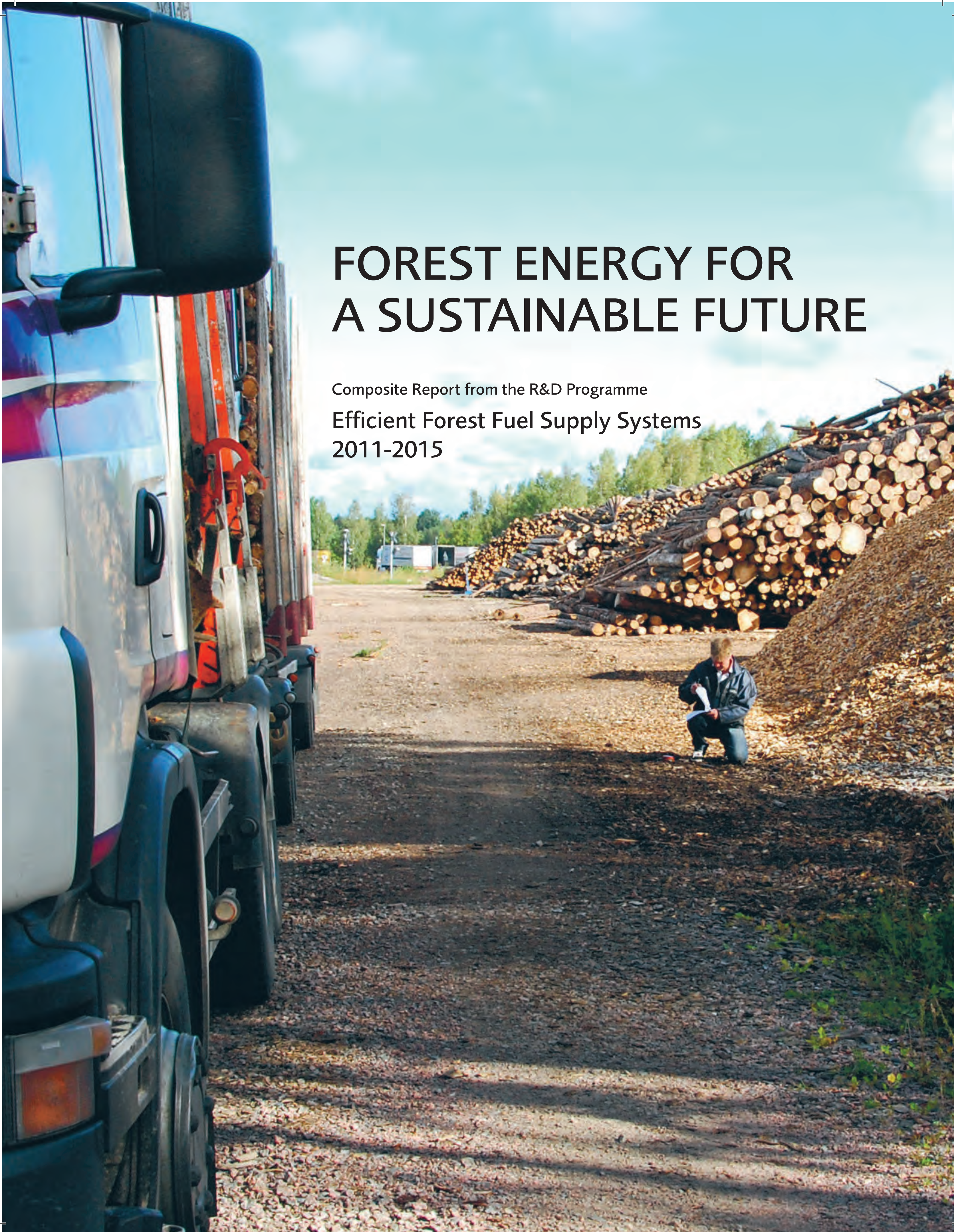


FOREST ENERGY FOR A SUSTAINABLE FUTURE

Composite Report from the R&D Programme

Efficient Forest Fuel Supply Systems 2011-2015

Transport accounts for nearly 30 percent of the costs of handling forest fuel up to the point of delivery to the end customer. Since a landowner's net income from forest fuels is, at best, low, reducing transport costs can increase the viability of harvesting forest fuel in much of Sweden, and also increase the use of renewable energy. However, if this is to be attained, the entire logistics chain must be efficient.

FOREST FUEL LOGISTICS
– EFFICIENT TRANSPORTS

Johanna Enström, Skogforsk

Forest fuel logistics covers everything from technical issues like side shields when transporting partly delimbed energy wood to complex issues like location bartering and transport management. Terminals and storage also affect both costs and product quality. All parties involved in logistics and storage must collaborate in the work to improve technology, methods and logistical tools.

Higher payloads

Three 74-tonne chip trucks have been studied in the ESS programme. The vehicles are also part of the ETT (One More Stack) project, and all three vehicles were commissioned in 2014. They are 25.25-metre side-tipping truck and trailer combinations that hold approximately 150 m3 and have a legal payload of almost 50 tonnes. The potential fuel saving for 74-tonne trucks is 10-13 percent compared with conventional 60-tonne vehicles. To realise this potential, a high load utilisation is needed, which has been attained so far. The next stage is to lengthen one of the chip trucks to 33.7 m (gross weight 98 tonnes) by connecting a link between the truck and trailer. A new research project to test and evaluate this is under way.

In addition to these three chip trucks, a chipper truck system is being tested in which a 32-tonne chipper truck with a 42-tonne trailer works in collaboration with a 74-tonne chip truck configured as above. Trailers are exchanged at the landing, so the chipper truck is mainly used for chipping, with only occasional trips to heating plants, while the chip truck does most of the transport. Compared to a conventional chipper truck, the increased gross weight enables the use of a powerful chipper on the truck, without sacrificing any transport capacity because of the larger trailer.


MVB
MVB

Chipping with a 74-tonne rig.

Up to now, permits have only been issued for heavier trucks in research projects, but the Swedish Government is monitoring developments and, as a first step, a 64-tonne gross weight has been permitted since 1 June 2015.

The issue of gross vehicle weights is under discussion in many parts of the world. In southern Europe, there is opposition to large trucks, but even there the issue is being discussed. Examples of countries that have recently increased gross vehicle weights are Norway (60 tonnes) and Finland (76 tonnes), and 60-tonne vehicles are also being tested in the Netherlands, Germany and Denmark.

Side shields for safe transport of partly delimbed energy wood

Tree sections and partly delimbed energy wood present a challenge for transport. These assortments make it difficult to attain a high payload, and material can fall off if an ordinary timber truck with stakes is used. As a possible solution, light metal side shields were tested; these could be easily fitted to and removed from the stakes on a timber truck.

The shields did not increase payloads, but road safety was improved. As loading and load securing proved to be faster with the side shields, the conclusion was that their use was worthwhile over short transport distances.

Bartering of forest fuel

Today, forestry companies commonly barter pulpwood and timber, to match supplies with customer requirements and reduce transport distance. As yet, the practice has not been so common for forest fuel, but a simulation of the supply in Mälardalen has shown great potential. Average transport distance could be reduced by 3-15 percent if companies could freely barter forest fuel with one another. One obstacle is that it is difficult to objectively describe the value and quality of the stored forest fuel assortments – the parties know what they have but not what they will receive.

System optimisation

In order to simplify the choice of system for comminution and transport, a web-based analysis tool, Opium, has been developed by Creative Optimization Sweden AB. In the tool, the user selects point of delivery, terminals available for load transfer and onward transport, and sees which assortments and comminution and transport systems are available. The optimal system selection and destination of the forest fuel is presented simply and clearly on a map. The tool is free to use, and is available from http://opium.creativeoptimization.se/

Intermodal transports

A major project run at the University of Gothenburg has examined the possibilities for intermodal transports of biofuel, i.e. transport using the same container on both truck and train; this can also apply to ship transport. No economic gains were found when handling biofuel in the same container from forest to industry gate using trucks and trains. However, the study did show the importance of choosing the right terminal to create a successful transport chain and minimising the number of handling stages in a supply chain that includes both road and rail transport.

Karttunen et al. (2013) are more positive about the possibility of transporting forest fuel in a single load carrier. However, the study is based on an innovation, a composite container with associated unloading rig, which is not yet on the market. The composite container has been shown to effectively prevent the chips from freezing to the floor and walls of the container, which is otherwise a problem when the material is stored in a container for some time.

The problem of chips freezing to container walls during transports on trucks has also been examined in the ESS programme, but no clear answer could be found about how to treat the containers to prevent the problem. Today, most chip trucks and chip trailers have composite floors and walls, as this reduces the kerb weight of the vehicle. As a side effect there is no problem with chips freezing on to either the floor or the walls. As the same materials are used in composite containers, introducing this type of container could improve transports if they can be made durable enough.

Terminals

Correct location is the most critical factor for a successful forest fuel terminal, according to an interview study. Terminals, particularly railway terminals, must be sited in areas where large volumes of fuel are produced, and a location near the forest also allows the terminal to be placed away from built-up areas. High material turnover is also important, and good measurement facilities. Service, flexibility, skills, orderly layout, and smooth-running terminal logistics were also emphasised as strengths.

A company owning its own terminal can have a competitive advantage, but a commercial terminal may be more cost effective because of coordination gains, such as increased use of measurement facilities and the possibility of return loads.

A geographical analysis showed that 95 percent of Sweden's logging residue and stump volumes is located within the catchment areas of existing terminals, and 65 percent is within the catchment area of existing railway terminals. Many catchment areas overlap, suggesting there are too many terminals in some parts of the country, while other parts of the country lack terminals.

Approximately 30 percent of forest fuel in Sweden passes through some kind of terminal. Many terminals are small, and over half the volume passes through terminals that are smaller than two hectares. Standardised measurement takes place at only half of these small terminals, and at even fewer of the medium-sized terminals. This is a challenge for the sector now that the new Swedish Timber Measurement Act has come into effect.

Storage

Storing chips at a terminal entails a risk that the chipped material can become remoistened and biomass may also be lost. Another risk is fire because of heat generation. The risks increase as the proportion of fine fractions increases, so it is important not to comminute the chips into finer fractions than necessary.

The irregular demand for forest fuels results in an uneven utilisation of comminution equipment, which increases costs. Efficient storage of chips could be a way to even out machine utilisation, thereby reducing comminution costs. A study examined whether covering piles of chips with a semi-permeable cloth can protect against remoistening. Half of a 6.5-metre pile of chips was covered with this cloth, which prevented the chips becoming remoistened by precipitation but allowed water vapour to escape. After seven months of storage, the chips in the covered part were drier and had a higher heating value than the chips in the uncovered part. Substance losses were also lower in the covered half.

Ship transport and port logistics

Is it economically viable to transport forest fuel by ship from northern Sweden to Mälardalen in central Sweden? A cost estimate transporting chips by ship between Umeå and Stockholm showed a cost for transport, handling and storage in the ports of SEK 83 per MWh. The ship transport accounted for 71 percent of this cost. This is a high cost in relation to the energy price of forest chips at the user, which was approximately SEK 190 per MWh in 2014. Despite the cost, some large users must still receive forest fuel by train or ship, but it is highly probable that railway solutions can be found that are cheaper than ship transport.

The study included interviews with personnel from ports, shippers and dock companies, where the representatives were asked about which factors are important for ship transport. For the customer, the most important are opening hours, unloading capacity, and that ships can be accommodated at short notice.

Normally, some type of material handler with a knuckle boom loader is used in the ports, often with a clamshell bucket or orange peel bucket specially designed for chips. This is a technology that could also be interesting for rail transports.

MORE EFFICIENT CHIP TRUCKS

– IMPORTANT FOR FOREST FUEL

Johanna Enström & Henrik von Hofsten, Skogforsk

Currently, three chip trucks with a gross vehicle weight of 74 tonnes instead of the usual 60 are being evaluated in commercial operations. Skogforsk is monitoring fuel consumption and load utilisation, and practical experiences relating to the vehicles are being compiled. Operations were monitored over two winter months, and here we present the results.

Heavier and longer trucks have been studied for approximately seven years in Sweden. Much of the research has taken place within the ETT (One More Stack) project. Studies have shown that fuel consumption per tonne km for a 74-tonne roundwood truck without crane is nearly 13 percent less compared with a corresponding 60-tonne truck. Cost savings are around 10 percent, but this potential can only be realised if full payloads can be utilised. However, volume capacity is also important for dry forest fuel assortments. In Sweden, trials are currently under way involving 17 roundwood trucks and 8 chip trucks that exceed current weight or length restrictions.

The 74-tonne vehicles are no longer than today's maximum length of 25.25 m, and have a maximum payload of 49 to 50 tonnes. Their road-handling properties are as good as those for new 60-tonne vehicles, for example in terms of braking distance. Consequently, there are no road safety issues, and road wear is not increased because the weight is distributed over nine axles instead of seven. Problems can arise with bridges, where the gross vehicle weight is the limiting factor. The Swedish Transport Administration has identified a road network, mainly comprising European motorways, in which all bridges can support 74-tonne vehicles. At present, this road network does not include all the roads on which the test vehicles are operating, but the Swedish Transport Administration is working to extend the network.

The introduction of heavier (and longer) vehicles is very much a political issue. It is therefore important that research results are disseminated to decision-makers, so that they can be implemented. The Swedish government has permitted 64-tonne vehicles with seven axles since 1 June 2015, while tests involving 74-tonne, 90-tonne, and even longer and heavier vehicles will continue.

PHOTO: ANDREAS LINDHOLM/SÖDRA

Three vehicles – three different conditions

The three 74-tonne vehicles in the study were all commissioned in 2014. They are side-tipping trucks that hold approximately 150 m³ and are 25.25 metres long. They are in principle identical, but have been driven under different conditions, so the results are not directly comparable. All three vehicles run completely or partially on RME (rapeseed methyl ester), depending on local access to filling facilities. Unfortunately, there have been a number of problems relating to clogged fuel filters; as a result, the Södra vehicle has reverted to normal diesel fuel until new filter types have been developed. This problem is not specific to 74-tonne vehicles.

Ove Lindkvist Transport (Foria) transports forest chips for Söderenergi between the railway terminal in Nykvarn and the Igelsta combined heat and power plant in Södertälje. This is a distance of 20 km, of which half is on motorway and the other half includes three roundabouts and just as many junctions. The proportion of time for loading is relatively high, due to the short distance. Weighing takes place at the terminal, and the vehicle can generally be filled with sufficiently heavy material to attain a full payload. The truck transport comprises the final part of a railway system, where forest chips are brought to the terminal by train from various parts of Sweden. Because the truck runs as a shuttle between the terminal and the heating plant, the loaded distance, i.e. the proportion of total driving distance in which the vehicle is loaded, is around 50 percent.

Södra Eget Åkeri operates a 74-tonne vehicle in its ordinary transport operations in south-east Sweden, which involves various types of transports between Södra's industrial plants. The truck is mainly used to transport bark, chips, pulp bales and sawn timber. Like the haulier's other vehicles, the 74-tonne truck is driven on a specific route. Loaded distance is 68 percent, which can be regarded as very high.

Kent Åkerströms transport, a member company in Dalafrakt, operates a 74-tonne vehicle for transporting various assortments between Stora Enso's industrial plants in northern Svealand and Bergslagen, where the geography is different to that in southern Sweden. The haulier actively tries to find return transports, which has increased loaded distance to 67 percent.

Table 1. Fuel consumption of each vehicle per transported tonne and kilometre. Load utilisation, loaded distance, and mean transport distance all affect fuel consumption.

	Fuel consumption, (ml/tonne km)	Load utilisation, %	Loaded distance, %	Mean transport distance with load, km
Lindkvist Transport	31.6	97	50	22
Södra Eget åkeri	18.5	95	68	148
Åkerströms åkeri	17.3	98	67	176

Fuel consumption data is retrieved directly from the computer in each vehicle through the Scania Fleet management system. In order to calculate fuel consumption per transported tonne, the driver records the weight for each trip. Skogforsk then compiles all the data.

Fuel consumption for the Södra and Åkerströms vehicles is very low compared to other vehicles in the ETT project. The hauliers are careful not to overload, as overload fines are high, so we regard average load utilisation figures of 95-98 percent as very good. The large difference in fuel consumption between Lindkvist and the others is not at all surprising in view of the different conditions in terms of transport distance and loaded distance. Instead, it illustrates the importance of not comparing apples with pears. Other differences that may have affected the result are the varying length of follow-up period between vehicles, as well as the proportion of RME and diesel fuel used.

In practical operation, the 74-tonne vehicles have performed very well. Because of a rather different axle configuration, brought about by the extra axles, these rigs are actually more flexible and provide better road handling in cramped situations than the corresponding 60-tonne vehicles. The regulations regarding axle distance in the EU module system contribute to the good road handling, but this also means that the rear overhang of the trailer is rather large, so there is some risk of overload on the rear axles.

The vehicles are built according to the European module system (EMS) with truck, dolly and trailer. This makes it possible to insert a link between the dolly and the trailer and extend the vehicle to 34 metres. Already from the start of the project, there were plans to do so with the Lindkvist chip truck. The vehicle would then weigh 98 tonnes, distributed over 12 axles, and the load volume would be over 200 m³. A project involving such a trial, financed by Vinnova, is currently in the starting blocks.

In a transport chain, it is important to work with every part in order to ensure efficiency in the chain as a whole. At Söderenergi, for example, trains have been lengthened by adding more wagons, and the efficiency of truck transport from the railway terminal to the Igelsta CHP plant has been improved by using the 74-tonne vehicle.

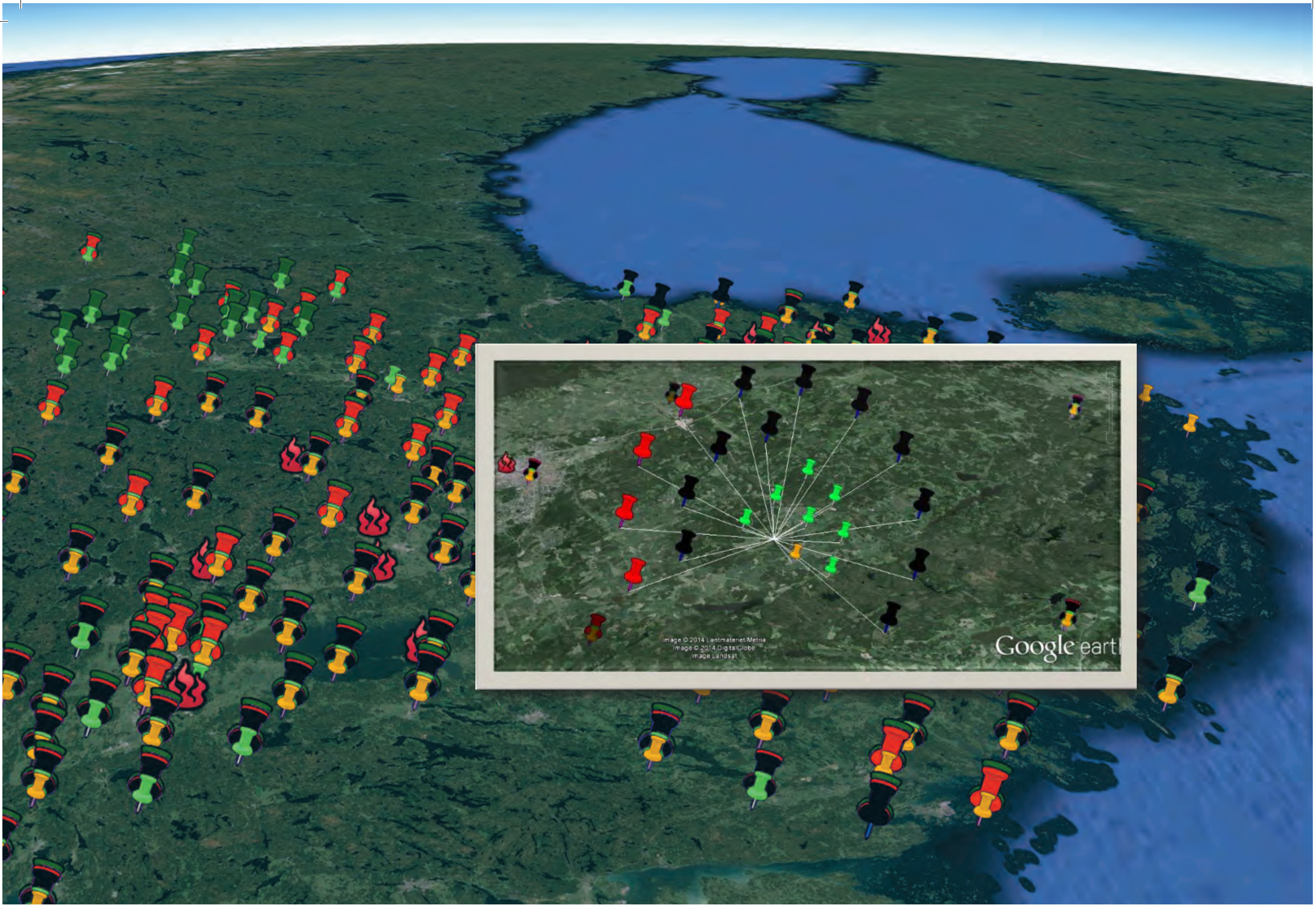
In many cases, truck transport is the only alternative. Working to improve efficiency through active planning of return transports is very beneficial, as can be seen clearly in fuel consumption per tonne km for the 74-tonne rigs operated by Södra Eget åkeri and Åkerströms åkeri. Greater load capacity is then one of several important contributions to efficient and sustainable transports.

Future work

- Improving the efficiency of transport now includes a project investigating a 98-tonne vehicle for Söderenergi.
- Skogforsk is helping the Swedish Transport Administration to identify important routes on which the forestry sector could introduce 74-tonne vehicles. This will give guidance about where to start upgrading sub-standard bridgesr.
- Wear and total economy regarding 74-tonne vehicles should be followed up until the vehicles are replaced.
- The Swedish Transport Administration HCT programme is also conducting important research involving longer and heavier trucks. The research ranges from effect on road wear to system effects of longer and heavier trucks. Skogforsk's ETT project will continue until 2016.

"Ship and train are always our primary transport modes, but we must always use trucks for the final stage from the railway terminal. Consequently, more efficient trucks benefit society as a whole – the natural environment, the traffic environment and the competitiveness of industry all benefit."

Olle Ankarling, fuel manager at Söderenergi.



LOCATION BARTER CAN IMPROVE EFFICIENCY OF CHIP TRANSPORTS

Petrus Jönsson, Johanna Enström, Lars Eliasson & Rolf Björheden, Skogforsk

In Mälardalen, efficiency of chip transport could be improved by approximately 12-15 percent if hauliers bartered biofuel volumes with each other. This is shown by simulating biomass supply in an area characterised by a large number of heating plants and many fuel producers with overlapping areas of activity.

Chips are mainly delivered by truck, and transport accounts for approximately 20 to 30 percent of the total forest fuel supply cost. For timber and pulpwood, a relatively common procedure is location barter, where forestry companies barter volumes of the same assortment with each other to reduce transport costs. One of the benefits is that the number of return transports can be increased.

Up to now, location barter has not been applied to any great extent for forest fuels. In order to investigate the potential, an analysis was carried out using data from SDC. The study involved 42 heating plants, five hauliers, and 4500 landings with GPS coordinates. The total demand of the heating plants was approximately 1.75 million tonnes DM/year.

The first step in the analysis involved calculating the mean transport distance for the actual transports from landings to the heating plants during the study period. This was followed by two different simulations. The first involved both internal and external destination, which means that the exchanges could take place both within a company and between companies. This was followed by a simulation where only external destination was allowed. In this, no location barter within a company were permitted – all bartering must involve two different companies.

Table 1. Number of transports and mean transport distance for the five companies. The table also shows potentials for reducing mean transport distances with internal and external destination.

Company	Number of transports per year	Mean transport distance, km	Reduction in transport distance with internal destination, %	Reduction in transport distance with external destination, %
A	6157	54.5	12	6
B	2759	54.7	11	12
C	6500	56.6	15	5
D	7276	48.4	12	9
E	545	82.8	2	3

In the model 'pure' exchanges on a one-for-one volume basis were assumed, as the aim of the analysis was only to investigate the potential for location barter. In reality, moisture content and quality of wood chips affect the value of the chips, and must be taken into account in bartering.

The analysis shows great potential for location barter, as shown in Table 1. Seen over the whole year, between 9 and 24 percent of transports could be bartered, with the level depending on the company. Total transport distance could be reduced by 10-15 percent if the hauliers could freely barter biofuel volumes with each other.

Interviews

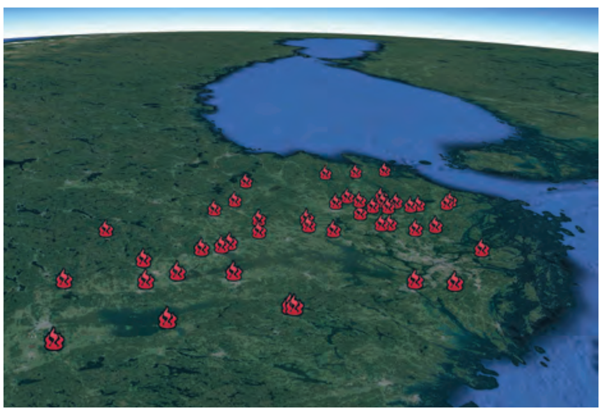
We also asked four forestry companies operating in central Sweden for their views on forest fuel barter. The interviews showed that three of these had already tested some sort of location barter. This did not involve bartering as such – instead it involved purchasing material from one another. However, because many of the deals are made with the aim of reducing transports, we can still regard this as location barter.

There are two possible ways in which location barter can take place. When companies barter forest fuel, ownership is eiter transferred at the landing, and the company acquiring the forest fuel becomes responsible for chipping and/or transport; or ownership is transferred at the point of measurement, i.e. the selling companies haulier delivers material to the customer on the basis of the companies acquiring agreement with the customer.

In the first case, there may be problems if the landowner does not approve the arrangement while, in the second, the customer's approval is normally required. Most forestry companies expressing their views on bartering forest fuel said that they preferred delivering on the basis of each other's agreements, but both approaches are used.he company´s Uncertainty about what is being traded was taken up as a major problem by all the companies in the survey. The product and its quality are poorly defined and, unlike pulpwood, there are no fixed pricelists for forest fuel, which increases sensitivity in the transaction. Within ESS, work has been carried out to define standardised fuel assortments (see page 14), and standardised product descriptions are needed to provide good conditions for location barter

Future work

- A theoretical potential of 10-15 percent reduction in transport costs raises the issue of whether the sector can afford not to continue investigating the concept of location barter.
- Location barter of forest fuel can reduce transport costs, and a pilot project to investigate this could involve interested companies. Here, Skogforsk could act as coordinator, and provide an analysis that indicates flows where the companies could benefit from bartering.
- A clear description of products would reduce the risks for companies that barter forest fuel volumes. The work must be carried out in parallel.



The small fire symbols represent the heating plants in the analysis. The pins in the larger diagram on page 106 show the landings of the different forestry companies.

FOTO: MIKAEL FRISK/CREATIVE OPTIMIZATION

OPTIMISED COMMINUTION AND TRANSPORT

Mikael Frisk, Mikael Rönnqvist, Patrik Flisberg & David Bredström, Creative Optimization

A correct choice of method for comminution and transport of forest fuels is important for profitability in the supply chain. The choice is not always self-evident, because it depends on various factors, including distance between forest and heating plant. The best method also varies between assortments, and can depend on where comminution takes place and the mode of transport.

Determining which comminution/transport system is most cost-effective at a certain distance is a relatively simple calculation, providing sufficient data is available about the costs. However, determining which system is best for many different distances simultaneously requires detailed knowledge about the road network, a correct calculation of the best route option, and calculation of distances between forest, terminal and industry. If the results are to be shown in map form, in order to quickly gain an impression of which combination of comminution equipment and transport vehicles is most cost-effective in different locations, a tool is required to visualise the results.

The web-based analysis tool, Opium, developed by Creative Optimization Sweden AB with support from ESS, is a decision-support tool that helps the user to quickly gain an overview of which system alternatives are most cost-effective for a selected delivery point.

Opium is designed so that the user can steer the calculations by making six simple choices:

1. State the delivery point to which the calculation applies, either choosing from a drop-down list or by clicking on the map.
2. Select whether the calculation is to consider terminal handling, either for comminution and reloading to another vehicle, or just for reloading to another truck or train.
3. Select the unit and moisture content to be used when presenting the result. The default unit is m³ loose and normal moisture content.
4. State the assortment, logging residue or energy wood, and system alternatives available (combination of comminution equipment and transport vehicle). There are five possible system alternatives per assortment, and one of them includes transport by rail where possible.
5. Set a cost profile. Here, the user can either choose default values or enter their own values so that the calculation corresponds to the user's actual costs for different system alternatives.
6. State whether the calculation is to limit transport distance and/or total cost. For example, the user can specify that areas from which it is more expensive to deliver forest fuel than a given maximum total cost are not shown on the map. The same applies for maximum transport distance.

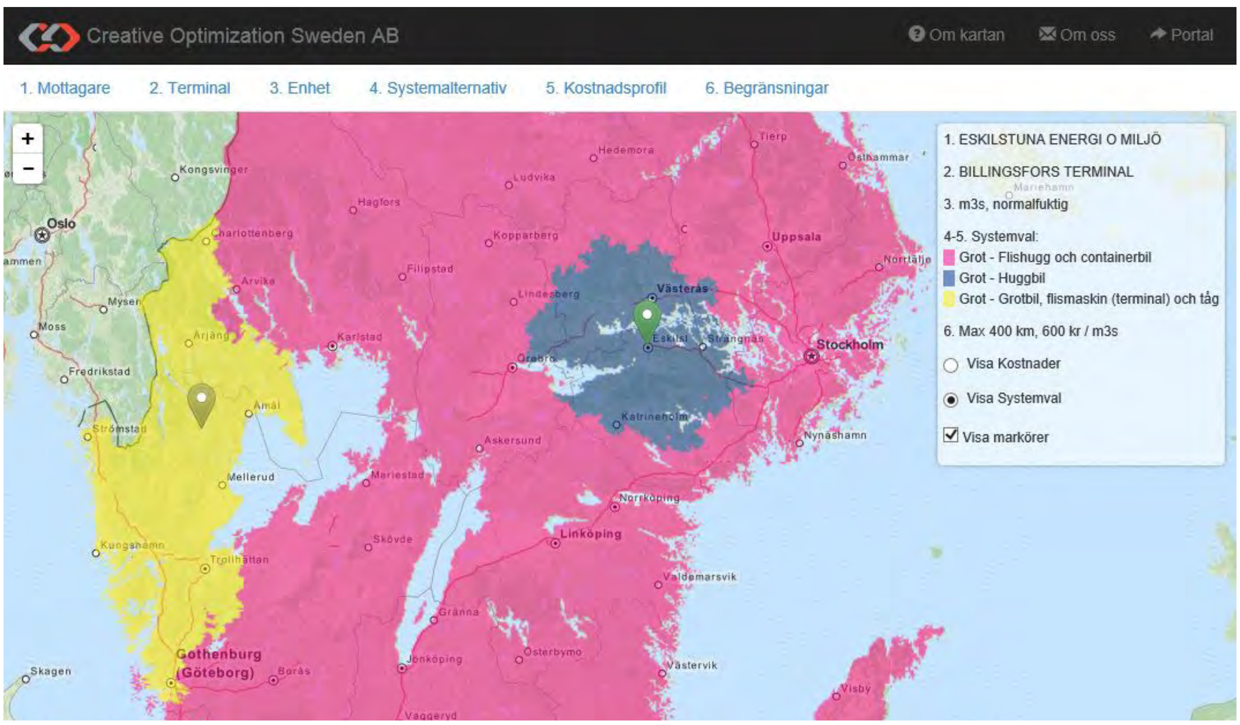
The result is presented in two ways: 1) the relationship between the lowest cost in a certain location and the user-defined maximum total cost, shown in the form of a colour scale (green corresponds to 0-25 percent of the maximum cost, blue 25-50 percent, purple 50-75 percent, and red 75-100 percent); 2) colours showing which system alternative is the most cost-effective.

An information box on the map shows the choices the user has made. To obtain the exact costs for a certain location, the user can click on the map, which brings up an information box with transport distance and cost to a selected delivery point and terminal.

Opium includes 189 delivery points and 174 terminals. At 19 of the terminals, material can be transferred from truck to train. Rail transport is possible to 19 different delivery points.

In order to calculate correct transport distance, a grid of 5-km squares was placed over Sweden. From the centre point of each square, the distance to all delivery points and terminals is calculated using the SNVDB and the route selection function Krönt Vägval 2.0. Rail transport is calculated as the shortest route by rail from the terminal to the delivery point.

The tool is free to use, and is available at: http://opium.creativeoptimization.se/



SHIP TRANSPORT OF FOREST FUEL

Johanna Enström, Skogforsk

The market for forest fuel has decreased in recent years, but new biofuel-powered combined heat and power plants and new bio-based products are expected to generate greater demand in the future. This could greatly increase the need for long-distance transport. Up to now, long-distance transport has mainly involved rail transport, while imported material (largely recycled wood) has been transported by ship. Between 2016 and 2018, two large combined heat and power plants are expected to become operational in Mälardalen with a total demand of 4-5 TWh of biomass.

A pilot study was carried out to examine the possibilities for using coastal maritime vessels for transports of wood chips from northern Sweden to Lake Mälardalen in central Sweden. The aim was to describe current cost levels for ship transport and storage, loading and unloading of wood chips. We have also compiled examples of 'best practice' for ship transport and cargo handling in ports under Swedish conditions.

Interviews were held with representatives of four Swedish ports with experience of handing wood-based fuels, as well as purchasers of maritime transports, shipping agents and dock companies.

Handling

Today, chips are not shipped from Swedish ports. This project examined the situation in Estonia, where sawmill chips are loaded with a material handler. A bottleneck in

Loading of sawmill chips in Kunda, Estonia.

the loading operation was transport of the material by truck from the storage site to the quay. This delayed the work of the material handler, as it had to wait for material.

Material handlers are generally used for loading and unloading chips. Some contractors prefer an orange peel bucket for unloading on the quayside, as this type can more easily dig down into the tightly-packed chips. For loading or unloading directly from or to a vehicle, a clamshell bucket may be more suitable, as it reduces waste and can more easily pick up the final material in the pile. As far as possible, chips are unloaded directly from the ship to a truck but, when no truck is available, the chips are stacked on the ground instead. A wheel loader can then move the material. Handling systems vary greatly between ports.

Harbour cranes generally have a high level of utilisation, and various accessories are used for different types of cargo. Effective productivity of approximately 180 tonnes per hour for loading, and 140 tonnes per hour for unloading, was assumed in the analysis (calculated over one shift, including downtime). These figures are relatively high, but not unrealistic for a large crane or a large material handler.

The ports included in the study all have limited loading space on the quay, but offer customers storage a short distance away. Truck transport is usually required between the storage area and the quay. In Swedish ports, there is generally access to measuring facilities, and VMF wood measurement officials are commissioned either directly by the customer or are available on request. Large combined heat and power plants with their own harbours may have various types of permanent solutions, and new measurement technologies for large facilities are under development.

Customer requirements of a port

The unloading capacity in the harbours is crucial, and is affected by the port's opening hours, as unloading and loading generally take longer than one shift. If the port is not open 24 hours a day, and the ship cannot be completely loaded or unloaded during opening hours, costs can quickly escalate, as the ship stands idle until next day. Most ports promise a certain unloading capacity, but the figures they state are not necessarily binding. Specific requirements apply for ports in the Stockholm area, where, in particular, limits on noise levels are a challenge. For other ports, the following factors were mentioned as being important:

- Working hours.
- Unloading capacity (linked to working hours).
- Flexibility, the ability to adapt operations and accommodate ships quickly to prevent waiting time.
- Safe storage of the chips on an asphalt surface.
- Correct and proper compaction in the port of loading. Certain equipment is needed, such as a sufficiently powerful crane to lift a smaller machine onto the ship.
- Surveillance of the chips, visually and using temperature measurements.
- Separation from other players.
- Possibility for sampling the loads. When wood products are imported, Swedish Board of Agriculture requirements must be met (for example, to prevent entry of insects).
- Good infrastructure for road transports.
- The ice situation in the port. It is cheaper to transport material in the summer.

Material handler with orange peel bucket unloading chips in Hargshamn.

Cost

A rough estimate of the cost of transporting chips by ship between Umeå and Stockholm (no entry to Lake Mälaren) is presented in Table 1. All costs in the example are conservative estimates. For example, no extra costs are included for overtime work. In the calculations of ship transport costs – by far the biggest cost – it is assumed that a return load is available. Larger vessels offer normally more efficient and cheaper transport, but the large loads require extensive storage areas close to the port. Loading also involves several shifts, which can entail added costs for overtime and/or compensation for night work or downtime for the vessel. In the Baltic Sea, bulk vessels where capacity exceeds approximately 12,000 m³. are uncommon.

Table 1. Cost example for a chips transport from Umeå to Stockholm

Storage 1 month on asphalt	2,92	SEK/m^3	3.59	SEK/MWh
Dock handling, loading	15	SEK/tonne	6	SEK/MWh
Dock handling, unloading	9	SEK/tonne	3.6	SEK/MWh
Loading with crane	12.2	SEK/tonne	4.9	SEK/MWh
Unloading with crane	15.7	SEK/tonne	6.3	SEK/MWh
Ship transport*	56.7	SEK/m^3	59	SEK/MWh
Total			**83.39**	SEK/MWh

*) Cost estimated by an experienced shipping agent.

The port of Stora Vika has invested in an electrical harbour crane, and harbour manager Milan Tomich is very satisfied. "Because it's run on electricity, the crane is much quieter, which is important for us, as people living nearby have previously complained about noise. The cable can be a problem, but since we were able to specify the machine to 690 V (instead of the standard 450 V), the cable is relatively thin, which makes things easier."

Average cost for purchase and production of logging residue chips in Sweden in 2013 was approximately SEK 209/MWh (page 37). However, we assume that transport from the forest to the port of loading is SEK 24/MWh, i.e. half of the average total transport cost from forest to industry gate due to a shorter transport distance on road. The total cost for chips transported from Umeå to Stockholm including ship transport will then be SEK 268/MWh. As the energy price of forest chips at the user in 2013 was approximately SEK 199/MWh (Swedish Energy Agency), it is clearly not viable to transport the chips from Umeå by ship.

However, the example does not provide a full picture. Using only locally sourced forest fuels is often not an option for large combined heat and power plants in the Mälardalen region because supply does not meet demand. The use of trucks and trains may be limited, and if a proportion must be transported by ship, the Swedish forestry sector must instead be able to match other imported biomass-based raw materials on price. Here, it can be pointed out that maritime transport of wood chips from Riga to the UK is in a similar price class to that of transport between Umeå and Stockholm. A heating plant that can accept rail deliveries of forest fuel can probably find a transport option from northern Sweden that is considerably cheaper than sending the material by ship.

The costs were estimated before the new sulphur regulations came into effect in January 2015. However, the new regulations coincided with a historically low oil price, so low-sulphur fuel is cheaper today than the price of fuel with a higher sulphur content was in 2013. There is still a certain competitive disadvantage in relation to maritime transport using cheaper fuel, but the significance of the fuel for the total cost has nevertheless fallen. This means that the transition to low-sulphur fuel for Swedish maritime shipping has been less dramatic than expected.

INVEST IN THE RIGHT FUEL TERMINALS

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Dimitris Athanassiadis & Mikael Öhman, SLU

No less than 95 percent of Sweden's logging residue volumes and stumps is located within the catchment areas of forest fuel terminals. There is little need for new terminals, but the new regulations regarding measurement of forest fuel assortments make it important to choose which terminals to invest in.

Many forestry companies are reviewing their terminal structure, for example by conducting flow analyses with the Skogforsk software, FlowOpt. In collaboration with SLU, Skogforsk has carried out a study that will supplement the companies' own analyses.

The project focused on three issues:

1. What factors lie behind successful establishment of terminals??
2. How do forestry companies look upon their ownership of terminals? When is it advantageous to own a terminal, and when is it better to use a commercially operated terminal?
3. Are more terminals needed and, if so, where?

Criteria for successful investment in terminals

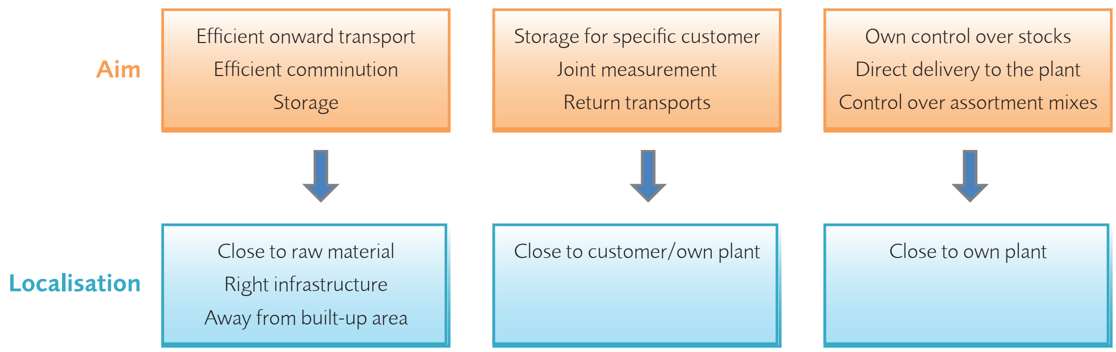
Literature studies enabled us to map important factors for terminal establishments. These factors were investigated in more detail through qualitative interviews with five representatives from forestry companies, four from energy companies, and four from logistics companies that run independent terminals. We were also looking for examples of 'best practice', so each company gave examples of successful terminal establishment.

According to all interviewees, the most important success factor was location. However, strategies for deciding on the location of a terminal varied according to its purpose. Figure 1 shows the different strategies.

Other important factors were:

- **Volume**. A large terminal for forest fuel stores 50,000-100,000 m³ of chips over the course of the year. For a railway terminal, with costly investments in tracks, it is not enough to store such volumes seasonally; turnover must be several times per year.
- **Measurement facilities**. The planned flow should tolerate an investment in, for example, scales, possibly in collaboration with other players.

Figure 1.



- **An asphalt surface for handling chips** is positive, on condition that the customer is prepared to contribute to the investment or that such an investment is required to win the contract.
- **Skilled personnel with focus on the customer**. Service-minded and flexible personnel, capable of carrying out various types of work at the terminal, are required. Flexibility towards the customers was an issue mainly raised by the logistics companies.
- **An orderly site and terminal logistics**. When the drivers can find their way around easily, internal handling is reduced. Some of the terminals have clear signs, so drivers could easily find their way to the correct area on the site. It is also important to plan the area so that the material is accessible for loading.
- **Commitment**. A committed project leader is needed in order to maintain momentum in the often lengthy process of establishing a new terminal.

Own terminal or collaborate with other companies?

Many terminals are situated close together, and have overlapping catchment areas. There should be great opportunities for collaboration, such as by shared ownership of measuring equipment. Combining terminals to generate coordination benefits may also be justified, or using a commercially operated terminal to avoid committing to a major investment. However, company views vary on the issue of joint use. Several forestry companies feel that logistics is a core activity and a competitive tool they want to control, which may be an obstacle for joint terminals. However, a joint measurement station may be a less controversial solution.

Are more terminals needed?

Because the supply of raw materials is a crucial factor, a geographical analysis was carried out of all terminals used for forest fuel handling, as well as all supplies of logging residue and stumps in Sweden. The aim was to find out whether there were areas that are not covered by the catchment areas of existing terminals. A separate analysis was carried out for terminals located within a kilometre of a railway.

Data on forest resources was retrieved from SKA-VB 08 and data on terminals was taken from SDC's inventory of terminals in 2012. Each terminal was assumed to have a catchment area with a radius of 75 kilometres.

PHOTO: STOCKARYDSTERMINALEN AB

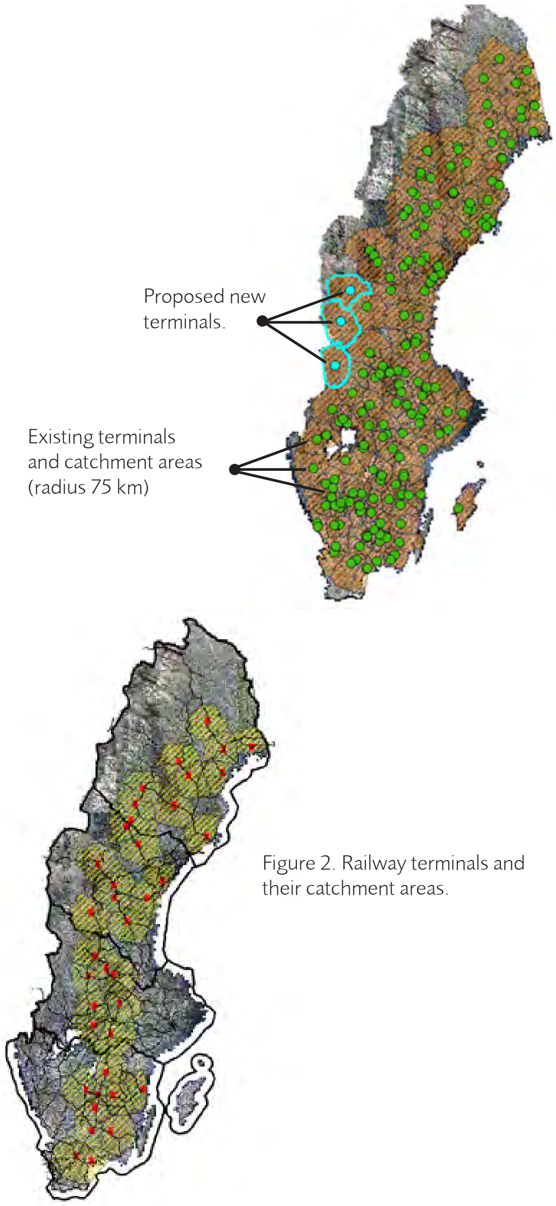


Figure 2. Railway terminals and their catchment areas.

The largest volumes outside catchment areas of existing terminals were found in western Dalarna (Figure 2). However, when other aspects are taken into account, it is not certain that this would be the best location for new terminals. The interviews showed more support for upgrading existing terminals at strategically important locations with appropriate infrastructure. Existing railway terminals capture approximately 65 percent of the available forest fuel, a figure that seems high in view of the small proportion of forest fuel that is transported by rail today. Several of the companies in the study were positive to the idea of using railway terminals.

Future work

- Internal logistics at terminals, and support for these, should be studied further. It is also important to investigate how improving communication in the supply chain can help to improve the efficiency of internal logistics.
- The move towards new bio-based products will probably influence how the forest raw materials will be used and how they should be handled. Terminals may come to play an important role in a diversified flow, and this should be examined in collaboration with the producers of these products.

EFFECT OF COVERING ON LARGE-SCALE STORAGE OF CHIPS

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Comminution of forest fuel to chips is an expensive process, partly because of the low machine utilisation caused by the seasonal nature of the activity. One way to reduce costs is to utilise the machines for a longer period and store the chips. This also makes it possible to meet sudden increases in demand. Costs of winter road maintenance can also be reduced, because some of the forest fuel has already been delivered to the terminal.

Storage of chipped forest fuel generates heat, and can lead to spontaneous combustion. A number of studies show that storing chips can lead to high substance and energy losses, higher that when non-comminuted material is stored. However, a moderate heating of the pile is positive, because the material then dries and the effective heating value increases.

One way to minimise the negative effects of storage is to cover the chips with material that prevents precipitation from remoistening the chips, while also allowing water vapour to escape. A number of pilot studies involving the Toptex fibre cloth have shown that fuel quality is preserved and, in certain cases, even improved. Fuel quality and substance losses were studied in large-scale storage of wood chips covered with the Toptex cloth at terminals.

Logging residue chips were placed in a pile approximately 6.5 m high, with an estimated volume of 1450 m³. Half the pile was covered with the Toptex fibre cloth, and the other half was left uncovered. Moisture content, ash content and

temperature were measured at the start of the trial and twice in the period June 2013 to January 2014. Substance losses were also measured.

In the first three months of storage, the moisture content decreased from 51 percent to 48 percent. The reduction was the same in both halves of the pile. After approximately seven months of storage, the moisture content in the covered part of the pile had fallen to 45 percent, while the figure remained unchanged at 48 percent in the uncovered part. The difference in moisture content between the two halves was noticeable from a height of approximately two metres and upwards. After seven months, the moisture content at a height of 4.5 metres was 39.7 percent in the covered half, compared with 54.7 percent in the uncovered part.

Temperature increased at approximately the same rate in the covered and uncovered parts of the pile. In the first month of storage, the temperature increased from 20°C to 64.2°C, and then to 75.1°C in the subsequent three weeks. Substance losses, expressed as the percentage loss of dry matter, were measured after three months of storage to 4.4 percent in the covered part, and 4.2 percent in the uncovered part. After seven months, substance loss was 5.3 percent in the covered part and 7.3 percent in the uncovered part.

If both moisture content and substance losses are considered, the energy content after four months of storage was unchanged, in both halves of the pile. After seven months, energy content remained at the same level in the covered part, but had fallen by seven percent in the uncovered part. This can be an effect of a combination of higher substance losses and unchanged moisture content.

The conclusion is that fuel quality can be improved and energy content preserved if the pile of chips is covered with a ventilating cloth that protects the biomass from precipitation but allows water vapour to escape. The economic calculation depends on three factors: the price of the chips, the total cost of covering, and changes in energy content. As the cloth can be reused several times, covering of piles of chips is probably viable.

PHOTO: ERIK ANERUD/SLU

Future work

- Covering of chips should be tested at a larger scale – one important issue is how many times a cloth can be reused.
- Experience shows that length of storage can be difficult to know in advance, so it can be unclear whether a pile of chips is worth covering. The use of specific planning support for forest fuel storage may increase the possibility of benefiting from covering. Cooperation and communication in the supply chain can also increase predictability. These aspects should be examined in more detail.