounted chippers are considered more competitive.

 # 7 Solutions for compressing logging residues on the forwarder (e.g. Bruks ABAB, Dutch Dragon Press Collector etc.)

The innovation is generally considered as a failure by 46% of the experts and as a success by 11%. Most common reasons for failure were lack of a productivity increment (21%) as well as increased cost (33 %). Almost half of the experts, 43%, did not leave any comment.

Many experts argued that big loads can be achieved without compressing and thus productivity does not increase compared with common forwarding without a compressing unit. In steep terrain where machine access is limited the trees are extracted whole and processed in the landing, hence compressing on the forwarder is no longer relevant.

Opportunities: High productivity in suitable conditions; as the forwarding distance and the size of the harvesting area increase this solution becomes more interesting.

 # 8 Terrain chippers

Nineteen out of 28 experts had an opinion about this innovation. With a few exceptions the interest for this system was low. Some of the reasons were 1) large investment and high production cost (42%) and 2) complicated logistics (18%); the fact that this machine needs a shuttle forwarder for transporting the chips to the landing makes the system hot and liable to delays. Some experts mentioned that in many countries there is a lack of end user for the large production of chips necessary to get a good economy for the equipment. Furthermore terrain chippers are heavy equipment that requires firm soil and flat landscape in order to be used most efficiently. Together these problems and requirements make this a relatively expensive and difficult technique to use. Terrain chippers are considered as complementary solution in the main system that is transporting the logging residues to the roadside and chipping it there.

Opportunities: In suitable environments such as popplar plantations, large stands in even terrain with good bearing capacity and logging residues accumulated in piles terrain chippers could perform well. An expanding bioenergy sector could very well pave way for this innovation.

 # 9 Loaders equipped with a scale for measuring how much material is loaded on a e.g. forwarder or truck (in general)

Seventeen out of 28 experts had an opinion about this innovation. This product is generally considered as a success mainly because it helps to keep the loads within the load limit (65% of the responses). In that way penalties for loading over the weight limit for transportation are avoided. Adjusting the load of the forwarder to current site conditions e.g. when travelling slopes and wet areas, contributes in decreasing soil compaction and rutting as well as in preventing that the forwarder is damaged. Some experts suggested that moisture content would be interesting to collect at the same time as collecting the mass of the logging residues. That would make payment to the forest owner faster and more accurate. Negative remarks about the innovation were predominantly that it breaks too easily. There is room for this innovation to grow, since some experts said this system is not currently in their country or area.

 # 10 Harvester head that can rapidly switch from harvester to log-grapple and back (e.g. Konrad Woody, Zoeggeler etc.) - 14 answers, 8 did not answer

This innovation is considered as a (future) success by 7 experts and as a failure by 6. According to the experts this is a field of technology where innovations will continue to come. This involves both the development of harwarders (machines that can both harvest the trees and load the logs on their load space without requiring a change of tools in their crane tip) and heads that can rapidly switch from harvester/processor to log-grapple. The latter is popular on truck mounted cable cranes with built on crane processors. This kind of combi-machines offer an economic solution by buying one machine instead of two. The drawbacks seem to be that despite their flexibility the machines are generally performing worse than the purpose build machines, according to some experts. An expert mentions that too complicated hydraulics may be a drawback for the tool.

Opportunities: It is indicated that in areas where space is limited it is an advantage to only have one machine that performs two functions (e.g. processing and loading).

4. Summary and conclusions

Innovation is a key factor for development and progress at a company, regional and national level. This publication explores different aspects of innovation activities and products in the forest technology sector and tries to answer to some important questions; What criteria are companies using to measure the success or failure of an innovation? What innovation barriers are the companies facing and how are they tackling them? Why some specific innovations have succeeded while other failed?

The findings may be summarised as follows:

- Companies assess the performance of an innovation using specific criteria that are related to customer relations, product development process, financial performance, and company benefit. This study shows that customer relations i.e. customer satisfaction, high product performance level and meeting of quality guidelines are the most important. Company benefit (e.g. growth of demand of the products of the company) also seemed to be prioritized.
- The most important barrier for innovation was lack of financing, especially for new high-risk projects. This is further supported by the fact that the forest technology sector is a small market and that development costs are high. Lack of skilled engineers was occasionally seen as a barrier as well.
- The most important solution to barriers seem to be collaborations with customers, both to get a feel for what customers want, but also to better introduce new technology in a sometimes reluctant and conservative world. Furthermore, collaborations with universities and research institutes is becoming more important as those will help unlock additional funding for development of new innovations
- Drivers for innovations are tied to competitiveness (to stay on top, offer the best products, being one step ahead of competitors). There was also a few who felt rather passionate about innovation in general, so a genuine interest in product development seem to be an important driver as well.
- Innovations that increased productivity of the operations, reduced the cost and were flexible (can work in most conditions) were identified as successful. On the other hand innovations that are poorly marketed, require complicated logistics, can only be used in specific conditions and have a low productivity were considered as a failure.

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Appendix 1

Phase 1

Definition of the criteria/sub-criteria

C1: Customer related measures: Market expectations of a new product/ innovation and also expectations of a market success after launching

SC11**: Customer acceptance:** the customers find the product useful

SC12: **Customer satisfaction:** The product meets customer´s needs and expectations

SC13: **Revenues/turnover goal:** the income a company received from the sale of the specific product

SC14: **Revenue/turnover growth:** The increase rate of the income the company received from the sale of the specific product

SC15: **Meet market sales goals:** Goal for market share

SC16: **Product Unit sales goals:** Amount of units expected to be sold under a certain period.

C2: Financial performance: Expectations of maximizing the return on investment for product development as well as expectations that the product will attain margin and profitability goals.

SC21: **Break even time, payback period**: The length of time for the discounted value of future cash flow from the sale of the specific product to equal the cost of making the specific product

SC22: **Attains margin goals:** The percentage of profit the company gets on each sale

SC23: **Attains profitability goals relative to investment:**

SC24: **Internal rate of return/Return on Investment**: Profits from the sale of the specific product in relation to capital invested to produce it

C3: Product specifics: Expectations of optimizing quality, product development time and cost, and ensuring project progress according to process related goals

SC31: **Development cost**: The amount of money spent to develop a product

SC32: **Launched on time**: Launched on time

SC33: **Product performance**: That the product performs as intended

SC34: **Meet quality guidelines**: Meet product functionality/quality company standards

SC35: **Speed to market**: From idea to final commercial product. If possible even duration of each development phase

SC36: **Duration of demand**

C4: Company benefit: Expectations that the new product will increase the profit of the whole company

SC41: **Proportion of the total sales by the new product**

SC42: **Influence on the overall profit of the company**

SC43: **Growth of demand of the products of the company**

Appendix 2

Phase 2

Questionnaire to the companies on barriers and drivers to innovations

Company size in terms of employees and turnover (sales would also be important):

Region/market you are situated in:

How many new products to the market do you have per year?

What are the barriers for innovation that you face?

At which part of the innovation process/product life are the barriers occurring?

What can you do/are planning to do to overcome the barriers?

What are the drivers of innovation for you?

Appendix 3

Phase 3

Questionnaire to experts on success and failure of innovations

Dear (name of the expert)!

We are contacting you in order to ask your opinion on some innovative forest machines/equipment.

In WP6 of the INFRES project, we are working in a study in which we would like to find out the reasons why some innovations were rapidly commercialised and accepted, while others were not. That could help us define the success factors for innovation in forest machinery, which is a rather ambitious goal – yet an attainable one.

If you have studied some of these machines, or had the opportunity to make an opinion about them, we would like you to tell us quite frankly if you think that the machines listed below were successful or not, and also how you would explain their success (or lack thereof).

Of course, you do not need to offer your opinion about all the machines in the list. If you do not feel knowledgeable enough about any of the machines in the list, you simply skip it/them. We only want to hear the opinions you feel comfortable enough to offer. This is not a carpet survey.

In fact, we have only selected a small group of specialists, whom we feel are serious and experienced professionals. We value your opinion and we hope you can offer us same good advice. This will be a part of a report that we elaborate on technology foresight and barriers of innovation in biomass harvesting

Thank you very much in advance. Please send us your expert opinion by May 28th.

Best regards

The group behind WP6

Innovation list:

#1 Cone-screw chipper

2 Crane with a pivoting outer boom

3 Harvester heads with multi-tree handling accumulating arms

4 Mini feller forwarders for use in thinning operations

5 Bundlers

6 Truck mounted chippers and grinders

7 Solutions for compressing logging residues on the forwarder

8 Terrain chippers

9 Loaders equipped with a scale for measuring how much material you load on a e.g. forwarder or truck

10 Harvester head that can rapidly switch from harvester to log-grapple and back

Table I. Expert affiliations for phase 3.

Affiliation	Country	Region
CNR – Timber and Tree Institute	Italy	South
Danish Forestry Extension A/S	Denmark	North
EnerForest	Portugal	South
French Institute of Technology for forest based and furniture sectors	France	West-central
Finnish Forest Research Institute	Finland	North
Forest Research Institute	Poland	East-central
Forest Technology Center of Catalonia	Spain	South
Forestry Commission	UK	Islands
Forestry Research Institute of Sweden	Sweden	North
Irish Forestry Board	Ireland	Islands
Mendel University	Czech Republic	East-central
Slovenian Forestry Institute	Slovenia	East-central
Stora Enso Wood Supply	Finland	North
Swedish University of Agricultural Sciences	Sweden	North
Technical University of Dresden	Germany	West-central
Technical University of Madrid	Spain	South
Technical University of Munich	Germany	West-central
Czech University of Life Sciences Prague	Czech Republic	East-central
Transylvania University of Brașov	Romania	East-central
University of Copenhagen	Denmark	North
Warsaw University of Life Sciences	Poland	East-central
Waterford Institute of Technology	Ireland	Islands

INFRES PROJECT CONTACTS

Coordinator

Prof. Antti Asikainen & Researcher Johanna Routa

Finnish Forest Research Institute (METLA), Finland

antti.asikainen@metla.fi, johanna.routa@metla.fi

METLA

Contact information for this publication

Dimitris Athanassiadis
SLU, Swedish University of Agricultural Sciences
Department of Forest Biomaterials and Technology
Skogsmarksgränd
SE-90183Umeå, Sweden
Phone: +4690-786 8304
E-mail: dimitris.athanassiadis@slu.se