Potentials for Savings by Implementing RFID and Telematic Technologies in the Timber and Biomass Supply Chain

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Abstract. While RFID and telematic technologies already enjoy wide implementation among retailers and logistics providers, their use in timber and biomass logistics is still in a phase of initial testing and pilot projects. Implementable technologies provide cross-organizational functionalities and facilitate the optimization of the supply chain 'from the forest to the factory'. Naturally, timber and biomass supply processes confront logistics with special challenges. Moreover, there are constraints and a need for further developments. Nonetheless, these technologies have been effectively and successfully implemented in a number of projects. The standardization of information technology will be a fundamental prerequisite for the acceptance of RFID and telematic technologies.

Key words: Biomass and timber logistics, marking technologies, telematics & RFID

INTRODUCTION

Among other factors, the diverse types, quantities and numbers of potential sources and sinks and means of transportation employed complicate any description of the numerous logistics processes related to the development of raw materials from forest and field, especially for the wood processing industry or renewable energy recovery. Conventional methods of logistics control and measurement only capture these processes in part. Innovative developments in the field of electronic information technologies are opening tremendous potentials for the improvement of logistics processes (Von Bodelschwing, E. et al., 2001; Fraunhofer IFF, 2005).

Innovative telematic technologies furnish potential to cut timber logistics costs. Cost pressure and structural modifications are 'drivers' intensifying the use of telematic technologies, especially among public forestry operations. Telematic technologies cut costs substantially by minimizing duplicated data acquisition, the time spent on searching for or being guided to a site, inspection work and the period of roundwood and biomass storage. Mobile services such as deck and job order management, off-road navigation and condition monitoring are particularly helpful.

Marking timber assortments with RFID holds forth further potential for rationalization. Electronic marking and identification make the timber supply chain more efficient up to the mill. RF marking could be used to reliably identify individual logs and correlate data relevant to the wood processing industry, e.g. quantity, quality and owner data. Mobile terminals could transmit the data to central

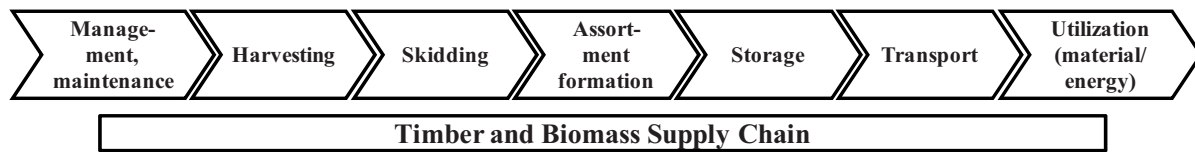databases and internal systems where it would be immediately available to others involved in the process.

| Manage-ment, maintenance | Harvesting | Skidding | Assort-ment formation | Storage | Transport | Utilization (material/ energy) |

Timber and Biomass Supply Chain

Fig. 1. Stages of timber and biomass supply.

However, format changes and non-standardized interfaces still frequently typify information exchange between Central European actors involved in timber logistics. Data is often exchanged on paper. This regularly forces subsequent actors who intend to process or save communicated data electronically to recapture or re-enter it.

The Logistics and Factory Systems Business Unit of the Fraunhofer Institute for Factory Operation and Automation IFF has been working on processes of the timber supply chain from the forest to the factory since 1999 and additionally on problems of biomass logistics since 2005. The unit specializes in research and development of logistics supporting information systems and services that organize the planning, control, monitoring and controlling of material and information flows in complex supply chains more efficiently. Its work includes both research projects and industrial development projects in which potential and process analyses are performed and systems, e.g. telematics and RFID, are implemented in the field.

This paper provides an overview of the Fraunhofer IFF's current projects, development work and solutions in the context of approaches to research and development for timber and biomass logistics.

The necessity of research of timber and biomass logistics as well as a multitude of potential approaches and the challenges of their practical implementation can only be appreciated when one is familiar with the distinctive features of timber and biomass logistics in general and in Germany in particular.

THE TIMBER AND BIOMASS SUPPLY CHAIN

Timber logistics processes proceed in an open and dynamic system with a plethora of immediate relationships and unclearly specified system boundaries. Timber supply chains are comprised of a combination of humans and equipment, i.e. they are socio-technical systems, and their complexity makes them impossible to capture as a whole. Hence, only certain aspects are mappable and traceable, and only when a particular viewpoint has been adopted. The viewpoint selected here incorporates peripheral factors, processes, information flows, material flows, actors, their roles, technical systems and technologies.

Timber logistics processes cover every operation from harvesting through delivery to a mill. Processes such as forest stand planning and maintenance or mill operations are not considered direct elements and thus are only analyzed secondarily (see Fig. 1). The large number of actors, their types of interaction and the great diversity of products define the specifics of the timber logistics processes.

Timber type and quality define timber assortment specifications, which require different methods of processing in the timber industry

The overall timber supply chain from the 'forest to the factory" encompasses the individual processes of harvesting, skidding, assortment formation, storage and transport.

Harvesting involves the felling, delimbing, debarking and cutting of marked trees. Different harvesting technologies (e.g. power saws or harvesters) are employed.

Skidding entails hauling individual logs to a skid road whence several logs are simultaneously skidded to the truck road.

Assortment formation subsumes all processes that supply customers individually based on their respective intended uses of the timber. Timber collected in decks may be separated into industrial timber and sawmill wood. Chiefly longwood, logs and industrial timber are used in the timber supply chain. Biomass chips are also frequently transported. Since this requires on site timber processing, such assortments tend to be formed in piles.

Storage and intermediate storage denote the deposition of timber in decks at the edge of the truck road. More finely structured woody biomass (brushwood, branch material, etc.) is stored in stacks, piles or bundles instead of decks.

Transport involves hauling assortments or decks away from a storage site by truck, rail or even ship to the mills where they are processed or to other buyers.

Individual stakeholders usually organize timber and biomass supply processes based on business decisions. The costs incurred are influenced by the

- number and structure of biomass assortments,
- current demand for biomass,
- potential for available biomass,
- methods and technologies for processing biomass,
- means of transport,
- hauling distances,
- storage technologies,
- storage requirements,
- buyer locations and
- infrastructure.

HIGH GRADE TIMBER, INDUSTRIAL TIMBER AND ENERGY WOOD

The high grade timber, industrial timber and energy wood process chains are important (see Fig. 2).

The high grade timber process chain is highly individualized. Every single veneering and sawmill wood log is marked. The marking contains information on quality or origin. Since timber quantities are small and their monetary value is high, usually every log is recorded and marked with its dimensions and quality characteristics.

Industrial timber is produced during logging or forest thinning. Poor dimensions or quality characteristics make it unsuitable for use as a higher grade in sawmills or veneer mills. Industrial timber is normally mechanically or chemically pulped and subsequently processed into composite wood panels, groundwood,

woodchips, pellets or pulp. Industrial timber is normally delivered directly from the forest in the form of long logs or precut cordwood with typical lengths of one or two meters. Marking every log is not cost effective since the sales units are large (decks or bulk). Hence, only information on supplier, quantity, quality, etc. is captured from truck loads arriving at a mill. This information facilitates delivery and dispatch inspection as well as invoicing. Hence, industrial timber is only marked on the deck or bulk level for reasons of labour and cost.
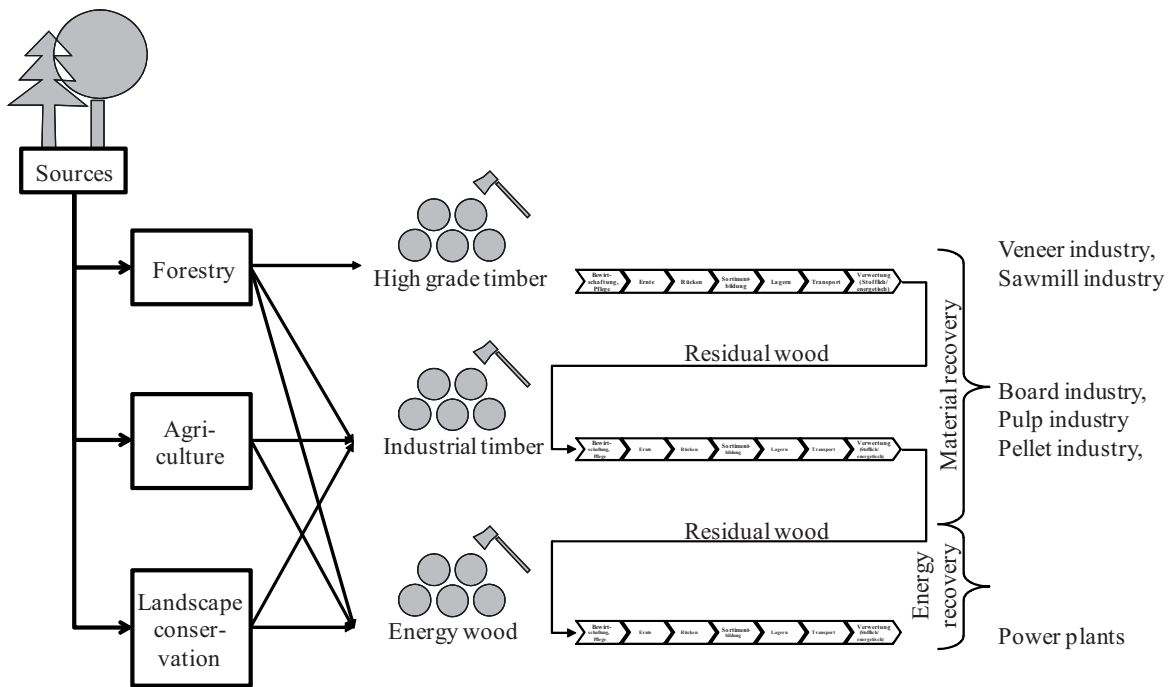

Fig. 2. The three basic process chains.

Marking is least advanced in the energy wood process chain because the biomass structures impede attachment and feasibility. Since quality and assortment characteristics constitute important information for the organization of logistics, researchers are also starting to work on energy wood marking.

SPECIFIC CHALLENGES OF THE TIMBER SUPPLY CHAIN

The German timber supply chain from the forest to the factory differs from the Scandinavian chain inasmuch as a large number of actors (forest owners, forestry operations, private forestry contractors, carriers, trucking companies, timber buyers and retailers, wood processing industry, etc.) interact. Various partners in this inhomogeneous and complex network collaborate in different processes and exchange information at a multitude of interfaces.

In addition to technical problems at the interfaces between individual actors in the timber supply chain, organizational and informational deficits in particular have an adverse effect on the economically optimized and ecologically sustainable value added of timber. Forestry operations, wood processing industry and other actors involved in the process chain plan and control their activities according to internal

50

and normally functional criteria and individual spheres of responsibility (e.g. purchasing, logistics and marketing). Interactions and influencing factors among actors and their impact on the cost effectiveness and efficiency of internal and cross-organizational processes are often disregarded (Ehrhardt et al., 2006; Wäsche, 2007; Ehrhardt et al., 2008).

Forestry logistics often faces special challenges:
- Timber and biomass properties (shape, weight and volume) as commodities,
- Harvesting with manual, semiautomatic and fully automatic methods at dispersed and constantly changing locations,
- Harvesting of heterogeneous quantities and assortments for different methods of further processing at individual locations,
- Impact of weather (harsh environment) and
- Cyclical changes of infrastructure (road restrictions, protected areas, weather).

Primary challenges for a large number of different actors involved in the process are:
- Locating (intermediate) storage sites, i.e. search times in forest and field,
- Identifying assortments for producers and buyers,
- Reconciling discrepancies in quality and quantity between data captured at the site of production and at a buyer's facilities,
- Dealing with remainders during transport,
- Minimizing losses by unauthorized transport or theft,
- Eliminating format changes in complex communication and
- Working with non-standardized interfaces.

LOGISTICS COSTS

In Germany, the timber supply chain from the forest to processing into material and energy is highly complex (Von Bodelschwing et al., 2001). The process and information flows generated by a multitude of actors and service relationships in the chain increase indirect supply costs which are usually not transparent and hence neither qualifiable nor quantifiable. As a result, indirect supply costs are frequently not entered in costing and pricing. Thus, while timber providers may be aware of the (procurement) costs of services, e.g. harvesting, skidding or transport, during their planning, they usually lack an overview of the total process costs that offset the 'value' of the timber supplied.

Consequently, decisions on timber marketing and assortment are usually only incorporate direct costs of supply and obtainable market prices but disregard other criteria and influencing factors. Hence, a holistic analysis of the expenses and costs incurred in the forest-factory supply chain in conjunction with a determination of the 'timber value' would have to incorporate direct as well as indirect costs of supply and logistics. Otherwise, it would be impossible to already optimize timber's value added economically and ecologically during harvesting.

Supply chain management methods and tools provide bases and options to analyze aspects of value added and organize the timber supply chain with emphasis on logistics. The ultimate goal is to organize the supply chain so that organizations and companies no longer reach decisions based on overall cross-organizational value added rather than on individual business interests. Supply chain management hinges on cross-organizational coordination of the material and information flows throughout the entire value added process with the goal of optimally organizing the overall process in terms of time and cost. Logistics interfaces influence the smoothness of a supply chain's operation most. The goal must be to optimize the interfaces by eliminating unnecessary activities and resource consumption at system transitions in order to optimize costs.

This is precisely where the current research at the Fraunhofer IFF in Magdeburg is eliminating the existing gaps[1]. Researchers are performing extended analyses of the actual state of the timber supply factors in Germany in correlations between actors and their expenditures, costs and logistics processes as well as related information flows with the intention of compiling a survey of influencing factors and interactions. Initial isolated cost analyses have already established that indirect costs constitute 9-13% of the total costs.

SOLUTIONS IN FORESTRY

The term ´material Internet' denotes a trend in logistics towards monitoring and evaluating the condition of mobile logistics assets in conjunction with their surroundings. Distinct marking, time-based localization and condition monitoring of goods, load carriers and handling, transport and transportation equipment as well as personnel are the prerequisites for the identification of motion sequences and local concentrations of logistics assets as the basis for internal and cross-organizational analyses of logistics processes.

Telematic and RF technologies are driving the innovation behind the development of the material Internet. Telematics combine telecommunication and computer technologies. Radio frequency identification (RFID) employs radio technologies to automatically identify and localize objects.

Information on the type, quantity, current position and condition of identifiable logistics assets and the near real-time availability of this data in expediting systems are assuming a central role in logistics. Accompanied by trends towards miniaturisation and mobility in electronic information exchange and continually dropping costs, new markets are opening for autonomous logistics assets equipped with communication modules and sensor systems which optimize company and logistics processes.

As in other industries, the use of RF and telematic technologies in cross-organizational timber development, supply and processing facilitates and benefits logistics by:

- Detecting the quality and condition of logistics assets (e.g. timber and biomass) and related job orders (harvested – stored – transported),
- Representing the secure supply chain beyond organizational and national borders (chain of custody),
- Clearly identifying logistics assets (assortments, units, staff, tools, etc.) at any point in the logistics process,
- Determining the position of logistics assets (localizability) and tracking (and tracing) them and
- Providing route guidance to logistics assets down to the last meter, even off the public roads.

These capabilities are augmented by aspects that benefit users with special needs in forestry and wood processing industries. The use of telematic and RF technologies generates the following improvements in information exchange between individual actors:

- Reliable execution of processes through:
- Increased process efficiency (eliminating format changes and multiple data acquisition),
- Invoicing reliability,
- Completeness (complete transport),
- Condition monitoring (statuses),
- Situational control (weather, protected seasons, etc.).
- Clear identification of assets (e.g. chain of custody for certification and qualification and quantification of types of ownership and lands),
- Definite localization of assets (e.g. locations, logs, storage sites, equipment, staff and transport units).

Telematic and RF success stories from retailers, logistics providers and the automotive industry have had an impact on the industry despite isolated doubts about the technologies' applicability under the conditions in forestry and wood processing industry. Reports of increased sales, reduced losses by theft, minimized search times and material losses and reliable invoicing have helped establish RFID in timber logistics processes.

RFID IN FORESTRY

In theory at least, RFID is well suited for the harsh operating conditions in forestry (Knehr, 2005; Fleisch et al., 2003; Ehrhardt et al., 2006). Since reading does not require a visual connection between the transponder and reader, dirt, ice and snow do not interfere with RFID identification. Transponder technology enables easy tracking of the whereabouts of timber in the supply chain and thus controlling the rate of loss. It should become possible to individually identify logs from a small private forest and allocate them to suppliers for bulk timber marketing. Extracting data automatically when reading RFID tags would save time and costs for data entry and thus ensure that the data is of high quality. Near real-time

transmission of information on the delivery status and geographic position of lots would provide expediters in mills an effective tool to control timber flows.

Such considerations have delivered impetus for various research projects with different objectives and focuses on specific aspects of RF use in roundwood logistics. Different projects have employed different RF transponder frequency ranges depending on the stated objectives and the desired improvements.[2]

RFID TECHNOLOGIES IN THE HIGH GRADE TIMBER PROCESS CHAIN

Prompted by the potentials of RF technology many projects have demonstrated in many domains of logistics, Cambium Forstbetriebe and the Forstliche Versuchs- und Forschungsanstalt FVA among others have initiated and completed numerous roundwood logistics projects focusing on single log marking (see Table 1).

Log Tracking System LTS

Cambium Forstbetriebe and DABAC GmbH jointly created a commercial tracking system based on Progress software for the forestry and wood processing industry's value added process. It facilitates continuous timber tracking from its original location to processing. Data is documented and supplied to the organizations involved in the process for control and invoicing. The distinctive feature of this effective solution is the high number of partners, which enabled a 1:1 distribution between providers and buyers. Processes entailing several providers and buyers or even service providers were disregarded.

Freiburg Transponder Cycle

The Forstliche Versuchs- und Forschungsanstalt FVA collaborated with the engineering firm Föller & Partner to develop an innovative marking system for roundwood based on commercial RFID systems. Their goal was transponder reusability. The RFID tags are either mechanically or manually attached to the end faces of logs with the aid of a specially developed nail. Paper making industry endorsed the practicability of this transponder mount since it is a biotech material produced from renewable raw materials. Thus, production offcuts can be marketed without sacrificing quality. The transponder itself is retrieved and, thus available again for marking.

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[2] The frequency range depends on the intended purpose (single log marking or commercial timber identification) as well as on the given boundary conditions in the process, e.g. possible or desired read ranges. In addition, the selected frequency range also co-determines transponder costs and thus becomes a factor in business decisions.

Table 1. Selected projects on RF in roundwood logistics (2008)

Project	Project emphasis	Marking method	Tag	Information system	Read method	Focus
Log Tracking System	Data manage-ment	Single log/ manual Sawmill wood	Nail (plastic)	Web-based Stand alone	Single log/ manual (terminal)	Integrated identification in every process step but 1:1 ratio between timber providers and buyers ('simple' IT solution)
Freiburg Transpon-der Cycle	RFID applicati on and shearing device	Single log/ manual sawmill wood	Disc on timber carrier (timber and plastic)	None	Single log/ manual (terminal)	Complete removal of the tags at the mill and potential reuse
Optimizati on of the Flow of Goods in the Timber Harves-ting Chain	Mechani cal tag applicati on (har-vester)	Single log/ harvester Industrial timber, sawmill wood	Smart-card (plastic)	None	Single log	Mechanical application of tags during harvesting
Wilwer-ding data Cargo GmbH	Data manage ment	One tag per deck/ manual	Smart-card (plastic)	Web-based Stand alone	Deck/ manual	Cost reduction by minimizing the number of tags on 1 deck
Indispu-table Key	System based on IAD concepts	RFID/bar code/ LNP Sawmill wood			Single log, board	Integrated identification from forest to sawmill

Indisputable Key[3]

Twenty-nine partners from five countries are collaborating on the Indisputable Key project which is developing a methodology, advanced technologies and systems for complete traceability, including standards for information transfer: The goal is to improve the use of timber and optimize forest production through the chain of transformation while minimizing environmental impacts.

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[3] For more information, see http://www.indisputablekey.com/

RFID TECHNOLOGIES IN THE INDUSTRIAL TIMBER SUPPLY CHAIN

Although the logistical problems are identical for low grade (industrial timber) and high grade assortments, RFID technology is presently only used to mark single high grade roundwood logs.

Here, too, the plastic carrier materials of the transponders in use diminish the acceptance of RF technology, particularly when they remain in the timber and thus potentially cause damage in subsequent processing in paper and pulp or MDF and particleboard industry (e.g. machine jams). A process has been developed to automatically remove tags from high grade roundwood but it is too complex and expensive for industrial timber assortments.

Since they are geared towards individual logs, all processes that identify timber in a factory (tag reading) are unsuited for low grade timber logistics (see Sect. 2.2). Single log identification is fundamentally required for industrial timber and it is ultimately too expensive as well. Buyers need to be able to identify timber on a truck at the mill to allocate a delivery of roundwood assortments to different orders and thus owners. This necessitates automatic, simultaneous bulk reading of any logs marked with RF tags. Automatic single log reading is impossible (without separating the logs) and manual methods are too labour and time consuming.

The number of logs that have to be marked during harvesting to effectively identify the origin of industrial timber at a mill (gate-based bulk reading of timber on a truck) has not yet been established. No studies have been conducted to determine the minimum detectable electronic marking per truck load for every site of origin (i.e. whether every second, fifth or tenth log has to be marked during harvesting) or the costs incurred in the process. Additionally, bulk timber marking raises another important issue: How are the quantities of data generated to be handled, i.e. who will manage the information and how? Put differently, how should the 'intelligence in timber' be managed in the process? Data processing and management that supports broad implementation of RF technology in low grade timber logistics has not been developed. Issues of integration, e.g. in internal order management systems, are unresolved and there are no methods and standards to integrate extensive RF transponder data in information systems and transmission routes, e.g. to utilize the information flow and content for machine harvesting and mill acceptance. One open issue is whether to transmit every individual RF transponder ID or an origin ID stored on several tags, e.g. an order number or a plot or subplot key. While the former entails the transmission of large quantities of data and potentially longer computing times during identification when received at a mill, the latter requires write methods to export origin ID to the tag.

The project 'Intelligent Wood' is addressing open questions related to commercial roundwood assortments in particular[4]. The project is running from 2008 through 2010 and the results, specifically their integration in IT, manufacturing and

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logistics systems as well as formulated standards, shall be transferrable to higher grade assortments.

In a partner consortium including the Fraunhofer IZM, Thüringer Landesanstalt für Wald, Jagd und Fischerei (TLWJF), metraTag GmbH, Gicon GmbH, Wahlers Forsttechnik GmbH and the Kuratorium für Waldarbeit und Forsttechnik (KWF), the Fraunhofer IFF is working in the project 'Intelligent Wood" on developing tags with (carrier) materials, which do not interfere with buyers' production processes when they remain in the timber and are simultaneously suitable for bulk reading (for roundwood identification on a truck at a mill). In addition, equipment compatible with the tags is being developed to identify the origin of roundwood on a truck at a mill by means of bulk reading (gate). The project is also researching software for the acquisition, management and exchange of RF identification data as an integral part of job order and invoice management in the timber supply chain from the forest to the factory.

The newly developed transponder and gate have so far delivered extremely promising results in the field tests for their future usability in the field. Consensus on the design of an IT solution implementable cross-industrially in Germany, including an IT infrastructure with standardized IT processes, has been more difficult to reach. One challenge of designing an IT infrastructure is the analysis of pros and cons of transponders with a unique internal ID and writeable transponders, i.e. tags that store individual data for various application scenarios and their comparison from the perspective of cost effectiveness, IT security and organization. While not yet final, the latest results of the project work have thoroughly demonstrated the expediency of the different approaches in various scenarios of timber logistics. However, transponders with a unique internal ID have proven preferable for commercial timber logistics for reasons of work, costs and organization.

The results of the project will be documented in a final report at the end of 2010.

IT TECHNOLOGIES IN THE ENERGY WOOD SUPPLY CHAIN

The depletion of such fossil fuels as coal and crude oil is making new approaches to energy recovery imperative. However, the substitution of coal and crude oil with biomass may also generate new problems. More intensive utilization could lastingly damage forests. Competition between agriculture and forestry is also critical. The utilization of residual biomass provides a promising alternative. Residual biomass logistics are challenging, though, and entail high costs. IT, telematic and marking technologies may well be implementable much as they are in the high grade and industrial timber industry. An international consortium, lead-managed by the Fraunhofer IFF has been assembled in the project Best4VarioUse to research pressing issues in the energy wood sector related to IT technologies.

Among other things, the project is:
•   Piloting methods and services that build upon regionally specific and comprehensive site and supply strategies while utilizing and adapting existing IT solutions, e.g. to optimize storage sites and transport,

- Testing and piloting solutions and methods to plan, control and monitor material flows and eliminate specific barriers to action,
- Developing ICT that identify biomass, capture it on site and attribute to logistically relevant site, quality and condition information and developing support services to plan, control and monitor the overall process chain.

OUTLOOK: THE NEED FOR STANDARDS

Information exchange between actors in forestry timber logistics is plagued by non-standardized formats and interfaces (Dietz, 2009). Deficits in information logistics largely caused by absent standards for data exchange and communication would be a prime starting point for applied research and development. Efficient IT aided supply chains could ensure that interfaces and formats are compatible and thus facilitate a smooth process flow. Ideally, all the actors involved in the supply chain would have the information relevant to them at their disposal to optimize their process flows.

No single solution in Germany let alone in Europe will be able to optimize every supply chain. A multitude of actors and different business processes demand the standardization of data exchange and communication at interfaces with the goal of developing efficient information logistics to optimize timber logistics. The achievement of this goal will entail analyzing information requirements, optimizing information flows and standardizing data exchange formats while simultaneously assuring high technical and organizational flexibility.

To this end, the Fraunhofer Institute IFF in Magdeburg is cooperating with industry partners and multipliers to develop standards for data exchange and communication. Their long-term goal is to advance standardization, keep standards up-to-date and adapt standards to the changing technical and organizational requirements.

So far, projects related to other important European standards have focused on data and exchange formats. Forestry continues to lack IT standards, e.g. for mobile equipment, interfaces or supply systems. This situation is increasingly threatening to obstruct the dissemination of IT standards. Basically caused by IT providers' market strategies, these problems will only be eliminated when the actors in timber logistics define the minimum requirements, i.e. implement technical standardization. Hence, not only data standards but also technical standards and specifications or guidelines are needed.

Not only the optimization of the material flow throughout the forestry timber supply chain but, above all, the optimization of the related information flows will also open substantial potentials for rationalization. This will necessitate extending standardization from products to information technology. Initial approaches to standardization have been devised and now have to replace the existing isolated solutions. Data formats have to be standardized for the existing basic data structures. Then, they will be transferrable to attached EDP systems and adapted for specific companies or organizations. Numerous completed projects clearly demonstrate that the standardization of information flows and related data formats will satisfy a demand and is feasible. In the future, importance will be increasingly

attached to international collaboration in the domain of logistics in general and information logistics in particular. The challenges of globalization will not be mastered in Germany or Switzerland alone. They require systems solutions that bundle resources and synergy potentials. These will only be implementable with international collaboration and the development of standards.

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