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

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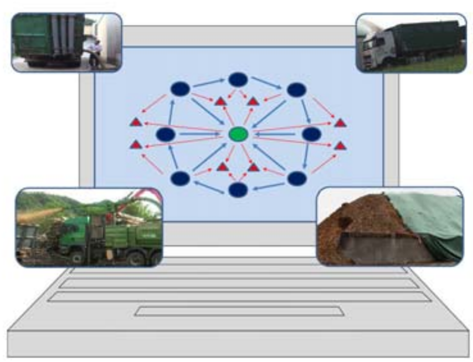
TEST BENCH MODEL FOR LOGISTICAL BUSINESS ANALYSIS D3.4



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Freiburg, December 2014

Preface

The research and development project 'Innovative and effective technology and logistics for forest residual biomass supply in the EU – INFRES' is funded by the EU through the 7th Framework Programme and is coordinated by the Finnish Forest Research Institute (Metla). INFRES aims at high efficiency and timely delivery of woody feedstock to heat, power and biorefining industries.

INFRES focuses on the development of equipment for logging and processing energy biomass, along with transportation solutions and ICT systems to manage the entire supply chain. The aim is to improve the competitiveness of forest energy by reducing fossil energy consumption and material loss throughout the supply chain. New hybrid technology is to be demonstrated in machines and new and improved cargo-space solutions are to be tested in chip trucks. Flexible fleet management systems are being 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 the entire forest energy supply chain.

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

This publication, "Test bench model for logistical business analysis", focuses on how the economic efficiency of biomass markets may be improved with the help of an online auction portal.

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Title	Test bench model for logistical business analysis
Author(s)	Taner Türkmengil, Matthias Dees, Eric Jessup, Juliana Walkiewicz and Thomas Quetri
Abstract	This report focuses on potential improvements of economic efficiency of biomass markets with the help of an online portal. An online portal provides market transparency for the location and properties of wood material piles that can be purchased for chipping. Such transparency would allow buyers to consider logistics when selecting piles for purchase. Logistical improvements in terms of chipper use optimisation and transport cost can result in lower procurement costs. This is tested in a case study for the wood chip raw material market, where two different market functioning scenarios in south-western Germany were compared: Scenario 1, a "Traditional trade scenario" reflecting the current market functioning with limited market transparency, where sellers and buyers act based on established bi-literal relations; Scenario 2, a "Trade based on transparent market scenario" with an online tool simulating full market transparency, where buyers have full information on the supply. In this second scenario, all forest owners and other material suppliers enter their offered wood piles in an internet based tool together with the geographic location and a description of basic properties. Potentially, this tool could include an auction functionality. The specific aim of the case study was to evaluate the cost savings in the supply chain network of biomass. The results reveal that up to 15% savings in truck transport costs and 30% savings in chipper relocation costs could be achieved under the conditions of the study area (namely: well developed road network and the economic and technical circumstances of 2012). The main reason for high cost savings is that the market transparency provides the bioenergy firms with complete information on available supply, giving them more flexibility in optimizing the operating costs. The results indicate that online auction portals have the potential to greatly improve the competitiveness of the market.
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1 Background

The market for alternative energy is growing throughout Europe; this also includes the wood energy market. The market for wood energy has slowly evolved from a traditional wood use in rural areas to modern wood chips and pellets technologies. In terms of market organization, foresters and forest owners have traditionally relied, and still largely do, upon their personal contacts to regional wood energy companies for wood energy material harvesting. This leads to a price formation that is not reflective of the true value of the good, since other potential buyers are excluded and the buyer cannot select piles to optimise logistics. In turn, the efficient functioning of the market is limited or constrained with respect to its main component: optimization, i.e. the minimization of supply costs (of the buyer) due to the transport costs of material and machinery. This optimization is only possible if the demand side is aware of the location and offer price of all material on the market and if adequate market prices are established. It also relies on market participants accepting to use tools that allow such transparency.

As the successful process of price discovery is mainly dependent on the numbers of market participants and their access to available market information concerning the goods being traded, one potential remedy for this market inefficiency in the wood chip production sector is the use of a web based **Supply portal** that provides full information on the supply to all buyers of wood piles (the biomass storage of material to be chipped at roadside landings). Based on the increased transparency achieved by such a system, potential buyers can select the offers with piles that allow a minimization of logistical costs since the piles chosen are, for example, closer to their facilities, closer to their customers, or spatially grouped in clusters. This reduction has three dimensions when considering:

- Chipper relocation between landings (or roadside storages)
- Transportation of chipped material from forest to customer
- Transportation of chipped material from forest to the buyer's terminal area and later to the customer

Such systems can address large regions or can be implemented for dedicated regional markets only. In addition, such systems can also include the functionality of a **Sales portal / Auction portal** that may be based on auction or other price and sales approaches. However, to achieve the efficiency gains of reduced travelling distances and time that are possible via the transparency of the supply, this functionality is not necessary.

Besides the cost benefit via optimized chipping and transport logistics, further benefits may be achieved for the market participants, including:

Buyers:

- Less time spent inspecting the wood piles (time and fuel costs)
- More options available, resulting in a significant reduction in costs of operation and reflected in the capacity to pay for the raw material
- Allows greater selection differentiation based on price attributes that are valued in the market; this information is now made available to the seller who can alter how the stacks are created and the attributes associated with each
- Significant improvements in the coordination of activities related to:

    - Mobile wood chipper and truck scheduling and allocation
    - Truck travel costs
- Improve the overall economic performance by considering all aspects mentioned above

Sellers:

- Depending on the region, it could bring many more buyers to the market and thereby expand the market
- Less time spent finding buyers
- Contribute to an achievement of higher prices
- Reduce the cost for sanitary measures (bark beetle infected material)
- Improve the overall economic situation of the enterprise by considering all aspects mentioned above

The authors of this report claim that the costs resulting from the described situation are large, especially the loss due to disorganization when measured at the market level and across a broad geographical level, which ultimately limits the market for wood energy throughout Europe. This report offers an alternative and illustrates the impact of the market inefficiency through the development of an optimization model that characterizes both biomass flows, given existing “relationship” based price discovery and that of an “online” auction. This is developed from data of existing bioenergy firms operating in southern Germany.

2 Methods and data collection

2.1 Compared trading alternatives and technical study objective

In the study, two scenarios are compared:

Scenario 1: "Traditional trade scenario" - Current market functioning with limited market transparency

Sellers and buyers act based on established bi-literal relations and the market overview on wood piles on the market is limited to all market participants.

Scenario 2: "Trade based on transparent market" - Online tool based on full market transparency

Trade is based on a transparent market. Buyers have full information on the supply since all forest owners and other material suppliers enter their offers in an internet based tool together with the geographic location and a description of basic properties. This tool could include an auction functionality.

Analysed aspects:

Overall price for chipping and transport in both situations and their difference.

2.2 Methods

In the simulation, studies methodologies from operations research are applied for the following two optimisation issues: the transshipment problem and travelling salesman problem (Winston 2004).

Transshipment problems are defined as satisfying the demands of customers in the least costly way. In a transshipment problem, shipments are allowed between supply points and transshipment points and between transshipment points and demand points, whereas in transportation problems the shipments are allowed between supply points and demand points.

In the simulation studies performed, energy wood storages are defined as supply points, the bioenergy firms as transshipment points and the final wood chip customers as demand points. As Figure 1 indicates, shipments in the model occur either from energy wood storage directly to the final wood chip customer or from energy wood storage to the final wood chip customer via the bioenergy firm, according to the demand requirement of the customers. Small sized customers require dried wood chips; that is the reason for chips to be transferred to the bioenergy firm first, in order to be dried, either naturally or artificially. In contrast, the large sized customers, such as major heat plants, can also use the non-dried chips and can, as a result, use chips directly from the energy wood pile. Thus, two general transport schemes apply (Figure 1).

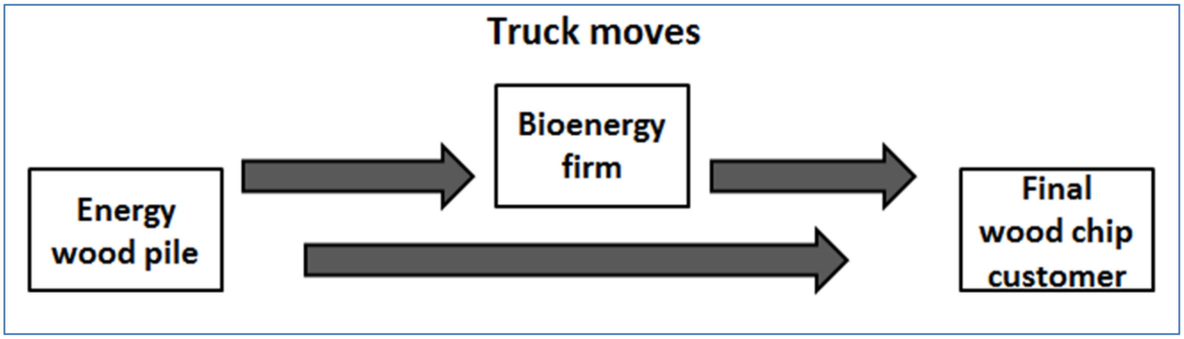

Figure 1. Truck movement simulation; the transshipment problem.

Travelling salesman problems are defined as visiting all the demand points in a one complete tour in the least costly way. In the travelling salesman problem, the agent begins travelling from the origin point, visits the demand points, and returns to the starting point.

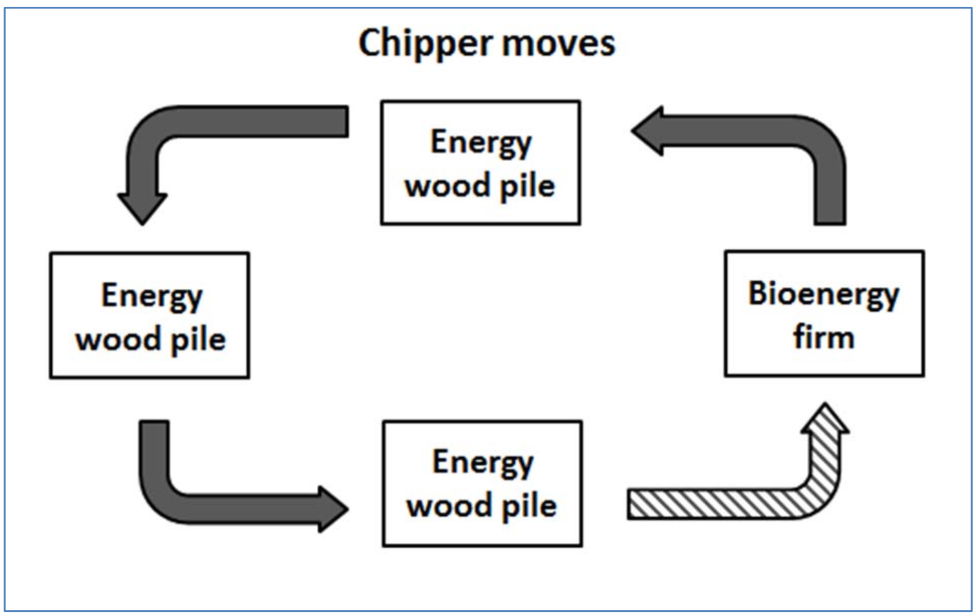

Figure 2. Chipper movement simulation; the travelling salesman problem.

In the model, the agent is assumed to be the bioenergy firm's chipper. The chipper starts travelling from the bioenergy firm, moves along the selected supply points (energy wood piles), chips the energy wood pile and moves to another supply point. At the end of the simulation, the chipper moves back to the bioenergy firm, thus completing the tour (Figure 2).

The simulation is encoded in GAMS (General Algebraic Modelling System) and is solved via the mixed integer programming approach. The distance information, as well as the time to travel information between each supply point, customer and firm, is calculated in ArcGis.

2.3 Data collection and scenario details

The simulation models were developed to represent real-world conditions in south-western

Germany. Three bioenergy firms are located in the model; they are based on characteristics consistent with currently operating wood energy firms. For the traditional trade scenario, supply points and the customers of the bioenergy firms are located in their certain proximity. Figure 3 below represents the three bioenergy firms, their supply regions and their respective supply points in the simulation models.

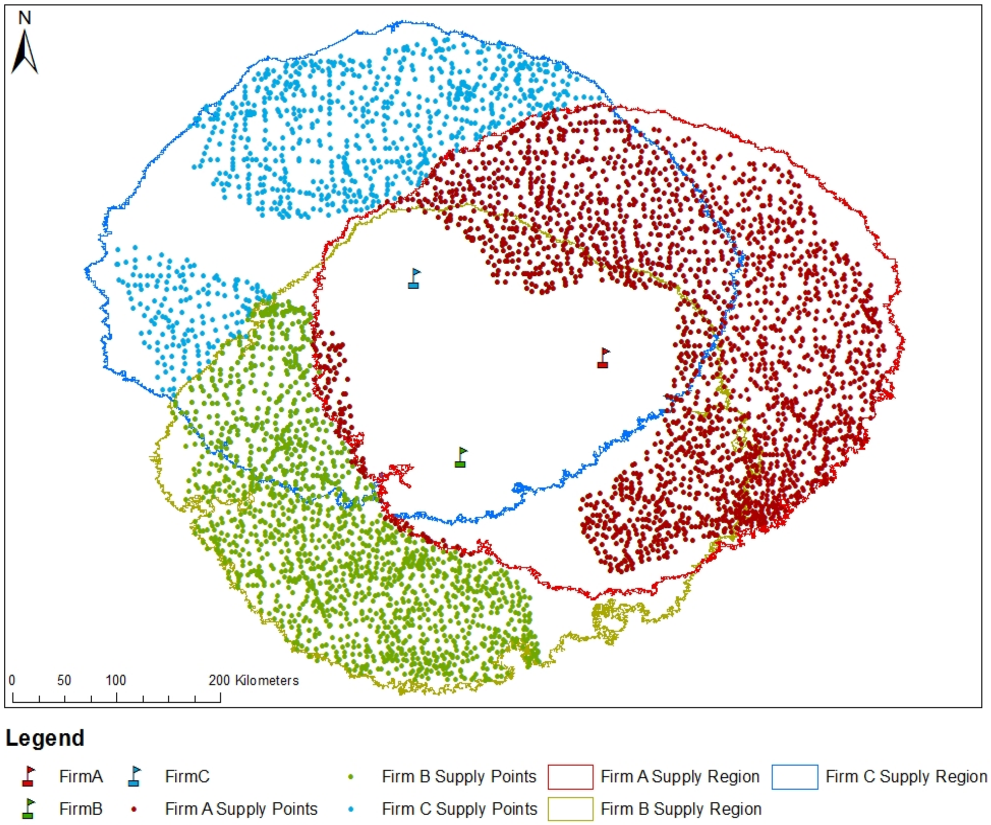

Figure 3. Supply points and supply regions of the bioenergy firms.

In the second scenario, the “trade based on transparent market”, the bioenergy firms are assumed to have the same market power and the same number of suppliers and customers. Each bioenergy firm has 20 small sized customers, respectively, and one large heat plant is served by all the three bioenergy firms. Figure 4 below represents the bioenergy firms and their customers; red points represent the customers of firm A, green points represent the customers of firm B and blue points represent the customers of firm C. The large heat plant is also shown in Figure 4, represented by the sign “H”.

A local bioenergy firm assisted with the development of the test data set. Suppliers and customers are located in the respective operating region of firms A, B and C. The information on distances originates from the interviews with the local bioenergy firm. Subsequently, location IDs in the model were created in ArcGIS, as well as the distance to and from each supply point and firm and customer. It was assumed that the two other primary bioenergy firms had similar operations.

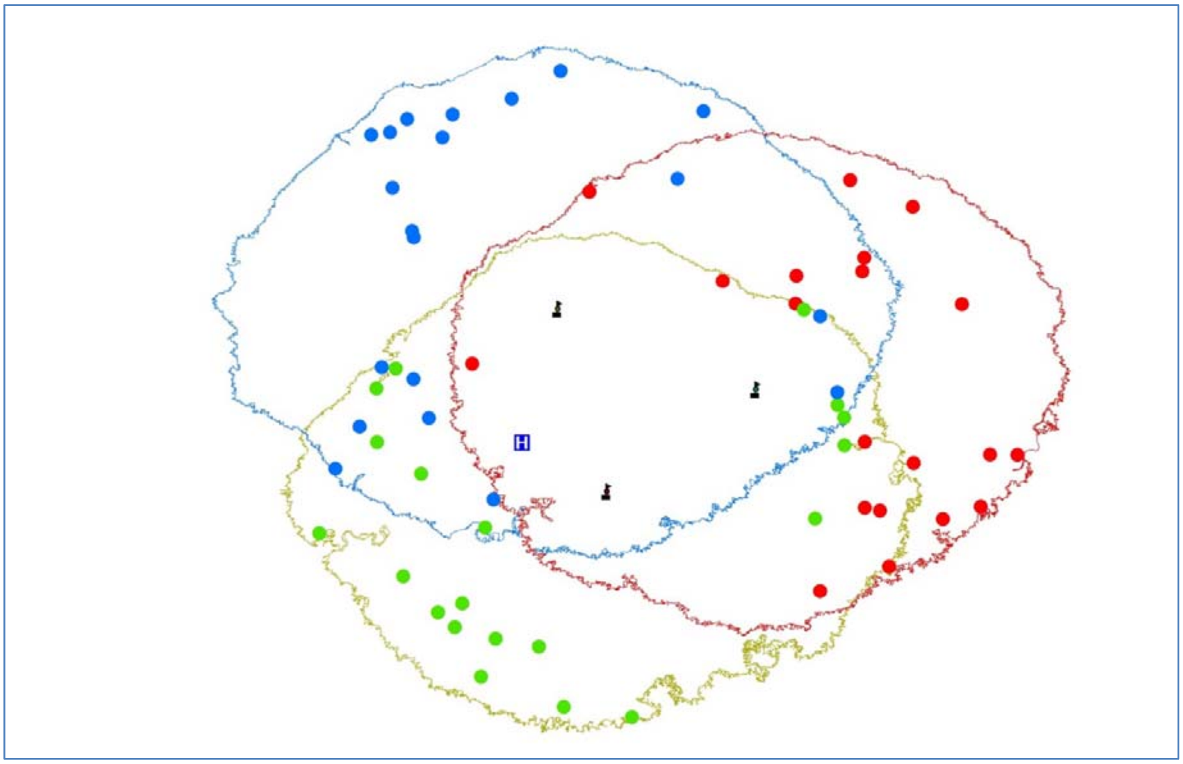

Figure 4. Customers of the bioenergy firms.

The monthly supply and demand amounts were also acquired through the interviews with the local bioenergy firm. They are based on: the total volume that the firm handles every month; how much of that volume goes to the heat plant and to the other customers; and a typical supply amount at each location. The seasonality effect was also considered when determining the monthly supply and demand amounts, again based on the information from the local bioenergy firm. The cost parameters used in both models, such as chipping cost per cubic meter, vehicle operating cost per km travelled and labour cost per hour, were obtained from a local bioenergy firm and reflect the economic and technical conditions in southern Germany, Upper Rhine Valley in 2012 (Table 1).

Table 1. Cost parameters used in simulation studies and the respective values.

Cost parameters	Value
Fuel cost and labor cost for chipping (per m³ chipped volume)	5.689 €/m^3
Chipper relocation cost (fuel)	0.81 €/km
Chipper relocation cost (labour)	26.16 €/hr
Divert truck transport cost (fuel)	0.96 €/km
Divert truck transport cost (labour)	26.16 €/hr
Backhaul truck transport cost (fuel)	0.81 €/km
Backhaul truck transport cost (labour)	26.16 €/hr

Two scenarios were created in the simulation model, one for the current market functioning in the region, where each firm has a limited number of supply points per each month and predetermined number of customers with their monthly demands. In this scenario, firms try to optimize their total operating costs given available supply. The second scenario represents transparency as given in online auction model, where the firms have the complete information of the available supply in that particular month, giving the firms more flexibility on optimizing their operations.

In both simulation models, three bioenergy firms are simulated. Each firm has the same number of supply points and the same number of customers. With their trucks and chippers, firms can collect piles from supply points and either bring them to the firm, or directly transport to final customers, if that customer is a heat plant.

Three main constraints are considered in the simulation models. The demand constraint states that the monthly demand amount of every customer of the three bioenergy energy firm must be satisfied. According to the supply constraint, the shipments from every supply point cannot exceed the available monthly supply amount of that supply point. As for the final constraint; the amount of shipments arriving to each bioenergy firm for every month should be exactly equal to the shipments departing from each bioenergy firm for every month.

Operation costs consist of chipping cost, chipper relocation cost and truck transport cost.

3 Results

A comparison of the truck transport costs, chipper relocation costs and the total costs for the two scenarios is displayed below.

Table 2. Truck transport cost per cubic meter chipped volume (in €) for the two simulation scenarios.

Month	Current market functioning (in €)	Online auction model (in €)	Percentage savings (%)
1	0.62	0.54	13.72
2	0.50	0.43	14.28
3	0.53	0.48	10.17
4	0.54	0.50	8.15
5	0.53	0.50	6.48
6	0.80	0.72	10.16
7	0.74	0.71	3.95
8	0.77	0.76	1.37
9	0.56	0.49	11.84
10	0.51	0.44	13.23
11	0.53	0.46	12.20
12	0.55	0.48	12.23
Average	0.60	0.54	10.00

Table 3. Chipper relocation cost per cubic meter chipped volume (in €) for the two simulation scenarios.

Month	Current market functioning (in €)	Online auction model (in €)	Percentage savings (%)
1	0.16	0.13	13.42
2	0.14	0.10	23.36
3	0.14	0.12	12.17
4	0.16	0.15	4.73
5	0.18	0.13	29.77
6	0.22	0.17	21.55
7	0.21	0.20	4.29
8	0.23	0.22	1.62
9	0.15	0.11	27.11
10	0.15	0.12	18.66
11	0.15	0.12	18.98
12	0.13	0.12	12.32
Average	0.17	0.14	17.65

The chipping cost per cubic meter is taken to be the same in both scenarios, 5.689 Euro per cubic meter, since the amount that is chipped for each month is exactly equal to the sum of the customer demands per month and the customer demand between the scenarios does not change.

Table 4. Total logistic costs per cubic meter chipped volume for the two simulation scenarios.

Month	Current market functioning	Online auction model
1	6.47 €	6.36 €
2	6.33 €	6.22 €
3	6.36 €	6.29 €
4	6.39 €	6.34 €
5	6.40 €	6.31 €
6	6.71 €	6.58 €
7	6.64 €	6.60 €
8	6.69 €	6.68 €
9	6.40 €	6.29 €
10	6.35 €	6.25 €
11	6.36 €	6.27 €
12	6.37 €	6.29 €
Average	6.46 €	6.37 €

It was found that with transparency, as given in online auction model, each firm has an increased set of supply points, many of which are closer and more optimal for their operations. Hence, this reduces the miles travelled for chip trucks and minimizes the chipper relocation, yielding a minimized total cost for each firm.

In the case studies, up to 15% savings on truck transport cost per cubic meter occur when an online portal is introduced to the test market, providing the bioenergy firm access to the entire available supply. Savings on truck transport cost observed are 10% on average, with an increase in winter months as supply in the market increases, giving more flexibility to the bioenergy firms to minimize their truck transport costs. Furthermore, case study results show that an online auction can produce up to 30% savings, 18% on average, on chipper relocation cost per cubic meter. Similar to the savings on truck transport cost, the savings on chipper relocation cost is observed to increase in winter months, when the overall supply increase and the bioenergy firms are able to choose more efficient supply points for their operations.

4 Discussion and Conclusions

The special aspects analysed in this report are cost reduction opportunities achieved by logistic optimisations via a **Supply portal**, as well via a **Sales portal / Auction portal for woody biomass for chipping.** General economic advantages that can be achieved via online auctions are described, for example, by Bajari, and Hortacsu 2004. Online auctions for raw wood from forests are already well established in many countries (Martin 2009, Kingsbury et al. 2011, Farina et al. 2013). However, in the majority of cases these portals do not yet explicitly consider the location in geo-coordinates and/or do not include low price material, i.e. the wood to be chipped. With the current study we show that an economic advantage based on logistic optimisations could be one incentive to establish such systems.

The comparison of the two scenarios shows a substantial cost reduction effect due to logistical efficiency gains. Such efficiency gains and cost-reductions can be achieved simply by greater market transparency on the supply side, since all the bioenergy firms then have complete information on available supply. In the online auction model, each firm faces an increased set of suppliers, many of which are closer and more optimal for their operations. Hence, this reduces the distance travelled for chip trucks and minimizes the chipper relocation giving a minimized total cost for each firm.

Online auction portals can also bring about more adequate market prices for both sellers and buyers in the markets, by revealing the true value of the piles according to its properties. Hence, portals would eliminate the undervaluation of the piles in the summer months, where the demand for the piles is low, as well as the overvaluation of the piles in the winter months, where the demand for the piles is higher.

It can also be mentioned that the percentage of savings on operating costs highly depends on the supply base of the first scenario. It may also be the case that some firms do not change their supplier selection much, since their optimal suppliers are already selected in the first scenario.

It should be noted that the results represent the case study region. Other case study regions, where the number of bioenergy firms and their market power differ, can yield different results and, hence, savings. Different demand and supply data used in the simulation can also influence the results. It should also be noted that the cost levels here only include the labor and fuel costs. Capital and maintenance costs together with insurances and management costs were assumed to be the same in both scenarios and thus omitted in the analysis.

It can be concluded that the establishment of online auction portals has the potential to greatly improve the competitiveness of biomass, bringing about cost reductions in logistical means, improved marketing transparency and, hence, more adequate market prices for piles.

The efficiency gains that can be realized with a real system will depend largely on the degree of the participation of all market participants and on their capability to identify the theoretically optimal price.

For the practical introduction of a **Trade portal** (may it be a **Supply portal** or an **Auction portal**) it would be necessary to analyse the

- Acceptance of market participants for such a system

- Acceptance with / without sales functionality
- System costs and system financing
- Portal organizing institution

Practically, an online trade portal should have the following features, amongst others:

- A digital map/geographic information system where suppliers can provide information on the location, quantity, quality (species, size, etc.) and temporal and physical accessibility of the material they offer, separate for each location, and including their contact details
- A map with an adequate geo-referencing system and adequate map background (e.g. a topographic map and/or aerial ortho-images and/or road network data)
- A data base for the supply data with import and export functionalities
- A functionality that enable all sellers the entry of data on each new wood piles that they offer
- A functionality that erases all wood piles following sale
- A functionality that allows a transparent overview of all data on the market for buyers
- An export function for all buyers that enables them to import the data into their internal system to identify optimized price offers for the single piles
- If required to achieve acceptance, a functionality that partly restricts the accessibility of information

The adequate solution may differ from region to region depending on the forest ownership structure and further structural properties.

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