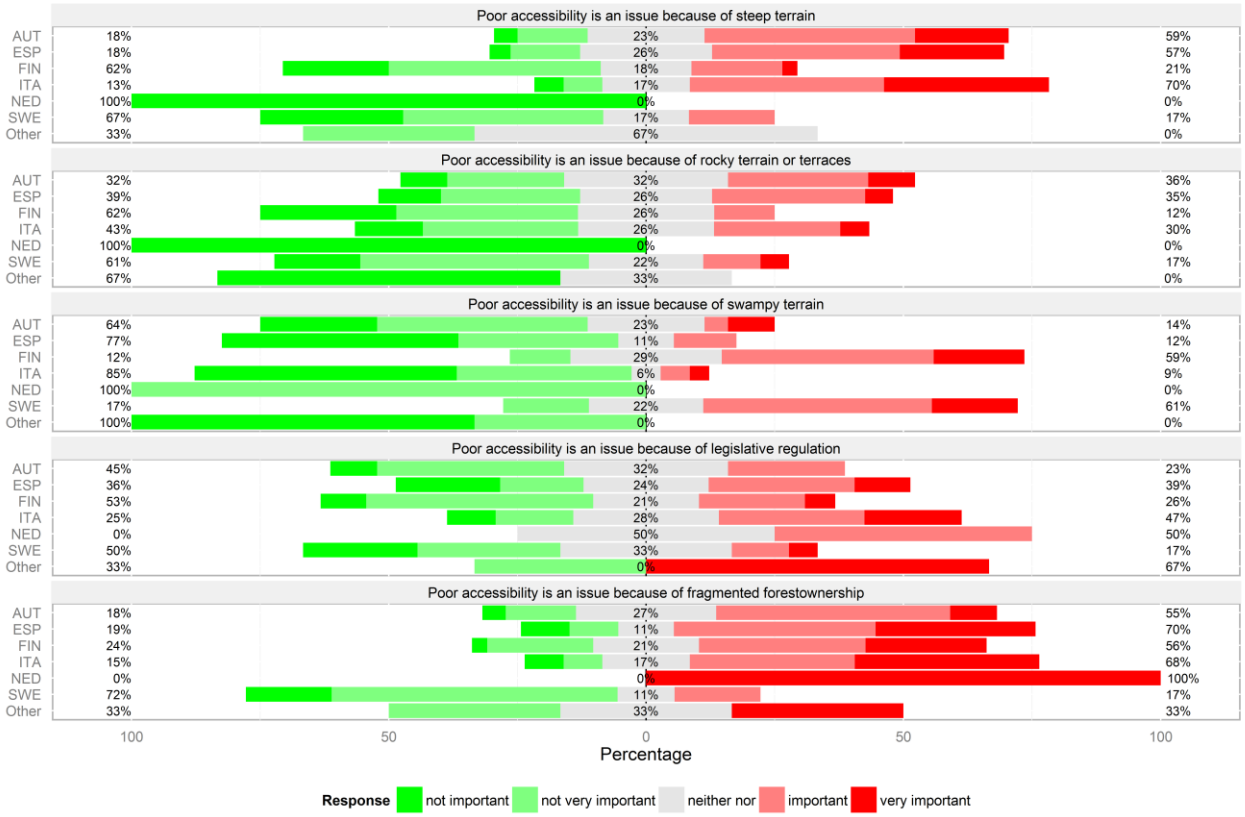
Supply chain performance and re-engineering

A supply chain network is a complex system of processes and related material flows. In case of the fuel wood supply chain, processes include harvesting in the forest, extraction to the forest road, comminution either at the forest road, a landing or at the heating/power plant and finally a transport process, whereas the material flow includes wood in different states of conversion. The cost efficiency of fuel wood supply can be hampered by bottlenecks all along the chain from the forest to the plant. Further, the decision on which supply chain to employ is often complicated and puzzling. Lastly, in a bigger context, where to locate storage areas and how to arrange the supply chain network on regional level, also in terms of minimized greenhouse gas (GHG) emissions, is a particular challenge. In order to address these issues, INFRES, by collaboration of research institutions on European level, conducted a study on bottlenecks in the fuel wood supply chain, developed an easy to use tool for comparing supply chains and a model for solving the multi-criteria optimization problem of profit maximization and GHG emissions minimization through decisions about chipping location, transport mode and volume and terminals used.

Bottlenecks in the fuel wood supply chain

From August 2013 to February 2014, an online-survey on bottlenecks in the fuel supply chain was conducted. In total, 206 questionnaires were returned fully filled from participants from Spain, Italy, Finland, Austria, Sweden, the Netherlands, Poland and Romania. Participant's organization types included entrepreneurs, administrational bodies, research institutes, forest owners, universities, interested representatives, machine manufacturers and energy industry, as well as other forestry related services like IT service providers, sawmills, training facilities, media and consultants etc. All bottlenecks were categorized and analysed both on country and organization level.

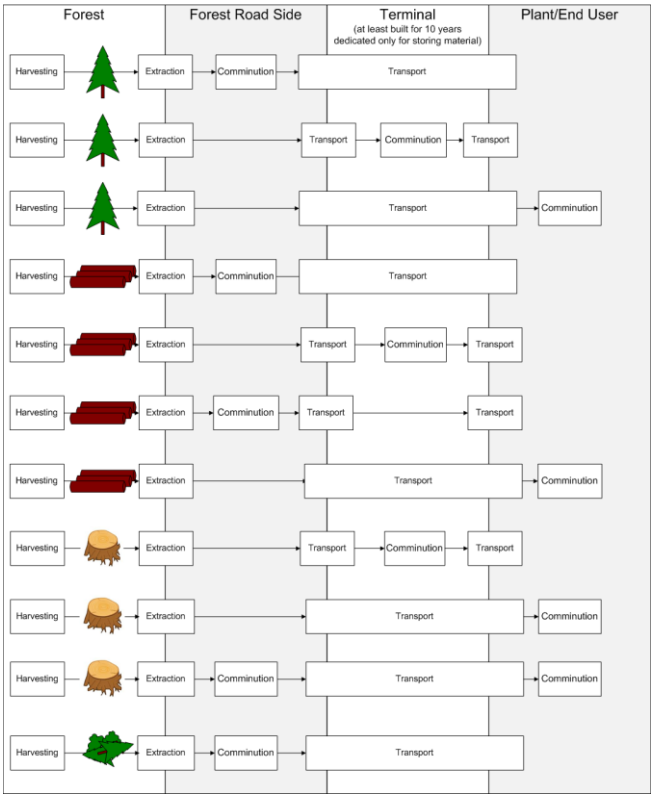


Example graph of bottlenecks analysis output. Responses are displayed by quantity and sums for the subsets "not important or not very important" (green and light green), "neither nor" (grey) and "important and very important" (light red and red) are displayed.

The study's respondents are most concerned about transport related issues, like long transport distances and cost-ineffective transport. Low load capacity of trucks is an issue in Austria and Spain, where the legal gross vehicle weight limit is below the Finnish and Swedish one. As expected, terrain and climate related issues differ according to the topography of the respondents countries. Whereas Austrian, Italian and Spanish respondents are concerned about steep terrain, Finnish and Swedish concerns emphasize on inaccessibility due to swampy terrain. A common European bottleneck is a lack of landings, landing space and storing places for drying and processing of fuel wood. A lack of market for fuel wood and the lack of solid and steady demand are issues very important to the respondents. Subsidy related issues didn't make the European top ten, but where a widely discussed topic in the comments from Finnish, Italian and Spanish respondents. In contrast to northern Europe, where operator's training is much more institutionalized, Austrian, Italian and Spanish respondents report a lack of experienced personnel for operating state of the art harvesting technology. In southern Europe a lack of suitable and modern equipment is an issue too.

Bottlenecks in the fuel wood supply chain are manifold, often related to the countries topography and climate, ownership structure, legal system and forest culture. In total, the number of bottlenecks encountered is larger and much more diverse than expected. Therefore there are no all-purpose solutions. It can be concluded that transport, instable demand and lacking or poorly organized market and fragmented forest ownership are the common European bottlenecks, even if they cause different problems in different countries. Solutions for these problems can only be a combination of technological improvements, adaptions in the legal framework and policies in terms of subsidies and wood mobilization measures and raising public awareness for forest utilization.

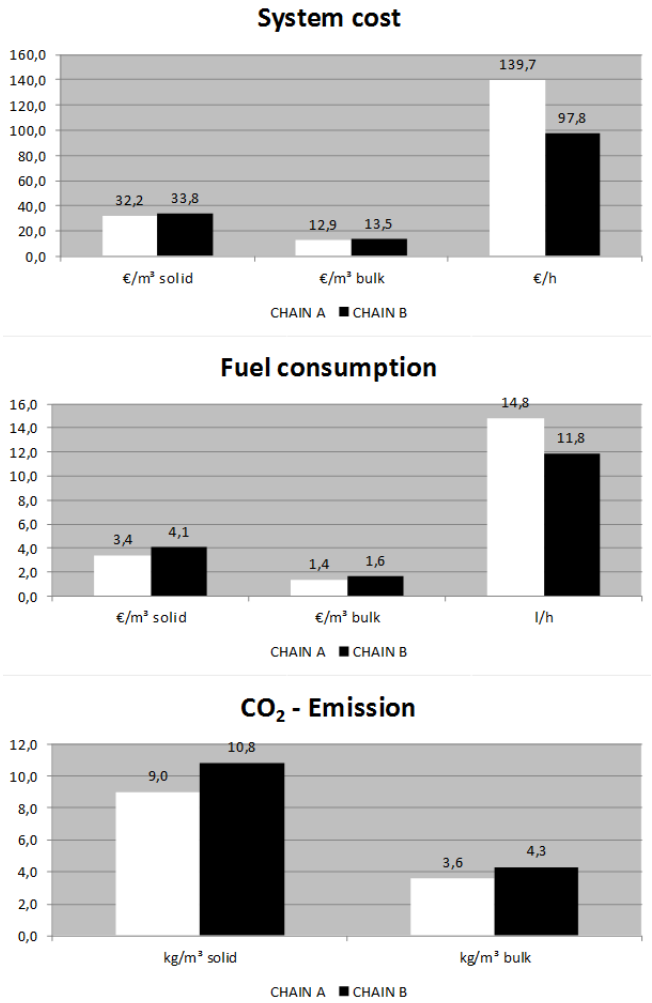
Fuel wood supply chain comparison



Abstracted fuel wood supply chains, taking into account location and material type.

Systems engineering is an approach that displays material flows of processes, which can be either positive (commodity flow) or negative (sink flow). In case of a fuel wood supply chain, commodity is wood and sinks are fuel, manpower etc. These flows are displayed as a system of linear equations which is then solved by means of a quadratic matrix to provide a unique solution. This approach can be employed to help an entrepreneur to decide on which supply chain to choose for a certain operation. Therefore an easy and universally applicable tool for comparing different supply chain options – e.g. current and possible future ones – is necessary.

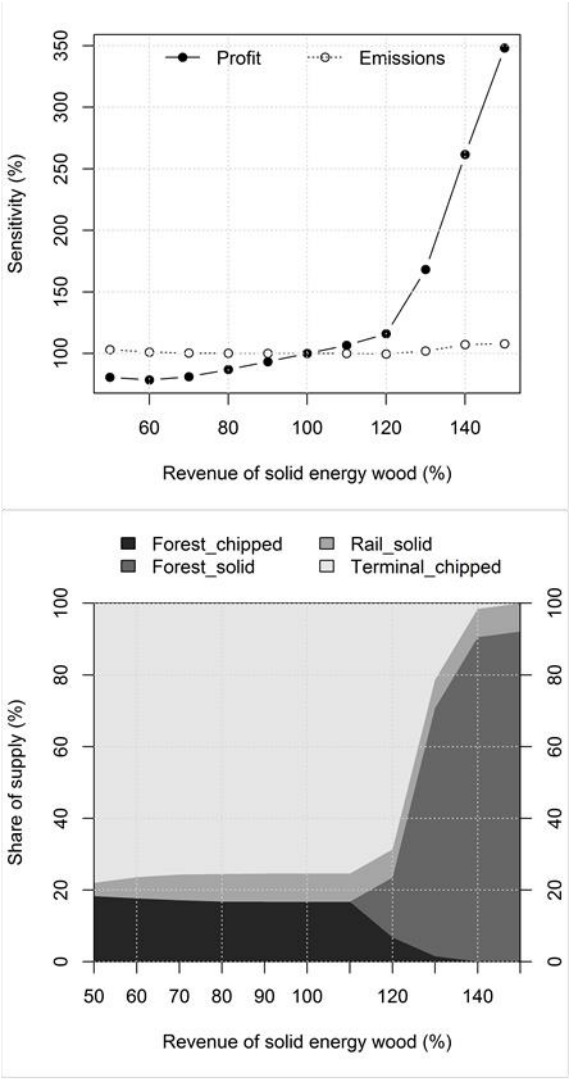
From process maps sketched during an European expert's workshop, 11 supply chain options for four source material types (stumps, whole trees, stems, logging residues) were abstracted. The developed Excel© –tool comprises of three main blocks, for which data is needed: first, productivity of the processes (output), second, their fuel consumption (input), and finally their costs (input). Then the working time per day, the delay share, personnel costs and fuel costs have to be specified. Finally the desired work load is specified. This calculation can be done pairwise, so that two supply chains can be compared. The output of the calculation includes total system cost (€), fuel consumption (l) and CO_2 – emissions (kg) per m³ solid and bulk volume, as well as per hour, both as table and graph. Finally the working hours (h) and days (d) are displayed.



Example graphical output of the developed supply chain comparison tool. Supply chains can be compared in terms of costs, fuel consumption and CO_2 emissions.

Current fuel wood supply chains can be easily mapped by focusing on processes and where they are carried out. When taking a look at the abstracted supply chains, one can see that it's basically a question of where the conversion from the original fuel wood material (stumps, stems, whole trees or residues) to chips takes places. Means and productivity of transport are closely related to this fact. The developed tool for comparing supply chains is open for any adaption according to the user's interest and could be improved by more detailed procedures for deducting the input parameters. Equipped with proper flexibility in order to fit to any conditions that may occur, the developed scheme is a useful tool for a rough pre-estimation and comparison of supply cost, required time and emissions of different supply chain options.

Supply chain optimization on regional level



Pareto analysis for a regional fuel wood supply network. Sensitivity of the profit and the emissions against a changing revenue of solid energy wood delivered to the plants (top) and sensitivity analysis of the share of supply in terms of changing revenue for solid energy wood (bottom).

The replacement of fossil fuels with forest biomass should help mitigate Greenhouse Gas (GHG) emissions. However the supply of energy wood is challenging because of high supply costs and rapidly increasing demand. A multi-criteria optimization problem (MOP) has been formulated, whereby the profit must be maximized and the GHG emissions have to be minimized. The objective function includes decisions about chipping location, transport mode and volume and terminals used. To solve the MOP, the weighted sum scalarization approach was used to derive Pareto optimal points by stepwise changing weights from maximum profit to minimal GHG emissions.

For demonstration, the MOP was applied to a large-scale network of approximately 10,000 sources, 356 storage locations, 119 freight stations and 228 sinks with a demand of 700,000 dry tons per year. In an effort to minimize GHG emissions, 30% of the woody biomass should be chipped at the terminals, about 50% directly in the forest and the rest at the plant, which results in emissions of 24.3 kg CO_2/ton and a profit of 3.0 €/ton. If the profit should be maximized, GHG emissions will only increase by 4.5%, whereas the profit more than doubles from 3.0 to 7.4 €/ton. Decreasing moisture content (M) will increase the profit noticeable. Decreasing M from 40 to 30% will double the profit from 5.10 €/ton to 12.00 EUR/ton. If revenues are stable and independent from M, a profit increase from 6.00 €/ton at a M of 40% to 10.00 €/ton at a moisture content (M) of 30% can be observed. Emissions decrease with a decreasing M is less prominent compared to the profit (4%) of the CO_2 emissions per dry t.

For more information and sources, please read the full report "Full supply chain performance and re-engineering report" available at www.infres.eu. The supply chain comparison spreadsheet is also available on the website.

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INFRES Newsletter 8 l March 2015

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