VF-Rapport 2/01

Pilot actions for energy saving in transport of goods

Nordic examples

A report from Phase 2 of the European Commission
SAVE -project XVII/4.1031/Z/97-229:
"Energy saving in transport of goods – a pilot project in rural natural resource based industries"

By
Otto Andersen[1], Eivind Brendehaug[1], Kyrre Groven[1], Ulla Suutari[2], Jarkko Lehtinen[2], Hans Hjortsberg[3] and Peter Ahlvik[3]

[1]Western Norway Research Institute
[2]VTT - Finland
[3]Ecotraffic R&D AB - Sweden

WNRI Report

Title:
Pilot actions for energy saving in transport of goods. Nordic Examples.

Report number: 2/01

Date: February 2002

Grading: Open

Project title: Energy saving in transport of goods – a pilot project in rural natural resource based industries.

Number of pages: 160

Researchers: Otto Andersen, Ulla Suutari, Jarkko Lehtinen, Antti Permala, Peter Ahlvik, Hans Hjortsberg, Bengt Sävbark, Kyrre Groven, Eivind Brendehaug and Karl G. Høyer

Project responsible: Karl G. Høyer

Financed by:
European Commission DG XVII

Subject heading:
energy saving, goods transport, rural resource based industries

Summary:
This report presents the results from a pilot action project on energy saving in transport of goods in three Nordic countries. The main object of the project is to develop and implement actions, strategies and measures for improved energy efficiency in transport of goods. The project uses 3 cases of natural resource based industries, one from each of the three Nordic countries Norway, Sweden and Finland. The cases are fish export in Norway, wood (paper) export in Finland and agricultural products (mainly grain) in Sweden. One company in each of the three countries are selected and pilot actions are identified and carried out in each of the companies.
The project constitutes 3 main phases: 1) Basic analytic activities, 2) Pilot actions in 3 “case”-companies and 3) Actions and measures in regional policies. This report presents the results from phase 2 of the project. This phase has included pilot actions at three levels; reduction of fuel consumption, increased load factor and transfer of goods from road to rail and sea.

Other publications from the project:

Andersen, O., O. Uusitalo, P. Ahlvik, H. Hjortsberg, K. Groven and E. Brendehaug. *Energy in transport of goods. Nordic Examples.* VF-Rapport 6/99.Vestlandsforsking, Sogndal.
Andersen, O., U. Suutari, H. Hjortsberg, K. Groven and E. Brendehaug. *Measures and actions in regional policies for energy saving.* VF-Rapport 3/2001.Vestlandsforsking, Sogndal.
Andersen, O., O. Uusitalo, U. Suutari, J. Lehtinen P. Ahlvik, H. Hjortsberg, K. Groven and E. Brendehaug. *Energy saving in transport of goods* **-** *a pilot project in rural natural resource based industries***.** VF**-**Rapport 4/2001.

ISBN nr: 82-428-0195-9
ISSN nr: 0803-4354

Price :
NOK 200,-, SEK 200,-
FIM 140,-

Preface

This report presents the results of a pilot action project under the European Commission DG XVII –programme Specific Actions for Vigorous Energy Efficiency (SAVE). The content of the report is the sole responsibility of the publishers, and it does not in any way represent the views of the Commission or its services.

The main object of the project is to develop and implement actions, strategies and measures for improved energy efficiency in transport of goods.

The report contains the results from the second phase of the project. This phase has consisted of analysis and implementation of pilot actions in for energy saving in transport of goods in the three Nordic countries Norway, Finland and Sweden.

The report is edited and partly written by researcher Otto Andersen at Western Norway Research Institute, who also has been responsible for co-ordinating the project. The report is based on contributions from several other researchers both at Western Norway Research Institute and the two partners VTT and Ecotraffic R&D. Each contribution is however based on comments and suggestions by all three partners.

Several people within the transport sector have contributed to the content of the report, and we are most thankful for all their help.

Sogndal, February, 2002
Karl G. Høyer

Contents

List of Tables

List of Figures

Summary

The project "Energy saving in transport of goods - a pilot project in rural natural resource based industries" is carried out with financing from the SAVE II-program in the European Commission DG XVII.

The main object of the project is to develop and implement actions, strategies and measures for improved energy efficiency in transport of goods.

The project uses 3 cases of natural resource based industries, one from each of the three Nordic countries Norway, Sweden and Finland. The cases are fish export in Norway, wood (paper) export in Finland and agricultural products (mainly grain) in Sweden. One company each in Norway and Finland and two companies in Sweden are selected and pilot actions are carries out in each of the companies.

The project constitutes 3 main phases: 1) Basic analytic activities, 2) Pilot actions in 3 "case"-companies and 3) Actions and measures in regional policies. This report presents the results from phase 2 of the project. This phase has included an analysis and implementation of pilot actions for energy saving in transport of goods connected to the case companies.

In Norway the results from the pilot actions indicated that fish transport from Western Norway to the continent has an average energy use for down-trip and return trip of about 0,22 kWh per tonnekm. The return trips give lower energy efficiency. This is caused by low load factor. If the load capacity had been fully utilised on return trips, the energy efficiency could be improved to about 0,18 kWh per tonnekm.

Different driving style could have a great influence on fuel use and thereby energy efficiency. Our cases show that non-economic driving could increase fuel consumption with 25 percent. The energy saving potential in today's lorry transport is greatest in mountain and hilly areas.

The actual energy saving effect in the today's lorry transport is 5 % according to the result in the transport company Nistad in Western Norway. For the whole fish export transported on lorry this would give an energy saving effect of about 12.000 tonne fuel or about 115 mill kWh.

If all the fish export from Norway to the European continent where transported by train the total reduction in energy use could be about 70.000 ton fuel or nearly 700 mill kWh. This calculation is based on the assumption that our four cases give a representative picture of transport distance and transport mode in the today fish export. This is not necessarily right, but our calculation gives an estimate of the future energy saving potential.

During the project period transferral from road to rail and ferry were done for two of the four case routes. Rail based transport with dried cod to Italy reach a reduction in energy use at 60 % compared with lorry based transport. The effect comes from the more energy efficiency train transport used on the whole distance from Western Norway to Verona in Italy. The transport is similar in time efficiency (5% difference) to the lorry-based transport in 1999.

The other implemented action frozen fish to Boulogne-sur-Mer in France, is based on ferry and train transport. Here the reduction in energy use is "only" about 20 percentage, caused by

the train from Åndalsnes to Oslo. The energy saving effect is limited due to the long ferry distance Oslo-Rotterdam. Ferry is less energy efficient than lorry transport.

In Finland the energy use in the case company UPM-Kymmene Group and their transport chain, from Voikkaa paper mill to the customer in Cologne, Germany is analysed. The energy use is calculated for transporting 8 800 tonnes paper. The amount of raw materials is estimated from their yearly volumes in proportion to yearly production of paper. The energy use includes loading, unloading and other handling of goods except for the possible handling in Germany, which differs from the handling in Finland. The total energy use of the transport chain amounts to 2 971 MWh, which is 0,34 MWh per paper tonne. From the energy efficiency, kWh/tonne-km, it is evident that the train transport in Germany is more energy efficient than the train transport in Finland. This is probably due to the fact that transport distances in this case are shorter in Finland than selected distance in Germany, and that the share of electric locomotives is larger in Germany than in Finland.

The study of energy use in the Swedish case company ODAL provided an overall idea of the approximate amount of energy used in different parts of the transport chain. The transport chain has been divided into the steps “farmer-to-silo”, ”silo-to-silo”, “to export”, and, in the special case, also “from export harbour to import harbour”. The figures in different parts of the chain are partly uncertain and can differ up to 20% or more, especially since the transport volumes differ considerably between years and regions in ODAL. However, the data could be used to show, which the areas of main energy use are, and the potential for energy-saving activities. The important factors in energy saving, such as the choice of transport mode and distance between producer and consumer, etc., are also highlighted via the study of energy use and pilot actions.

It can be noted that about 30 % more energy is used in the “silo-to-silo” step (11,3 GWh/year) compared with the “farmer-to-silo step” (7,41 GWh/year). The distance is also longer in the “silo-to-silo” step. The average energy efficiency in “silo-to-silo” is however larger, about 0,15 kWh/tonnekm, compared to 0,67 kWh/tonnekm for “farmer to silo”. The “farmer-to-silo” step includes more use of tractors, which are also assumed to have a lower load factor than lorries. About 65% of the grain in ODAL is exported and the energy use for transport to export harbours in Sweden is about 12,2 GWh/year.

The special case study called “Söderköping” illustrates the great effect of a short transport distance and high-energy efficiency of the transport mode. The special case has more than 50% higher energy use per delivery (about 136 kWh compared to 84) compared to the average for the general farmer-to-silo transport case. The main explanation for this is the more frequent use of tractors as the transport mode and a longer average distance to the silo (about 18,9 km compared to 11,4 km). The average energy efficiency in the special case is about 0,77 kWh/tonnekm.

1. Introduction and background of the project

Transport accounts for a large share of total energy use both in the Nordic countries and in the European Community as a whole. It is the societal sector that has been subject to the largest percentage increase in energy use the last twenty years. While other sectors generally have stabilised or reduced their energy use the later years, it has continued to increase both in transport of passengers and goods. The increase in road transport, in volume of transport work as well as energy use, has been particularly large. Much of this transport has a low load factor and generally has much lower energy efficiency than rail and sea transport. Traditionally sea transport has been of particular importance in the transportation of goods to and from the Nordic countries, and has been performed with high load factors and energy efficiency. The last couple of decades this form of transport has however lost much of its former importance. Rail transport has at the same time generally not increased in the volume of transported goods. The result has been a lowering of energy efficiency in total in the transport of goods.

Natural resource based production has always been a major segment of the industrial structures of the Nordic countries. This has also in general been the case in other rural regions within the European Community. Transportation of goods to and from these industries similarly accounts for large shares of the total transport volumes. This constitutes a background for the project *" Energy saving in transport of goods – a pilot project in rural natural resource based industries"* and the choice of project "cases" for actual implementation of pilot actions. All "cases" are transport in connection to rural natural resource based industries in the 3 Nordic countries Finland, Norway and Sweden.

One objective of this project has been to generate knowledge from the 3 "cases" that can be transferred to other forms of transport of goods both in relation to export and import. This implies that the project includes an *analytical part* on opportunities and potentials for improved energy efficiency in industrial transport of goods in general. The intention has been to establish a basis for continued actions after the project period has ended.

The main objectives of the project has been:

- To develop and implement actions, strategies and measures for improved energy efficiency in transport of goods.
- To gain knowledge of the conditions and effects of such actions, strategies and measures through pilot actions in 3 different rural, natural resource based industries.
- To analyse the conditions for transferring this knowledge to other forms of transport of goods with the intention of establishing a basis for continued actions after the project has ended.

The project constitutes 3 main phases:

1. Basic analytic activities
2. Pilot actions in 3 "case"-companies (company level). This phase includes an evaluation of the effects of the pilot actions
3. Actions and measures in regional policies (policy level).

This report presents the results from phase 2 of the project.

1.1. Methodology

Phase 2 of the project has constituted of preparing and performing the pilot actions in the case-companies. The data material has been obtained from the two sources 1) Documentation from the case companies and 2) Interviews.

Both the preparations and implementation of the actions has been carried out through *structured interviews* with employees at the different levels in the companies.

The actions has been implemented through internal company processes, which involved *participation* by project researchers and a *constructive dialogue* between company employees and researchers. This gave the basis for systematising the experiences and results both through evaluation and participatory observation.

1.2. Case study questions

The questions which was asked the company employees during the case studies were covering the following main aspects:

1). Questions regarding reduction in *fuel consumption:*

Which actions can the companies implement in order to reduce fuel consumption in *today's lorry based* transport?

Which actions are in this context necessary at *different levels in the companies*, especially at these levels:

- Management level
- Garage level
- Driver level

Which strategies can the companies develop in order to secure a process towards *continuous increase* in the lorry based fuel economy?

2). Questions regarding the increase the *load factors* in today's lorry based transport:

Which actions and strategies can the companies implement in order to *increase the load factor* in today's lorry based transport?

How can especially the potential for *transport on the return trips* after delivering of goods be utilised in this context?

3). Questions regarding the *transferral of goods* from lorries to more energy effective rail- and ship transport:

Which actions and strategies can the companies implement in order to achieve a transferral of goods from lorries to more energy effective rail- and ship transport?

How can especially the potential for combined transport be utilised in this context?

1.3. Evaluation of results

The aim of this part of the project has been to evaluate the effects of pilot actions as performed during phase 2. It has consisted of the following activities:

- An evaluation of the conditions for implementing actions and strategies at the different levels in the 3 companies. This has mainly been based on participatory observations.
- An evaluation of the actual and potential energy saving effects of pilot actions and strategies. This has mainly been based on systematic reporting made by the involved researchers through the whole phase 2. The energy saving effect has been evaluated in relation to the following variables:
  - Fuel consumption in lorries
  - Load factors in lorries
  - Transfer of goods to rail- and ship transport.
- An evaluation of potential energy saving effect of transferring actions and strategies identified through the project to other industrial sectors in order to achieve greater energy efficiency in transport of goods in general.

2. The pilot actions in Norway

2.1. Introduction

This report is part of the European Commission DG XVII –project "Energy saving in transport of goods - a pilot project in rural natural resource based industries" coordinated by Western Norway Research Institute (WNRI) with participation from Technical Research Centre of Finland (VTT) and Ecotraffic Research and Development in Sweden.

Natural resource based production has always been a major segment of the industrial structures of Norway. Transportation of goods to and from these industries accounts for large shares of the total transport volumes. This is also the situation in the fish industry, the Norwegian case in this project.

2.2. Objectives

The main objective of the project is to develop and implement actions, strategies and measures for improved energy efficiency in transport of goods. This report describes the pilot actions, which have been carried out in Phase 2 of the project. Phase 1 served as the basis for the implementation of the pilot actions and strategies, while Phase 3 deals with measures in regional policies.

The report focuses on:

- Energy use in today's transport of fish (the year 1999)
- Pilot actions and necessary conditions for implementation of the actions
- Actual and potential energy saving effects of the pilot actions
- Possible transferability of the actions and strategies to other industrial sectors

2.3. Methodology

The project-plan was to develop and implement pilot actions and strategies to increase the energy efficiency in transport of fish, in three different ways:

- To reduce the *fuel consumption* in today's lorry based transport
- To increase the *load factor* in today's lorry based transport
- To achieve a transferral of goods from lorries to the more energy efficient rail and ship transport

The project design is based on a case-methodology, as described by Yin (1994). A transport enterprise transporting fish from Western Norway to the continent, is chosen as the Norwegian case-company. A wide range of actions and strategies has been implemented in the case company and their effects on energy efficiency have been determined. Based on the present situation in the case company, the main focus of the study has been on transferral of goods from road to rail, and reduction in fuel consumption.

Methodologically, the actions and their implementation are based on *structured interviews* with employees at the different levels in the company and through *constructive dialogue* between company employees and researchers. This has given a basis for systematising experiences and results both through formal evaluation and participatory observation.

The project design is in part based on the classic experiment: Measuring the effect by manipulating one variable while other variables remain constant. As transport companies are facing shifting circumstances maintaining stable experiment conditions has become a major methodological challenge.

Four transport routes were selected as objects for implementation of actions and strategies, and in order to evaluate the energy use. The routes were chosen based on the following principles:

- The study needs stability over time for measurement of the energy use, to implement actions and to evaluate the effects on the same routes. Unstable routes are not suitable for the study.
- Chosen transport route should carry a sufficiently quantity of fish
- Different fish products and routes with different destination structure ought to be covered.

The energy use (in kWh/tonnekm) was measured before actions were implemented. The situation in the basis year (before actions) was used for comparison to assess the effects of the pilot actions.

One main problem has consisted of variation in the routes. Two of the first four selected routes have later been discontinued due to changes in customer contracts. The case company explains the increasing unstable situation in the transport sector the last year by the change from long-term contracts between the exporter and the transport companies, to a spot market situation.

In order to obtain comparable data for measurement of reduction in *fuel consumption* in today's lorry based transport, we have used a design which take into account variable factors. The requirements for the comparison was:

- The same lorries and identical total weight were used
- The same drivers were used
- Only lorries, which had completed their "running-in" period (after 30.000 km), were used.

In order to minimise the effects of seasonal differences in weather condition the recordings were done in autumn 1999 and autumn 2000.

In order to measure the effect of transferral of goods from road to rail, we have compared the distances where transport mode has changed during the project period. The test design for this effect differs from the test used for assessment of effects of driving style. Here, the energy use in tonnekm by the lorry transport by all drivers is averaged. This is compared with the energy use in tonnekm for the same distance by rail.

2.4. Energy use in the today's lorry transport

Description of the case company, Waagan Transport AS

The following presentation is based on information from the manager of Waagan Transport (WT), Per Waagan. The company was founded in 1969, limited company since 1976. The head office is situated in Vegsund (since 1988), 15 km off Ålesund in Møre og Romsdal county. The trucks driving for the company have three types of ownership: 1) leased from Volvo, 2) owned by WT and 3) contracted trucks. The use of the two last categories is decreasing.

The company was originally based on transportation of furniture. Today, WT also distributes general goods (routes in Møre og Romsdal). For the wholesale dealer BAMA, the company also distributes fruit and vegetables. Since 1985, WT has been transporting fish with refrigerator vans, mainly Norwegian salmon to Europe.

Domestic offices and offices abroad

Branch offices are located in Ørsta (since 1989) and Molde (since 1994), in Møre og Romsdal county. WT has a fine-meshed distribution system for general cargo between Møre og Romsdal and other parts of Norway, and in particular within Møre og Romsdal county.

The export department of WT has a freight network all over Europe. A subsidiary company in Denmark, earlier EB Transport in Skagen, has cold storage facilities since 1994 for sorting and forwarding deliveries of Norwegian salmon (since 1994). WT also has a freight terminal in Padborg, on the border between Denmark and Germany.

Quality certification

WT was ISO 9002-certified in 1994. The manager of the company however considers this only to have limited effects in the market, while the process of establishing certification implied substantial costs for the firm. The experience in the company is that very few customers are willing to pay extra for using a certified transport company.

Data compilation

The energy consumption in lorry transport of fish from Western Norway to the continent has been measured. Two types of data were compiled from the case company:

1) Energy use on four different transport routes (described in more detail below).
2) Average energy use in various transport routes from Western Norway to the continent.

In the project, four routes were selected. The criteria for selecting the special routes have been described earlier in chapter 1. The routes are described below. A map of each route and more detailed description of the routes is shown in attachment 1. The four case routes are (Kleppe, 1998-2000):

A) Fresh and frozen herring from Western Norway to Poznan in Poland. The route is lorry transport from Ålesund to Trelleborg (in Sweden), ferry to Rostock, and lorry transport the last distance through Frankfurt an der Oder (on the Polish border) to Poznan.

B) Dried cod from Western Norway to Torino in Italy. The present route is lorry transport from Ålesund to Gothenburg, ferry from Gothenburg to Kiel, lorry transport from Kiel to Manching, rail transport (lorry on rail) from Manching to Brenner, and lorry transport on the last distance to Torino.

C) Fresh saith filet from Western Norway to Bremerhaven. The route is lorry transport from Ålesund to Moss (south-eastern Norway), ferry from Moss to Hirtshals (Denmark), and lorry transport from Hirtshals to Bremerhaven.

D) Fresh (and frozen) white fish from Western Norway to Boulogne-sur-Mer in France. The route is lorry transport from Ålesund to Oslo, ferry to Kiel, and lorry transport on the last distance.

The routes are described in more detail in the attachment.

The energy consumption was measured using the on-board Volvo Road Relay system. This is an electronic log that measures parameters such as distance, time, fuel consumption, speed, idle- and economy driving. The drivers had the responsibility for operating the data-system themselves after being instructed by the company manager. In addition to the electronic data from the Road Relay system, the drivers completed a written log for each trip with information regarding:

- Cargo weight
- Driving route
- Weather
- Fuel tanking
- Traffic situation (traffic jams etc.)

The manual log gave important information for interpretation of the data from the Road Relay system. For instance, the fuel consumption could be controlled with the log. In most cases, the differences between the Road Relay system and the manual log were within ± 1-3 percent.

Energy efficiency

In the two tables below we have summarised the energy use from the measurements. The first table gives data from the four routes, and the other table gives data from general measurements.

Table 1 Energy use in lorry fish transport from Western Norway to the continent.

Case-route	Payload, trip[1] average (tonnes)	Energy efficiency, average (kWh/tonnekm)	Empty driving, average (km)	Total distance per trip, average (km)	Number of trips on which the calculations are based
A	18	0,22	n.a.	3700	3
B	22	0,16	n.a.	4600	1
C	16	0,22	83	2500	5
D	17	0,20	104	3650	3

n.a.= data not available

The table shows the average energy use on down trip and return trip for four routes (data collected 1999-2000). For case A and B data for empty driving were incomplete. The low specific energy use in case B can be explained by the higher load factor for this case route. Note that the data in case B is only based on one trip.

General measurement during a longer period driving with variable routes is shown in table 2. These also indicate energy efficiency in the range 0,20-0,22 kWh per tonnekm. Payload is however not available for the individual trips, but an average value is assumed (17 tonnes).

Table 2 Average energy use in lorry fish transport from Western Norway to the continent.

Km, total	Number of measurements	Period	kWh/tonnekm	Driver number[2]
59000	1	Winter -99/00	0,224	1
55000	1	Summer –99	0,206	2
78000	7	1999-2000[3]	0,20-0,21	3 & 4

In the four cases routes described earlier in this chapter the load factor is generally lower on return trip than down trip. Hence the energy use per tonnekm is lower on the down trip compared to the return trip. Figure 1 illustrates this.

[1] "Down trip" is used to express the trip from loading place in Western Norway to the destination on the continent. "Return trip" is used for the trip from the European continent to Norway. "Trip" is used to express the sum of down trip and return trip.
[2] A specific number is designated for each driver (to be able to analyse the effect of driver style)
[3] Spring, summer and autumn in 1999 and 2000.

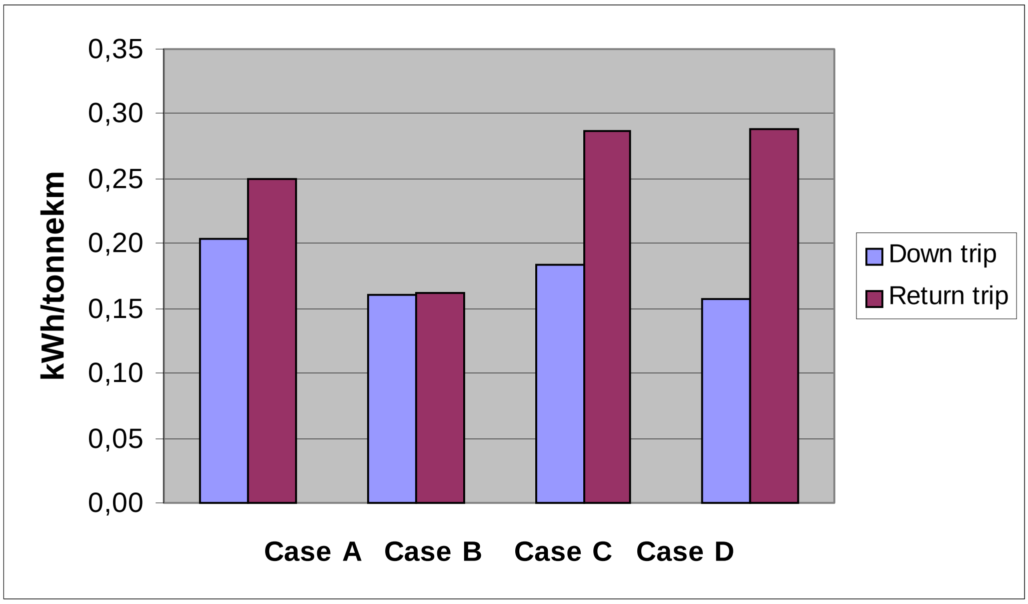


Figure 1 Energy use per tonnekm on down trip and return trip for four different routes.

In figure 1 data is collected during 1999-2000. In case B the load factor is 100 percent on return trip. The difference in energy efficiency on down trips between case C and D is difficult to explain. Topography is a possible explanation. Driving distance on the European continent in Route C is relatively shorter than the corresponding distance for route D.

In case A the higher energy use per tonnekm in the down trip could partly be explained by the driving style on this down trip. In the manual log for this particular route, the driver has entered: "hard driving".

Energy use by the ferries contributes to a substantial part of the total energy use. In case B and case D the ferries are responsible for nearly half of the total energy use due to the long ferry distances in these cases. The figure below shows this.

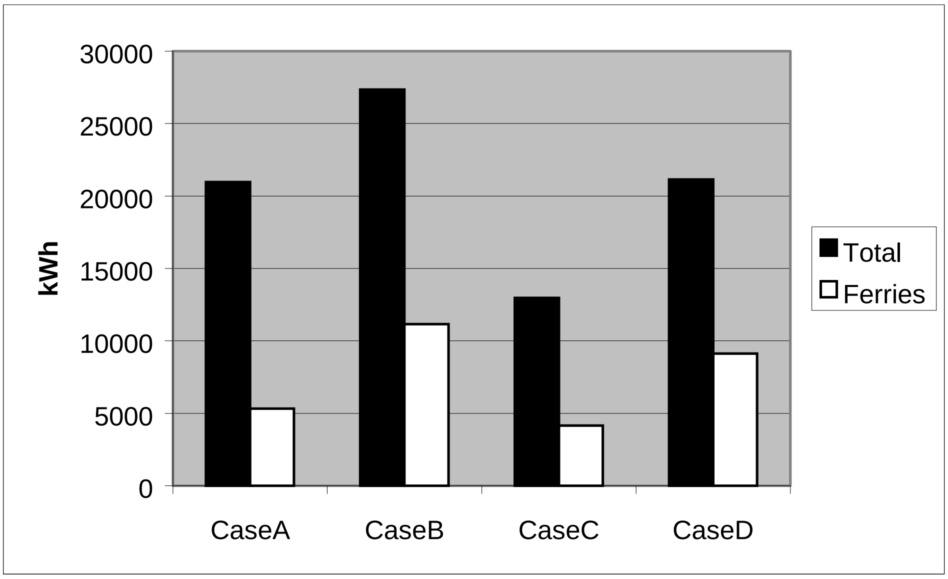


Figure 2 Energy use by the four cases of transport of fish round trips between Norway and the European continent. Total energy use and energy use by ferries.

Effect of driving style, load factor and topography

Trips made by different drivers on the same distance and with the same load factor, have been compared in an attempt to assess the effect of different driving style. The most striking effect is shown in figure below. Each distance is marked with a single point.

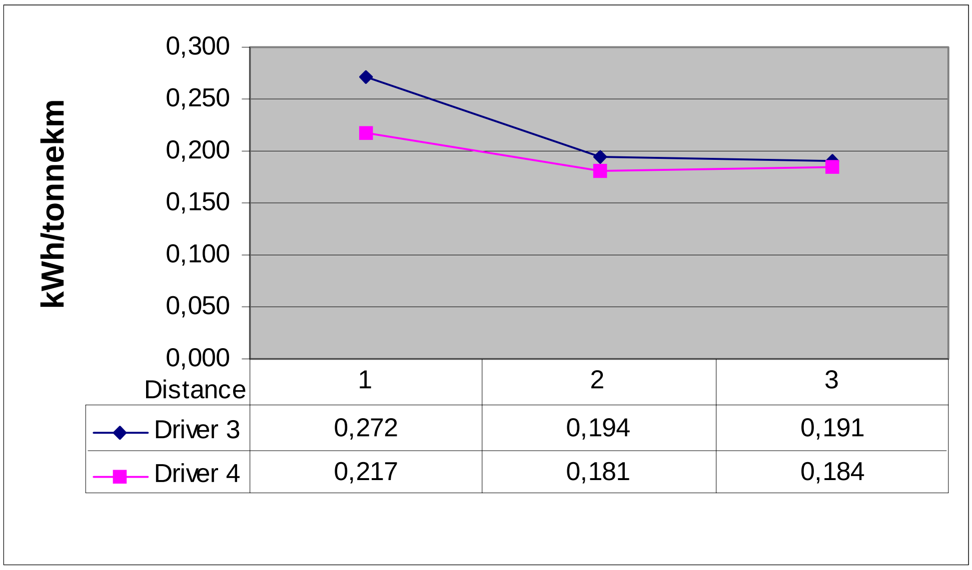


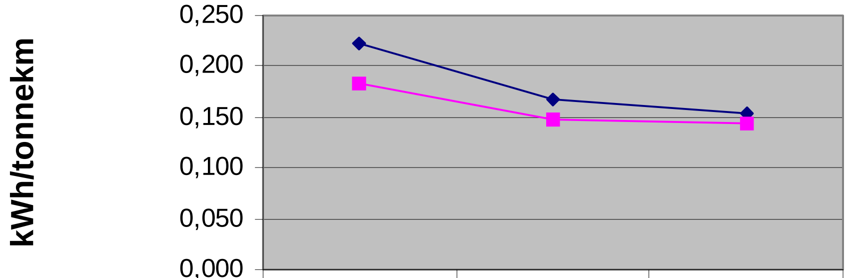
Figure 3 Effect of driving style on energy efficiency.

In Figure 3 the graphs show the same routes and truck weight, different driver and truck. The distances are: 1= Ålesund-Otta, 2= Otta-Trelleborg, 3=Trelleborg-Poznan.

Driver 3 had 25 percent higher energy use per tonnekm than driver 4 on the first distance, Ålesund-Otta, at the route carrying herring to Poznan. Driver 4 practises traditional driving, while driver 3 has explained the result with “hard driving”. This example shows a large difference in energy use due to differences in driving style. In addition to this difference Hjortsberg and Ahlvik (2001) have found that eco-driving compared with traditional driving results in approximately 10 percent reduction in energy use. Focusing driving style within the enterprise could therefore make substantial energy savings.

From Otta to Oslo, the second distance, the difference between the drivers is reduced to 4 percent. According to the logbook this difference could be explained by rain and traffic jam for driver 3, where driver 4 had good weather and no traffic problems. The result on the last distance, Trelleborg to Poznan, with nearly the same energy use, could support this explanation.

As we have shown before, the energy efficiency is usually lower on return trips. This is caused by lower load factor. There are differences in energy efficiencies due to variations in load factor, even with smaller differences in load factor. The figure below shows the energy use per tonnekm for two down-trips by the same driver and truck.

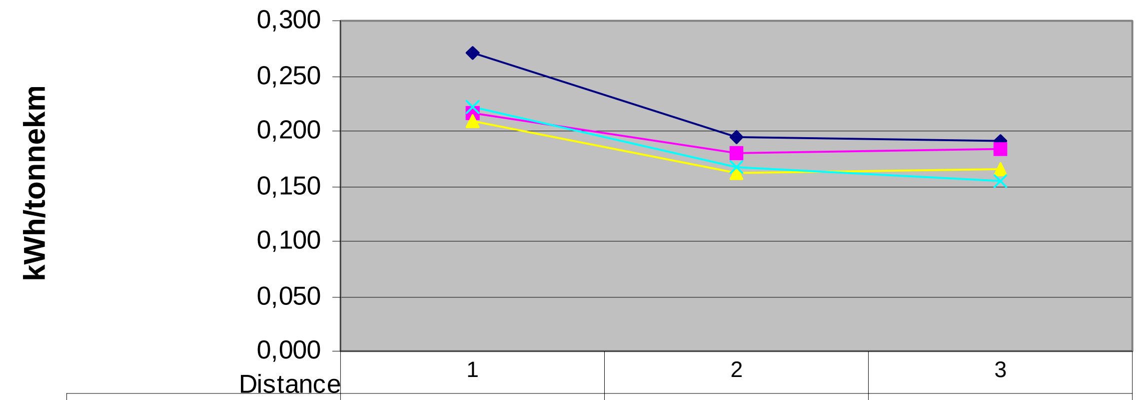


Distance	1	2	3
Payload 21 tonnes	0,223	0,166	0,154
Payload 25 tonnes	0,183	0,147	0,144

Figure 4 Effect of difference in load factor on energy efficiency.

In figure 4 the graphs show the same driver and lorry on the two down trips. The down trip with payload 25 tonnes took place under good driving conditions while the other (21 tonnes payload) had partly rain on distance one and two. This could also contribute to the difference in energy efficiency. Driving in Western Norway with hilly topography gives larger differences in energy efficiency between the two trips. This illustrates the importance of high load factor especially for driving in mountainous regions.

Our data indicates lower energy efficiency when driving on the eastern parts of the European continent compared with driving in Western parts, but the data set is too limited to draw such a conclusion. The figure below shows energy efficiency by different routes and drivers.



Distance	1	2	3
21 tonnes to Poznan	0,272	0,194	0,191
21 tonnes to Poznan	0,217	0,181	0,184
22 tonnes to Torino	0,210	0,162	0,165
21 tonnes to BSM	0,223	0,166	0,154

Figure 5 Energy efficiency by different routes and drivers.

In figure 5 the distances are: 1=Ålesund-Otta, 2=Otta-Oslo and 3= different distances on the continent. The figure shows close energy efficiency for three of the drivers on the first distance, Ålesund to Otta. In connection to figure 3 we have explained the large difference in energy efficiency for one of the drivers to Poznan. The difference at distance 2, Otta to Oslo, could partly be explained by higher load factor for the lorry to Torino. In addition the two drivers to Poznan had rain on this distance while the other drivers had nice and dry weather.

Summary

The measurement of the energy use in the four case lorry routes can be summarised as follows:

- The data on energy efficiency in fish transport from Western Norway to the European continent shows an average energy use for down- and return trip of approx. 0,22 kWh per tonnekm.
- The return trips have lower energy efficiency, than the down trips due to lower load factor. If the load capacity had been fully utilised on return trips, the overall energy efficiency could be improved to about 0,18 kWh per tonnekm.
- Even with relatively good utilisation of load capacity today there is a potential for further energy efficiency improvements by increasing the load factor.

- Different driving style could have a great influence on fuel use and thereby energy efficiency. One observation shows that non-economic driving could increase fuel consumption with 25 percent.

- The energy saving potential in today's lorry transport is largest in areas with rugged topography.

2.5. Description of actions and the conditions necessary for their implementation

In the report from phase 1 of this project we have described potential pilot actions (Andersen & al., 1999). Here we present the selected actions that we planned to implement during the project period: actions to reduce fuel consumption, actions to increase load factor and actions to the transfer of transport mode. We also describe the necessary conditions for implementation of the actions.

Actions to reduce fuel consumption

The presentation of the actions is structured as: 1) Driver information and motivation and 2) Already implemented actions. We also present the energy saving work in another company, Nistad transport.

Driver information and motivation

The case company Waagan Transport has earlier focused on driving style to reduce fuel consumption. In the early 1990's the company was encouraging its drivers to drive economically. For example it was banned to let the engine run "idle" for extended time periods. In 1994, at the time when a computer information system were installed in the trucks, drivers at Waagan Transport were competing in minimising the fuel consumption. According to manager Per Waagan, there is a difference between older and younger drivers when it comes to awareness of fuel costs: For instance, younger lorry drivers are prone to neglect the importance of avoiding idle running when the car is standing still.

Expansion of the company during the last years has made it more difficult to control driving pattern at the individual level. In connection with renewing the truck fleet in 1996, Volvo requested a driving course for all drivers in the company. About 80 percent of the drivers completed the energy-economy course (Waagan, P., 1998-2000).

The company was willing to continue this work. The plan was first to establish a driving course for some of the drivers in order to measure the effects on fuel consumption. Subsequently, a new driving course for all the drivers in the company was to be held. The course intended to focus on energy efficient driving with these subjects:

- Develop the driving style
- Reduce driving resistance
- Avoid idle driving
- Route planning
- Choose the most energy efficient top and average speed.

The course was to be carried out in co-operation with VOLVO. VOLVO was willing to take the responsibility for teaching the drivers in the spring of 2000 (Nordvik, 1999-2000). For different reasons, described in 3.4.2, the course has not been offered. To compensate this we have made efforts to use experiences from another transport company working with energy saving issues. This is described in the Chapter 3.1.3 below.

Actions already implemented in the company

The management at WT emphasises the importance of providing the best engine technology available. The company renews the lorry fleet every second year, and selects the most energy efficient engine, trailer type and cooling system. The lorries are being replaced after 150.000-170.000 km. Other actions already implemented in the company are (Waagan, P., 1998-2000):

- Removal of extra equipment on the lorries which causes air resistance (e.g. signs on roof).
- Changes of air and diesel filter at regular intervals, by WT's own garage.
- The garage employees perform lorry cleaning (removal of ice, snow and dirt) as often as possible to avoid ear resistance increased weight of the lorries. The frequency of the cleaning varies somewhat, from cleaning after every trip to cleaning every fortnight.

Nistad Transport company

This presentation is based on information from Arne Nistad, manager of Nistad Transport company. The company is located in Western Norway and also carries foodstuff for the industry, but not fish. The company has 19 lorries used in long distance transport and shorter distribution- and supply transport.

In April 2000 the company started a developing process with the aim of reducing energy consumption in lorry transport by 5 % during one year. The information and motivation work included actions such as:

- Energy saving course for all drivers
- Examinations
- Motivation and competence developing processes in groups of drivers

Participation in this process is mandatory for all drivers. An important element is to organise the drivers in three groups according to where they live. Fuel reduction aims are established for each whole group and not individually. This gives a constructive competition between the groups to reduce fuel consumption, and focus on teamwork.

The company has reached their initial goal regarding energy saving. Measurements during the first year indicate an average fuel reduction of about 5 %. Energy saving effect differs from driver to driver, the largest measured effect is 20 %. Large reductions have been measured both for long distance transport and for shorter distribution and supply transport. This corresponds to the findings in the Swedish case, where a test showed that changes in driving style, ("eco-driving"), could decrease fuel consumption up to 10 % in lorries (Hjortsberg and Ahlvik, 2001).

In addition to lower fuel cost, the energy saving work has had positive economical effects by reducing maintenance on the lorries and reduced wheel and tire wear. Nistad Transport company has plans for further work on these issues in the years to come.

Actions to increase load factor

Actions to increase load factor have been on the agenda in discussions with WT, and it was concluded to investigate the possibilities of co-operation with other transport companies to better utilise load capacity on return trips. However, only limited improvement possibilities in this area have been identified.

Actions for transfer to more energy efficient transport modes

Transfer of goods from road to rail has been implemented as an important strategy in WT during the project period. This has given the project an unique position to measure the energy saving effects from this transferral. Another action has been to streamline the custom routines for paying taxes on the ships from Norway to the continent, making this form of transport more attractive to use.

From road to rail

This sub-chapter is based on information obtained from Per Waagan (Waagan Transport) and Knut Brunstad and Kjell Owrehagen from Norwegian Railways (NSB). Before the project period WT had been in contact with NSB trying to establish transfer of goods from road to rail on the route between Åndalsnes and Oslo. The SAVE project gave an opportunity to address this issue again, and in a broader context. Western Norway Research Institute therefore suggested for Waagan Transport to contact NSB again concerning the possibility of transporting semitrailers on rail from Åndalsnes to Oslo.

This effort was successful, and during the winter 1999/2000 negotiations between WT and NSB gave results. On February 14th 2000 a contract was signed for transport of trailers on rail from Åndalsnes to Oslo, a distance of about 450 km. According to the agreement, WT was to use NSB transport services for all cargo between Møre og Romsdal county to Oslo or through Oslo. In August 2000 the first of these transports was taking place.

This intermodal transport is based on "huckepack" technology giving opportunities to combine all means of transportation: road-, rail- and sea-transportation. The first distance from the west coast of Norway, mainly the Western part of Møre og Romsdal county, is done by truck to Åndalsnes. The distance from the WT terminal (close to Ålesund) to Åndalsnes is 110 km. In Åndalsnes the semitrailers are placed on rail to Oslo. The train has two departures per day from Åndalsnes to Oslo at 06.30 and 21.00 and two return departures from Oslo. The trip takes nine hours each way. The maximum payload at the Rauma railway is approx. 550 tonnes per train, limited by the steep climb up the valley Romsdal. Each train carries 8-10 semitrailers in addition to ordinary containers.

About 50 percent of WT's total transport volume towards Eastern Norway, exports included, is by the year 2000/2001 carried by train to Oslo. In autumn 2000 the fish transport from Oslo to the European continent was transported both on rail and road. Transport of dried cod from Western Norway to Italy by train started in the middle of November year 2000. From Oslo this transport takes 48 hours to Verona in Italy, from where the fish is transported by lorries to the final customers.

Frozen herring and mackerel to Boulogne-sur-Mer are transported with rail from Western Norway to Oslo and with ship from Oslo to Rotterdam, from where the lorries bring the fish to the customers in BSM. In France efforts are made at present to permit implementation of the huckepack-system on rail. In this way WT has developed an intermodal transport chain based on truck, train and ferry from the Western coast of Norway to the continent.

Barriers at the customs control

WT has re-negotiated the customs control at the Colorline ships. The aim was to streamline the routines for paying the customs duties and taxes. On some of the routes the customs control has constituted a barrier to the use of ship transport. WT has succeeded in their efforts to solve this problem, and the customs control procedures have been improved. Thereby this barrier has been overcome (Waagan, K., 2000).

Necessary conditions for implementing actions

Necessary conditions for implementing actions are described according to this structure:

- Generally necessary conditions
- Conditions to reduce fuel consumption in today lorry's transport
- Conditions to the transferral between transport modes

Genera conditions

In the 1980's Waagan Transport tried to develop energy efficiency as a part of an environmentally image used in marketing to obtain competitive advantages. However, they found no potential for translating such goodwill into a transport payment premium. Their customers did not want to pay more for a more environmentally friendly transport service (Waagan, P., 1998-2000).

To reduce the energy use beyond the level required by public laws and regulations, a commercial company such as WT needs an economical motivation. Increase in income or reduction in costs could provide such motivation. Reduction in energy use could also be a strategy to make a positive image and thereby enabling the company to keep their market share. Necessary conditions for turning energy efficiency into a business strategy are therefore actions that bring the company in position to:

- Reduce costs, or
- Increase income, or
- Get other competitive advantages (e.g. positive image)

Conditions to reduce fuel consumption

Based on the experience from this project, the following question seems important when implementation of actions in a case company is concerned: Are the actions, and the implementation processes, suitable or compatible with the main processes going on in the company? If not, it seems to be very difficult to implement new actions and strategies.

Another important experience is that combining implementation of actions with measurements of the same actions at the same time is difficult in the transport sector. This is a sector where rapid changes occur, and the time available for implementation of such development processes is limited. The intention was to implement a driving course to develop energy efficient driving, and the effects of the course were to be measured. This objective required measurements made before and after the driving course. The measurements before implementing the action were time- and resource consuming for the case company in 1999. Being ready to start the driving course in the spring of 2000, the company had practical problems: It was difficult to gather the drivers at one place at the same time for a course without reducing the custom service, and it would be expensive to teach them one by one. In the meantime two of the drivers got sick for a long time, and two others changed to newer lorries. The plan for measuring the effect of the training course was therefore not carried out.

For the reasons indicated above, the implementation process took much time, and for some period the project overlapped with another main process in the company: developing transferral of goods from road to rail. This process changed the conditions for implementation of a driving course drastically. The distance with probably the greatest energy saving potential, the hilly and steep Norway, was reduced substantially. In addition, the company changed their organisation to a large extent in important ways by hiring transport services from other companies.

A third factor which influenced the conditions for reducing the energy use is, according to the case company, a new phenomenon the last years: All types of fish transports are rush deliveries and have to be delivered exactly on time. The customers of the fish-exporter are emphasising short delivery times. These are not the best conditions for choosing the most energy efficient driving style. This situation could also sometimes make it difficult to choose the most energy-friendly transport route. Delayed deliveries from the exporter to the transport company reinforce this problem.

To sum up the project experiences: Important conditions for reduction of fuel consumption in today's lorry transport are:

- Actions and strategies have to be adapted to other main processes going on in the company
- The hard competition in the transport sector makes it difficult to spend enough time on developing processes
- The increasing demands for "just in time" deliveries make it difficult to use the most energy efficient driving style.

Conditions for the transferral from road to rail

Both WT and NSB have made preparations to initiate fish transport on rail. Here we focus on conditions necessary to realise the introduction of intermodal transport between road and rail on the line Åndalsnes - Oslo.

<u>Waagan Transport (WT)</u>

This presentation is based on information from Per Waagan. WT's motivation for transferral of goods from road to rail is reduction in costs. Driver wages represent 40 percent of total costs in the company, and it is impossible to compete with other companies on the European continent with "eastern European (low) wages". Transferral of goods to rail is one solution for reducing costs for wages. Another motivation is to develop a more flexible transport system with road, rail and sea. Rail transport may also improve the transport company's public image. Positive environmental image might bring new customers to the company.

Investments in 49 new trailers with the huckepack system is the most important action made by WT to realise the transferral to rail transport. These kinds of trailers are adaptable for different transport modes. WT has also changed its organisation. In both ends of the rail transport segment they are now hiring services from other transport companies.

To obtain experiences, WT has started transporting furniture and some fish products through this new intermodal transport chain. In autumn 2000 fresh salmon was difficult to include in this system due to non-optimised logistic chain. When the punctuality is improved WT is going to include fresh fish in these intermodal transport chains.

This transferral of goods from road to rail has given a substantial reduction in the volume of goods transported by WT on road. In the coming years, with also fresh fish being transported on rail, the mode change will have been carried even further. The important factor for these operations is a streamlining of the logistic chain to improve the stability of the deliveries.

Norwegian railways (NSB)

Here we present preparations done both by NSB Cargo and The Norwegian National Rail Administration. The presentation is based on information from Knut Brunstad and Kjell Owrehagen in NSB Cargo.

Enlarging tunnels:
The transport of semitrailers on train demands larger space than traditional goods trains. This implies that some tunnels need to be enlarged to facilitate this type of combined transport. In August 2000 Raumabanen (Dombås – Åndalsnes) was ready for such transport after preparation work of The Norwegian National Rail Administration. The administration is responsible of the rail infrastructure.

Intermodal rail equipment:
NSB Cargo has procured wagons for semi-trailer transport. They also obtained new trucks especially adapted for handling semitrailers. The first third of the rail distance from Åndalsnes to Oslo is not electrified. Hence NSB uses diesel trains at this distance. At Otta the diesel locomotive is changed with electricity locomotive, and opposite on return. The change to electricity train at Otta means lower utilisation of the trains compared with using the diesel train the whole distance to Oslo.

Streamlining the timetable:
In summer 2000 NSB Cargo changed the timetable on the CombiXpress on Rauma Railway in order to facilitate WT fish transport. This new timetable might cause problems in the future due to potential conflicts between goods trains and passenger trains. The plan is to develop the passenger train services with faster trains, but this will increase the need for passing lines for trains going the same direction. The policy in NSB is to give the passenger trains priority before goods trains.

Waagan makes cumulative effects:
In year 2000 WT was the only transport company using the Åndalsnes-Oslo line for fish transport. When the intermodal transport co-operation between WT and NSB Cargo was published in august 2000, NSB received many inquiries from other transport companies. In 2001 therefore, two new large transport companies are going to transfer goods from road to rail using this line. Our case company has apparently started a process among the transport companies resulting in a substantial reduction in energy use in transport of goods. In NSB Cargo this process is mentioned as “the Waagan effect”.

2.6. Routes for rail transport of fish from Norway to the European continent

Norwegian Railways has in co-operation with Swedish Railways (SJ) established transport possibilities for fish on rail with connection to rail transportsystems on the European continent. This gives the unique opportunity to transport fish from e.g. Narvik in northern Norway all the way to Verona in Italy, a distance of about 2700 km.

The transport product is called “CombiXpress” and comprises the option of bringing semi-trailers, ordinary containers and Swap bodies with the same train. The customers can order reservation or buy transport services daily. The transport of fish by semitrailers on train has increased during 2000. In Norway these lines are adapted for intermodal transport (www.nsb.no):

- Oslo- Åndalsnes
- Oslo-Trondheim
- Oslo-Narvik
- Oslo-Kristiansand-Stavanger

Further plans include the opening of parts of the line Trondheim-Bodø before the end of 2002 for this type of transport. More long-term plans exist for Oslo-Bergen, but this requires much work due to the many tunnels on this route. Below we give a short presentation of the rail transport routes from Scandinavia to the continent. So far, by year 2001, the main fish transport route consisting of rail from Norway to the European continent is performed with Arctic Rail Express (ARE) and Padborg-Oslo Rail Express. Scandinavian Rail Express also transports some fish cargo to Italy (Owrehagen, 2001).

Arctic Rail Express (ARE)

This rail serves fish transport from northern Norway (Finnmark, Troms and northern part of Nordland county). The trip takes 36 hours with departure from Narvik (Norway) or Gällivare (Sweden) through Sweden to Hälsingborg and across Denmark to Padborg. The connection to Padborg was established in year 2000 with direct connection to Malmö and Padborg without any reloading. See the map.

In January year 2001 there were six departures from Narvik to Oslo, and one to Padborg each day. NSB is making efforts to increase the volume to Padborg. The volume of fish carried by ARE was about 2700 containers, or about 30000 tonnes in 1999 and 2000 each year. This is one half with fresh fish and the other half with frozen fish (Bertnes, 2001).

The utilisation is 60 percent on the trip from Narvik to the continent, and 100 percent on the return trip. Total cargo weight for one train is 700 tonnes, and a normal fish transport contains about 300 tonnes of fish.

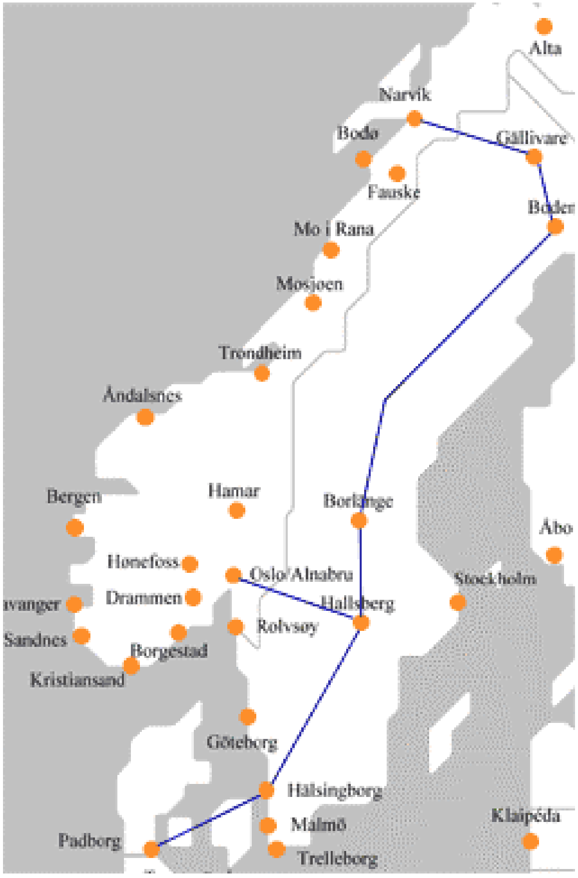


Figure 6 Artic Rail Express from Narvik/Gällivare to Padborg.

Source: www.nsb.no

Scandinavian Rail Express

The Scandinavian Rail Express has connected the "CombiXpress" in Scandinavia to different combitrains-systems on the continent since 1997. There are five weekly departures from Oslo to Travemünde, Duisburg, Cologne, Mannheim and Basel. Train-time from Oslo to Basel is 36 hours. There is also connection to Verona and Milano in Italy. This transport route is now often used for dried fish from Norway to Italy. See figure 7.

In 1999 the timetable was changed to get better connections with the ferry from Trelleborg to the continent, and the transport volume increased (Owrehagen, 2001). Scandinavian Rail Express is established in co-operation between NSB Cargo and Rail Combi AB in Sweden.

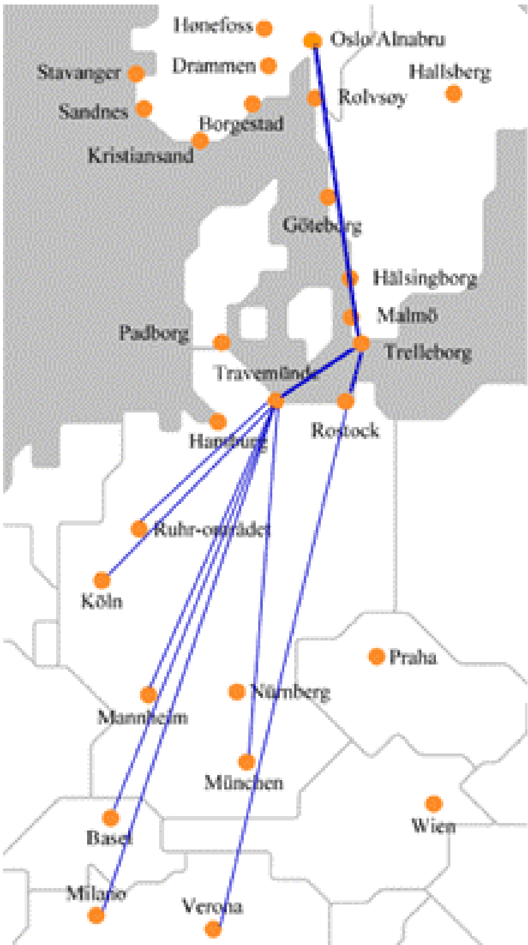


Figure 7 Scandinavian Rail Express (SRE), Oslo-Trelleborg-the European continent.

Source: www.nsb.no

Padborg - Oslo Rail Express

After the opening of the Öresund bridge a new combi-express train between Oslo and Padborg was started. This connection is adapted especially for fish transports to the continent, with departure from Oslo every Friday to serve the fish market on the continent over the weekend.

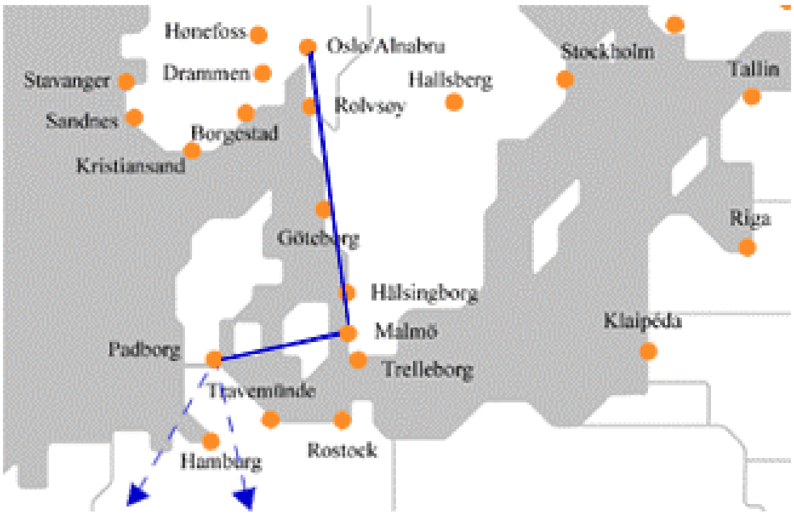


Figure 8 Padborg – Oslo Rail Express.

Source: www.nsb.no

2.7. Energy saving effects

In this chapter we present the energy saving effect of the performed pilot actions and the potential possible actions. The focus is on energy saving effects in the lorry transport, and the effect of transfer of transport mode from lorry to rail and sea. The effects are shown both for our four cases and for the Norwegian fish export as a whole.

Energy saving effects of actions in today's lorry transport

In the following we present an estimate of the energy saving potential in the lorry transport of fish exported from Norway. The calculations are based on the four cases. We assume that these four cases are representative for Norwegian fish export. This is a rough estimation, presumably good enough to illustrate the energy saving effects.

The energy saving potential in the present lorry transport is about 5 %, according to the energy saving results in the company Nistad Transport in Western Norway. Total volume fish export by lorry from Norway was 3 222 557 tonnes in year 2000 (Dahle, 2001). Assuming 5

% decrease in fuel consumption in this transportation we obtain an energy saving potential at about 12 000 tonnes fuel or about 115 million kWh. The table below shows this effect.

Table 3 Energy saving potential in the present lorry transport of fish from Norway to the European continent (round trips).

Export by lorry, year 2000 (tonnes)	3 222 557
Export by lorry[1] (kWh/tonne)	317
5 % reduction, (kWh)	114 864 998
5 % reduction, (tonne fuel)	11 769

[1]Average of the four cases.

Energy saving effects of transfer to rail and ship

In this chapter we present the potential energy saving effects of a transfer of fish transport from road to rail and sea. The calculations are based on the four cases of fish transport from Western Norway to the European continent (described in chapter 2). Today's lorry transport is the basic alternative.

The fuel consumption, distances, duration and average loads for the basic alternative are shown in Table 4. Data for this transport is based on the measurements made during the project for round trips (from Norway to the European continent and back to Norway). Data were collected in the period 1999-2000.

Table 4 Average[4] fuel consumption, distances, duration and loads for the basic alternatives for fish transport.

Case	Lorry fuel consumption (litre)	Road distance (km)	Ferry duration[5] (hrs)	Rail distance (km)	Total duration (hrs)	Payload (tonne)
A	1537	3161	16	-	96	18
B	1659	4622	28	436	158	22
C	904	2515	14	-	98	16
D	1232	3644	44 (14)	-	134	17

For all cases and alternatives the distance from the west coast of Norway near Ålesund to Åndalsnes (about 110 km) is done by lorry. During the project period a change in transport mode was implemented for case B and D. Dried cod (case B) is transported by train on the main distance from Åndalsnes to Verona (Italy). Lorry is used the last distance to Torino. This route is named B_R in the subsequent text of this chapter. In Case D lorry transport is

[4] The numbers are averages for each of the cases. Case A and D are each based on three round trips, B on one and C on five.
[5] The number in parenthesis is the route with ferry between Moss and Fredrikshavn.

replaced with rail and Cargo ferry (no passengers). Frozen herring and mackerel are transported with rail from Åndalsnes to Oslo, with ship from Oslo to Rotterdam, and lorry the last distance to Boulogne-sur-Mer. This route is named D_{FR}. These two intermodal transport routes were established during autumn year 2000, and have replaced lorry-based transport.

To achieve major improvements in energy efficiency a mode change from road to more rail and sea is however assumed to be necessary. The effects of such mode transfers on the energy-use are analysed by the Nordic Transportpolitical Network in the InterregIIc-programme in the report "Optimal transport corridors based on a sustainability- requirement". The data material from the report has been supplemented by updated data from the analyses in this SAVE-project. Here we use the scenarios from the InterregIIc-report for year 2015 to illustrate the potential energy saving effects for alternative routes to our cases. This include assumption with railway bridge across the Fehmarn Belt (Rødby-Puttgarden):

* *Case A* (fresh herring to Poland) with train to Poznan. This route is named A_R.
* The sea alternative in *Case B* (dried cod to Italy) is ship from Ålesund harbour to Genova, and lorry the last distance to Torino. This route is named B_B.
* *Case C* (fresh saith filet to Germany) with the two alternatives rail (C_R) or sea (C_B). The rail alternative includes rail from Åndalsnes to Bremerhaven. For the sea alternative, we assume ship the whole distance from Ålesund harbour to Bremerhaven.
* The ship alternative in *Case D* (fresh and frozen white fish to France) is by ship the whole distance from Ålesund harbour to Boulogne-sur-Mer. This route is named D_B.

For calculation of energy and time expenditure, we assume the same average payloads on the alternative routes as on the actual transport by lorry. The energy factors shown in table 5 are applied. Note that two types of ferry are used: Traditional ferry carrying both passenger and goods, and Cargo ferry only carrying goods.

Table 5 Factors applied in the energy use calculations for rail and ferry

Means of transportation	Energy use (kWh/tonnekm)
Traditional ferry[6] (at 50% load factor)	0,50
Cargo-ferry[7] (at 80% load factor)	0,35
Lorry[8] (at 60% load factor)	0,26
Train[9], electric (at 70% load factor)	0,06
Ship[10] (at 70% load factor)	0,08

Source: Hansen, Høyer and Tengstrøm (2000), and data collected in this SAVE project.

It is apparent from the table above that the energy efficiency of ferry is low compared with the other transport modes, especially train and ship. Contribution to the total energy use from traditional ferries is relatively large, even though the distances of the distances with transport of lorries on ferries are short compared with the total transported distances. From this one can conclude that the transport by lorry is more energy-efficient than when the lorries are transported by traditional ferry. This is the situation in the basic alternatives.

In the scenarios we have no traditional ferry use assuming railway bridge across the Fehmarn Belt. The distances with lorry, rail and ship, total duration and energy use for the scenarios are present in table 6. The calculation is based on round trips, from Norway to the European continent and back to Norway. Actions implemented during the project are in grey.

6 This is applied to all routes with ferry (for people, cars and cargo), except for the alternative route to BSM (D_{FR}). The energy data is based on Hansen, Høyer, Tengström (2000)

7 The energy use factor is calculated from data received from DFDS Tor Line. They have a cargo-ferry route from Oslo to Rotterdam, carrying only cargo. This energy data is used on the route D_{FR}.

8 Lorries are used for distances at 300 km and shorter. This explains the higher energy use factor than on long distance lorries.

9 Trains are assumed to be powered by electricity only. The trains for goods transport are assumed to have maximum speed of 120 km/hr and with carriages for transport of containers/semitrailers on 2 storeys. Already at the end of the 1990's Swedish and Finnish rail transport averaged 0,03-0,04 kWh/tonnekm (load factor 60-70). A higher energy use factor than this is used to compensate for the weight of containers/semitrailers and the need for cooling of the fish during the transport.

10 This is energy use for traditional long distance cargo ship using less energy than the ferries.

Table 6 Distances, duration and energy use in the scenarios of fish transport.

Case	Lorry distance	Rail distance	Boat/ferry distance	Total duration[11] (hrs)	Energy use (kWh)
A_R	226	3574	0	108	4918
B_R	826	4674	0	166	10894
B_B	814	0	10686	438	23463
C_R	226	3074	0	90	3891
C_B	0	0	2700	116	3456
D_B	0	0	3300	139	4488
D_{FR}	826	900	2056	128	16802

A comparison between the basic alternatives (with lorry transport in 1999) and the scenarios (rail transport, ship transport and ferry and rail based transport) is shown in table 7. The results are present in percentage change compared with lorry transport in parenthesis. Actions implemented during the project are in grey. The basic alternatives is based on are actual data from lorry transport. The scenarios are based on calculated data from implemented actions and potential transferable alternatives.

Table 7 The energy use (kWh) for the scenarios compared with the basic alternatives.

Main transport mode/case	**A**	**B**	**C**	**D**
Lorry based transport (1999)	20959	27341	12975	21145
Rail based transport	4918 (-77 %)	10894 (-60 %)	3891 (-70%)	
Boat based transport		23463 (-14%)	3456 (-73%)	4488 (-79%)
Ferry and rail transport				16802 (-21%)

Table 8 Time use for the scenarios compared with the basic alternatives.

Main transport mode/case	**A**	**B**	**C**	**D**
Lorry based transport (1999)	96	158	98	134
Rail based transport	108 (+13 %)	166 (+5 %)	90 (-8 %)	
Boat based transport		438 (+177 %)	116 (+18%)	139 (+ 4 %)
Ferry and rail transport				128 (- 4 %)

Rail based transport with dried cod to Italy (B_R) is *implemented* during the project in our case company. The reduction in energy use is large, with 60 % lower energy use than lorry based transport. The effect comes from the more energy efficient train transport used on the whole

[11] An average speed of 80 km/hr is assumed for trains. In addition 6 hours waiting time at each of the loading/recoupling locations. The average speed of ships is assumed to be 14 knots. In addition there are a loading and unloading time of 4 hours at each port. This is low due to the improved efficiency of the port operations. The average speed for lorries (including rest hours) is assumed to be 60 km/hour. This might appear to be low, but as pointed out earlier, the lorries are assumed to be used mainly for shorter distances in distribution- and supply transports.

distance from Western Norway to Verona in Italy. The transport is similar in time efficiency (5% difference) to the lorry-based transport in 1999.

The other *implemented action* D_{FR}, frozen fish to Boulogne-sur-Mer in France, is based on ferry and train transport. Here the reduction in energy use is “only” about 20 percent, caused by the train from Åndalsnes to Oslo. The energy saving effect is limited due to the long ferry distance Oslo-Rotterdam. Ferry is less energy efficient than lorry transport.

The other alternatives of transferral result in lager potential in energy use reduction. From the tables above it is clear that the train transport of fresh herring to Poland (Case A_R) is close to being as time efficient as the lorry based transport. The increase in time use is 13%, or 12 hours. The reduction in energy use is however immense, with 77% lower energy use than lorry based transport. This is due mainly to the use of the energy efficient train, but also from the reduced ferry distance. This calculation assumes bridge across the Fehmarn Belt (Rödby-Puttgarden).

One of the three ship alternatives, dried cod to Italy, gives only little reduction in energy use because of the long ship distance into the Mediterranean. The transport by ship (B_B) is more time consuming, but since the product is dried cod, this is of less importance due to the long durability of the fish product. The important question is not the time efficiency in itself, but rather if the delivery reaches the destination at the time agreed upon. Even if the sea transport, as is also the case for the ferry transport, may be affected by increased storm activity from climate changes, “loose couplings” and “simple interactions” enable it to deliver at the time agreed upon, though not as fast as the rail transport.

The sea transport, by ship (not ferry), is more energy efficient than the lorry based transport. In alternative C_B and D_B the ship caused a reduction in energy use at about 70-80 percent compared to lorry transport. These calculations are based on the important assumption using the same large ships as overseas transportation between Europe and America and Europe and Asia.

The transport of fresh saith filet to Germany by rail (C_R) does not differ much from the lorry transport in terms of time duration (8 % difference). The energy saving is in addition large with a reduction in energy use of 70%. The transport by sea to Bremerhaven (C_B) takes 18 % more time than the lorry based transport. Even though the time of transport (58 hours one way) does not seem prohibitive, the reduced time efficiency may reduce the likelihood of sea transport as the preferred choice. The energy saving of the sea transport compared to the lorry based transport for this case is quite large, with a reduction in energy use of 73%.

The transport of fresh whitefish by ship to France (D_B) is almost as time efficient as the lorry transport, taking 9 hours longer. The long ferry distance is part of the lorry-based transport can explain this. The reduction in energy use by the sea transport in this case is large, with 79% lower energy use than lorry based transport.

2.8. Potential effect for all fish transport

The potential energy saving effect of a transfer of fish transport from road to rail has been estimated. The energy use in rail transport of fish is only 30 % compared with lorry transport. If all the fish export with lorry on road from Norway to the European continent were transported by train the total reduction in energy use could be about 70.000 tonnes fuel or nearly 700 mill kWh. This estimation is based on the assumption that the four cases are representative in terms of transport distance and transport mode in the present fish export.

This is not necessarily correct, but the calculations give an indication of the future energy saving potential.

2.9. Conclusions

Fish transport from Western Norway to the continent shows an average energy use for down-trip and return trip of about 0,22 kWh per tonnekm. The return trips have lower energy efficiency due to low load factor. If the load capacity had been fully utilised on return trips, the energy efficiency could be improved to about 0,18 kWh per tonnekm.

Different driving style could have a large influence on fuel consumption and thereby energy efficiency. Hard driving could increase fuel consumption with 25 percent compared with traditional driving in areas with rugged topography in selected cases. While “eco-driving” could decrease fuel consumption with approx. 10 percent compared with traditional driving. This shows a very large range of possible fuel consumption due to the driving style.

Two pilot actions to increase energy efficiency have been carried out:

- Actions to reduce energy consumption and to increase the load factor in today’s lorry transport
- Actions to achieve transferral of goods from lorries to more energy efficient rail and ship transport.

The result shows that it is possible to reach a 5 % reduction in the energy use in the lorry transport at company level actions containing information and motivation measures among the drivers. These actions comprise energy saving course for all drivers, examinations and motivation and competence developing processes. Participation has been mandatory for all drivers. An important element is to organise the drivers into groups and establish fuel reduction aims for the whole group and not individually. This gives a constructive competition between the groups to reduce fuel consumption, and focus on teamwork.

For the whole fish export from Norway transported on lorry, a 5 % reduction in fuel consumption would give an energy saving effect of about 12.000 tonnes fuel or about 115 mill kWh a year. This estimate is based on an assumption that our four fish cases are representative for Norwegian fish export as a whole.

In general, commercial companies need economic motivation to reduce the energy use more than to a level required by public laws and regulations. Such motivation could come from an increase in income or reduction in costs. Reduction in energy use could also be a strategy for developing other competitive advantages (e.g. positive image) to keep their position in the market without particular possibilities to increase income or to reduce costs.

The following additional conditions for reduction of fuel consumption can be identified in today’s lorry transport:

- Actions and strategies have to be suitable with other main processes going on in the company
- The hard competition in the transport sector makes it difficult to spend much time on developing processes like information and motivation of drivers
- The increasing demands for “just in time” deliveries make it difficult to use the most energy efficient driving style.

During the project period transferral from road to rail and ferry took place for two of the four case routes. In rail-based transport with dried cod to Italy, reduction in energy use amounts to 60 % compared with lorry based transport. The effect comes from the more energy efficient train transport used on the whole distance from Western Norway to Verona in Italy. The train transport is nearly similar in time efficiency to the lorry-based transport.

The other *implemented action* concerns transport of frozen fish to Boulogne-sur-Mer in France, which is based on ferry and train transport. In this case the reduction in energy use is “only” about 20 percent. The energy saving effect is limited due to the long ferry distance Oslo-Rotterdam as ferry is less energy efficient than lorry transport.

The other potential alternatives of modal shift give larger reduction in energy use. Transferrals of goods from road to rail transport in three cases (from Western Norway to Poznan, Bremerhaven and Boulogne-sur-Mer) give an average reduction in energy use at about 70 %. This calculation assumes bridge across the Fehmarn Belt (Rödby- Puttgarden).

For the ship alternative the reduction is at the same level for the transport to Bremerhaven and BSM, whereas the ship transport to Italy uses nearly as much energy as the lorry transport due to the long sea distance. It is important to note that these calculations are based on the use of large vessels made for intercontinental sea transport.

A transfer from today’s road transport of fish from Norway to the European continent to rail transport could give a reduction in energy use at about 70.000 tonnes fuel or nearly 700 mill kWh. This calculation is based on the assumption that our four cases are representative in terms of transport distance and transport mode in the present fish export.

Specific necessary conditions for transferral of goods to rail in the case company Waagan Transport were the possibilities for reducing costs for wages. Another goal was to develop a more flexible transport system with road, rail and sea. Rail transport makes it also possible to improve the public acceptance. Positive environmental image might bring new customers to the company.

Another necessary condition is investment in new trailers with the huckepack system adaptable for different transport modes. In autumn 2000 fresh salmon was difficult to include in this system due to non-optimised logistic chain. When the punctuality is improved WT is going to include fresh fish in these intermodal transport chains.

Also Norwegian Railways (NSB) and The Norwegian National Rail Administration have done preparations to establish a transferral to train transport by enlarging tunnel profiles and investment in intermodal rail equipment. There is a potential conflict between cargo trains and public trains in the future. With increasingly faster public trains, there would be a need for passing lines also for trains in the same direction.

In year 2000 Waagan Transport was the only transport company using the Åndalsnes-Oslo railline for fish transport. When the intermodal transport co-operation between WT and NSB Cargo was published in august 2000, NSB got many similar inquiries from other transport companies. In 2001 two new large transport companies are therefore going to transfer goods from road to rail using this line. Our case company has apparently started a process among the transport companies resulting in a substantial reduction in energy use in transport of goods. In NSB Cargo this effect is mentioned as “the Waagan effect”.

3. The pilot actions in Finland

3.1. Introduction

The main aim of the project is to develop and implement actions, strategies and measures for improved energy efficiency in the transport of goods. This is a pilot project covering actions within rural, natural resource based industries from three different branches. Three companies, one each from Finland, Norway and Sweden, serve the function as project – "cases" in order to give a solid framework around the pilot actions and the development of the strategies and measures. The three branches are the forest industry (Finland), fishing industry (Norway) and agriculture industry (Sweden).

3.2. Objective

In Phase 2 of the project, the main objective is to apply pilot actions in the case company and to investigate measures to reduce energy use in other industries, as well. The Finnish part of the project deals with forest and especially the paper industry. The Finnish case company is UPM-Kymmene. A description of the case company can be found in the Phase 1 reportfrom the project (Andersen & al., 1999). Within the case company one export transport chain is selected and thoroughly examined. This transport chain covers transports of raw materials to Voikkaa mill and the transport of paper to the customer in Germany and the associated energy use (see Figure 9). In addition, the energy use of handling is included in the calculations.

3.3. Methodology and system boundaries

The energy use of the case transport chain which includes the following phases is studied:

- transport of raw materials: logs, kaolin and chemical pulp
- paper handling at the mill
- transport to the export port (Kotka) and handling at the port
- sea transport

The manufacturing process of the paper and transports inside the mill are not included in the study. In addition, the energy production phases are excluded. Consequently, the energy use in the transport chain can be different when the whole life cycle is taken into consideration.

The present energy use is calculated with a calculation model, which is presented in Chapter 3.17. Pilot actions and their evaluation are also carried out with the model. The basic data for the calculation model is collected from UPM-Kymmene and various previous studies on energy use in transport. Firstly, the report describes the phases of the case transport chain. Then the calculation model and the evaluation of the pilot actions, and the results from them are described. Finally, the report is concluded with summary, main findings and some discussion.

Figure 9 Case export chain from Voikkaa Mill via Port of Kotka to Lübeck.

The transport volumes of the case export chain in 1998 are shown in Table 9. The distance in the transport of logs is an example of a typical transport distance.

Table 9 Transport volumes in case transport chain.

DISTANCE	TRANSPORTED GOODS	KM	TONNES	TRANSPORT VOLUME, 1000 TONNE-KM
Forest - Voikkaa mill (example, direct lorry)	log	100	407 077	40 708
Forest - Voikkaa (example, train)	log	140	171 231	23 972
Voikkaa-Kotka/Hamina, lorry	paper	65	189 500	6 545
Voikkaa-Kotka/Hamina, train	paper	65	178 750	11 618
LPR-Voikkaa	chemical pulp	100	114 000	10 260
Kotka-Voikkaa	kaolin	65	134 500	8 743
Kotka-LPR	transfer	120	0	0
Kotka/Hamina-Lübeck, ship	paper	1 285	33 000	42 405
Lübeck-Cologne, train/lorry	paper	490	8 800	4 324
Total			1 236 858	148 575

Floating is not included

The paper production at Voikkaa mill amounted to 480 000 tonnes in 1998, while the whole paper production of UPM-Kymmene was 7 489 000 tonnes.

In Figure 10, the main material flows of the case are shown. Voikkaa is located in Southern Finland, and the transport distance to the port is quite short. Logs are transported to the mill from the surrounding area, kaolin is mainly transported from the port of Kotka and chemical pulp from Lappeenranta. An other UPM-Kymmene paper mill, Kymi Paper in Kuusankoski, is located almost next to Voikkaa mill. Due to the geography of Finland, sea transport is usually required for exports. The paper of the Voikkaa mill is mainly exported via ports of Kotka and Hamina. A few paper lots can be exported via other ports, too.

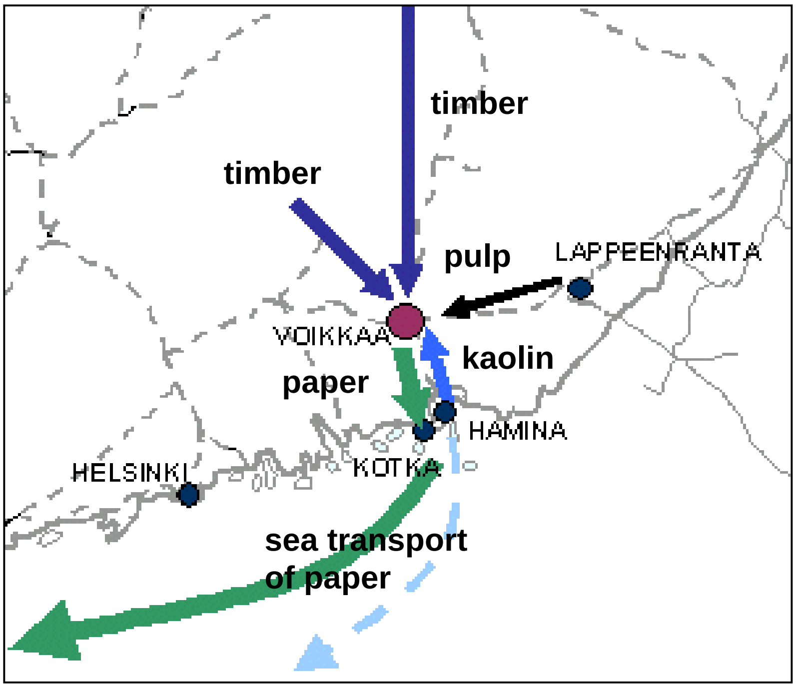


Figure 10 Studied material flows in Voikkaa paper mill.

3.4. Environmental issues in logistic chain

Environmental issues are an important competitive factor, and taking them into consideration is also important for the company image. Customers and consumers are not only interested in the environmentally friendly manufacturing process but also in the whole life cycle, of which transport and handling are essential parts. Thus, an energy-efficient transport chain as well as an environmentally sound logistic chain is a significant contributor to environmentally friendly products.

The Finnish forest industry has paid much attention to environmental issues, and requires the same from subcontractors, too. However, the environmental assessment of a transport chain is not a simple task owing to the practices and types of actions as well as the measuring systems, which vary a lot between companies. The problems that occur in measuring environmental performance could be such as in the following list. These are the problems from one Finnish port operator's point of view:

- lack of commonly accepted indicators

- defective comparability of data
- difficulties in defining interfaces, e.g. when performing life cycle or cost analysis
- how to measure environmental costs
- producing data per lot or item
- information systems are not planned for generating environmental data
- different environmental knowledge and know-how

UPM-Kymmene has favoured rail transport already for more than five years. Due to increased transport of paper by train, the logistic expenses have decreased. The Finnish railways (VR) transports almost 80 % of UPM-Kymmene's products in Finland. In Central Europe approximately 30 % of UPM-Kymmene's products is transported by train, and the objective is to raise this share to 50 % in five years. In Finland the increase potential in rail freight transport is not significant anymore. In Central Europe the obstacles for increased rail transport have been the problems in capacity and timetables. In addition, the location of customers limits the increase in paper rail transport in Central Europe; only few customers have rail connections, and the paper must be transported by lorry anyway (Kauppalehti, 2000).

3.5. Energy use calculations

In reality, in energy use there is a difference depending on whether a lorry is driven with a full load or empty. However, usually the fuel consumption is indicated as consumption, litres per 100 km, in which case the consumption is usually the average between the consumptions of an empty and a full lorry.

One calculation of the difference of the consumption of an empty and full lorry (VTT Communities and Infrastructure 2000) is with the full trailer combination lorry (of 60 tonnes lorry), where the difference between the empty and full consumption is about 17 litres. In other words, if the full lorry consumes 50 litres / 100 km with a full load, its consumption when empty is 33 litres / 100 km, which is 66% of the fuel consumption with full payload. According to the calculations of Metsäteho, the full trailer combination lorry (60 tonnes) transporting raw wood consumes 42 litres per 100 km when empty and 62 litres per100 km loaded with 42 tonnes (Oijala, 1995).

However, it is problematic to define the energy use of the return transport and the difference in the fuel consumption when there is a return load, of which the load factor is, e.g. 60 %. Even if the proportion of fuel consumption and weight of transported goods are almost linear, the problem is to define the actual load, which can vary a lot. In this case study the lorries are assumed to be either empty or full. The lorry is considered as full when the load factor is approximately 95%, i.e. the load of 38 tonnes when the capacity is 40 tonnes.

In the calculation model of the case, the kilometres that the lorry has driven empty and loaded have been counted, and the fuel consumption and energy use have been calculated according to them. Likewise the kilometres of a full train have been counted in the rail transport chapter.

In addition, the energy use of transporting empty wagons is also estimated. One problem in the road transport of the case is the profitability of the so-called triangle: the distance in which it is more economically and environmentally reasonable to drive a triangle (A - B - C-A, See alternative 1 in Figure 11) in order to get a return load, compared with driving directly back with an empty lorry (A - B - A; alternative 2 in Figure 9). “The empty side of the triangle", (the transfer distance) is allocated to the loads in relation to the transported kilometres in this case.

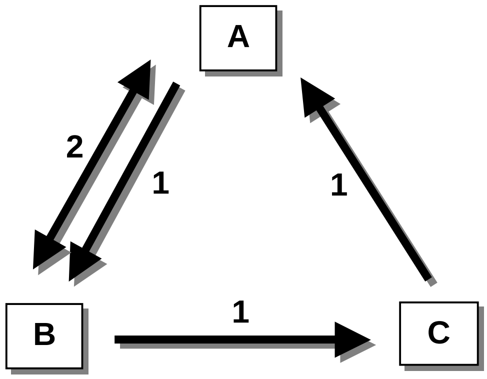


Figure 11 A triangle describing the alternative points to take the return loads.

In addition to the properties of a lorry, other things that affect fuel consumption are, among others:

- the terrain, in other words how hilly and winding the road is
- surface material of the road
- the number of stops, for example at traffic lights and crossroads

When calculating the energy use of transport by lorry, the effect of idle running (in the factory, in the harbour) and stops, on total energy use, have to be taken into consideration. Furthermore, in a northern climate the seasons also affect fuel consumption.

In Finland's project case, a calculation model for energy use in the transport chain was constructed. This model was used when the energy use of the chain was calculated and the pilot actions were examined. In the calculation model the return loads and empty driving were taken into consideration by separately calculating the kilometres, which the lorry drove with a load and without a load. For these kilometres then, different figures of fuel consumption were used. The total fuel consumption can be divided according to the transported tonnes and tonne-kilometres. In the model, the possibly lower fuel consumption of less than maximum loads was not taken into consideration even though the consumption can be considered to be nearly linear with respect to the weight of the load (VTT Communities and Infrastructure 2000). In most cases, the used fuel consumption was selected corresponding to the average load of the lorry.

In the calculations of this case the distance which the lorry drives without a load is multiplied with a factor 1.2 in order to cover all driving e.g. from garage to the mill. This factor is initially used by Metsäteho only for the transport of timber, but due to the fact that the distances of other raw materials to and paper transport from Voikkaa mill are relatively short, this factor is also applied in other transports.

In sea transport, the load factor was taken into consideration only when the energy use was allocated to the transported tonnes, because the weight of the load has really no significance on the fuel consumption of the ship. If a ship is carrying no cargo, it has to take on a certain tonnage of water in order to preserve its stability. In the allocating of the energy use average, load factors were used for the load and possible return load.

In order to equalize the use of different sources of energy the net heat contents and conversion factors (Statistics Finland, 1998) have been used. By using these factors the diesel oil consumption of lorries and work machines, the light fuel oil consumption of diesel trains, and the heavy fuel oil consumption of ships are all converted to kilowatthours.

The accounting principles are clarified in more detail in Chapter 3.17.

3.6. Forest industry transport in Finland

Measured by kilometrage (trip x number of trips), the forest industry is Finland's greatest provider of transport. In 1997 the domestic transport volume for the forest industry was estimated at 15 billion tonne-kilometres, i.e. approximately one third of the country's total transport volume. The combined amount of tonnage carried in 1997 came to almost 100 million tonnes. Among the goods groups, only gravel and other surface deposits were transported to a greater extent than this (approx. 200 million tonnes).

Some 60 % of domestic transport volume comprised the transport of wood raw materials from the forests - in the case of imported timber from the country's borders - to the place where they would be used, including the haulage of by-products (chips, sawdust, etc) from the wood products industry. Most of the other domestic haulage from the forest industry consisted of product transport from production plants to harbours or domestic consumers, and the remainder of the transport of other raw materials (pigments, chemicals, energy raw materials) to the mills (Forest industries, 2000).

The greatest share of domestic waterborne transport is made up of coastal fuel transport and short distance material transport. The forest industry's share of water transport in 1997 came to around one fifth of the total transport and 10 % of the kilometrage. Domestic water transport in the forest industry consists primarily of timber floating and inland water transport. In addition, some 5 % of the forest industry's product export is loaded on to vessels in the harbours of the Saimaa region.

The forest industry's share of transport abroad from Finland in 1997 was an estimated 33 %, the share in sea export almost 60 %, and of all export approximately 20 %. The amount of exports from the forest industry was approximately 17 million tonnes and the imports approximately 12 million tonnes. Two-thirds of export comprised chemical forest industry products, and the rest wood industry products. Imports consisted primarily of raw timber (Forest industries, 2000).

3.7. Terminology

There are numerous different terms for lorries with and without trailers, semitrailers etc. Terminology used in Finnish case study is presented below.

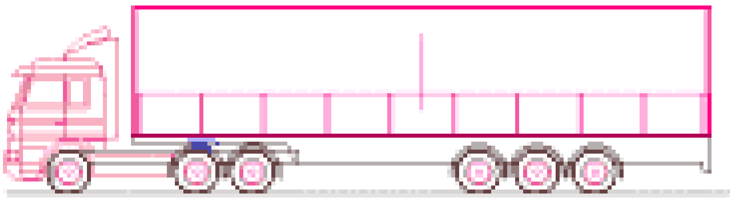


Figure 12 A semitrailer.(Picture: SKAL www-pages 2000)

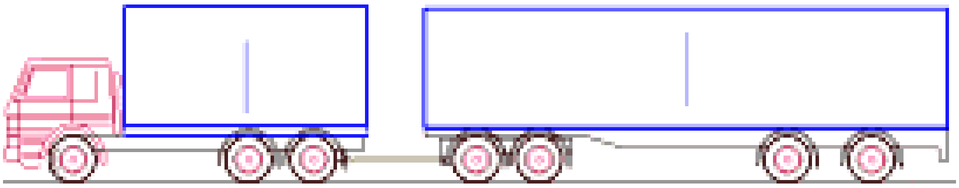


Figure 13 An articulated vehicle.(Picture: SKAL www-pages 2000)

The terms are used only when the difference between a semitrailer and an articulated vehicle is required to make evident. Otherwise the word "lorry" is used to describe both of them. The articulated vehicle is also known for example as

- road train
- full trailer combination tuck

among other possible terms. The maximum total weight for the articulated vehicle amounts to 60 tonnes in Finland. In the study 40 tonnes is used as the maximum total weight for the semitrailer.

3.8. Raw materials

Timber

Transporting timber in Finland

Transport by the forest industry by road in 1997 amounted to almost 80 million tonnes, of which two-thirds consisted of timber haulage. The forest industry's share of the goods kilometrage by road came to around a third. By rail, transport by the forest industry accounted for over a half of the total haulage from the standpoint of both tonnage and kilometrage. The total amount of product and raw material transport by the forest industry came to almost 25 million tonnes in 1997, with raw timber, including imported timber, accounting for over a half (Forest industries, 2000).

The average transport distance of timber was 137 km in Finland in 1998. The average transport distance of direct lorry transport was 100 km, the average railway transport distance including the preceding lorry transport was 288 km and the average waterborne transport distance was 284 km. From all timber, 80 % was transported by lorry, 16 % by train and 4 % by floating or by ship (Säteri & al., 1999).

Timber procurement at Voikkaa mill

The mill makes an order for timber in cycles of 3-4 months. The timber procurement is centralized within UPM-Kymmene and is taken care by UPM-Kymmene Forest Department.

The budgeted transport of logs at Voikkaa mill was 672 000 m^3 in 1999, of which

- 475 000 m^3 (71 %) by lorry,
- 140 000 m^3 (21 %) by train and
- 57 000 m^3 (8 %) by floating.

From the surroundings of Voikkaa mill (Kouvola, Kuusankoski and Valkeala area) the logs are mainly transported by lorry, from the area of Pieksämäki and Mikkeli the logs are transported by train and from Kangasniemi, for example, by floating (see Figure 14). The goal is that the logs should be at the mill three weeks at the latest after felling.

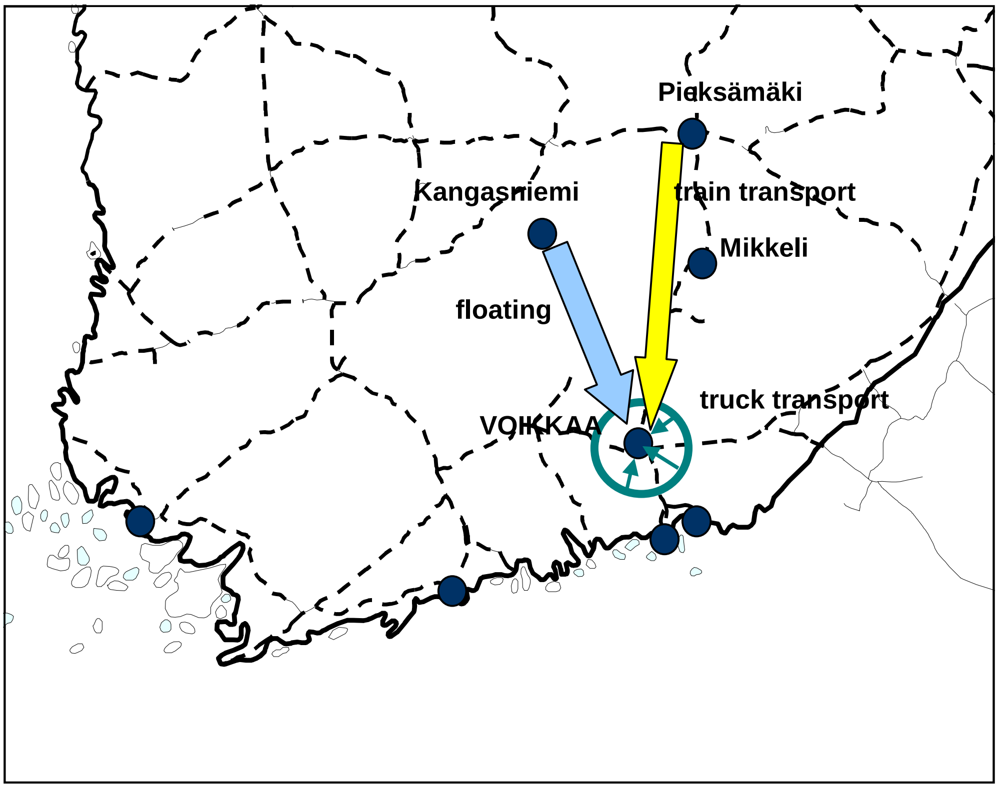


Figure 14 The main timber procurement areas and the modes of transport, Voikkaa mill 1998.

The transported log volumes and transport modes in 1998 to Voikkaa mill are presented in Table 10 below.

Table 10 Volumes of logs and the modes of transport to the Voikkaa mill in 1998.

TRANSPORT MODE	LOG VOLUME, M^3 *	LOG VOLUME, TONNES	NUMBER OF LOADS	VOLUME/LOAD
lorry	504 000	407 077	9 622 loads	52 m^3/load
train	212 000	171 231	4 530 wagons	46.8 m^3 / wagon
floating	72 000	58 154		
total	788 000	636 462		

* all cubic metres are in cubic metre solid measures

At the mill the timber is discharged by log stackers from the lorry or rail wagon to the woodroom (see Figure 15). From the woodroom the logs are taken to the sawing place where the logs are sawn into short pieces of approximately 1-1.5 metres. Owing to the structure of the trailers and wagons planned for transporting the logs, there are no return loads from the mill.

Figure 15 The log stacker (Foto:UPM-Kymmene, 2000).

Fuel consumption of the wood-handling machines is represented in Table 11 below. The fuel consumption converted to kilowatthours amounted 1.46 kWh per handled timber tonne in 1998. There is no significant difference whether the rail wagons or lorries are unloaded. The floated timber is not included in these fuel consumption figures.

Table 11 Wood-handling machines at Voikkaa mill and their fuel consumption in 1998.

MACHINES: VALMET KTD 1510 AND SISU RTD 1523	
Fuel consumption, litres	89 236
Working hours, h	5 842
fuel consumption, l/h	15.3
fuel consumption, l/timber tonne	0.15
fuel consumption, kWh/timber tonne	1.46

floated timber tonnes not included in handling

Transport of timber by lorry

According to the Finnish forestry research centre, Metsäteho, the average lorry-load in the transport of logs is 52 cubic metres, which is approximately 42 tonnes (Oijala, 1995). Logs are mostly transported by 60-tonne-lorries. In the timber lorries there is also a grapple for loading and discharging the logs. The grapple weighs approximately 3 tonnes. According to Metsäteho, the fuel consumption of a 60-tonne timber lorry is 62 l/100 km with a maximum load and 42 litres per 100 km when driving empty. Loading and discharging the logs consumes 7 litres of fuel per load total, including both loading and discharging (Oijala, 1995).

Figure 16 Transport of logs by a 60-tonne-lorry(Foto:UPM-Kymmene 2000).

Transport of timber by train

Mainly domestic timber is transported by rail to Voikkaa. There are no return loads for rail wagons but the empty wagons are transferred back to railway yards or train loading places. At the railway loading place the logs are loaded and the full train is transported to the railway yard of Kuusankoski (the city close to Voikkaa). There the train is usually divided into two shorter trains because the whole timber train, which quite often consists of approximately 20 wagons, cannot be handled in one go at the Voikkaa mill. The logs are measured in Kuusankoski.

Figure 17 The reloading of logs from the lorry to the railway wagon (Foto:UPM-Kymmene 2000).

In the rail transport of logs the goal is that at least ten wagons can be loaded without stopping (without transporting the wagons). Furthermore, the main principle is to get the whole/full train ready for transport as early as possible. UPM-Kymmene Forest Department notifies Finnish Railways (VR) of the number of required wagons. The rail transport of timber is scheduled a month ahead. The schedule, however, usually changes by approximately 30 %. Controlling the rail transport of timber requires much resources since there are over 100 railway loading places, in which the logs are loaded into rail wagons and transported to Voikkaa mill. UPM-Kymmene does not have its own wagons and locomotives but uses Finnish Railways as a subcontractor.

In the following table there is an example of one rail transport timetable to the mill of Voikkaa. The timber trains usually have a load of 1 000 - 1 200 m^3.

Table 12 A timetable of a rail transport of timber to the mill of Voikkaa.

Time	
DAY 1:	
06:49	Empty wagon train leaves from railway yard to rail loading place of timber (where the logs are loaded from lorries onto the wagons)
09:10	At the railway loading place of timber
10:00	Wagons are in customer use (in this case UPM-Kymmene)
The train is loaded during the day and possibly during the next night. One lorry of 60 tonnes can transport and load approximately four wagons in one day.	
DAY 2:	
10:42	The train departs from the railway loading place to Kuusankoski (railway yard next to Voikkaa mill), arriving latest at 18:00 in order that the logs can be measured the same day.
13:50	Arrival at Kuusankoski railway yard. Measuring takes approximately 2 hours, after which the logs are transported to the mill.
DAY 3:	
Empty wagons are transferred to the Kuusankoski railway yard, where the full train of empty wagons is coupled together.	
14:35	Train of empty wagons departs.

3.9. Kaolin

Kaolin[12] is imported from England to the Port of Kotka (Mussalo). The transport company monitors the amount of kaolin at the mill and transports the kaolin automatically when needed. At the port, the kaolin is loaded by bucket charger into a lorry (usually in this case a full trailer combination lorry of 60 tonnes). At the mill, the kaolin is dumped into a silo. The kaolin is not only stored at the mill but also at the port. Currently kaolin is transported from Kotka to Voikkaa by road only.

Table 13 Transported kaolin to the Voikkaa Mill in 1998

	TRANSPORTED KAOLIN IN 1998, TONNES
As coating pigment	104 500
As filler pigment	30 000
Total	134 500

Combining the kaolin and paper transports is one measure to increase utilization of return loads since their material flows are mainly opposite. Kaolin is transported mainly by lorries of 60 tonnes from Kotka to Voikkaa and paper in the opposite direction. Combining these transports has been tried at Voikkaa, but it has been stopped because of some problems that occurred. One problen has been the cleaning of the lorry after the transport of kaolin. Since the kaolin is powdery material the lorry must be cleaned very carefully before transporting

[12]Kaolin (china clay) = mineral used in papermaking as both a filler and a coating pigment

paper. Cleaning takes a relatively long time compared to the time that the actual transport takes, since the distance between the mill and the port only is 65 kilometres. However, this problem can be solved by special lorries that have a double floor; one can be used while transporting kaolin, and another is put down for the transport of paper.

3.10. Chemical pulp[13]

Chemical pulp is transported by road from another UPM-Kymmene mill in Lappeenranta to Voikkaa. In addition to kaolin, also the transport of chemical pulp can be combined with the transport of paper. In this case, paper is transported by lorry from Voikkaa to the port of Kotka, from where the lorry is driven approximately 120 km to Lappeenranta in order to transport chemical pulp from Lappeenranta to Voikkaa. The distance between the pulp mill in Lappeenranta and Voikkaa mill is approximately 100 km (see Figure 18).

The volume of chemical pulp transported to Voikkaa mill in 1998 amounted to 114 000 tonnes. The only currently used mode of transport is road transport. The average load is approximately 40 tonnes by a full trailer combination lorry of 60 tonnes.

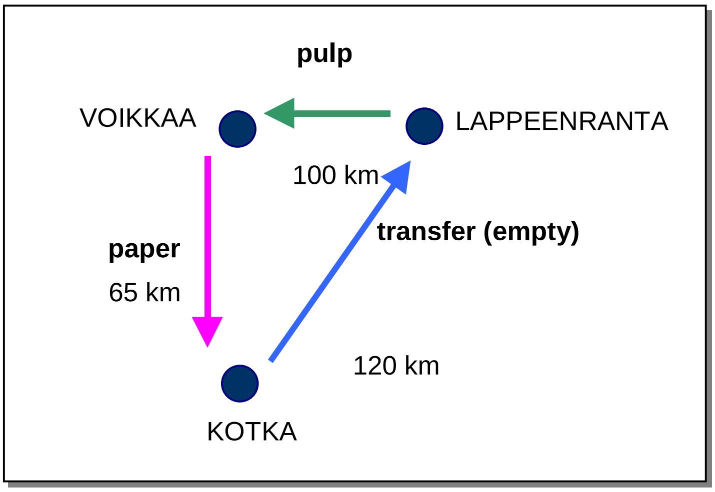


Figure 18 Transport of paper and chemical pulp form a triangle.

In addition to chemical pulp and kaolin, the papermaking process requires many other materials as well. It is possible to take other raw materials into account as well in the calculation model of this project. Miscellaneous raw materials can be interesting when new potential for return loads is studied. However, the definition and energy use of miscellaneous raw materials are not covered in this case study.

---

[13] Chemical pulp = pulp in which wood fibres have been separated by chemical means

3.11. Handling of paper and loading at the mill

Paper is loaded by forklift into rail wagons, lorries and containers. The lorries are loaded in three shifts. The trains spend approximately 12 hours at the mill, and they can be loaded directly after the paper rolls come out of the papermaking process. There are two warehouses at the Voikkaa mill. The forklifts in the warehouses are Toyota liquid gas forklifts in one and Toyota diesel forklifts in another warehouse. The fuel consumption and operating hours as well as the paper tonnes handled in the warehouses are presented in Table 14 below.

Table 14 Paper handling in two warehouses of Voikkaa mill in 1998 (Suutari 1999)

	FORKLIFTS	PAPER VOLUMES IN 1998, TONNES	FUEL CONSUMPTION	OPERATING HOURS PER YEAR
PK 11-18	3.5-tonne diesel	322 057	31 166 litres (Neste tempera green)	9 426
PK 16-17	3.0-tonne liquid gas	157 597	25 454 kg (liquid gas)	5 213
Total		479 654		14 639

The energy use in paper handling at the mill is shown in Table 15. The table includes both warehouses. When the energy use in kilowatt-hours per tonne is examined, it can be seen that the liquid gas forklifts use twice as much as the energy used by diesel forklifts. This difference can be caused by many factors. For example, the liquid gas forklifts used at Voikkaa are older than the diesel forklifts.

Table 15 Handling of paper at Voikkaa mill in 1998.

	ENERGY USE PER HOUR		ENERGY USE PER HANDLED TONNE	
	l or kg/h	kWh/h	l or kg/tonne	kWh/tonne
PK11-18 (diesel)	3.3 l	32.2	0.097 l	0.94
PK16-17 (liquid gas)	4.9 kg	62.8	0.162 kg	2.08

The total energy use from paper handling at the mill is calculated in Table 16 below. Furthermore, the weighed average kWh per handled paper tonne is presented in the table.

Table 16 Total energy use and energy use per tonne in handling of paper in 1998 at Voikkaa mill.

	KWH	KWH/TONNE
pk11-18	303 593	0.9
pk16-17	327 364	2.1
Total	630 957	1.3 (average)

3.12. TRANSPORT OF PAPER FROM THE MILL TO THE PORT OF KOTKA

The transport modes from the mill to the port are road and rail. The share of transport by road was approximately 55 % in 1998 at Voikkaa mill, and the rest was transported by rail. The planning and scheduling of the lorry transports is outsourced to a forwarding company, Combitrans, and the rail transport is handled by Finnish Railways (VR).

Transport of paper by road

Transport service company

The transport service company Combitrans organizes and plans the lorry transport of all the raw materials and paper (except timber). Combitrans also handles orders of wagons. Combitrans monitors the production of paper and gets information on the paper lots in order to plan and schedule transport. Bookings for shipping companies are taken care of by UPM-Kymmene Seaways. If a certain paper lot is manufactured early enough it is transported by train to the port. When the closing time for the ships approaches and the paper transport by train takes too long the paper must be transported by lorry.

It is not common that Combitrans monitors the processes closely. The transport is organized quite independently of Voikkaa mill. For example, at UPM-Kymmene’s mill in Lappeenranta, Combitrans’ duty is just to carry out the transport. Contracts, for example, with Finnish Railways are UPM-Kymmene’s but Combitrans controls and schedules transport by train as well.

In the road transport sector, Combitrans is in continuous contact with the trucking companies and it provides the information on transport demand in the area. Combitrans has two kinds of contracts with the subtracting trucking companies; some trucking companies work permanently for Combitrans and others are employed when increased capacity is needed.

Transport of paper by road

In the following table there is an example of a transport schedule for paper transport by lorry from Voikkaa mill to the port of Kotka.

Table 17 An example of a timetable, transport of paper by lorry from the mill to the port.

Paper rolls, average load 36-40 tonnes, lorry of 60 tonnes (total mass)	
Time	
6:00	Loading at the mill
7:00	Departure from the mill
8:00	Lorry is in the front of port gate
8:15	If everything goes fluently, the lorry is in the front of warehouse in 15 minutes
(Different paper lots in the same load can be discharged into various warehouses)	
9:15	Lorry departs from the port
10:15	Lorry is back in Voikkaa
If the transport of paper were combined with the transport of kaolin, the schedule would look as follows:	
6:00	Loading at the mill
...	
12:00- 13:00	Back at the mill with a full kaolin load
approx. 15:00	Lorry drives to the garage with a paper load, and the driver changes

*Transport of paper in container***s**

Containers have been used in the transport of paper at Voikkaa mill since 1997. The containers are loaded at the mill, and the lorry driver waits until the container is loaded (approx. 30 minutes). All containers are transported to the port by lorry so that two 20´ containers are transported at the same time by one full trailer combination lorry, and one 40´ container by one semi-trailer combination lorry. The number of containers transported from Voikkaa in 1998 and 1999 and their average loads are shown in Table 18.

Table 18 Containers at Voikkaa in 1998 and 1999. (Mölsä 2000)

	1998	1999
Tonnes transported in containers	74 000	48 000
number of 40' containers	1 694	1 431
number of 20' containers	2 218	1 074
40' average load, tonnes	21.3	21.1
20' average load, tonnes	17.1	16.4

Due to the differencies between containers, the maximum load capacity of them may vary. In this study the used maximum load capacities are 18 tonnes for a 20' container and 24 tonnes for a 40' container. When examining the load factor of containers, it is to be noted that the weights of a container, a load and a lorry altogether must not exceed an the allowed maximum weight. Consequently, the load factors of the containers can not be increased significantly.

There are usually 10-12 handlings in the export chain of the paper from Voikkaa to Europe (the paper is usually taken straight to a printing house).

Fuel consumption

The values for fuel consumption presented in Table 19 have been used in this case and for the calculation model when calculating the transport of paper, kaolin and the chemical pulp.

Table 19 Fuel consumption (full and empty) and maximum loads of a trailer combination lorry, semitrailer, 20' container and 40' container. (VTT Communities and Infrastructure 2000)

	MAXIMUM LOAD	FUEL CONSUMPTION	
	tonnes	Load factor 100%	Load factor 0%
		l/100 km	l/100 km
Articulated vehicle	40	48	32
Semitrailer	25	40	29
20' container	18	24	16
40' container	24	40	29

The fuel consumptions of the lorry used in this study are from another project of VTT Communities and infrastructure, where the emissions and energy use of different modes of transport per tonne-km were calculated. The results of the project can be found in WWW-pages of the LIPASTO model **http://www.vtt.fi/yki/lipasto/** (in Finnish). In this case study the fuel consumption of the lorries before 1991 is used, because the real ages of all lorries transporting raw materials and products of Voikkaa mill are difficult to establish. The use of average fuel consumption values would have been even better, but the difference is not significant.

Rail transport of paper

General

Wagons used at Voikkaa in rail transport:

- 2-axis G-wagons (mostly used at Voikkaa)
  capacity approx. 25 tonnes per wagon
- 4-axis SIM-wagons
  capacity approx. 60 tonnes per wagon (higher rolls can be loaded into the SIM wagon than into the G wagon)

Figure 19 SIM wagon used in transport of paper.

An example of a timetable for rail transport of paper from Voikkaa mill to the port of Kotka is represented in table below.

Table 20 A timetable for rail transport of paper from the mill to the port.

Time	
DAY 1:	
19:55	Empty wagons depart from the port
21:00	Wagons are at the Kuusankoski railway yard
DAY 2:	
06:00	Wagons are transferred to the loading place to Voikkaa mill
.	Shunting at Voikkaa
.	The train is loaded during the day and transferred back to Kuusankoski in the evening
21:50	The train departs from Kuusankoski to the port of Kotka (at 23:10 to Hamina)
23:10	Arrival at the railway yard of Hovinsaari (in the port of Kotka) (arrival in Hamina at 00:17)
Steveco (the port operator) controls and plans the wagons from Hovinsaari railway yard onwards to the ports of Hietanen and Kantasatama (parts of the port of Kotka)	
DAY 3:	
When the train is transferred to the discharging places in the morning, the wagons are discharged by 14:00.	

Separate trains run to both Kotka and Hamina. In general in the rail transport of paper at Voikkaa mill, the returning wagons are empty, and it can be assumed that the same wagons which have come full to the port return empty back to the mill (in practice they are not precisely the same wagons). In the rail transport of paper, the train goes from Kuusankoski to the railway yard of Hovinsaari where it is divided in parts; the front part continues to Kantasatama and the rear to Hietanen. The wagons are sorted according to the unloading points. VR Cargo gets a ready load in Kuusankoski from which it leaves only goods of Kuusankoski (small lots are not collected from other mills in the neighbourhood of Kuusankoski). From smaller mills, the paper load has to be collected but not in Kuusankoski, since the volumes of Voikkaa and Kymi Paper (paper mill next to Voikkaa) are adequate. The volumes are steady, and at the moment two trains per day run. If the volumes decrease, the second train is cancelled. On the other hand, if the volumes grow, however, then the capacity will be enough for some time still.

Shunting

In the factory of Kuusankoski (UPM-Kymmene Kymi Paper) there are two diesel locomotives used for shunting. The engines operate in two shifts (16 hrs/day/engine) and Voikkaa uses 45% of the engine capacity.

Table 21 Energy use in shunting at Kuusankoski and Voikkaa (Pik, 2000).

	ENERGY USE PER OPERATING HOUR	ENERGY USE PER TONNE (AVERAGE)
Fuel consumption (litres)	27	0.35
Energy use (kWh)	269	3.5

In the study, shunting has been calculated for the port and the mill separately. The shunting at the mill has been allocated to both timber and paper transport. Other shunting (the shunting of VR in general) has been taken into consideration due to the earlier studies (e.g. Pussinen, 1997), and added in the energy use of trains in the calculation model with the help of certain coefficients.

Energy use in rail transport

According to Pussinen (1997), the energy consumption of the goods train is 0.034 kWh/tkm by electric train and 0.11 kWh/tkm by diesel train. According to VR's Environmental report, the energy efficiency of the goods traffic of the Finnish State Railways (VR Group) in 1998 was 0.25 MJ/tkm (0.069 kWh/tkm) and in 1999 0.24 MJ/tkm (0.067 kWh/tkm), including both electric and diesel trains (VR 2000). The energy use considering all the transports decreased due to the increase in use of electric trains, to the taking into use of new Sr2 electric locomotives, and to the rationalization of operations. When examining the energy consumption of the train in the case, the following issues have been clarified:

- transported trip (km)
- share of the electric train and of the diesel train of the transported trip (in the factory of Voikkaa generally 76% and 24%)
- the information of the G-wagon is used as the measures of the wagon that transport the paper
- proportion of rail transport in transport of paper (45% of the paper tonnes, the rest is transported by lorry)

3.13. Handling of goods at the port and sea transport

Port operations

The operating principle of the port of Kotka is illustrated in Figure 20. In practice the port of Kotka consists of many separate ports: Kantasatama, Hietanen and Mussalo.

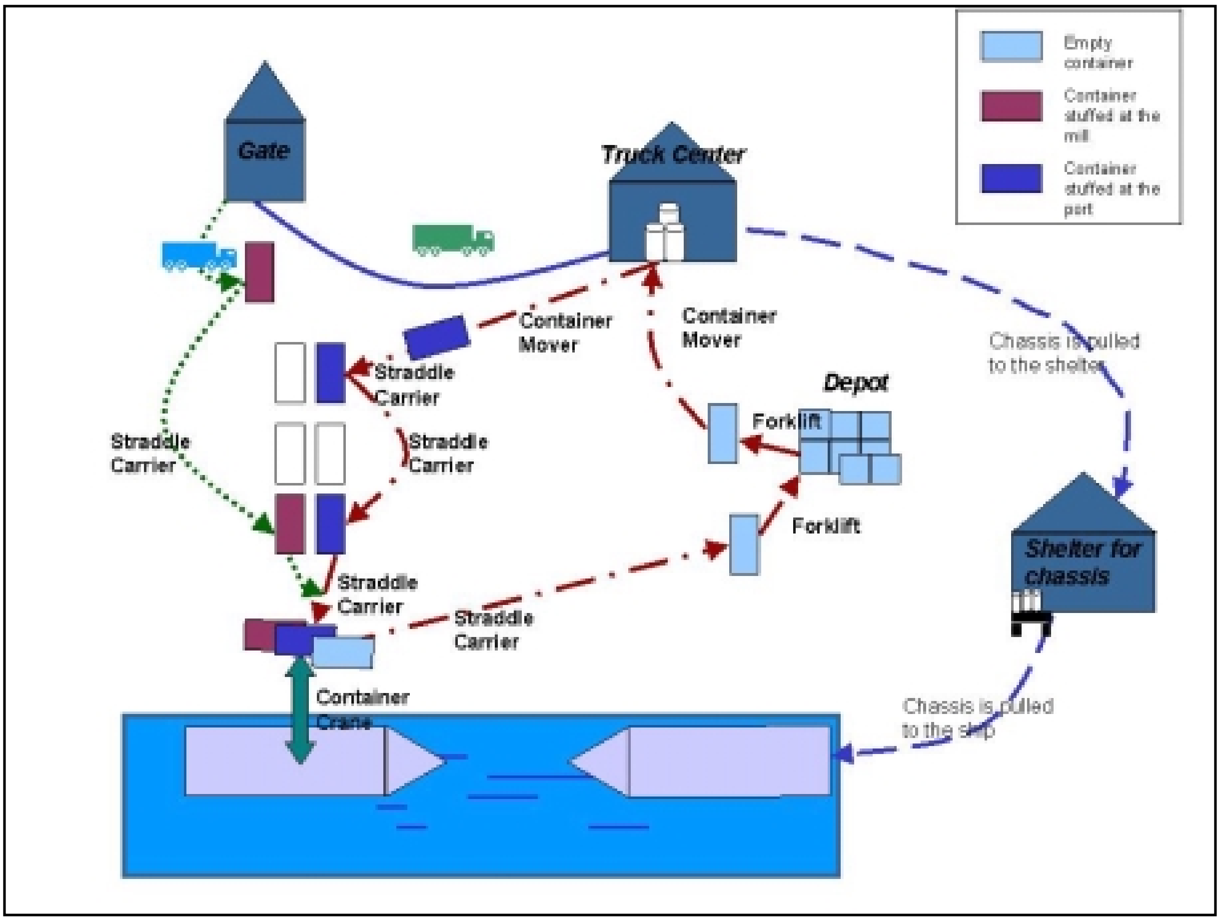


Figure 20 Operating principle in the port of Kotka (Arminen, 1999).

The lorry transport in the harbour can be described as follows:

- The lorry comes to the gate, Steveco (a port operator) feeds the information about the lorry of UPM beforehand to the system (at least a shipment lot).
- At the gate the driver goes to the gate office where it is informed that the lorry is coming; => the foreman will reserve suitable equipment.
- When the paper is not in containers, the lorry drives to the unloading to the Lorry Centre where the load is unloaded by forklift lorry to the chassis (cargo is unitised for the sea transport).

- The paper is unloaded mainly directly to the chassis but if it does not go directly onto them, then the rolls are stacked on the floor.

- The chassis is transferred to the shelter for chassis where it waits for the transfer to the ship.

- The chassis is pushed to the ship.

It takes approximately 20-40 minutes for the lorry in the port (it takes longer to unload paper rolls onto a chassis than stack them on the floor). Mainly a ro-ro load is transported to Lübeck. The basis for optimization of operations and infrastructure at the port is the effectiveness of the handling. Efficient operation in the port saves energy as well. The factors of efficiency that the harbour operator can influence are among others:

- efficient machine use

- low warehouse piles

- short drives

From the point of view of the harbour handling, there is no difference in whether a lorry or a railway wagon is unloaded. The trains come to the port from the railway yard of Hovinsaari. Sorted trains are driven to the railway yard of Hovinsaari from which they are led, e.g. to Hietanen (the warehouse-specific sorting is performed already in Hovinsaari). In Hietanen the forklift lorry of 3-4 tonnes discharges the paper roll or a pallet at a time onto the chassis. If the paper is stored, then a small forklift lorry can handle a pile for a bigger forklift lorry (about a 12–tonne forklift), which takes it to the warehouse. Most of the outgoing paper to Lübeck is unloaded directly to a chassis; the small forklift lorry reloads the paper directly from the railway wagon to the chassis. When the load has been made, the chassis is transferred to the chassis shelter (likewise in lorry load handling). The goal is that the wagons are unloaded in about two hours.

The problem with containers is the fact that some equipment for the handling of containers is always needed. If it is already located in the lorry, it will use the some of the capacity of the transported tonnes.

The kaolin is stocked in a bulk warehouse and discharged by a bucket loader to the funnel from where the conveyor belt transports it to the warehouse. The ship that transports kaolin is usually full, and the kaolin is loaded in Rotterdam into the ships that export paper from Finland. The ship, which has transported kaolin, must be cleaned after the transport.

Port operator's goals:

1. Transport efficiency and handling efficiency
2. Saving of energy
3. Reducing emissions
4. Reducing the amount of waste and recycling of the waste
5. Environmentally safe production

Steveco has obtained new straddle carriers for the container handling. At night and at weekends the containers are arranged (housekeeping), in which case the direct energy consumption in the harbour can increase, but the waiting times of the lorries and ships are shortened. The part optimisation of the transport chain is not reasonable but attention must be paid to the wholeness. The growth of the energy consumption in one phase of the transport chain may save energy elsewhere in the chain. The main problem in clarifying the environmental effects of the harbour handling and of energy consumption is in the data acquisition. The present information processing systems do not produce data for monitoring environmental effects.

Other problems in clarifying the environmental effects of handling are, among others:

- the handling does not generate "the consignment note" in which case it is not possible to obtain the lot-specific information.
- activity-based costing is not used
- the machine-specific grouping (pulling equipment, container handling, forklift lorries, cranes) has not succeeded; nowadays the energy consumption and the emissions are calculated due to ways of loading (the containers, bulk, storlo)

The environmental costs in the harbour constitute about 1 % of the turnover (in the factories 2-4 %). The port operator can count the conveyor systems as environmental investments.

3.14. Energy use at the port

The harbour operators' environmental competitiveness was monitored in the project of the Finnish Ministry of Transport and Communications "Environmental competitiveness of port operators - definition and tool" (Ministry of Transport and Communications Finland, 1999). The purpose of the project was to define and develop a practical method to monitor the environmental competitiveness of logistics service companies. The indicators have to be generally approved and they should function as part of environmental management in service companies, but also give customers real comparable indicators of logistics. The environmental competitiveness of port operators was defined with a balanced scorecard that included five elements. One of these elements was operational efficiency and environmental impacts, in which comparable indicators from real company data was calculated. Six Finnish stevedore companies participated in the project.

The port operation has been grouped into a storlo, container and bulk operation. In general, the cranes of the port belong to the Port Administration. The energy consumption has been collected in the following table according to different ways of loading. The numbers are the averages of the harbour operators who have participated in the study on environmental competitiveness. For the unloading of kaolin in the port, the energy consumption of the bulk handling has been used. The handling of the paper has been calculated from the energy consumption of storlo loading except for the handling of containers, which has own energy consumption figures.

Table 22 Energy efficiency in handling of goods in the port. Averages of six port operators grouped by different loading ways [kWh / tonne handled goods](Ministry of Transport and Communications Finland, 1999).

	ENERGY EFFICIENCY (KWH/TONNE)
Storlo	3.9
Containers	6.8
Bulk	0.9
Whole port, average	3.7

By comparing the numbers, it can be seen that the loading of containers requires most energy whereas the bulk consumes one seventh. Among others, the container crane and the energy used by the transfer of empty containers affect the energy consumption of the harbour handling of containers.

In this study, the value of 0.38 litres (diesel) per tonne has been used for storlo, for the containers 0.52 litres per tonne, and for bulk 0.05 litres per tonne. These numbers for containers do not yet include the electricity consumption of the container crane.

The harbour of Kotka handled 134 000 TEU -containers (including empty ones), 79 000 pieces, in 1999. Ten to eleven per cent of the containers (about 7 900 pieces) was loaded ro-ro and the rest (71 100 containers) was loaded onto the ship with the container cranes. The weight of the containers altogether in 1999 was 1 050 000 tonnes (including the load, the weight of the container and the empty containers). The container cranes used nearly 1 000 000 kWh in 1999.

The energy use required by container handling amounted to 0.52 litres per tonne (5 kWh per tonne) in the port of Kotka. When the energy use of container crane 0.9 kWh /tonne is added, the sum of the energy use of container handling is approximately 6 kWh / tonne altogether.
To sum up the energy use at the port, the results of the case study calculation are represented below:

- paper, lorry or train transport: 3.6 kWh/tonne
- paper, 40' container: 6.18 kWh/tonne
- paper, 20' container: 6.12 kWh/tonne
- kaolin: 0.5 kWh/tonne.

The energy that is needed for the handling of the paper in the harbour is assumed to be the same as the energy use in storlo loading generally. The precise energy use of paper cannot be obtained since the handling phases - unloading the vehicle, storage, loading the chassis, transport to the ship, and stevedoring - are not calculated separately in the energy calculations of the harbour. Therefore, information systems provide no lot-specific data. In the examination of energy use at the port there is the problem that it is not known how much of which goods are handled: one batch can be handled by as many as eight different machines.

The effect of the driving behaviour by diesel forklift lorries on the energy consumption is also a point that could be taken into consideration.

Sea transport

UPM-Kymmene Seaways manages the planning of the sea transports of the whole company, operation and the freight contracts (a trend is to focus more and more on the regular liner traffic). The objective is that storage would not be required at the mill. The distance from Kotka to Lübeck is 1 236 km. The energy consumption of ships is allocated to load usually according to lane metres. The generally used relation of tonnes and lane metres is 3.05 tonnes / lane metre. For the paper this relation is a bit different (Tapaninen, Karsio 2000).

The energy use in the sea transport of paper from Kotka to Lübeck with the ro-ro vessel amounts to 0.12 kWh/tonne-km (Tapaninen, Karsio 2000). In the paper ships the load factor is usually good (about 85-90 %) on average, but, if for example, yearly ship-specific emissions and energy consumption are calculated, the load factor is usually lower since the same ship can transport many sorts of goods on many different routes. Usually consumer goods, etc. are transported from Central Europe to Finland as return loads. The load factor (=utilization rate) of the return transports will remain in 50 % on average if it is measured in tonnes. However, the load factor of the return transports is about 70 % when it is measured due to load metres.

The most significant factors when calculating the energy use of transport of paper by sea are:

- load factor (utilization rate)
- speed of the ship
- return transport

In particular, with regard to the storo and ro-ro ships, the speed is the most significant factor that affects the energy consumption of ships. Whether the ship runs empty, full or half full, has actually no effect on the energy consumption (only 1-2 %).

In this case study the fuel and energy consumption of the ship is calculated from the engine output (not including auxiliary engines). For example, when the engine output is 13 200 kW (e.g. Oihonna, a typical paper transporting ship of Finncarriers) the used value in calculations is 85% of that, i.e 11 220 kW, since the maximum power is usually not used (Finnlines, 2000). In addition, the maximum load capacity of the ship is calculated from DWT. It is assumed that approximately 10 to 15 per cent of the DWT is needed for other goods than actual transported load (e.g. luggage, crew, etc.). Furthermore, it must be taken into consideration that the load factor usually is not 100%, but for sea transport of paper it amounts to 90% in average (measured according to tonnes). The load factor for return loads from Central Europe to Finland (consumer goods etc.) is approximately 70% in average, when it is considered according to volumes. According to tonnes it remains lower, approx. 50%.

3.15. Transport from The Port of Lübeck to the customer

General

The transport from the port of Lübeck to the customer is not considered from a particular customer's point of view, but two areas in Germany (Hamburg and Cologne) have been selected. The transport to the customer is not included in the calculation model, and therefore no accurate energy consumption figures are available. However, the energy use in transporting paper in Germany can be estimated to be quite similar to Finland taking account of some minor differences. First of all, the lorries are smaller in Central Europe than in Finland. Secondly, the weather conditions are different; the cold energy consuming winter doesn't exist in Central Europe. On the other hand, there are more congestion in Germany than in Finland.

Distance from Lübeck to Cologne:

- by train 492 km
- by lorry 488 km

Containers or ships are not used for on-carriage transport from Lübeck to particular customers. The on-carriage transport - for example- to the final destination Hamburg is carried out - in each and every case - by lorry. Due to the fact of the short distance (Lübeck - Hamburg = approx. 70 km) these transports are treated as so-called "short distance traffic". Deliveries to the final destination Cologne are primarily performed by lorry, but also some by train (Schacht, 2000).

The shares of lorry and rail transport for UPM-Kymmene products in Germany are as follows: Lorry transport constitutes between 70 and 75 % , the rest of the volume is transported by rail. In the train transport, 90 % is by electric locomotives, while 10 % by diesel train.

The energy use of paper transport to the customer

The calculation model does not cover the transport in Germany in the case in all details, but the estimate of the energy use of paper transport from the port of Lübeck to the customer in Germany, however, can be calculated from the fuel consumptions in Finland. Since the allowed maximum weight for lorries is smaller in Germany than in Finland, the fuel consumption of a semi trailer is used (see Table 19). The energy use to the customer is calculated in the summary. It is essential to take into account that the energy use depends on the fact whether the lorry returns back with a full load or without a load. It can be discussed whether the factor used to describe the amount of other driving (refuelling, lunch breaks etc.), 1.2, is too big in this case, since the transport distance is long compared to transport distances in Voikkaa. However, this factor has been used in calculating the transport to the customer as well.

In the calculations, the average distance 490 kilometres from Lübeck to Cologne is used for both modes of transport. The energy use of the shunting work in Germany is assumed to be the same per paper tonne than in Finland, i.e. 3.5 kWh/tonne in average. The shunting is assumed to be performed twice, as in Finland too, so the total energy use of shunting amounts to 7 kWh/tonne.

The unloading of paper at the customer is assumed to use energy as much as the loading at Voikkaa, 1.3 kWh / tonne. This may vary depending on the forklifts used in unloading, but however, the differences are considered to be not significant.

3.16. Pilot actions within the finnish case company

Initial pilot actions were described in the report from Phase 1 (Andersen & al., 1999). Together with the case company UPM-Kymmene the list of pilot actions was modified. Owing to the complexity of the transport chain UPM-Kymmene is not able to directly affect all operation in the chain. Therefore, the list on actions applicable to UPM-Kymmene can do is presented below:

Transport from mill:

- Transport planning
- selection of transport mode
- selection of subcontractors
- monitoring the prime route implementation
- demand/supply mechanism
- payload and return loads

The Ports:

- Transport planning
- Objectives for port operators (it is possible to affect operations only indirectly)

Sea transport:

- Transport planning

Distribution to customer:

- Selection of tranport mode
- Selection of transport operators
- Monitoring the prime route implementation
- Payload and return loads

Transport planning of the whole transport chain:

- Strategic structural planning
- Route planning
- Storo/Roro, containers and railship: long-term planning
- Reduction of direct transport
- Long-term co-operation with subcontractors (preferred partners)

When the most important actions are summarized the list could look like this:

- Mode choice between mill and port; train, lorry, container, direct train, direct lorry, floating, canal
- Containerisation in the mill or port (intermodal)
- Selecting criteria for subcontractors
- Prime route follow-up (monitoring and measuring)
- Further potential for utilizing of return loads
- Routing for the whole chain

From these pilot actions the effects of mode change and further utilizing of return loads on the energy use are calculated with the help of the constructed model. The model is presented in Chapter 3.17. In addition, the effect of lower fuel consumption level is considered in the next chapter. The fuel consumption could be reduced for example by driver education.

The initial pilot actions consisted of four levels: management, driver and service levels, and level of logistics improvement. These levels haven't been used in Phase 2 anymore since the transport chain is composed of many different companies, and thus of many various management, driver and service levels. Consequently, the level, in which the case transport chain is considered, is actually the level of logistics improvement.

3.17. Calculation model

Introduction

This part of the SAVE research project concentrates on a case study of the energy use of a Finnish paper company that transports raw materials to the factory and sells paper to clients. The purpose of the study is to compare the energy use of different modes of transports in the transportation chain from the raw material to the end product. Special attention is paid to determine the possibilities of combining loads on vehicles for incoming and outgoing traffic, and a comparison is made between rail and road transport. An other purpose of the study was to determine the energy use of sea transport between Kotka in Finland and Lübeck in Germany.

The following diagram shows the material flow of a paper mill; in addition, a lot of other cargo than raw materials, like bark, arrives at the mill.

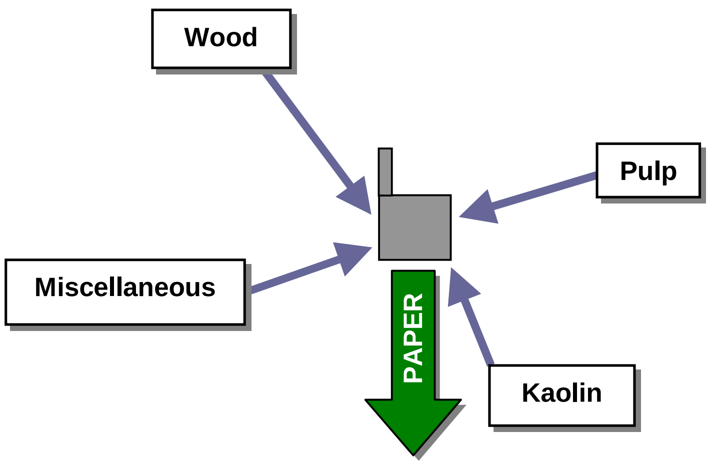


Figure 21 The flow of raw materials and paper

The raw materials are

- Wood / logs
- Kaolin
- Chemical pulp
- Miscellaneous raw materials

The logs mainly come from Finnish forests at an average distance of 80 kilometres from the mill, with the distance very seldom more than 300 kilometres. The majority (64 % of the tonnage) of the logs are transported by special lorries that can each carry 40 tonnes, and about 27 % of the raw material is transported by rail. Only about 9 % of the logs is transported by ship, but owing to the speciality of sea freight, this study does not include the ship transports of raw materials.

The kaolin comes to the mill from the UK via Kotka harbour, where it is stored in warehouses in large lots. This is a bulk cargo that is transported by articulated vehicles capable of carrying powder. The vehicles are equipped with a crane that can unload the cargo by lifting the trailer to allow the kaolin to flow directly into the silo.

Chemical pulp comes from Finnish factories by articulated vehicle. In this study, the kaolin comes from one factory located about 105 kilometres away from the mill.

Miscellaneous raw materials, such as lye, are transported by lorry, but these raw materials make up only a small part of the total volume. They mainly come from Finnish factories, or from the ports, and estimated to be 80 kilometres from the mill.

The paper factory also needs energy to produce paper. The transports of “bark residue” total about 250 000 tonnes per year. However, the transports of energy materials are not included in this study.

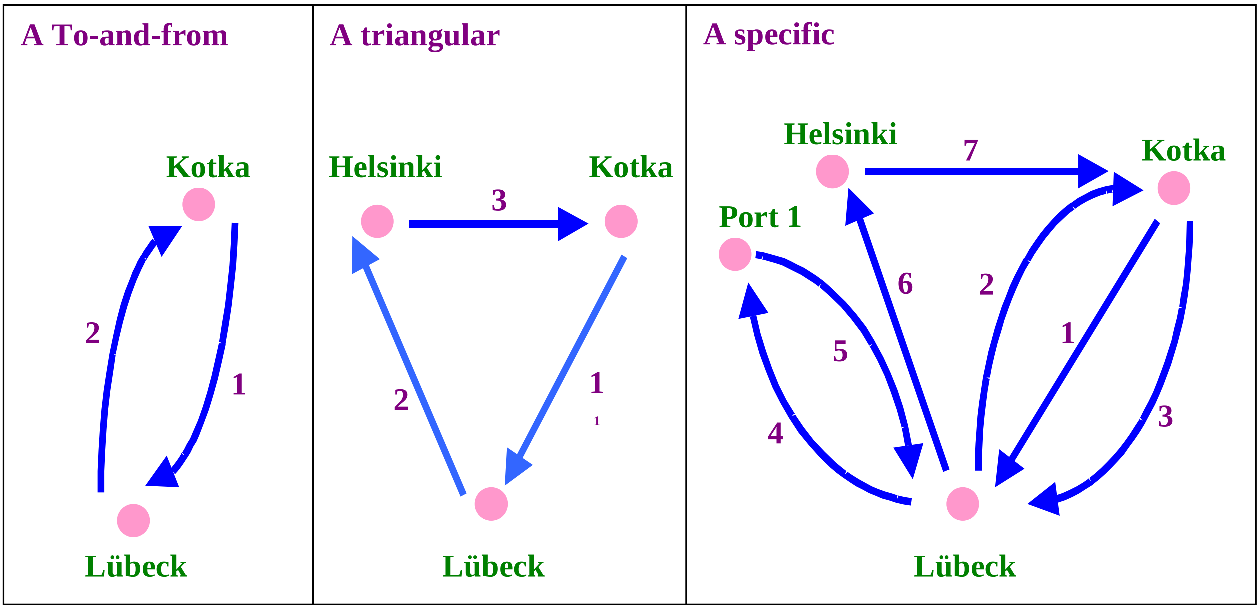
The paper is transported by different means of transport mainly via two harbours, Kotka and Hamina, to global clients. Kotka and Hamina are located close together, at a distance of only 20 kilometres apart. The paper is mainly transported by articulated vehicles, containers and rail. The cargo coming by rail and articulated vehicles is reloaded in the port warehouse on chassis and then pulled onto the ship. The containers go directly onto the ship. Two twenty-foot containers are hauled together by one articulated vehicle.

The cargo vessels calling at Kotka and Lübeck in Germany have three types of rotations:

- a to-and-from route between Kotka and Lübeck
- a triangular route between Kotka – Lübeck – Helsinki – Kotka
- a specific route

In the first and second case, the vessel calls at Kotka on a weekly basis. In the last type, the vessel makes one whole trip every two weeks.

The following figure illustrates the three types of ship rotations serving clients in the Kotka



area.

Figure 22 The rotation of cargo vessels between Kotka and Lübeck

Transport of logs to the mill

Transport by lorry

The transport is by lorries specialized in log transports. These units can each carry 40 tonnes of cargo. The lorrys are equipped with a crane and thus no other work force is required. It is estimated that the empty return is 1.2 times more than the actual distance. About 64 % of the logs are transported by lorry.

In the model there are three elements:

- Handling of logs
- Transport of full loads to the factory
- Returning the empty unit back to the loading place

Transport by rail

Rail transport comprises two phases. In the first phase, the logs are transported with lorries (above) to the nearest railway station. Once there, mainly the driver reloads the logs onto the railway wagons. The logs are pulled to a bigger station, where a whole train of 20 – 40 wagons is coupled and pulled to the station near the factory. A separate engine is needed to move the wagons between the factory area and the nearest station.

The model has the following elements:

- Handling of logs
- Trucking of full loads to the nearest railway station
- Returning the empty unit back to the loading place
- Railway transport of the full wagons to the railway station near the mill
- Returning the empty wagons back to the loading place
- Additional movements of the wagons
- Additional energy use that rail transports require
- Unloading of the logs at the mill

Additionally, a comparison between electrical engines and diesel engines has been made in this model

The comparison between these two means of transport is done according to the weight of the lots and the distance from the mill. The basic starting point is a typical forest located 100 kilometres away from the mill by road, 20 kilometres away from the nearest railway station, therefore 120 kilometres away from the mill.

The diagram below shows that, when the shipment is less than 300 tonnes, the energy use with lorries is lower than with a train. As the volumes exceed 300 tonnes, the train is more economical.

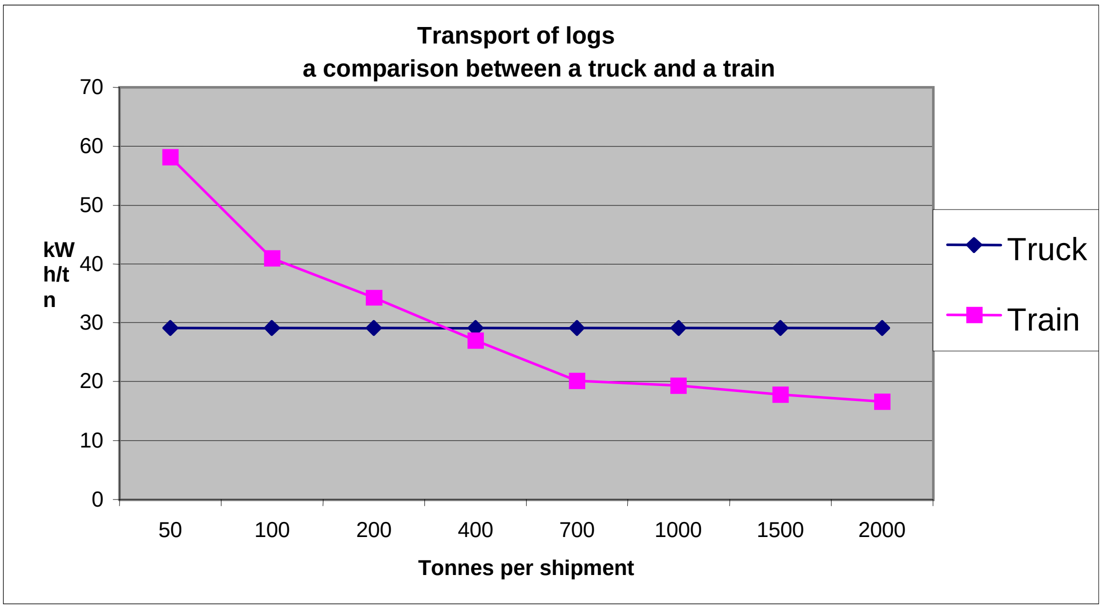


Figure 23 Transport of logs; comparing lorry and train.

Transport of other raw materials to the factory

Kaolin

Kaolin is transported from the port of Kotka to the Voikkaa mill. As Kotka is one important paper export port of the Voikkaa mill, there is potential for combining kaolin and paper on the same lorry. This has not happened so far, because of the following reasons (among others):

these products require different types of equipment
the benefit is limited, as the loss of time has proved to be greater than the benefit of combining the loads.

Being aware that some other factories have utilized kaolin reloads, we have included the possibility of using kaolin return loads for paper. As the kaolin volume (134 000 tonnes / year) exceeds the paper volume via Kotka by lorry, we assume that every paper load gets a return load, if required.

The model has the following elements:
- Loading at the port
- Trucking of full loads to the mill
- Unloading of kaolin at the mill
- Returning the empty unit back to the loading place
- Or trucking the empty unit from the paper port to kaolin port

Chemical pulp

Chemical pulp is mainly transported by lorries to the Voikkaa from the UPM-Kymmene mill in Lappeenranta. The total volume per year is 114 000 tonnes, which is more than the paper transports to Kotka. The distance from Lappeenranta to Voikkaa is approximately 105 kilometres, and the distance to Kotka port is 120 kilometres (from Lappeenranta). Technically it is possible to combine paper loads and chemical pulp. As the distance between Kotka and Lappeenranta is 120 kilometres, it seems evident that it is more economical to combine the return load with kaolin than with chemical pulp. The model takes into consideration both possibilities as well as today's practice of returning the empty unit to the loading place.

The model has the following elements:
- Loading at the shipper's factory
- Trucking of full loads to the mill
- Unloading of chemical pulp at the mill
- Returning the empty unit back to the loading place
- Or trucking the empty unit from paper port to the loading place

Miscellaneous raw materials

Miscellaneous raw materials are transported from different loading places to the mill. In the case study, the volume is relatively small – estimated at 10 000 tonnes.

The model has the following elements:
- Loading at the shipper's factory
- Trucking of full loads to the mill
- Unloading of miscellaneous raw materials at the mill
- Returning the empty unit back to the loading place
- Or returning the empty unit from the paper port to the loading place

Conclusion for energy savings by combining the trucking of return loads of raw materials and loads of paper

The Table 23 below presents the energy use (kWh) for "a normal day". The first column shows the name of the product, the second shows the volume in tonnes. The column "Present" shows the present energy use for a limited exploitation of return loads. In the fourth column, the transport of kaolin has been combined with the transport of paper (exploitation of return loads). In the fifth column, the transport of chemical pulp and the transport of paper have been combined. In the last column, both kaolin and chemical pulp have been combined with paper trucking.

From the table it can be seen that by combining kaolin and paper loads the energy savings is almost 18%, the highest percentage. The percentage for combining chemical pulp and paper gives only about 4 % energy savings. It is interesting to notice that it is more energy-efficient to drive the triangle with 120 kilometres "empty side", and 105 kilometres with a load of chemical pulp instead of driving only 65 kilometres empty from mill to the port. The reason for this is the fact that the "empty kilometres" (= no load) can be minimized with the help of a triangle.Thus one lorry must drive empty 120 kilometres. If both hauls are kept independent, the first lorry drives 65 kilometres empty and the second one drives 105 kilometres.

Table 23 Energy use in different transport possibilities.

Exploitation of return loads		Present method	Concentration to:		
			Kaolin	Chemical pulp	Combination of both
	Tons	kWh	kWh	kWh	kWh
Kaolin	367	5553	4249	5553	4661
Chemical pulp	312	7674	7674	7375	7439
Misc.	27	558	558	558	558
Paper	100	5127	3054	4676	3389
TOTAL, kWh		18913	15535	18162	16047
Savings, %			17,86	3,97	15,15

It can be seen from the chart above, that the model divides the energy saving for both incoming and outgoing (paper) cargo. This is covered in more detail in the next chapter.

Paper haulage from the mill to the port

The mill ships yearly about 184 000 tonnes of paper via Kotka port, which is about 40 % of the total production. About 55 % of the Kotka volume (100 700 tonnes) is transported by lorry (trailer combinations, semitrailers and containers). Trains transport about 45 %. The distance to the port is 65 kilometres. Normally the units arrive back to the factory empty.

Trucking of paper to the port

The model estimates four potential return loads for paper shipments:

- Loading of kaolin
- Loading of chemical pulp
- Loading of miscellaneous cargo
- Loading of different clients' cargo

The last of the above return loads is excluded from our study, because it is not relevant at a paper factory, but a normal procedure for a logistics / forwarding company.

The model estimates the savings on a yearly basis. This means that on a daily basis the maximal benefit is reached with a volume of 100 700 tonnes / 365 days, which is approximately 275 tonnes per day. As the loading of potential return goods (kaolin, chemical pulp and miscellaneous cargo) is more, about 700 tonnes per day, the shipments are always in imbalance, unless the shipments via Hamina and by rail are included in the total volumes.

The model has the following elements:

- Loading of paper at the paper mill
- Trucking of full loads to the port of Kotka
- Returning the empty unit back to the loading place
- Or returning the empty unit to the loading places of

    - Kaolin
    - Chemical pulp
    - Miscellaneous raw materials
        - The loading of the above products, haul to the factory and unloading
        - The unloading of the paper at the port is considered separately in the chapter “Port”

Train transport of paper to the port

Approximately 45 % (86 500 tonnes per year) of paper is transported by train to Kotka port. The cargo is unloaded at the port and loaded on a chassis and then pulled onto the ship. The train operation is multistage. A separate engine at the factory area handles the operations. The engine moves the loaded wagons to the nearest railway station. From there the wagons are pulled to the port operation area. New engines pull the wagons to the right sites at the port, and finally, after unloading pull them back to the port operation area.

The advantage of using rail is that with big volumes the energy consumption is advantageous compared to lorry transports. The disadvantage is that rail transport is not very flexible, especially with urgent shipments. This leads to an additional need to store the paper both at the factory and at the port. In practice, trains transport regular lots, which can be shipped in good time before the vessel departs. The urgent shipments are transported by lorries.

The model has the following elements:

- Loading of paper at the paper mill
- Operations of the mill’s engine in the mill area
- Moving the full wagons to the port operation area at Kotka
- Moving the full wagons to the sites at Kotka port and moving the empty wagons back to port operation area.
- Returning the empty unit back to the loading place
- The unloading of the paper at the port is considered separately in the chapter “Harbour”

A comparison between a lorry and a train in paper transports to the port

A comparison has been made for three possible versions:

The present situation
Concentrating all the shipments on lorries
Concentrating all the shipments on trains in the present situation

The factors that influence the versions:

- Transport volume of kaolin (tonnes)
- Transport volume of chemical pulp (tonnes)
- Transport volume of miscellaneous raw materials (tonnes)
- Transport volume of paper (tonnes)
- Exploitation of return loads for lorries

- Minimizing the fuel consumption

The present situation is the procedure that the paper mill is mainly using and this is described in the preceding chapters. Concentrating all the shipments on lorries means that lorries (articulated vehicles, trailers, and containers) haul all the shipments of paper. Concentrating all the shipments by train means that trains transport all the shipments.

The factors 1. (kaolin), 2. (chemical pulp) and 3. (misc. raw materials) correspond with the factory's yearly production on a daily basis. Therefore, they are constants. The paper volumes and the exploitation of return loads vary in the model (variables). The possibility for significant fuel consumption (>5 %) is estimated.

The charts below illustrate the maximal energy savings.

<u>The present situation</u>

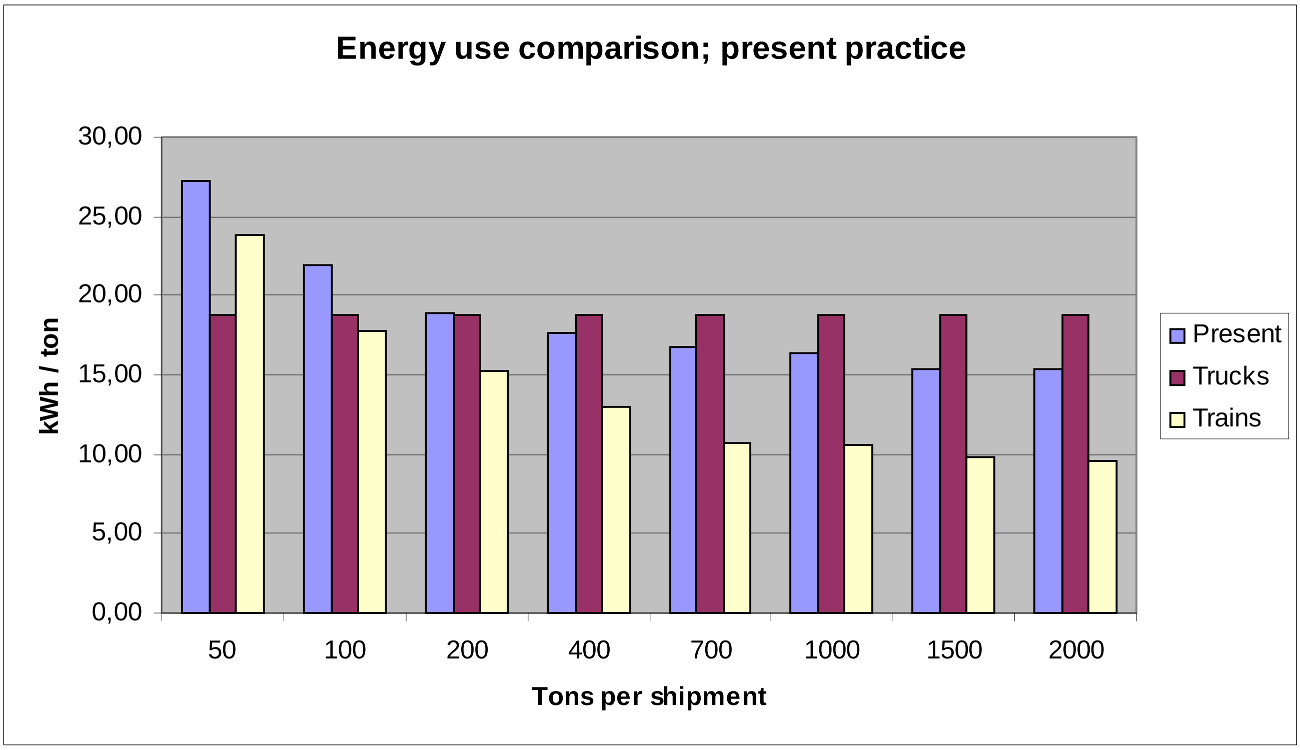


Figure 24 Energy use in the present situation

The bar chart shows the energy use for three alternatives. The first bar in the chart (“Present”) describes the energy use in a situation where both trains and lorriess are used according to today’s established practice. Return loads are not utilized and the fuel consumption is normal. The table shows that the energy use per tonne decreases as the weight of the shipment grows. When the weight of a shipment is 50 tonnes, the energy use in the present situation is approximately 27 kWh per tonne. Consequently, as the shipment is 2 000 tonnes, the energy use in the present situation is approximately 16 kWh per tonne.

The second bar in the chart describes the energy use for the alternative where all the shipments are concentrated on road haulage, but return loads are not utilized, and the fuel consumption is normal. The energy use per tonne does not change as the volume grows, because the synergy effect is limited. When the shipment size is less than 200 tonnes, the energy consumption favours road haulage.

The third bar in the chart describes the energy use for a situation where all the shipments are concentrated on trains. This alternative is more economical than the present situation. As the shipment is 2 000 tonnes, the energy use in the present situation is 9.5 kWh per tonne. This alternative becomes more economical than road haulage as the weight of a shipment exceeds 100 tonnes.

High utilization of return loads and fuel consumption

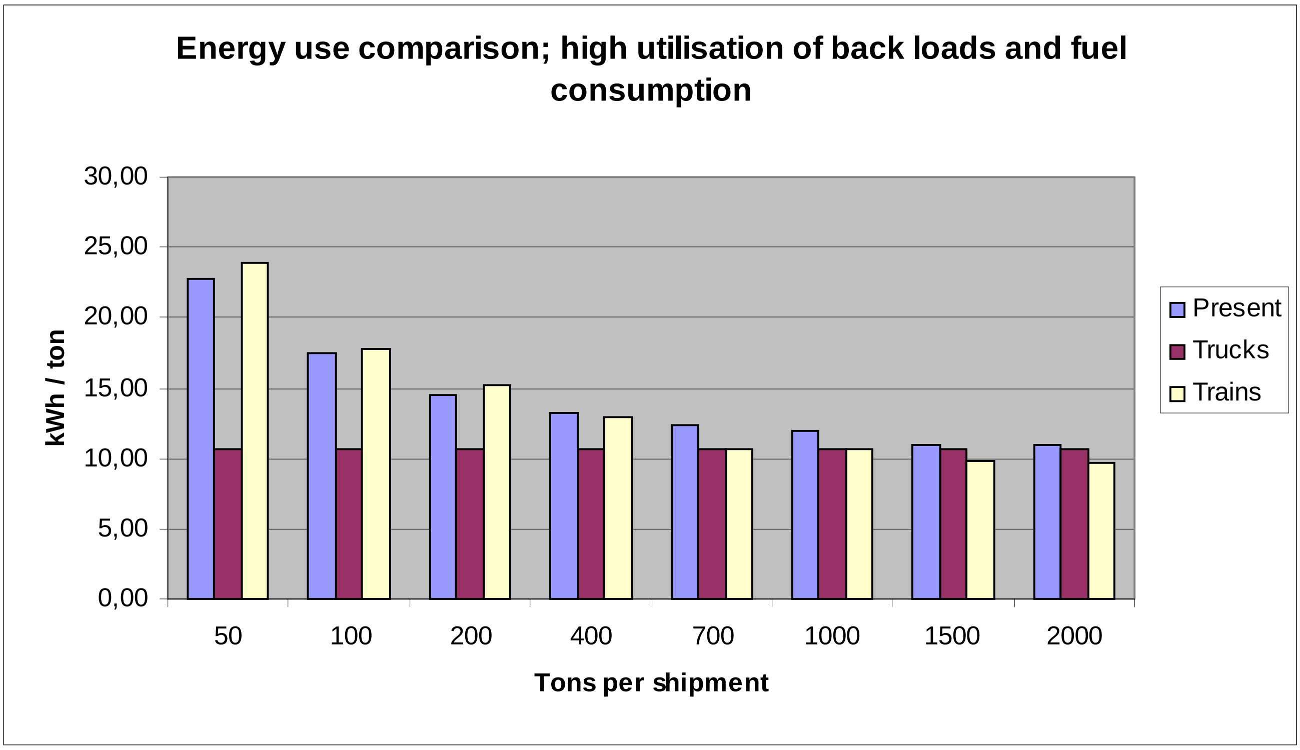


Figure 25 High utilization of return loads and of fuel consumption

This bar chart shows the energy use for the same three alternatives as in the previous chapter. The first bar in the chart ("Present") describes the energy use in the situation where both trains and lorries are used according to today's established practice, but return loads are utilized and the fuel consumption decreases 5 %. When the weight of a shipment is 50 tonnes, the energy use in the present situation is approximately 23 kWh per tonne. Consequently, as the shipment is 2 000 tonnes, the energy use in the present situation is approximately 11 kWh per tonne.

The second bar in the chart describes the energy use for an alternative where all the shipments are concentrated on road haulage, return loads are utilized and fuel consumption decreases 5 %. The effect of utilizing return loads strongly supports this alternative and makes road haulage favourable in most classifications. The consumption is 10.7 kWh per tonne. Additionally, our model takes account the energy saving also for the raw materials and divides the savings between both cargos. Therefore, on a company level, the saving is bigger than in this bar chart. The total saving is analyzed in “The energy use in a transport chain”.

The third bar in the chart describes the energy use for an alternative where all the shipments are concentrated on trains. This alternative is the same as in Figure 24, because the back haulage in this study is only defined as road haulage. However, we conclude that – presuming the cargo allows return haulage for trains – this alternative would become more attractive. Our estimation, based on the results of energy savings for road haulage, is that the energy saving could be 20–30 %. Additionally, this estimate does not consider the significance of engine type (electrical or diesel). This question is analyzed in Chapter 8.6 “The energy use in a transport chain”.

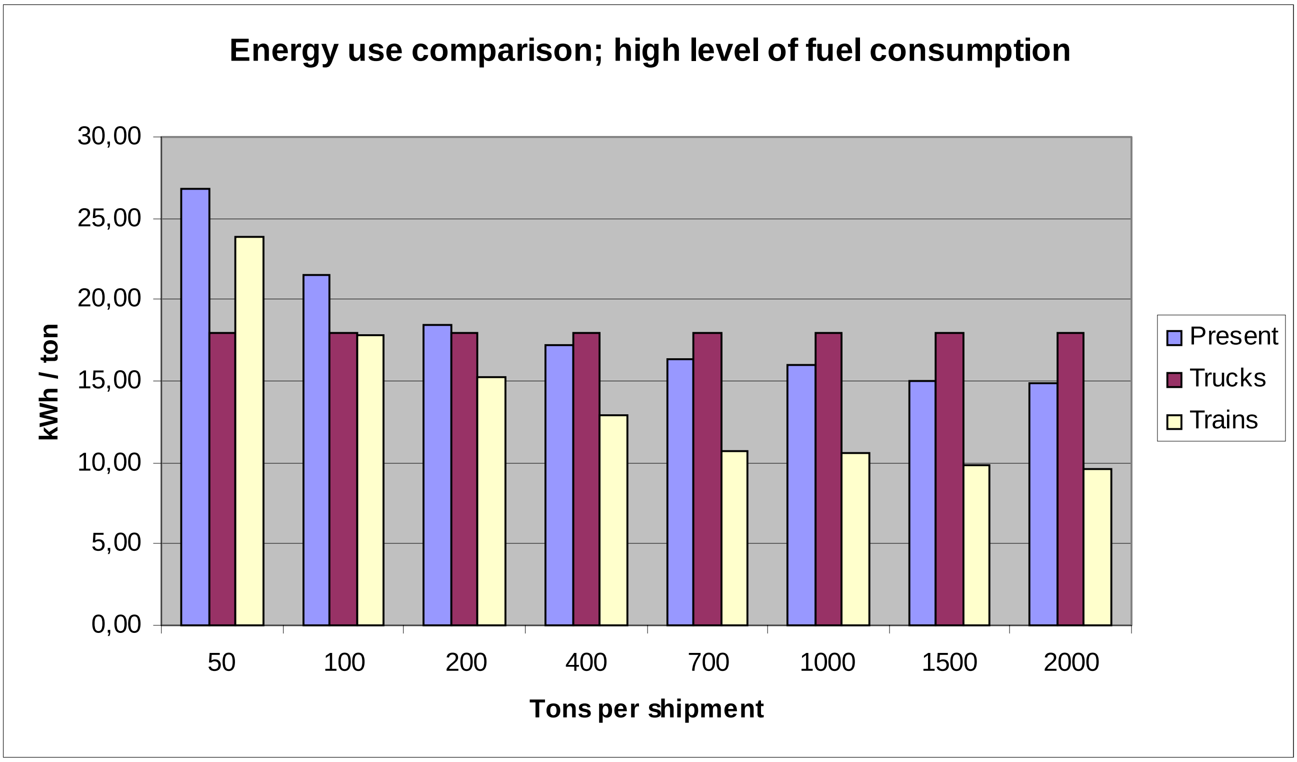


Figure 26 Minimized fuel consumption

This bar chart illustrates the effect of economical road haulage in energy use. During our study, we received slightly different values for the fuel consumption. Some drivers have acquired modern lorries and accessories to reduce fuel consumption. This model corresponds to Figure 24, page 68. The difference is that here a 5 % saving in fuel consumption is considered.

From the table it can be seen that the energy use for lorries is 17.9 kWh per tonne. Compared to the corresponding value of Figure 24 (18.8 kWh per tonne), the energy savings is approximately 5 %.

Port operations and sea transport

Port operations

The paper that is transported by trains is reloaded at the port. One part of the paper is kept in the port storage until it is shipped and another part is loaded on a chassis on arrival and then pulled via a specific shed onto the ship.

The paper which arrives by lorry is handled according to the means of transport. The paper which arrives by articulated vehicles and trailers is reloaded in the same way as train transports. The paper which is loaded into containers (20´ and 40´) is put onto the ship in the same containers without reloading.

The port operators do not yet collect exact data on their energy use for different operations. Consequently, the numeric values are mean values of the total general energy use of the port. A comparison between different ports has not been made, because of the previous reason and because Finnish ports in those areas (Helsinki, Kotka and Hamina) concentrate on different types of services, and thus they are partly not comparable with each other.

The model has the following elements:

- The handling of loose cargo
- The handling of containers in the port area
- The container lift into the ship
- The handling of bulk cargo

Sea transport

The cargo vessels calling at Kotka and further at Lübeck, Germany, have three types of rotations:

- to-and-from route between Kotka and Lübeck
- triangular route Kotka – Lübeck – Helsinki – Kotka
- a specific route

In the first and second case, the vessel calls at Kotka on a weekly basis. In the last type, the vessel makes one whole trip every fortnight. The different rotations depend on the market situation. The shipping companies try to optimize the productivity of their fleet by changing the ships and rotations according to the market requirements. However, they maintain their good service by granting exact loading times for the cargo vessels. It is typical that the same vessel arrives at the specific port on the same day, weekly or every second week.

The energy consumption does not much depend on the weight of the cargo. Only about 2 % of the energy use depends on the weight. The weight of the ship exceeds many times the weight of the cargo, and the safety of the ship requires that, if there is no cargo, water is pumped into the ballast tanks.

According to a shipping company, the speed of a ship is the best indicator of its energy use. The optimum speed of Finnish liner vessels is approximately 17 knots. At higher speed the fuel consumption increases rapidly.

The energy use can be estimated quite reliably by dividing the total energy use of a ship by the total cargo the ship transports during its round trip (kWh per tonne kilometre,) and then weighting the value according to the kilometres that the specific shipment requires.

It therefore follows that the energy consumption depends on the capacity usage of the ship. Since this is not dependent on the shipper, and as the exact energy use of one client is partly speculative, we do not estimate the most attractive possibilities. We compare ´"the most wasteful" rotation with "the most effective" rotation.

The model has the following elements:

- The rotation of the ship on a weekly or fortnightly basis
- The distances between the ports
- The maximal power of the ship (kW)
- The used power (kW)
- The maximal cargo capacity
- The normal loading measure to different destinations
- The speed in knots

Conclusion of energy use for harbour operations and sea transport

The following table gives the energy use in the harbour and for sea transport, both kWh per tonne and kWh per tonne-kilometre. Because of the mean values of the energy use at the port and during the sea transport, the model gives constant figures in all weight categories.

Table 24 Energy use for the handling in the harbour and for sea transport, kWh/tonne and kWh/tonne-kilometre.

	kWh / ton	kWh / ton-kilometre
Harbour	4,30	4,300
Least effective	160,36	0,125
Normal	153,72	0,120
Most effective	149,21	0,116

The harbour energy use is 4.3 kWh per tonne. This is a slightly higher value than the stevedore company reports. The reason for the difference is that the company only counts the energy use that they are responsible for. The container lifts into the ships are included in these calculations. In the model it is estimated that the distance from the port gate to the pier is one kilometre.

The least effective ship uses 0.125 kWh per tonne-kilometre. This is 7.8 % more than the use of the most effective one. In total consumption the difference is considerable. An energy consumption of the least effective shipment of 400 tonnes of paper from Kotka to Lübeck is 64 250 kWh. The distance is 1 285 kilometres. The difference between the most effective (59 624 kWh) and the least effective shipment is 4 626 kWh.

The energy use in a transport chain

Restrictions of the model

The model is a holistic one that is defined in parts on the previous pages. There are some restrictions. First, the products selected are raw materials and paper. A lot of cargo arrives at the mill which does not belongs to these groups. An example is the energy transport that the factory needs to run the paper machine. Secondly, the kaolin is produced in the UK. The transport from the UK to Finland is not included. Thirdly, Kotka is one port that the mill uses. By connecting other harbours, especially Hamina port, the efficiency might change. Fourthly, this model does not consider capacity restrictions, which might influence the decisions made today. Lastly, the companies make many of their financial decisions according to money savings. Even though there are common features between energy savings and money savings, there are also differences: a lorry which does not move does not consume energy.

Prevailing practice

Table 25 on the next page reflects the paper mill’s energy use in a normal situation. The volume of raw materials represents a daily need; for logs it represents an average volume of one middle-seized cutting area. The transport is divided according to today’s practice between rail and road. Furthermore, there is no exploitation of return loads, fuel consumption or ships. The exploitation of other harbours is normal.

The headings of the table are:

- Logs by lorries
- Logs by trains
- Chemical pulp by lorries
- Miscellaneous raw materials
- Paper to Kotka port by lorries
- Paper to Kotka port by trains
- Harbours
- Ships

Table 25 Energy use – Normal operations

Energy use as:

			By Truck	By train	Total
Transportation of logs	tn	400	282	118	400
Transportation of Kaolin	tn	367	367	0	367
Transportation of Chemical pulp	tn	312	312	0	312
Transportation of Misc. raw materia	tn	27	27	0	27
Transportation of Paper	tn	500	227	273	500

Reference	418

Exploitation of return loads (auto) are	NORMAL
Exploitation of ships are	NORMAL
Fuel consumption	NORMAL
Exploitation of other harbors are	NORMAL

		Present situation				Concentration to							
		Trucks and Trains				Trucks		Trains/Present situation		Electric locomotive/logs		Diesel locomotives/logs	
		kWh	%	kWh/ton	kWh/tkm	kWh	%	kWh	%	kWh	%	kWh	%
Logs by trains		4608	4,04	38,92	0,28		0,00	10793	9,84	7643	7,17	13944	12,36
Logs by trucks		8186	7,17	29,07	0,29	11627	10,22		0,00		0,00		0,00
Kaolin by trucks		5553	4,86	15,13	0,23	5553	4,88	5553	5,06	5553	5,21	5553	4,92
Chemical pulp by trucks		7674	6,72	24,57	0,23	7674	6,74	7674	7,00	7674	7,20	7674	6,80
Misc. raw materials		558	0,49	20,35	0,25	558	0,49	558	0,51	558	0,52	558	0,49
Paper to Kotka by trains		3460	3,03	12,66	0,23		0,00	6111	5,57	6111	5,74	6111	5,41
Paper to Kotka by trucks		5127	4,49	22,61	0,29	9382	8,24		0,00		0,00		0,00
Harbor		2150	1,88	4,30	4,30	2150	1,89	2150	1,96	2150	2,02	2150	1,91
Ship		76858	67,32	153,72	0,12	76858	67,54	76858	70,06	76858	72,14	76858	68,11
Total consumption	kWh	114174	100,00			113802	100,00	109697	100,00	106546	100,00	112847	100,00
Savings (-)	%		0,00				-0,33		-3,92		-6,68		-1,16
Savings (-)	kWh		0				-372		-4477		-7628		-1327
Potential savings	kWh	-7628									MINIMUM		

Total energy use is summarised in the row “Total consumption”. The total consumption with the present mode is 114 452 kWh.

The table is divided into two main categories: the present mode and a situation where all the possible transports are concentrated to either road haulage or rail freight. Rail freight is further divided into a current relation between the engine type and finally between electrical and diesel locomotives for log transports.

The values are given in kWh and a percentage as the total. Additionally, the kWh per tonne and kWh per tonne-kilometre are given for the present situation. This figure is given including all the stages of operations, which are covered in more detail in the preceding chapters.

The ship transports clearly differ from the other parts. On the one hand, in the chain their energy use is approximately 70 % of the total, but on the other hand the efficiency is remarkable. The energy use per tonne-kilometre is 0.12, which is about 50 % lower than the use of other means of transport.

A model of minimized energy use

Table 26 in the next page illustrates an alternative where the energy use is minimized by exploiting return loads, utilizing the ship rotations and fuel consumption. The benefit for haulage exploitation influences the value of paper, kaolin, chemical pulp and potentially miscellaneous raw materials. Because the volume of paper to Kotka on a yearly basis is less than the raw materials the full benefit is not reached.

The use of electric locomotives instead of diesel decreases the energy use for trains. The estimation is restricted to the transports of logs only, but by comparing the values of train in the present situation (10 686 kWh) and electric locomotive (7 535 kWh), we can see that the saving is approximately 30 %. Compared to the diesel locomotive, the difference is about 45 %.

Table 26 Maximal energy savings

Energy use as:

			By Truck	By train	Total
Transportation of logs	tn	400	282	118	400
Transportation of Kaolin	tn	367	367	0	367
Transportation of Chemical pulp	tn	312	312	0	312
Transportation of Misc. raw materia	tn	27	27	0	27
Transportation of Paper	tn	500	227	273	500

Reference	418

Exploitation of return loads (auto) are	MAXIMUM
Exploitation of ships are	SOME EXPLOITATION
Fuel consumption	REDUCTION OF 5 %
Exploitation of other harbors are	NORMAL

		Present situation				Concentration to							
		Trucks and Trains				Trucks		Trains/Present situation		Electric locomotive/logs		Diesel locomotives/logs	
		kWh	%	kWh/ton	kWh/tkm	kWh	%	kWh	%	kWh	%	kWh	%
Logs by trains		4576	4,26	38,65	0,28		0,00	10686	10,13	7536	7,37	13837	12,74
Logs by trucks		7810	7,27	27,73	0,28	11093	10,56		0,00		0,00		0,00
Kaolin by trucks		4050	3,77	11,03	0,17	4050	3,85	4050	3,84	4050	3,96	4050	3,73
Chemical pulp by trucks		7311	6,81	23,41	0,22	7311	6,96	7311	6,93	7311	7,15	7311	6,73
Misc. raw materials		533	0,50	19,46	0,24	533	0,51	533	0,51	533	0,52	533	0,49
Paper to Kotka by trains		3460	3,22	12,66	0,23		0,00	6111	5,80	6111	5,97	6111	5,63
Paper to Kotka by trucks		2919	2,72	12,87	0,16	5342	5,08		0,00		0,00		0,00
Harbor		2150	2,00	4,30	4,30	2150	2,05	2150	2,04	2150	2,10	2150	1,98
Ship		74603	69,45	149,21	0,12	74603	70,99	74603	70,75	74603	72,93	74603	68,70
Total consumption	kWh	107413	100,00			105083	100,00	105444	100,00	102294	100,00	108595	100,00
Savings (-)	%		0,00				-2,17		-1,83		-4,77		1,10
Savings (-)	kWh		0				-2330		-1969		-5119		1182
Potential savings	kWh	-5119									MINIMUM		

The following figure combines the above tables and illustrates the energy savings potential. The lowest energy use is category 8 with a use of 102 000 kWh. Compared to the present use of 114 000 kWh, the potential savings of energy is about 10.5 %.

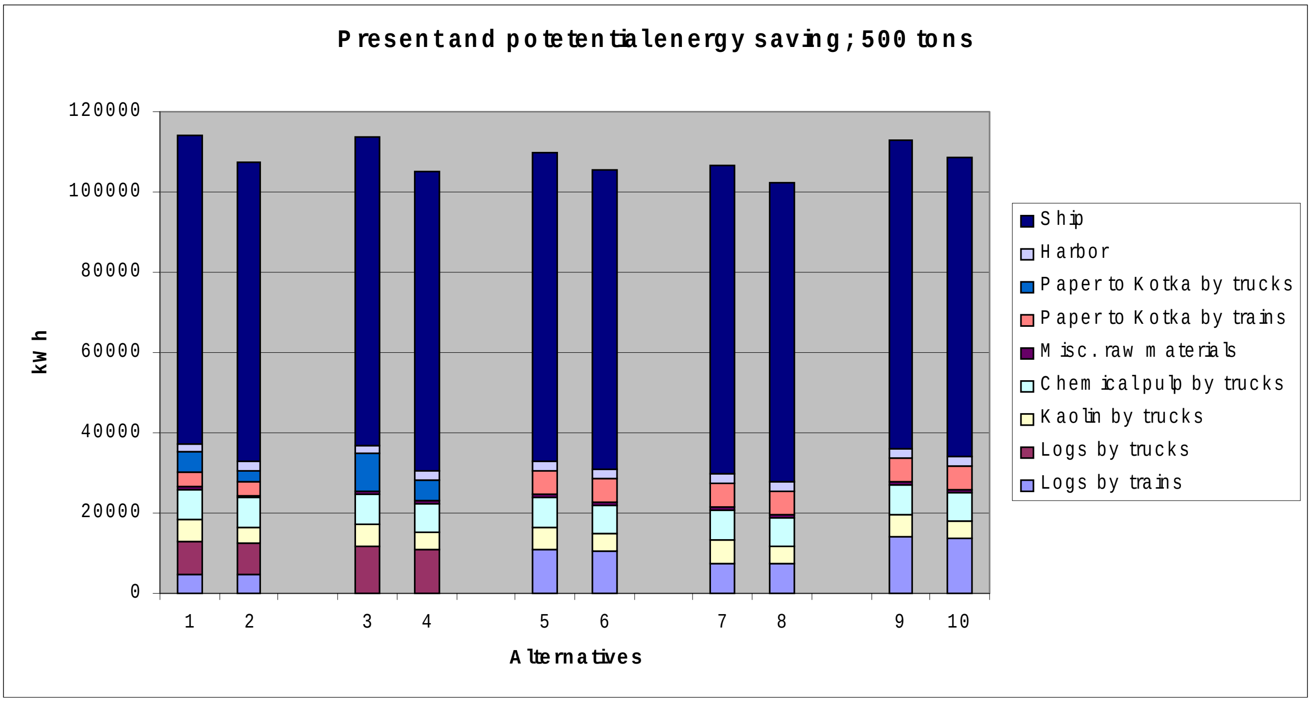


Figure 27 Present and potential energy saving; paper 500 tonnes, logs 400 tonnes

The categories in the Figure 27 are:

1. The present mode
2. The present mode including exploitation of return haulage, fuel consumption and minimized ship rotations
3. The present mode where all the possible transports are concentrated on roads
4. The mode where all the possible transports are concentrated on roads, including exploitation of return haulage, fuel consumption and minimized ship rotations
5. The present mode where all the possible transports are concentrated on rail
6. The mode where all the possible transports are concentrated on rail, including exploitation of return haulage, fuel consumption and minimized ship rotations
7. The present mode where all the possible transports are concentrated on rail with electric engines on the main route
8. The mode where all the possible transports are concentrated on rail with electric engines on the main route and including the exploitation of return haulage, fuel consumption and minimized ship rotations
9. The present mode where all the possible transports are concentrated on rail with diesel engines on the main route

10. The mode where all the possible transports are concentrated on rail with diesel engines on the main route and including exploitation of return haulage, fuel consumption and minimized ship rotations

The energy use fluctuates in the range of 100 000 to 120 000 kWh. The great significance of ship transports is clearly seen from the table. It easily dominates in importance over the other parts. The present mode has the highest energy use, but the differences are quite small. In all of the cases it seems evident that, by concentrating the haulage to either train or lorries, by utilising return loads and by some exploitation of shipments, the mill can save energy.

The figure below represents a shipment of 50 tonnes. The energy use fluctuates between 30 000 and 37 000 kWh. Small shipments favour road transports. As the volumes of kaolin, chemical pulp and miscellaneous raw materials remain at the same level in all classes, their weight in the table is big compared to the previous table. The value of category 4 is 31 000 kWh, while the present use is 36 000 kWh. The difference of 14 % is a potential saving.

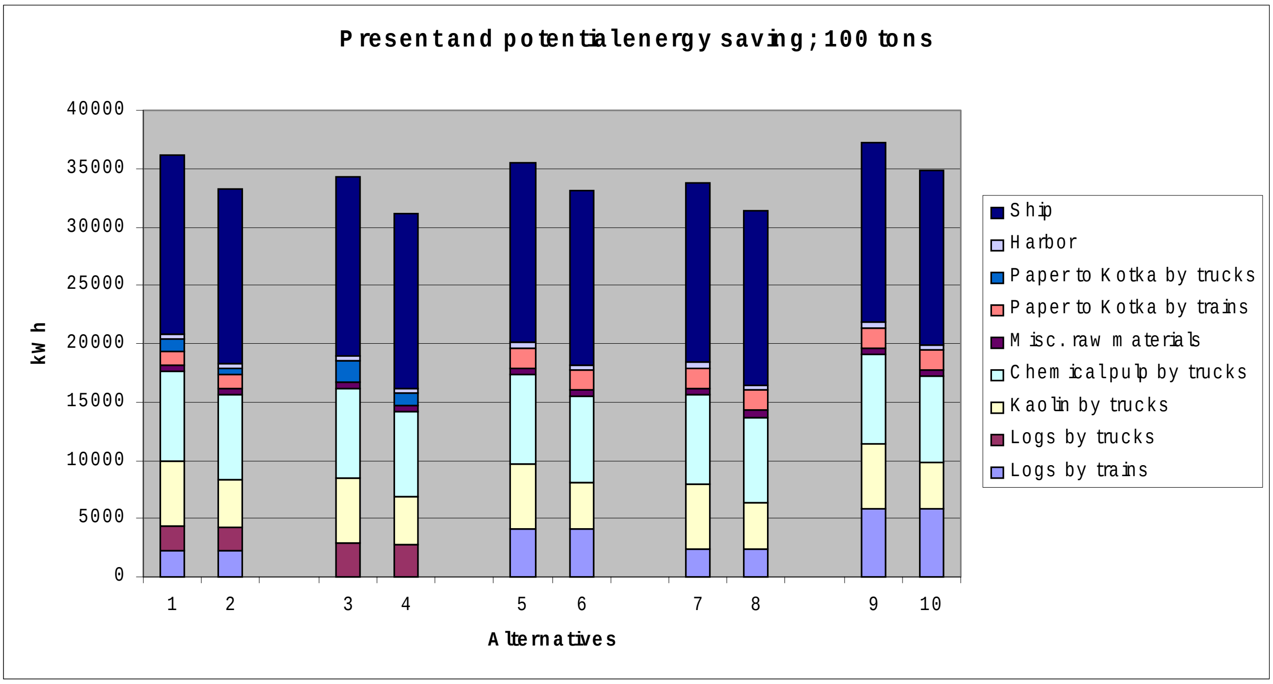


Figure 28 Present and potential energy saving; paper 100 tonnes, logs 100 tonnes

The Figure 29 illustrates a paper shipment of 1 000 tonnes. Big volumes favour rail transport. The lowest energy use (category 8) is 192 000 kWh, while the present use is 217 000 kWh (category 1). The difference is 25 000 kWh (exactly 24 829), which is more than 11 %.

The energy use of category 3 is higher than that of the present situation. This means that concentration on road haulage does not seem to produce energy savings, unless the return loads are on hand.

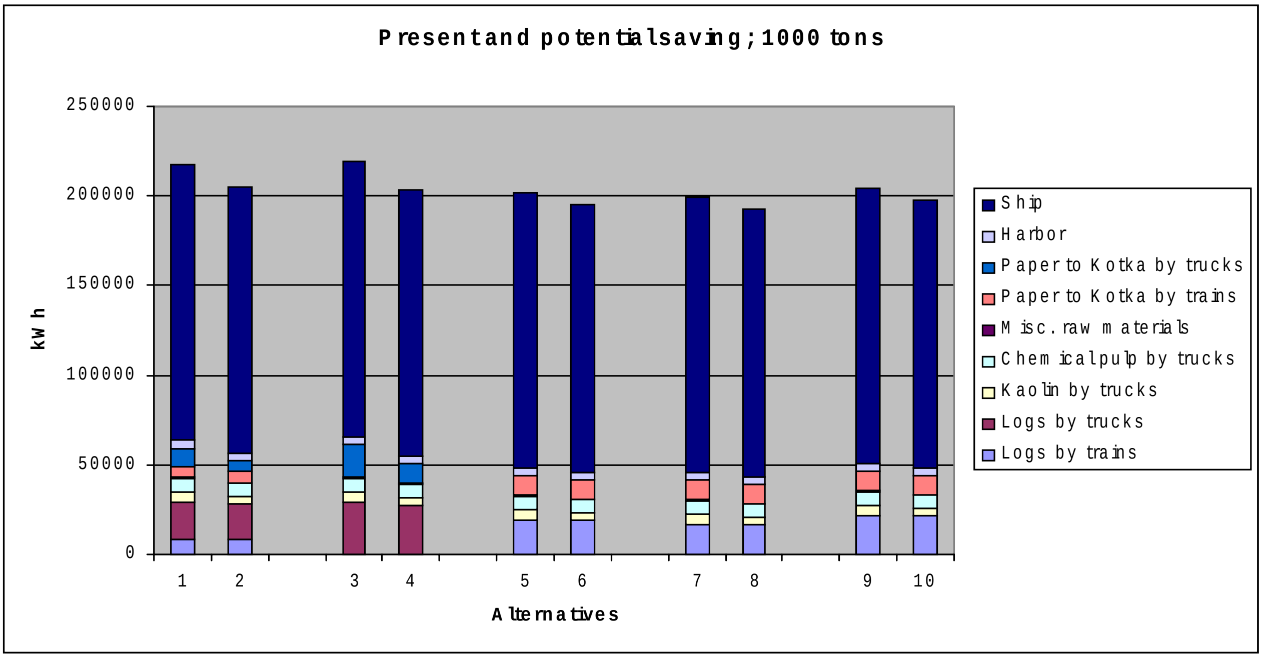


Figure 29 Present and potential energy saving; paper 1000 tonnes, logs 1000 tonnes

Conclusion – Further studies

Measuring the energy use in a transport chain requires the consideration of hundreds of large as well as small variables. Transport never takes place in static circumstances. Companies have to base their decisions on long-lasting structural solutions. Often the right option is not the maximum but the optimum.

In our study we found that there are possibilities to save energy in the transport chain. Low energy use favours concentrating on big lots. We found some opposing questions:

- Two harbours in the close proximity
- Lorries and trains providing the same kind of a service
- Some products that might be suitable to transport with return loads

Cargo vessels are economical when comparing energy use per tonne kilometre. Their share of the total energy use in the chain is about 70 %. Their energy use largely depends on the speed and implicitly on the loading volumes. We found some energy fluctuation between the vessels.

During our discussions we learned that by training the drivers some savings could be achieved. The fuel consumption varied some 5 % between the drivers. Some drivers did not know how much their consumption was. Some advanced drivers and logistic companies study very carefully the consumption and are keen to investigate into new accessories.

Careful planning is important for haulage. In particular, when there are many loading places for incoming and outgoing cargo, the possibility to combine the hauls requires the ability to control the transport chain.

Our model is structured for one case study with one kind of a transport chain. We are confident that the model could be a useful tool for any kind of authority as well as company that is interested in developing energy-saving logistical chains. To this end, more development of the model is required.

3.18. Summary and conclusions

In the table below the energy use in the case transport chain, from Voikkaa paper mill, Finland to the customer in Cologne, Germany is summarized. The energy use is calculated for transporting 8 800 tonnes paper. The amount of raw materials is estimated from their yearly volumes in proportion to yearly production of paper. The energy use includes loading, unloading and other handling of goods except for the possible handling in Germany, which differs from the handling in Finland. The total energy use of the transport chain amounts to 2 971 MWh, which is 0,34 MWh per paper tonne. From the energy efficiency, kWh/tonne-km, it can be seen that the train transport in Germany seems to be more energy efficient than the train transport in Finland. This is, however, firstly due to the fact that transport distances in this case are shorter in Finland than selected distance in Germany, and secondly, the share of electric locomotives is bigger in Germany than in Finland.

Table 27 The energy use of the transport chain of 8 800 tonnes paper from Voikkaa to Cologne, including transport and handling of both raw materials and paper.

	TONNES	KM	TONNE-KM	KWH/TONNE	KWH/TKM	ENERGY USE, MWH
Logs by trains[14]	3 139	140	439 478	19	0.14	60
Logs by lorries	7 463	100	746 284	29	0.29	217
Kaolin by lorries	2 466	65	160 279	15	0.23	37
Chemical pulp by lorries	2 090	105	219 450	25	0.23	51
Paper to Kotka by trains	3 960	65	257 400	13	0.19	50
Paper to Kotka by lorries	4 840	65	314 600	18	0.27	85
Port of Kotka	8 800		0	4		38
Ship	8 800	1 236	10 876 800	154	0.12	1 353
Port of Luebeck	8 800		0	4		38
Paper to Cologne, train[15]	2 200	490	1 078 000	34	0.07	75
Paper to Cologne, lorry[16]	6 600	490	3 234 000	149	0.30	985
Total	***59 158***	***2 756***	***17 326 291***			***2 989***
The transports include handling and reloading from one mode of transport to another. Kwh/tonne and kWh/tkm regarding all trains is calculated in this summary with a load of 1000 tonnes in order to eliminate the need of another locomotive.						

In Table 28 below there are collected energy efficiencies in road transport in Finland in this case when no return loads are utilized but the lorries are returning as empty.

Table 28 Energy efficiency in road transport of paper in the Finnish part of the case, return without loads, and no handling included.

	ENERGY EFFICIENCY(KWH/TONNE-KM)
Articulated vehicle	0.22
Semitrailer	0.30
20' container	0.25
40' container	0.34

[14] Including the lorry transport from forest to the railway station
[15] It is assumed, that energy use in the shunting in the case in Germany equals the energy use in shunting in Finland in the case (kWh/tonne)
[16] The lorry is assumed to return as empty. If the load factor in return would be approx. 100% the energy efficiency would be approx. 0.16 kWh/tkm.

According to calculations, the most important energy saving actions are:

- further utilization of return loads
- the use of electric locomotives instead of diesel ones in rail transport
- transport of big volumes in long distances by rail

Utilization of return loads is an important energy saving action. When looking for further potential for them, all material flows coming to the mill must be taken into account. Owing to nature of timber transport, it is almost impossible to imagine any return loads for them, but other raw materials and materials that are used for example for production of energy at the mill, can be potential return loads.

Electric train is more environmentally friendly and less energy demanding, at least when the use of transport mean is examined. However, the use of diesel locomotives cannot always be avoided. Rail transport is essentially more energy saving than road transport when the volumes are big and the transport distance is long. Advantages of rail transport are smaller when small lots are transported short distances. Nevertheless, the paper mill of Voikkaa produces paper in such amounts in one day in average that it can economically be transported by train. In Voikkaa's case, there are two ports in almost the same distance from the mill. At the moment, separate trains are going to each port. There could be a possibility to combine trains when the volumes are not energy-economically sufficient.

Due to the geographical location of Finland, the share of sea transport is already large in export chain. Thus, the waterborne transport can not be increased more since the use of inland waterways is limited during winter. Consequently, a more likely mode change is from road transport to rail transport. However, the transport by lorry can not always be seen as a most energy consuming alternative. In train transport the energy use of handlings (e.g. shunting) is often considerable.

The effect of the speed of the ship on the energy use is the most significant factor when the sea transport is in question. Owing to the large share of the sea transport in the chain, the small reductions in fuel consumption can generate remarkable savings when considering the whole chain.

The export chain of the paper is a complex transport chain where responsibility is shared for many partners. The optimisation of selected phases of the chain must be done with care; increase in energy use in one phase can decrease it in another and vice versa. In addition to energy use, other effects of energy saving actions on transport chain must be taken into account. Costs of different transport chains can't be excluded when the chains are compared to each other. Investments needed for changes has to be taken into consideration, too.

In addition, the communication has an important role in efficient transport chain.The great amount of partners and subcontractors create high requirements for data, information and knowledge transfer in the chain. However, the various information systems cause problems and difficulties that has to be solved.

This calculation model is constructed based on the specific case transport chain, and the results have been calculated based on the assumptions which are characteristic to that transport chain. However, the source data and basic energy use figures can be generalized to some extent, or at least they can be used as tentative energy use values in other types of calculations. It must be still recognized that the differencies in shares of various transport modes, different handling techniques, transport distances, load factor, among many other things, affect the energy use in transport chain. Thus, the calculations based on the same data can give quite diverse results depending on which assumptions have been made.

The calculation of the energy use of a particular transport chain is as reliable as the source data is. Therefore, the continuous developing of data on fuel consumption and energy use of different transport modes, as well as the handling of goods, is vital for this kind of calculations and analyses of the logistics chain.

4. The pilot actions in Sweden

4.1. Introduction

The trend in Sweden and in many other countries is towards more centralisation and concentration of provision production. The number of distribution points regarding provisions has been reduced by about a factor of 6 during the last 30 years. The development has according to the Swedish Environmental Protection Agency (1997), increased the need for transport activitiy. In the total supply chain of provisions, transport is responsible for about 15-20% of the energy demand. As the need for transportation increases, the energy use and the emissions of for example CO_2, becomes an increasing problem. In reaching EU's CO_2 reduction goal, energy saving actions could play an important role.

4.2. Objective

The main objective of this project is to develop and implement pilot actions, strategies and measures for improved energy efficiency in transport of goods. The pilot actions have been carried out in Phase 2 of the project, which this report describes. Phase 1, which has already been reported (Andersen et. al., 1999), will serve as the basis for the implementation of the pilot actions and strategies. The studies in this part comprise:

- Energy use in transportation of grain in ODAL
- A special case study
- Conduction of pilot actions

The results will mainly show the potential for saving energy and show the suitability of different pilot actions in our case companies and in the agriculture industry. The focus is on grain transport.

4.3. Methodology and system boundaries

An analysis of the energy use in the case company ODAL is outlined in the first parts of this chapter. In a special case study, the energy use in a route to Spain will be illustrated. The pilot actions will illustrate the potential to save energy due to different activities. The energy use regarding the transport of grain in general will also be discussed.

The methodology varies in the different parts of the report. Generally, it can be noted that the energy in transport of grain does not include transport at the farms or energy use at loading and unloading between the transport modes. Neither is loss of grain due to wear and spill when reloading included in the calculations. The load factors are average values based on weight per cent. The more specific methodology will be described in the different chapters. Please also note that the numbers in the report (in tables and figures) have been rounded off and might not always show the correct sum when added.

4.4. Energy efficiency factors

To calculate the energy use in agriculture companies like ODAL, the share between different transport modes and the amount of energy used for the different transport modes has to be known. The energy use for the transport is also, among other factors, dependent on the load factor, the weight transported and the size (load carrying capacity) of the vehicle used for each transport mode, e.g. lorry, tractor or ship.

The load factors for the transport modes are not known for all the deliveries, there is specially an uncertainty regarding the return trips. Some average figures have therefore been used (unless other is specifically expressed in the text). The load factor used in the calculations for the tractors is based on the assumption that the tractor has a load factor of 95% on the way to the silo and 5% on the way back. This assumption is derived from experiences and discussions with ODAL and SLU. The load factor weight-% for lorries is based on the assumption that the lorry takes 91% on the way to the silo and 20% on the way back. The total load factor becomes 56% for lorries. The load factor is based on statistics from SIKA/SCB and data from NTM and from hauliers used by ODAL (Ljungberg, pers. comm., 2000). No general load factor for ships has been used in the calculations. Specific load factors will be used for the relevant vessels in the samples for estimating transport volume and energy use. A more detailed description of the load factors and energy efficiency is included below and in chapter 4.

Energy efficiency factors in ASG

ASG, which is one of our case companies, has calculated some energy efficiency factors for the transports they use. ASG is a major transportation company and the transport volume (tonnekm) in the whole group of companies is more than 25 billion tonne kilometres around the world. The approximate percentage division between different transport modes was in 1997: Road, 31,5%, Sea, 61,1%, Railway, 5,2% and Air, 2,2%. This necessitates the use of some general energy efficiency factors to calculate the environmental impact. The average energy efficiency values used by ASG, 1997, are illustrated in the table below.

Table 29 ASG's energy efficiency in different means of transport

Type of vehicle	kWh/ tonnekm
Long distance vehicle	0,16
Local delivery vehicle	1,3
Semi-trailer towing vehicle	0,22
Goods train	0,042
Intermodal train[a]	0,043
Ship	0,056
Ferry	0,11
Cargo plane	6,0

[a] *"Intermodal train" includes a load carrier which can be transported with other transport modes. The load carriers are considered as payload.*

The described energy efficiency of the different vehicle types is about the same as NTM uses (NTM's figures was described in the report from phase 1 of this project). The exception is for: "Long distance vehicle" (ASG use 0,16, were the corresponding NTM-value is: 0,17), "Local delivery vehicle" (ASG use 1,3 and the corresponding NTM-value is 0,63!) and "Semi-trailer towing vehicle" (ASG use 0,22 and the corresponding NTM-value is 0,20). The difference for the "Local delivery vehicle" is considerable and the explanation for the ASG figure is probably due to different prerequisites. It can be noted that this figure has recently been replaced by a figure that is in the same region as NTM's figures (in the year 2000).

In the transport of ODAL's agricultural products, where companies like ASG are involved, specific data are used when such data can be found. Otherwise, the figures above from ASG and NTM are used when calculating the energy use in the transportation of grain and likewise, they are used to assess the potential savings through different pilot actions.

Energy efficiency in tractors

Data on exhaust emissions and the corresponding specific fuel consumption for tractor engines are generally limited to engine test bench data according to the ISO 8178 test cycle or the ECE R49 test cycle. These data cannot be easily utilised for calculating the fuel consumption for the particular type of transport to be assessed in our case. There are also much data available on fuel consumption for the use of tractors in different agricultural work. This consumption is often expressed in litres per hour or litres per ha (land). On the other hand, there is not much data available for fuel consumption in on-road use of tractors.

A study of transport by tractor on roads (driving in rural areas and on main roads) has been carried out by Hansson et al., (1998). The tractor studied was a Valmet 805 with four-wheel drive and turbo charged 4-cylinder engine having a maximum power of 70 kW (95 hp). The tractor had conventional wheel equipment and was otherwise equipped and adjusted for normal Swedish operating conditions. Data based on this tractor is illustrated in the table below.

Table 30 Facts about an average Swedish tractor (including return trips)

Type of tractor	Type of engine, power (kW)	Payload, average, tons	Load factor weight-%	kWh(fuel)/ tonnekm
Valmet 805	4-cylinder, 70 kW	4,4	50	0,88

The data on the tractor above has been complemented with a larger tractor with the average payload of 7,5 tons and with 10% lower energy use per tonnekm (0,79 kWh/tonnekm). The data regarding energy use for the samples has been calculated based on the weight on the grain delivery and with inter- or extrapolation of the data from these two tractors. The values in table 2 are based on a fuel consumption of 11,61 l/h and a speed of 27 km/h.

Energy efficiency in lorries

Lorries of two different sizes has been chosen and the data for energy use in the samples has been calculated based on the weight of the grain delivery using inter- or extrapolation. The factors for energy efficiency has been collected from SIKA/SCB, NTM and a study made by Gebresenbet & Ljungberg (2000) at The Swedish University of Agriculture Sciences.

More about these energy efficiency factors and other used energy efficiency factors can be found in chapter 7.7 called "Energy use in ODAL".

4.5. Description of production & transports

Description of production and transports in Sweden

The total grain production in Sweden was about 6 million tonnes in 1999 according to the Swedish Board of Agriculture (http://www.sjv.se/, 2000). The use of the grain production is shown in the figure below:

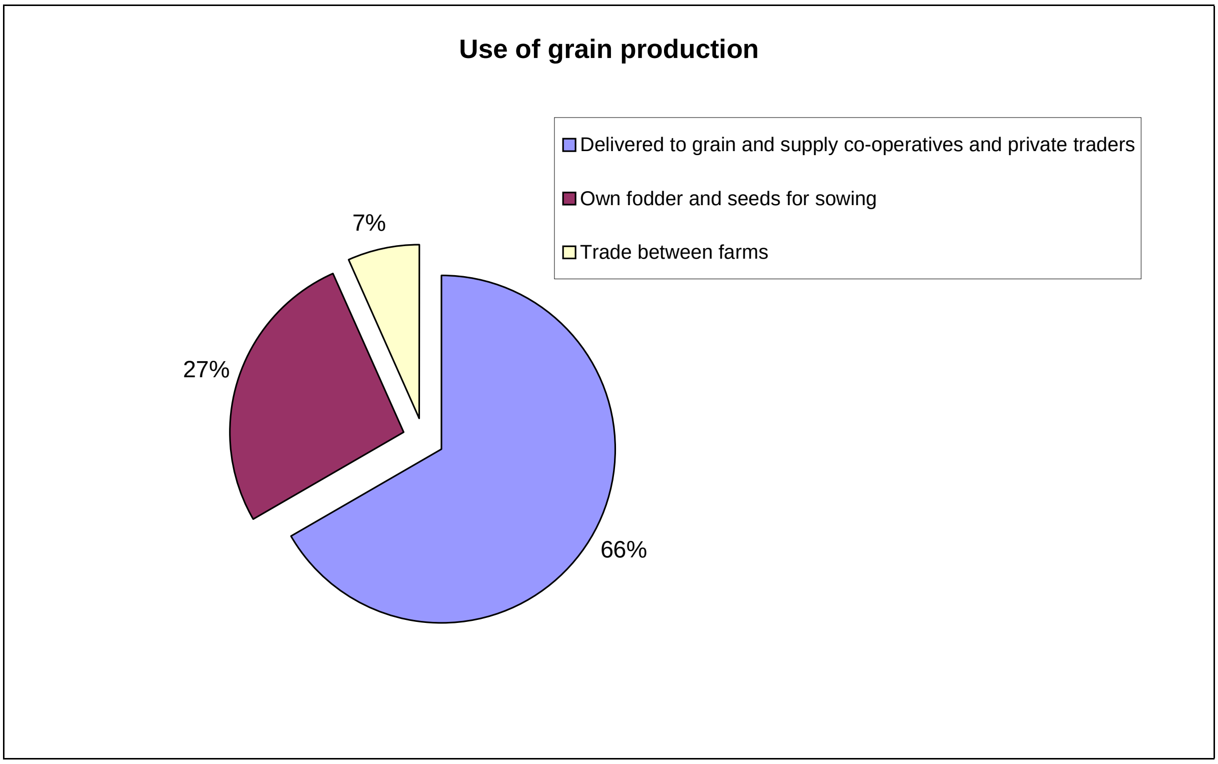


Figure 30 Use of grain production in Sweden, in % (Source: Gebresenbet & Ljungberg, 2000)

As we can see in the figure above, about 2/3 of the production is sold to co-operatives and private trading companies. About 27% is used internally as fodder and seeds for sowing. The rest about 7% is sold between farms.

The grain to "grain and supply co-operatives" and private traders (about 4 million tonnes) is transported mainly with tractors and lorries. The division between lorries and tractors is varying between years and an approximate division is illustrated in the figure below. In the figure the magnitude of flows back to the farms is also illustrated. This flow mainly consists of seeds for sowing, fodder and fertiliser.

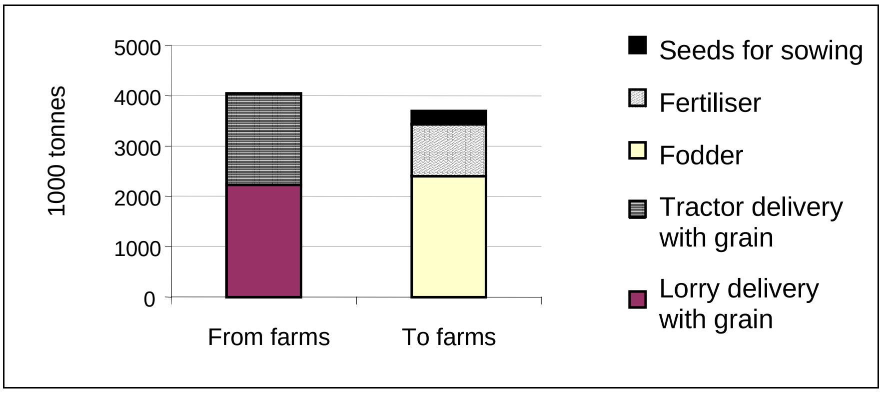


Figure 31 Flows from farms (grain) and to the farms (fodder, fertiliser and seeds for sowing) per year in Sweden, 1999 (Source: Gebresenbet & Ljungberg, 2000)

As we can see in the figure above, the use of lorry transports is larger than the tractor transports. It is also clear that the flow from the farms is higher than the flows to the farms. In addition to these transports, some grain is also delivered by train and ship. About 350 000 tonnes of grain was delivered domestically with ship and about 21 000 tonnes was delivered by trains in 1997 (Gebresenbet & Ljungberg, 2000).

Description of ODAL's transports

ODAL handles (e.g. dries, sells and stores) about 1,5 million tonnes of grain per year. The grain is used for different purposes and sold to different sources. The approximate use of the grain in ODAL is illustrated by the figure below.

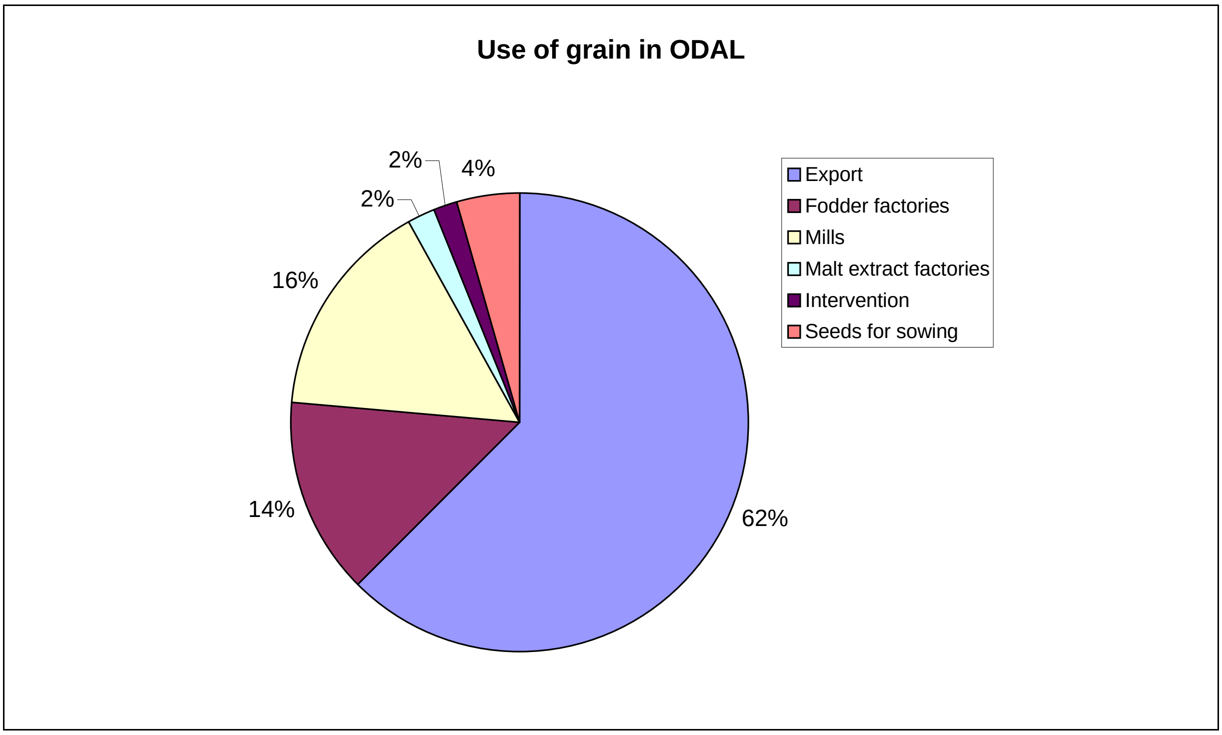


Figure 32 Approximate division of use of grain in ODAL a normal year. (Source: Gebresenbet & Ljungberg, 2000)

It can be noted in the figure above that intervention means that the Swedish Board of Agriculture buys grain when there is an overproduction in Sweden. Intervention is a way to raise the prices for grain and it is financed through the support from the EU. It is also important to realise that the use of grain varies considerably between years.

ODAL is located in the central region of Sweden and has access to ports both on the West and on the East Coast. The location of ODAL and other Grain and Supply Co-operatives in Sweden is illustrated in the figure below.

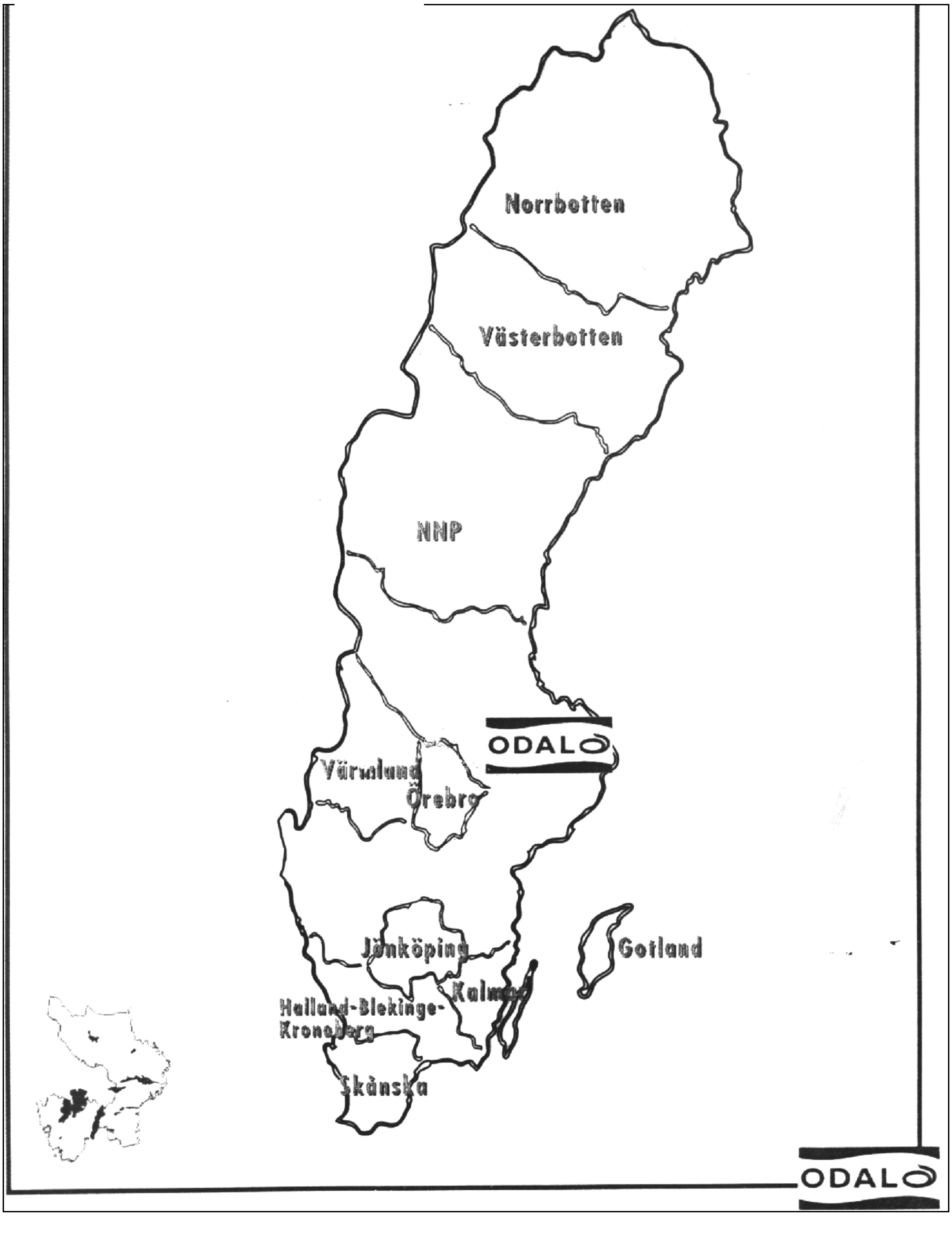


Figure 33 ODAL in relation to the other Grain and Supply Co-operatives in Sweden

ODAL's grain is transported by farmers, hauliers and transport and logistic companies. Many different owner-operators and transport companies thus own the lorry fleets, tractors and ships. The grain can be transported to a silo by the farmer himself or else it is collected by hauliers contracted through ODAL. Sometimes the farmers also transport directly to ODAL's customers. The number of silos in ODAL is about 89. Their location is illustrated in the figure below.

Figure 34 Silos in the ODAL region

The flow between these silos and from farmer to silo and to export constitute the transport routes that Ecotraffic and ODAL have studied. This also includes an estimation of the energy use in ODAL for different activities. This has been conducted through approximations of the amount of transported grain (tonnekm) and the energy efficiency of the different transport modes (kWh/tonnekm). The data on the transport volumes (tonnekm) was mainly collected from ODAL, whereas data on energy efficiency of the different transport modes primarily has been collected from SLU and ASG.

General methodology

Our method for the analysis of the transport volumes and energy use is based on dividing the transport chain into three main segments. At the first segment, the energy use in the transport from the farmer to the silo is examined. Segment number two consists of the energy use in the transport from silo to silo. The third segment is the energy use in the transport to export harbour. In a special case study a fourth segment, from export harbour to the import harbour (in a foreign country) is also studied. The fourth segment is elucidated through a selected route in the special case study called “Söderköping”. Consequently, no total energy use in ODAL can generally be calculated for the fourth segment, but this is done in the first three segments.

Farmer to a silo

To investigate the flows of grain and the energy use from the farmers to a silo, a sample of 80 farmers have been randomly chosen from the total number of about 12 000 farmers, who delivered during the harvest time in 1998. The 12 000 farmers represent about 80% of the total deliveries and farmers during the year so the total amount of farmers is estimated to be about 14 000 in 1998. Based on this sample, an assumption is made for the energy use of the other farmers in the ODAL region. One silo located in Söderköping is studied more thoroughly and the analysis is based on approx. 75% of the number of farmers who have been transporting grain to Söderköping.

Silo to silo

The destination of the deliveries to a silo is dependent on if the deliveries are going to Sweden or are for export. The share which is intended for export is illustrated in the next step “To export harbour” (see below). The method for the calculation of energy use for this part of the transport chain is, like in the “farmer-to-silo” step, estimated based on a sample. Subsequently, and an average transport volume and energy use has been calculated. The sample in the “silo-to-silo” step includes 120 deliveries of about 19 000.

To export harbour

A certain fraction of the transported grain "farmer -silo" and "silo-silo" is estimated to be destined to an export harbour based on export data from ODAL.

From export harbour to import harbour (in a foreign country).

The grain is shipped from the export harbours to many different customers and destinations. Most of those customers ennoble the grain (e.g. from malt to malt extract to beer etc.). Then it is sold again to other customers of whom some ennoble it again and sell it further. The energy use for this part of the transport chain is difficult to estimate, partly because foreign shipping companies carry out a major part of these transports. Transportation between an export and an import harbour is described in the analysis of the selected route. The delimitation is to only follow the chain to ODAL's customers (the import harbour). Further transports, for example within an importing country, will not be studied. This part will be further described under "Special case studies".

4.6. Transport volume in ODAL

Calculation of transport volume in ODAL

In this chapter, the transport volume (tonnekm) in the transportation of grain in ODAL is estimated. As mention earlier, the energy use and transport volume is estimated based on samples. Assumed return trips are also included. However, it should be noted that the focus is on the delivery trips of grain and not the return trips, which mainly include seeds for sowing, fodder and fertiliser. The results from the analysis of the transport volume of the different steps in the transport chain are described in this chapter. Before reporting the results from the calculations, we will start by making some general comments on grain transports.

Grain transports can be carried out by different kinds of vehicles. However the data and statistics has not been compiled by ODAL to serve this purpose. Therefore, the data is not complete in that sense that it is always possible to determine what type of vehicle that has been used for the grain deliveries. For example, in some cases several deliveries are lumped in one group. Therefore, we have classified the deliveries (especially in the data for the farmer-to-silo step where no indications of transport mode was present) based on the quantity of tons delivered. The classification was made after discussions with ODAL (Carlsson, 2000). The division is illustrated in the table below.

Table 31 Classification of data to different transport modes/means

<15 tons	Tractor
>15tons	Lorry
>300 tons	Boat

The table above indicates that if a delivery in our data material is below 15 tonnes, it is classified as a tractor delivery etc.

Farmer to silo

<u>Transport volume and data</u>

In the first stage, a random sample has been chosen comprising of 80 farmers from the total number of farmers who delivered to ODAL during the harvest period in 1998. From the data describing all the deliveries during the period, which are about 100 000, it was found that the number of farmers was about 14 000 and that they were delivering about 7,0 times each year. These figures are assumed valid for *a normal year* in the ODAL. The data is collected from ODAL's statistics on grain deliveries during the described period (Personal comm., Carlsson and Sjöö, 1999).

Based on the data obtained from the sample regarding the deliveries from these farmers (quantity, transport volume etc.), an average grain transport has been estimated. The average grain transport has been generalised to be valid for all the farmers delivering to ODAL.

The distances in the sample have been estimated by ODAL. The common method used by ODAL to estimate the distance between the farmer and the closest silo has been to use the known distance between the farmer and the church in the same rural district. Therefore, the distances should be considered as estimates. They are shown in the table below.

Table 32 Average values per delivery

	Average distance to silo (km), weighted	Average transport volume (tonnes/delivery)	Average transport volume (tonnekm), weighted
Delivery trip	11,4	9,87	113
Return trip	11,4	1,23	14,1
Total		11,1	133

The table above indicates that in the transport mix recorded, about 89% of the volume transported is delivered to the silo and 11% included in the return trip. The average per delivery has been calculated as the total value (distance, volume and transport volume) divided by the number of deliveries. The values for distance and volume have been weighted to account for the fact that the frequency of deliveries varies betwen the farmers. If the values are not weighted, the average distance is 13,7 km, while the total average delivery volume is 10,4 tonnes. The average delivery volume becomes 9,32 tonnes when return trips are excluded.

There is a certain difference between the average delivery and the average for each farmer. The reason for this inconsistency is that the number of deliveries and the delivered volume is different for each farmer. It is conceivable that the difference is greatest for the distance and the transport volume. The average quantities of deliveries per farmer and the average transport volumes are shown in the table below. These values are calculated by dividing the total transport volume (tonnes/year) delivered from each farmer, by the number of farmers. A similar procedure has been used for the transport volume (tonnekm).

Table 33 Average values per farmer and year

	Average transport volume (tonnes/year)	Average transport volume (tonnekm), weighted
Delivery trip	69,4	793
Return trip	8,66	99,1
Total	78,0	892

If the values are not weighted, the total average transport volume is 72,8 tonnes, while 65,5 tonnes when return trips are excluded. These values are about 7% and 6% lower respectively. A possible explanation for the lower volume (in the non-weighted case) is that the farmers living far away from the silos do not have as many deliveries and deliver as much per delivery as the ones living close to the reception silo. It could also be conceivable that the location of the silo was decided taking this situation into account, i.e. the silo was located as close to the greatest grain producers as possible.

Total in ODAL /year farmer to silo

Using the assumption that the average delivery for all the 14 000 farmers in ODAL is similar to the sample of 80 farmers, the total transport volume can be estimated. These results are shown in Table 34.

Table 34 Total in ODAL/ year

	Average transport volume (tonnes/year)	Average transport volume (tonnekm)
Delivery trip	971 000	11 100 000
Return trip	121 000	1 390 000
Total	1 090 000	12 500 000

If the values were not weighted total and excluding return trips the average transport volume (tonnes) would be about 7% and 6% lower respectively.

The division between different transport means

The division between the transport volume (in tonnekm) for the different transport means in the sample above is illustrated in the table below.

Table 35 Division between different transport means

	Number of farmers	%	Weighted -%
Tractor	70	88	67
Lorry	10	13	37
Total	**80**	**100**	**100**

As we can see in the table above, the percentage for lorries increases from 13% to 37% when the values are weighted. Observe that the figures in the table above do not include return trips. If return trips are included, the division (weighted) is 41% for lorries and 59% for tractors.

Silo to silo

In the second stage, the procedure has been similar as in the first stage. A sample of 120 deliveries has been chosen out of about 19 000 deliveries. The period is from 970801-980731. The distances have been estimated with a map program using the co-ordinates of the silos as input data. Based on the data obtained from the sample, the following average values were received.

Table 36 Average values per delivery

	Average distance silo to silo (km)	Average transport volume (tonnes/delivery)	Average transport volume (tonnekm), weighted
Delivery trip	70,5	55,3	3 900
Return trip	70,5	8,41	593
Total		63,7	4 500

Lorries cover 116 of the 120 deliveries in the sample (96,5%), sea transport 1 (1%) and tractor transport 3 (2,5%). The data for sea and tractor are considered to be too small to be presented here as averages. However, data for the lorries are presented below:

Table 37 Average for lorries silo to silo

	Average distance silo to silo (km)	Average transport volume (tonnes/delivery)	Average transport volume (tonnekm), weighted
Delivery trip	72	35,3	2540
Return trip	72	8,53	613
Total		43,9	3150

(More about the division between transport modes/means is presented further down in the report, after the total volume in ODAL has been presented).

Total in ODAL /year (all modes) silo to silo

The calculation of total transport volume in ODAL in this stage, is based on the number of deliveries during the period, which are assumed to be 19 000 a normal year. The result is seen in the table below.

Table 38 Total in ODAL/ year

	Average transport volume tonnes/year	Average transport volume (tonnekm)
Delivery trip	1 050 000	74 100 000
Return trip	160 000	11 300 000
Total	1 210 000	85 400 000

If the values were not weighted in total and excluding return trips, the average transport volume (tonnes) would be about 12% and 14% lower respectively.

There are data available for the total quantity delivered from silo to silo in ODAL but data on the total transport volume is not available for all deliveries. However, the total quantity delivered (at 887 000 tonnes/year) can be compared with the calculated value for the delivery trips of 1 050 000 tonnes per year in Table 38. This provides some estimation of the error in the sampling and calculation, since the difference is about 18%. As a comparison it could be mentioned that the calculated transport volume (tonnes/year) in the farmer-to-silo step was, in between at 971 000 tonnes per year.

As mentioned before, lorries cover 116 of the 120 deliveries in the sample (96,5%), sea transport 1 (1%) and tractor transport 3 (2,5%). If the allocation for deliveries is based on transport volume (tonnekm), the result becomes different (see table below).

Table 39 Allocation based transport volume (tonnekm)

	Tr. vol %
Tractor	0,1%
Lorry	62,9%
Sea	37,0%

The sample shows a good compliance regarding the division between different transport modes/means with the reference value for the whole population concerning the number of deliveries (in %). If the division would be expressed in transport volume (tonnekm) there are no data for the whole population. However, the total quantity during the period 970801-980731 is known and it can be divided between different transport modes/means.

The most frequently used transport modes from silo to silo in the whole population are shown below (expressed in number of deliveries and tonnes):

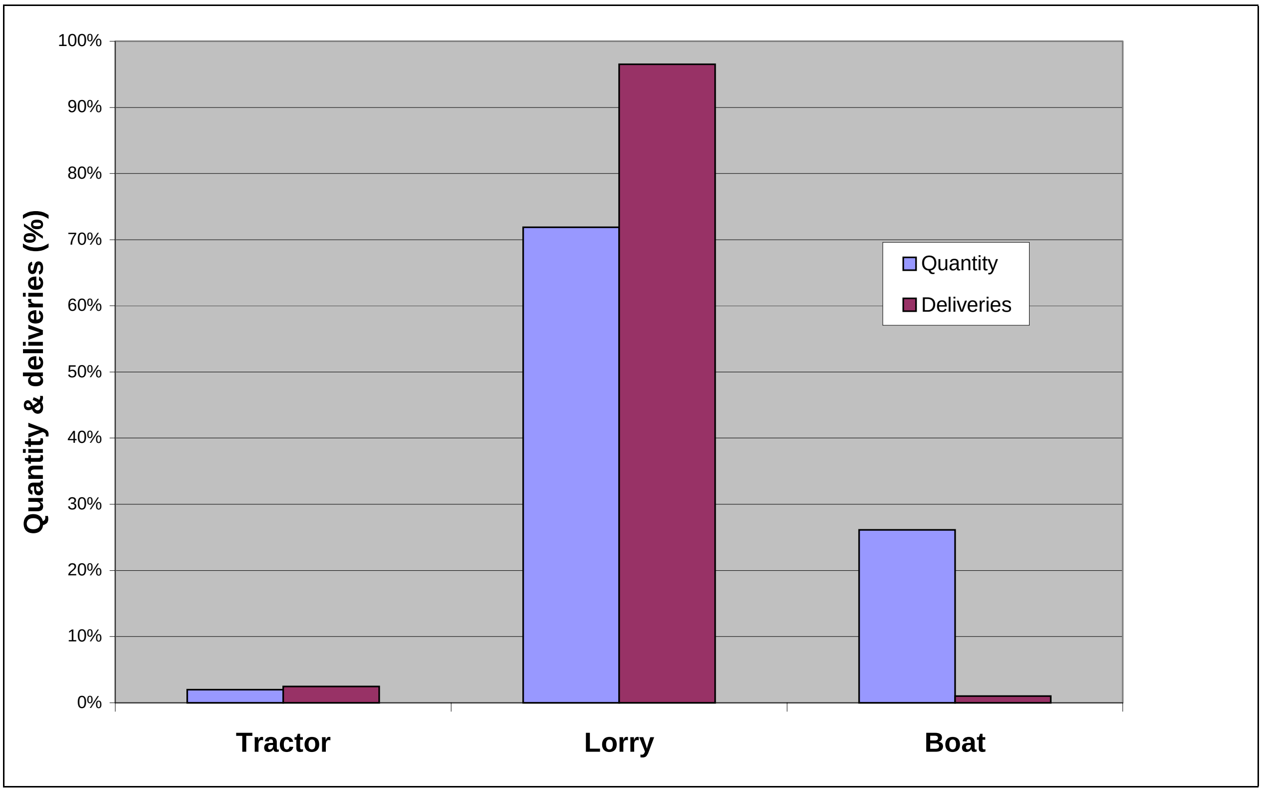


Figure 35 Most frequently used transport mode/mean based on quantity (tonnes) and number of deliveries respectively, in the whole population.

In the figure we can see that lorry is the most frequently used transport mode based on number of deliveries, with about 96,5% of the deliveries. Tractor transportation corresponds to about 2,5%. Boat transport represents 1%. However, the quantity on the larger transport modes is significant. When calculating based on transport volume (tonnes) this changes the allocation on transport modes so that ship stands for about 26%, lorries for about 72% and tractors for about 2% of the transports.

Type of grain

In the whole population during the period 970801-980731 oats and wheat dominated the number of deliveries and the quantity referred to grain type. The four mostly delivered types of grain for the silo-silo transport segment is illustrated in the figure below.

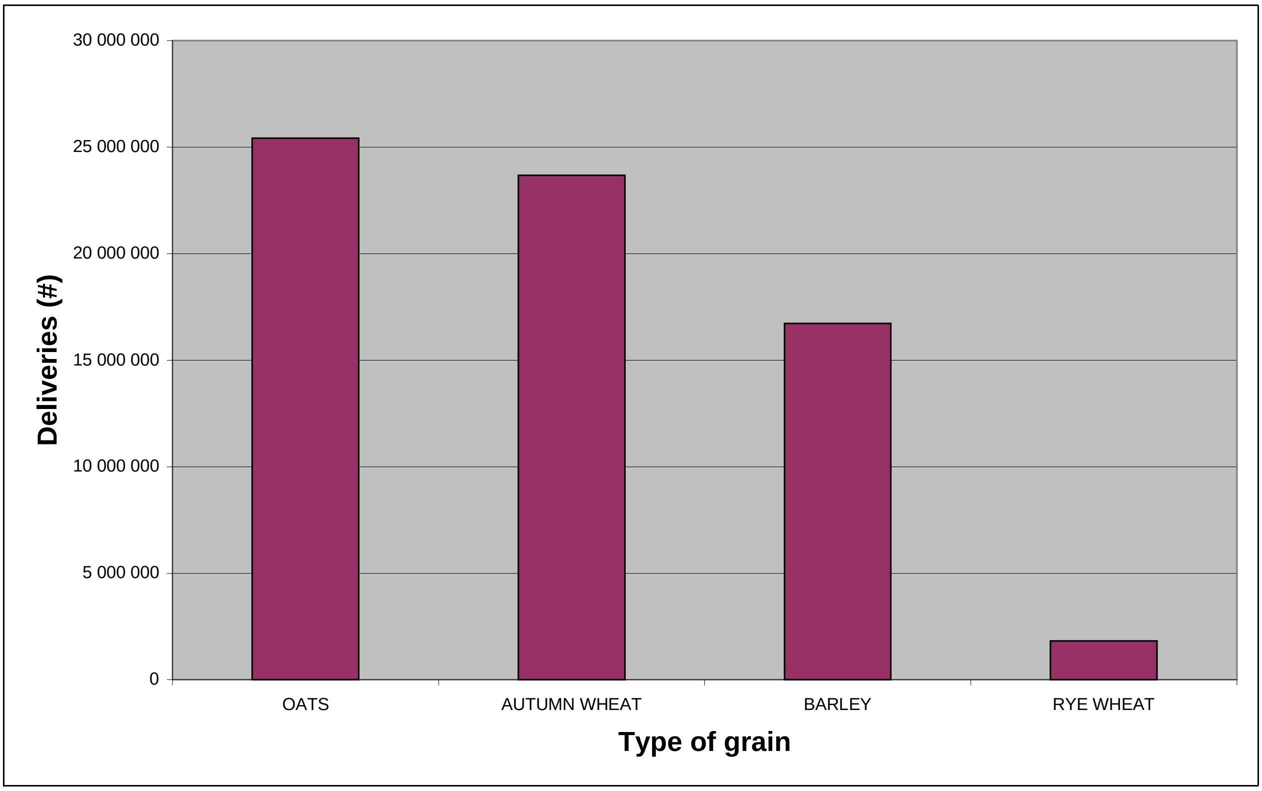


Figure 36 The four mostly delivered types of grain silo-silo (number of deliveries)

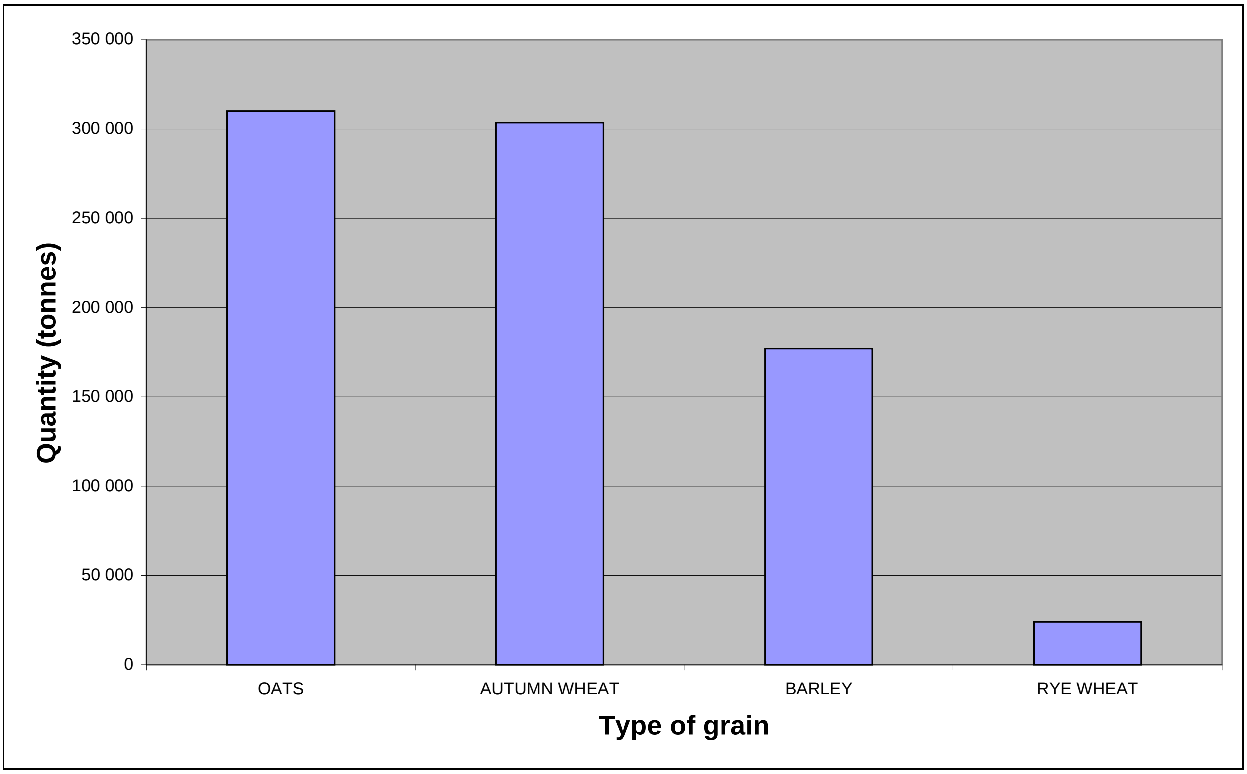


Figure 37 The four mostly delivered types of grain silo-silo (in quantity, tonnes)

During a normal year, wheat (different types of wheat) is the mostly transported product. This is the case in all steps including “farmer to silo” and “to export” (Thorn, pers. comm., 2000).

To export harbour

The amount of grain for export varies between years and since it is difficult, using the available data to decide how much of the grain that is exported, we have made an assumption after a dialogue with ODAL. According to ODAL (Lennart Vilhemsson, pers. comm., 1999), about 60-70% of ODAL's grain is exported. Some is exported directly from the farmer to the export harbour and some is delivered to a silo first and later to an export harbour. The assumption is that 65% of all the grain that is delivered by the farmers (and further on in all the links in the transport chain) is exported. We are also assuming that the average distances and transport volumes are the same in the “farmer-to-export” step as in the “farmer-to-silo” step. This is also the case for the silo-to-silo step. Therefore, the data reported below are not showing distances etc. but is presented as totals.

Total transport in ODAL /year (all modes) to export harbour

To calculate the total transport volume in ODAL in this stage, the average total transport volume from the chapter “farmer to silo” is multiplied with the factor of 0,65. The result is shown in the table below.

Table 40 Total transport volume per year from farmer to export

	Average transport volume (tonnes/year)	Average transport volume (tonnekm)
Delivery trip	631 000	7 220 000
Return trip	78 800	901 000
Total	710 000	8 120 000

About 65% of the total transport volume from silo to silo is also allocated to export harbour. The result is seen in the table below.

Table 41 Total transport volume per year from silo to export

	Average transport volume (tonnes/year)	Average transport volume (tonnekm)
Delivery trip	683 000	48 200 000
Return trip	104 000	7 300 000
Total	787 000	55 500 000

If the two tables above are summarised, the transport volume to export harbour in ODAL/year found. This is illustrated in the table below.

Table 42 Total transport volume per year to export harbour

	Average transport volume (tonnes/year)	Average transport volume (tonnekm)
Delivery trip	1 314 000	55 400 000
Return trip	183 000	8 200 000
Total	1 500 000	63 600 000

Wheat is the mostly exported product. Wheat is for example exported to Terragona in Spain and Bari in Italy using ships with a payload of about 25 000 tonnes. An approximate estimation is that about 500-700 000 tonnes of wheat, 300 000-400 000 tonnes of Barley and 250 000-300 000 tonnes of oats are exported a normal year in ODAL (Thorn, pers. comm., 2000). In chapter 4.8 a transport route to Terragona in Spain is elucidated.

Summary calculations of transport volume

The transport volume (in tonnes) of grain in ODAL adds up to about 2 million tonnes. According to a brochure from ODAL (1997) about 1.7 million tonnes of grain were handled. Hence, our calculations might include some overestimation. The transport volume of the return trips amount to about 1/7 of the grain deliveries. The figures are based on the knowledge that the number of deliveries from silo to silo during a normal year is about 19 000 and that the number of farmers in “farmer to silo” are about 14 000 a normal year. The volume exported represents 65% of the transport volume in "farmer to silo" and "silo to silo". When a subtraction of the 65% from the farmer-to-silo and silo-to-silo step is made, the results can be presented in a different form than the data shown above. The figures can now be summarised, which corresponds to the total transport volume (tonnekm) in ODAL. Table 43 summarises the results according to the calculations described above excluding return trips. Table 44 shows the same figures as in Table 43 but including return trips.

Table 43 Average transport volume (tonnekm) in ODAL/ year for domestic use, export and total, excluding return trips

	Farmer to silo	Silo to silo	Total in ODAL
Domestic use	3 890 000	25 900 000	29 800 000
Export	7 220 000	48 200 000	55 400 000
Total in ODAL	11 100 000	74 100 000	85 200 000

Table 44 Average transport volume (tonnekm) in ODAL/ year for domestic use, export and total, including return trips

	Farmer to silo	Silo to silo	Total in ODAL
Domestic use	4 370 000	29 900 000	34 300 000
Export	8 120 000	55 500 000	63 600 000
Total in ODAL	12 500 000	85 400 000	97 900 000

Observe that the column "Total in ODAL" does not include transports outside Sweden (e.g. transport between export and import harbours).

4.7. Energy use in Odal

Calculation of energy use in ODAL

The energy use for every individual vehicle used for delivery in the sample is not known. Nor is the exact type of each vehicle known. Therefore, the methodology of calculating the energy use has been to interpolate the energy use in the specific delivery. This has been done by using the quantity transported as a base for an interpolation between two basic types of tractors or lorries (This is also described in the chapter "Energy efficiency factors"). The two tractors used are the ones illustrated in the table below.

Table 45 Energy use in used tractors, including return trips

Vehicle	Payload, average, tons	Load factor weight-%	kWh (fuel) /tonnekm
Tractor 1	4,4	50	0,88
Tractor 2	7,5	50	0,79

The load factor (weight-%) is based on the assumption that the tractor has a load factor of 95% on the way to the silo and 5% on the way back. The maximum payloads for the tractors are 8,8 and 15 tonnes respectively. The data/energy use for the samples has been calculated based on the weight of the grain delivery and with inter- or extrapolation of the data from these two tractors. The energy use in the tractors is partly based on a report by Hansson et.al. (1998). The calculation is also based on the assumption that the energy content in the fuel is 9,99 kWh/l.

Table 46 Energy use in used lorries, including return trips

Vehicle	Payload, average, tons	Load factor weight-%	kWh (fuel) /tonnekm
Lorry 1	7,8	56	0,44
Lorry 2	19,4	56	0,25

The load factor weight-% is based on the assumption that the load factor for the lorry is 91% on the way to the silo and 20% on the way back. The maximum payloads for the lorries are 14 and 35 tonnes respectively. The total load factor of 56% is based on statistics from SIKA/SCB and data from hauliers used by ODAL as well (Ljungberg, pers. comm., 2000). The data/energy use for the samples has been calculated based on the weight of the grain delivery and with inter- or extrapolation of the data from these two lorries.

The energy use for the small lorry is based on adjusted data from NTM regarding a lorry involved in regional transports. NTM used 0,49 kWh/tonnekm for a corresponding lorry with maximum load: 14 tons and a load factor of 50%. Since the data from NTM was for a lorry used in regional transport, it is probably an overestimation of the energy use in grain transport. The energy use for the big lorry (maximum load 35 tons) is partly based on studies made by the Swedish University of Agriculture Sciences collected from Ljungberg (pers. comm., 1999.) at the Department of Agriculture Engineering. The studies showed an average fuel consumption of 4,9 l/100 km. The calculation is also based on the assumption that the energy content in the fuel is 9,85 kWh/l. This energy content is lower than in the previous case, due to the lower density of the diesel fuel used for on-road transportation in Sweden in comparison to the diesel fuel used for off-road purpose[17].

The total transport volume in the previous chapter has included return trips. Since the focus of the report is on grain deliveries, the energy use will be calculated mainly based on transport volume excluding return trips. The return trips often include seeds for sowing, fertiliser etc. In the following tables, the payload will be based on the delivery trips (corresponds to 95% and 91% of the payload for tractors and lorries respectively), since these are the focus in the energy calculation procedure (although note that the payload in Table 45 and Table 46 above is described as averages of the delivery and the return trip).

However, the choice of transport mode/mean and the route for the delivery trips affects the total load factor and the possibility for return trips. Therefore, the energy efficiency factors will still be calculated as averages between delivery trips and return trips, so that consideration is taken to the lower total load factor. This procedure will be further described in connection with the actual calculation in different segments below.

[17] More than 90% of the diesel fuel used for on-road transportation in Sweden corresponds to Environmental Class 1 (EC1). The Swedish specification for environmentally classified diesel fuels has three classes, where EC3 corresponds to the current European specification of diesel fuel and EC1 is the “best” fuel regarding its environmental effects (EC2 is between EC1 and EC3). However, the density of EC1 is lower than EC3, hence the lower energy content per litre of fuel.

Farmer to silo

Based on the described way to calculate the energy use above and the transport volume in the sample, some average energy efficiency factors for the sample "farmer to silo" has been found. These are described in the table below.

Table 47 Energy use and payload in used transport means

	Payload, per delivery, tonnes	Aver. energy use kWh(fuel)/ tonnekm
Tractor	7,54	0,88
Lorry	21,1	0,35
Average	9,32	0,68

The table shows that the average payload is much higher for the lorry than for the tractor, as expected. Likewise, the average energy use is much less for the lorry. The potential for decreasing the average energy use is about a factor of 2 (from 0,68 to 0,35 kWh/km). This is, of course, valid under the assumption that the load factors assumed will remain unchanged. Observe that the figures have not been weighted in Table 47. This is one of the reasons why there is a slight difference between these presented energy efficiency factors and the ones in Table 45 and Table 46. Note also that the payload in Table 47 represents 91-95% of the transport volume (tonnes) whilst Table 45 and Table 46 presents an average payload (including return trips) corresponding to 50-56% of the transport volume (tonnes).

Using this way to calculate the energy use and the data (transport volume and division between transport means) from the chapter above "Calculation of transport volume in ODAL", the average energy use in different cases has been calculated for the sample. The energy use, based on calculated energy efficiency factors and transport volume, is illustrated in the table below.

Table 48 Energy use in ODAL (kWh), farmer to silo

	Energy use/ Delivery	Energy use /farmer & year	Total energy use in ODAL, farmer to silo
Delivery trip	76,8	539	7 550 000

The total energy use in ODAL of grain transport is calculated with weighted data and assuming that the average number of farmers is about 14 000 a normal year.

Silo to silo

The method and the basic energy efficiency factors in the Chapter 4.7 for lorries and tractors are also used in this chapter. Energy efficiency factors for each transport mode/mean is also added. In the sample of 120 deliveries, there is only one ship included. This represents about 1% and is in correlation to the whole population. Therefore, the energy efficiency for that particular ship has been calculated. Likewise, the number of tractor transports is three, which also is in correlation to the whole population. It could however be questioned in this case whether the transport has been correctly classified, since the average payload in tractor transport silo to silo is more than double the corresponding payload in the farmer-to-silo step. On the other hand, the data on lorries, covering 116 deliveries should be data that are more reliable. The energy efficiency etc. in the sample is seen in the table below.

Table 49 Energy use and payload in used transport modes/means

	Payload, per delivery, tonnes	Aver. energy use kWh(fuel)/ tonnekm
Tractor	18,3	0,63
Lorry	35,3	0,21
Boat	1630	0,098
Average	55,3	0,17

As seen in the table above, the payload for the transports excluding return trips is 18,3 for tractors, 35,3 for lorries, 1630 for ships and 55,3 tonnes as an average for all transport modes/means. The energy use for the tractor transport (0,63 kWh/tonnekm) is clearly lower than in the farmer-to-silo case (0,88 kWh/tonnekm), whereas the difference for the lorries is even greater (0,21 vs. 0,35 kWh/tonnekm).

The load factor (weight-%) for the sea transport is based on the assumption that the ship takes 82% on the way to the silo and 0% on the way back (the average load factor is 41%). The figure is however, according to the ship owner not very representative since the deep draught is a problem in this particular distance. On another route the load factor could be increased to 50% as an average (almost 100% on the delivery trip) and the energy efficiency increases to about 0,075 kWh (fuel)/tonnekm. Sometimes it is also possible to transport goods on the return trips. Similar load factors as in the farmer-to-silo case has been anticipated for tractor and lorry transport (i.e. calculated average total load factors are 50% and 56% respectively).

Using the mix of transport modes/means described in chapter 4.6, the average energy use in different cases from the sample has been calculated. The energy use based on the calculated energy efficiency factor and the transport volume is illustrated in the table below.

Table 50 Energy use in ODAL (kWh), silo to silo

	Energy use/ Delivery	Total energy use in ODAL, silo to silo
Delivery trip	650	12 400 000

The total energy use in ODAL is calculated with weighted data and assuming that the average number of deliveries is about 19 000 a normal year. The ship transport has a great impact on the energy use per delivery (about 17 000 kWh compared to the average 650 kWh/delivery and 524 kWh/delivery for lorries), since the delivery volume is so sizeable. On the other hand, it reduces the energy use of the sample per tonne kilometre, which is considerably higher for the lorries (0,21 kWh/tonnekm) and the tractors (0,63 kWh/tonnekm). Lorries in the sample represent almost 97% of the deliveries.

To export harbour

Some 65% of the energy use in "silo to silo" and in "farmer to silo" is allocated to the export of grain. The sum of these fractions in illustrated in the table below.

Table 51 Energy use in ODAL (GWh), to export

65% of total energy use in ODAL, farmer to silo	65% of total energy use in ODAL, silo to silo	Total energy use in ODAL, to export harbour
4,91	8,03	12,9

Summary calculations of energy use

The figures are based on the knowledge that the number of deliveries from silo to silo during a normal year is about 19 000 and that the farmers in the farmer-to-silo transport are about 14 000 a normal year. The volume exported represents 65% of the transport volume in "farmer to silo" and "silo to silo".

When subtracting the 65% of the grain that is exported from the farmer-to-silo and silo-to-silo steps, the result for the domestic use of the grain can be calculated. Table 52 summarises the results according to the calculations described above.

Table 52 Average energy use (GWh) in ODAL/ year for domestic use, export and total.

	Farmer to silo	Silo to silo	Total in ODAL
Domestic use	2,64	4,33	6,97
Export	4,91	8,03	12,9
Total in ODAL	7,55	12,4	19,9

Observe that the column “Total in ODAL” does not include transports outside Sweden (e.g. transport between export and import harbours) and that the energy use is concerning grain deliveries. The average energy efficiency in ODAL is estimated to about 0,23 kWh/tonnekm.

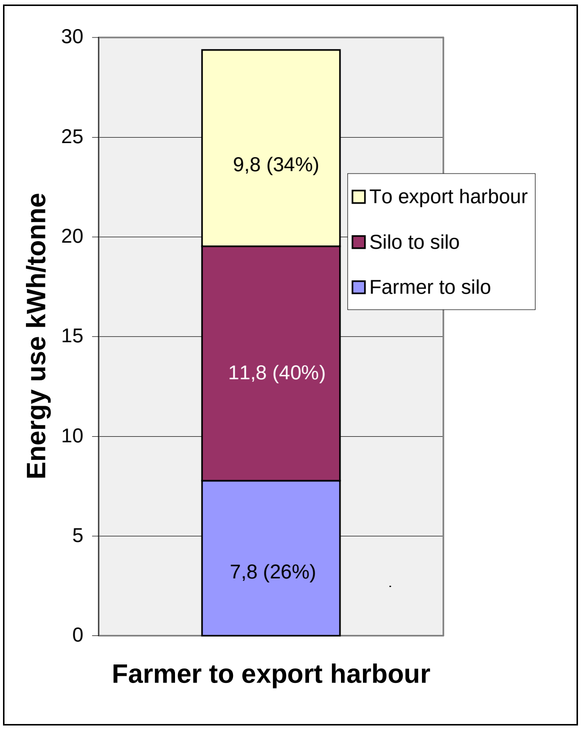


Figure 38 Energy use (kWh/tonne) in different steps in the transport chain, from farmer to export harbour

If the energy efficiency for the different steps “farmer to silo”, "silo to silo” and “silo to export harbour” is expressed in energy use per tonne, the results are depicted according to Figure 38.

As we can see in Figure 38, the Farmer-to-silo step has an energy use of 7,8 kWh/tonne. In the second step “Silo to silo” the energy use is 11,8 kWh/tonne. The difference is explained by the longer distance for “silo to silo” 70,5 km compared to about 11,4 km for the farmer-to-silo step. The difference would have been larger if there were not so many tractors with high energy use in the farmer-to-silo step.

The figure accordingly shows the importance of the distance and choice of transport mode/mean. The step called “to export harbour” is a mix of the other two steps and has an energy use that is in between the energy use of the other two steps.

4.8. Special case study “Söderköping”

In the previous chapters, the energy use and the transport volume in ODAL has been estimated. Since the data material, which the estimations is based on, is incomplete and estimations of this kind is not very precise, we have also carried out a more comprehensive study of the transport flows and the transport energy use to and from a silo in ODAL. The chosen silo is located in Söderköping. The data is more specific especially regarding the step farmer to silo and for the added step from “export to import harbour”.

Description of transports and methodology

In the farmer-to-silo step, the approximate distance and transport volume between the farmers and the silo in Söderköping has been calculated based on a sample of 95 farmers. This corresponds to about 75% of the total population (the sample in the previous farmer-to-silo step corresponded to less than 1% of the total population). The reason for not including all farmers was the lack of co-ordinates. The distance between the farmers and the silo in Söderköping has been calculated based on the co-ordinates for the farmers and the silo in Söderköping via a map program. The method to use co-ordinates and a map program should give more exact distances than the method in the previous farmer to silo step. The distances have been multiplied with the number of deliveries and the return trips and the amount of tons of grain to give the total amount of ton-kilometres (tonnekm).

In the silo-to-silo step, i.e. Söderköping to Djurön/Norrköping, the distances are known and the transport volumes (tonnes) are based on the previous step. The energy use for transport is however not specific for this silo-to-silo transport but the same as in the general silo-to-silo step in ODAL.

Regarding the step “from export to import harbour” it can be noted that the exported grain is generally shipped from the export harbours in Sweden to many different customers and destinations. Most of those customers ennoble the grain and then it is sold again to other customers of which some ennoble it again and sell it further. The energy use for this part of the transport chain is difficult to estimate partly because foreign shipping companies carry out a major part of the transports. However, the export chain will be described by an analysis of a selected route associated to Söderköping and between a port in ODAL and a port in a foreign country. The delimitation is to only follow the chain to ODAL’s customers (the import harbour). Further transports, for example within an importing country, will not be studied.

The data from this special case may serve as background in some of the following pilot actions or can be used to compare with the calculations of the general energy use in ODAL.

Calculation of transport volume and energy use

It should be noted that some farmers around Söderköping deliver directly to the larger silo in Norrköping (breaking point about 25 km south of Söderköping, almost none of the farmers north of Söderköping deliver to Söderköping) or Djurön. However, the study is focusing on those farmers who deliver to Söderköping.

The silo in Söderköping receives according to ODAL approximately about 5000 tonnes of grain per year. The farmers transports and delivers, (using tractors), almost all of the grain themselves to the reception plant. Söderköping can receive about 25 different fractions of grain (different sorts and qualities). There are four larger silos in the reception plant where grain can be stored. The grain is collected (finished) in late October and is stored during the rest of the year. After that, the grain is carried away sometime during the spring with lorries to Djurön or Norrköping. More than 95% of the received tons are delivered to Djurön or Norrköping. The allocation is about 50% to each destination (Berglin, pers. comm., 1999). In table 25 some facts about the silo located in Söderköping on which the calculations has been made is illustrated.

Table 53 Deliveries to Söderköping 1997-08-01—1998-07-31.

Amount received (tons of grain) about:	5 000
Number of deliveries:	509
Number of farmers:	126

If 50% of the grain from Söderköping goes to Norrköping and Djurön, this corresponds to about 2500 tonnes each year. This is a small fraction of the received quantity in Norrköping and Djurön. For example, Djurön has a turnover of about 400 000-500 000 tonnes of grain each year. The fraction from Söderköping to Djurön (about 2500 tonnes) will also be used as example in the energy use of transport from export to import harbour.

Note that the figures above (5000 and 2500 tonnes) are rounded off. The calculations below of the route will be based on the average values of transport volume and energy use from the used samples.

Transportation from farmer to Söderköping

Transport volume

The distances in the sample have been estimated by ODAL using co-ordinates in a map program. The distances and transport volume is shown in the table below.

Table 54 Average values per delivery

	Average distance to silo (km), weighted	Average transport volume (tonnes/delivery)	Average transport volume (tonnekm), weighted
Delivery trip	18,9	9,41	178
Return trip	18,9	0,85	16,1
Total		10,3	194

The table above indicates that about 91% of the volume transported (tonnes) are delivered to the silo and 9% included in the return trip. The situation in the previous farmer to silo calculations was about 89% on the delivery trip and 11% on the return trip and the distance was about 11,4 km. The relation between delivery trips and return trips are, however, uncertain and dependent on the assumptions of load factor of the transport modes/means. The actual return trips load factor could for tractors be less than the calculated 5% (Berglin, personal communication, 1998). This is also the case for lorries. However, the transport mean mix is dominated by.

The average values per delivery have been calculated as the total value (distance, volume and transport volume) divided by the number of deliveries. The values for distance and volume have been weighted so that consideration is taken to that some farmers seldom delivers. If the values are not weighted, the average distance is 17,0 km, while the total average transport volume is 9,89 tonnes. The total average transport volume becomes 9,12 tonnes when return trips are excluded. As can be seen in table 27, there is a certain difference between the average delivery and the average for each farmer. The reason for this inconsistency is that the number of deliveries and the delivered volume is different for each farmer. It is conceivable that the difference is greatest for the distance and the transport volume.

The average number of deliveries per farmer in the sample is about 3,7. The average transport volume per farmer and the average transport volume are shown in the table below. These values have been calculated by dividing the total quantity delivered by each farmer by the number of farmers. A similar procedure has been used for the transport volume.

Table 55 Average values per farmer and year

	Average transport volume (tonnes/year)	Average transport volume (tonnekm), weighted
Delivery trip	35,0	660
Return trip	3,17	60
Total	38,1	720

If the values are not weighted, the total average delivery volume is 36,7 tonnes and 33,9 tonnes when return trips are excluded. These values are about 4% and 3% lower respectively.

Provided that the average delivery for all the 126 farmers around Söderköping (the number of farmers during the period) is similar to the sample of 95 farmers, the total transport volume can be calculated. These results are shown in the table below.

Table 56 Total transport volume for transport to Söderköping/year

	Average transport volume (tonnes/year)	Average transport volume (tonnekm), weighted
Delivery trip	4 410	83 200
Return trip	399	7 540
Total	4 810	90 800

If the values were not weighted including and excluding return trips the average transport volume (tonnes) would be about 4% and 3% lower respectively.

The division between different transport means

The division between the different transport means in the sample above is illustrated in the table below.

Table 57 Division between different transport means

	Number of farmers	%	Weighted -%
Tractor	87	92	84
Lorry	8	8	16
Total	**95**	**100**	**100**

As we can see in the table above, the percentage for lorries increases from 8% to 16% when the values are weighted. Note that the figures in the table above do not include return trips. If return trips are included, the division (weighted) is 18% for lorries and 82% for tractors. The transports in the sample around Söderköping are mostly carried out with tractors in a much larger extent than generally in farmer to silo in ODAL (88%).

Energy use "Farmer to Söderköping"

The method and the energy efficiency factors in the Chapter 4.7 for lorries and tractors are also used as basis in the calculations carried out in this chapter. Using this way to calculate the energy use and the transport volume and division between transport means from the chapter above, the average energy use in different cases from the sample has been calculated. An average for the energy efficiency for this mix is approximately 0,77 kWh/tonnekm. The energy use based on transport volume and the calculated energy efficiency factors is illustrated in the table below.

Table 58 Energy use in transport to the Söderköping silo (kWh)

Energy use/ Delivery	Energy use /farmer & year	Total energy use in Söderköping
137	510	64 300

The total energy use in ODAL is calculated with weighted data and assuming that the average number of farmers is about 126 a normal year.

Transport from the Söderköping-silo to Norrköping/Djurön

Transport volume

After the grain has been stored in Söderköping from late October, the grain is delivered occasionally during the spring with lorries to Djurön or Norrköping. About 50% of the grain in Söderköping is transported to Djurön and about 50% to Norrköping according to ODAL (Berglin, pers. comm., 1999). These transports are generally carried out with lorries. The distance and transport volume etc. between Söderköping and Norrköping and Söderköping and Djurön is illustrated in the table below.

Table 59 Distance and transport volume Söderköping to Djurön and Norrköping respectively

		Average distance to silo (km)	Average transport volume (tonnes/delivery)	Average transport volume (tonnekm)
Djurön	Delivery trip	7,5	35,3	265
	Return trip	7,5	8,53	64,0
	Total		43,9	329
Norrköping	Delivery trip	9,0	35,3	318
	Return trip	9,0	8,53	76,8
	Total		43,9	395

The quantity per delivery and return trip is assumed the same as for lorries in the silo-to-silo transport. It should be noted in the table above that the distance between these particular silos is relatively very short. The average silo-to-silo transport in ODAL is about 70,5 km, which indicates a difference compared to the distance Söderköping to Djurön with almost a factor 10. This assumption could lead to that the energy use is somewhat underestimated, since it is likely that shorter trips have specific higher energy use (per km) than longer trips

Total in the case

The total transport volume in the case from Söderköping to Djurön and Norrköping respectively is illustrated in the table below.

Table 60 Total transport volume Söderköping to Djurön and Norrköping respectively

		Average transport volume (tonnes/year)	Average transport volume (tonnekm)
Djurön	Delivery trip	2 200	16 500
	Return trip	532	3 990
	Total	2 730	20 500
Norrköping	Delivery trip	2 200	19 800
	Return trip	532	4 790
	Total	2 730	24 600

Energy use

The energy use for transportation to Norrköping and Djurön is based on the method and the energy efficiency factors in Chapter 4.7 for lorries.

The energy efficiency factor for lorries is assumed to be 0,21 kWh/tonnekm. This factor and the payload per delivery are the same as in the step "silo to silo". The division between transport modes/means in this transport from Söderköping to Norrköping and Djurön respectively (in the basic alternative, 0-alternative) is based on the division in the step silo to silo. The difference is that no ship transports is expected. When ships are excluded the transport mode mix changes to about 0,2% tractors and 99,8% lorries (weighted figures). Since the difference between this and 100% lorries is negligible, 100% lorries will be used as the transport mix in the basic alternative. Using the mix of transport means in the 0-alternative and the described energy efficiency factors, the result becomes the following:

Table 61 Energy use in transportation to Djurön and Norrköping from Söderköping (kWh)

	Energy use/ Delivery (kWh)	Total energy use (kWh)
Djurön	54,6	3 410
Norrköping	65,6	4 090

Transportation from export to import harbour

Transport volume

The transportation mode from Djurön is (almost) exclusively ship transport (for export). The transport from Djurön to the customer is handled by either ODAL, SLR (Svenska lantmännen) or by the customer. SLR, which is owned by ODAL and other organisations for farmers, sometimes acts as a broker in arranging the transportation. Djurön has a turnover of 400 000-500 000 tonnes of grain each year. The reception plant in Djurön has about 30 customers. An average ship for export takes about 20 000 tonnes. This means in theory about 22-23 deliveries each season.

To follow and estimate all the transports to the customers abroad is complex. Therefore, one route for transporting wheat from Söderköping to Djurön and further to Terragona in Spain/EU will be examined and calculated to illustrate the energy use. In the transport to Terragona in Spain a normal transport is carried out with a ship loading about 25 000 tons. In general, the ship transport for export in ODAL follows a trend of increasing the size of the ships from 25 000 tons to 50-55 000 tons. The energy saving potential seems to mainly stem from the transfer to larger ships. The constraint is connected to the ports were there is not always possible to receive larger ships than those presently used (Thorn. pers. comm., 2000).

Foreign shipping companies normally carry out the transports. The agent for one of the largest companies “Uner and Jönsson” has contributed with data on which the distance, transport volume and partly the energy use for a normal transport has been estimated. This is illustrated in the tables below (Jakobsson, pers. comm., 2000).

Table 62 Transport volume etc. Djurön to Terragona

	Average distance to silo (km), weighted	Average transport volume (tonnes/delivery)	Average transport volume (tonnekm), weighted
Delivery trip	5334	25 000	133 000 000
Return trip	5334	20 000	107 000 000
Total		45 000	240 000 000

The load factor weight-% in for the route to Terragona is based on the assumption that the ship takes 93% (based on dwt) on the way to the port and about 74% on the way back. Note however that the return trips and the associated distance is hypothetical since few ships in this area go directly back to the harbour of origin. In the return trip factor, some positioning transports without load are also included. The general ship on which the calculation is based on has an estimated dead weight ton of about 27 000. The dead weight ton (dwt) is a measure for the load capacity but it also includes bunker oil etc so it is difficult to reach 100% in load factor of the dead weight tonnes of the ship. The load factors have been assumed based on discussions with the shipping agent Uner and Jönsson (Jakobsson, pers. comm., 2000) and the Swedish Shipowners Association (Karlsson, pers. comm., 2000).

Energy use

The method and principles in Chapter 4.7 are also used as the basis in the calculations of this chapter. However, the load factors and transport volume etc. described above is specific for this route. The estimated energy use is illustrated in the table below.

Table 63 Energy use in used ship, Djurön to Terragona, including return trips

	Payload, average, tons	Load factor weight-%	kWh(fuel)/ tonnekm
Boat	22 500	83	0,023

The energy use in the table above (kWh/tonnekm) is somewhat lower than for an average Swedish ship for domestic transportation according to NTM (1998-09-28). NTM uses about 0,056 kWh (fuel)/ tonnekm for a large freight ship (>8'dwt) in their calculations. Based on the prerequisites in Table 62 and Table 63, the energy use for the transport from Djurön to Terragona in Spain is calculated. The result is illustrated in the table below.

Table 64 Energy use in transportation from Djurön to Terragona (kWh) per delivery and tonne

	Energy use (kWh/ton)	Energy use/ Delivery (kWh)
Delivery trip	124	3 090 000

If the fraction from Söderköping to Djurön (see Table 60) is to be exported, about 2 200 tonnes/year would have to be transported. This is corresponding to about 8,8% of a normal delivery for an export ship. The energy use (kWh) of the Söderköping fraction in transport to Djurön's customer, Terragona, is illustrated in the table below.

Table 65: Energy use from Djurön to Terragona of the fraction from Söderköping (kWh)

	Energy use (kWh)
Delivery trip	272 000

Total energy use in transport chain in the special case study

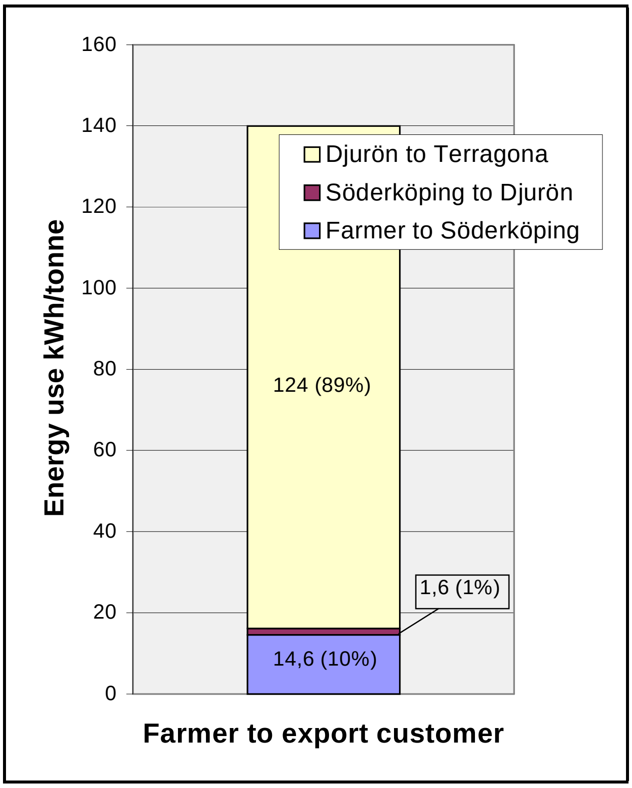


Figure 39 Energy use (kWh/tonne) in different steps in the transport chain from the farmer in the Söderköping region to Terragona in Spain.

In Figure 39, the energy use (kWh/tonne) in different steps in the transport chain from the farmer in the Söderköping region to Terragona in Spain is illustrated.

The first step "Farmer to Söderköping" corresponds to the general case for ODAL "Farmer to silo". Generally, in ODAL this step has an energy use of 7,8 kWh/tonne (see also Figure 38). The higher value to Söderköping is probably due to more transports with tractors and a longer distance (18,9 compared to 11,4 km). In the second step, "Söderköping to Djurön", which corresponds to the general case for ODAL "Silo to silo" the situation is quite the opposite. The distance from Söderköping to Djurön is almost 10 times shorter than generally in silo to silo in ODAL (70,5 compared to 7,5 km). Generally, this step has an energy use of 11,8 kWh/tonne. In "Söderköping to Djurön the energy use is about 1,4 kWh/tonne.

Note in this special case, that there are only 3 steps to the foreign country. In the general case we have 4 steps "Farmer to silo", "Silo to silo", "To Export", "Export harbour to import harbour". However, sometimes the second storage silo is the "export silo", which is the case in our selected route. Generally, the farmer to silo and silo to silo together adds up to 19,5 kWh/tonne. In Söderköping, the corresponding value is about 16,2 kWh/tonne. It should be noted, accordingly, that the special case is somewhat extreme compared to the rest of the transports in ODAL. This is in the sense that the transport distances are quite different. However, the differences in the farmer-to-silo step and silo-to-silo step in some extent counterbalance each other so that the difference when adding these two steps diminishes. This also illustrates the importance of studying local prerequisites to find where the largest potential to save energy is, since the probable difference between regions is obvious.

In Figure 39, we can note that the total energy use for the route is about 140 kWh/tonne. The second step in the route "Söderköping to Djurön has the lowest energy use 1,6 kWh/tonne and "Djurön to Terragona" the highest energy use 124 kWh/tonne. However, the distance is crucial, if the distance were the same in the latter as in the first step (about 7,5 instead of 5334 km), "Djurön to Terragona" would have an energy use of about 0,17 kWh/tonne.

4.9. Pilot actions within the Swedish case companies

Ecotraffic has investigated possible pilot actions to find the effect of different energy saving strategies. *Potential* pilot actions were described in the report from phase 1 in this project (Andersen et.al., 1999). Together with partners and case companies, Ecotraffic has chosen the following pilot actions:

1. Study of how structural rationalisation; in form of more drying and storage at the farmers and more of transport with lorries and possibly closing of silos; can affect the energy use.
2. Study of how a use of IT-based systems can affect the energy use.
3. Study of how a changed driving style can affect the energy use.

Pilot action 1: Effect of a structural rationalisation

This pilot action includes a study of the effect when a silo is shut down and the effects of more drying and storing at the farms. It also includes the effect of a change in transport mean e.g. from tractors to lorries which is a probable effect of the closing of silos.

Potential effect of a change in transport mode/mean

<u>Transport volume and energy use</u>

To find the effect of a change in transport mean, the energy use in the special case is used as reference and to describe the current energy use (see also chapter 4.8). In the transportation of grain today from the farmers to Söderköping, the mix of transport means is 92% for the tractors and 8% for the lorries. If lorries were to be used in 100% of the cases, the energy use would be reduced. The method and principles in 4.7 for lorries and tractors are also used as a base in this chapter. An approximate average for the energy efficiency for this new mix (with 100% lorries to Söderköping) is <u>0,39 kWh/tonnekm</u>. This is assuming that the transport volume and load factors are the same as before. The energy use based on transport volume and the calculated energy efficiency factor is illustrated in the table below.

Table 66 Energy use in transportation to Söderköping with 100% lorries (kWh)

	Energy use/ Delivery	Energy use /farmer & year	Total energy use in Söderköping	Diff. (%)
Current energy use	137	510	64 300	
100 % lorries	69,1	257	32 400	-50%

The difference is about <u>50% lower</u> energy use compared to the mix of transport means today. It can also be interesting to see the potential in energy saving when including the transportation from the silo in Söderköping to other silos as well. The two cases transport mix that appears is illustrated in the table below.

Table 67 Mix of transport means in the different alternatives

	Case 0	Case 1
Farmer to Söderköping	Lorry: 8% Tractor: 92%	Lorry: 100%
Söderköping-Norrköping/Djurön	Lorry: 100%	Lorry: 100%

As can be seen in the table above, there is no real potential in the silo-to-silo step in Söderköping. Therefore, the energy saving potential in the total chain is somewhat reduced.The energy use and saving potential in different alternatives is illustrated in the table below.

Table 68 Energy use in transport in the different alternatives (kWh)

		Case 0	Case 1	Diff.
Farmer to Söderköping	Per delivery	137	69,1	-50%
	Total	64 300	32 400	-50%
Söderköping-Norrköping/ Djurön	Per delivery	60,1	60,1	0%
	Total	7 500	7 500	0%
Farmer to Norrköping/ Djurön	Per delivery	197	129	-35%
	Total	71 800	39 900	-44%

In the table above, the figures in the step "Söderköping-Norrköping/Djurön" are an average of the energy use in transport to Norrköping and Djurön. The total case one leads to 35% lower energy use per delivery and 44% lower total energy use compared to case 0. The potential, in this case, to save energy is in the farmer-to-silo step, -50%. However, it should also be noted that the use of tractors is somewhat greater in the special case (about 92% compared to about 88% generally in ODAL), so the energy saving potential in farmer-to-silo transport might be a slightly lower. On the other hand there might also be a potential in some routes from silo to silo to save energy, if tractors are used in a larger extent than in the special case.

In the lorry transports between silos it is assumed that the load factor and the average payload is the same as in the silo-to-silo transport. This means that the payload and load factors are larger/higher than in the farmer-to-silo transport. If larger lorries could be used when picking up the grain at the farmers, the potential for energy saving could be even greater.

A study made by Gebresenbet & Ljungberg (2000) also showed that tractors have a higher energy use per unit grain delivered and a longer waiting time at the delivery point. During the harvest season, queues at silos/reception plants are a particular problem for both tractors and lorries. Effects of queuing are higher labour costs, emissions and energy use for idle driving. There is also an additional cost involved, since the vehicles can’t transport any grain when they are stuck in queues. The time used per delivery is greater for lorries but in relation to quantity, the lorries are more efficient. The study showed that the total delivery time was twice as long for tractors compared with lorries. The farmers who deliver with tractors are often transporting the grain directly after the harvest without reloading. The study showed that it is more time-consuming to transport by tractors than to pick up the harvest at the farms and transport by lorries. Direct transport with lorries from farm to silo is generally the most energy efficient option. Despite the extra time for loading and reloading, it was twice as time-effective to go a shorter distance with tractors and then reload to a lorry than to go directly to the silo with a tractor (Gebresenbet & Ljungberg, 2000).

A possibility to reduce the use of tractors would be to collect the grain at the farm with lorries, which have a loose platform body. First, the platform body is delivered to the field and the farmer can e.g. then fill this up with grain directly from the combine harvester. A disadvantage with this concept is that the loading and unloading is relatively time-consuming and that it implies some driving without load. Another possibility is to dry and store more grain at the farm and collect it with lorries.

Is it possible and realistic to replace all the tractor transports on the roads with other transport modes/means? If not, what are the major constraints? Interviews with two organisations in the agriculture industry namely ODAL (Johansson, pers. comm., 2000) and The Federation of Swedish farmers, LRF, (Hogfors, pers. comm., 2000) has been carried out mainly regarding transfer of goods between transport modes/means. This is described in the following.

Possibilities to change transport mean from tractors to lorries

The limitations in transferring goods from tractors to lorry transport (to silo) according to ODAL are mostly dependent on if the farmer can dry and store on the farm and if the lorry can reach the harvest storage on the farms (sometimes the roads are to poor). It is also dependent on if there are any available lorries, which are not reserved since there can be a shortage in the most hectic harvest time. An advantage with lorries instead of tractors is that a lorry can replace about 6-7 tractors according to the informant at ODAL (Johansson, pers. comm., 2000). If lorries carry out 50% of the transports today, maybe 75-80% could be possible in 10 years. The additional 20-25% is considered to be difficult to reach. Examples of reasons for this are that the farmers must perhaps get special equipment or improve the road to the farm so that a lorry can collect the harvest. To achieve the mentioned potential ODAL, stimulates the farmers to let a lorry pick up their harvest by offering them a higher price for the harvest. During the last 4 years, the amount of tractor transports has, as a result of this, been more than halved. (Johansson, pers. comm., 2000) So there is a relevant sector for transferral of goods between transport means. Even though 100% lorries is not realistic in the short term maybe 80% can be possible within 10 years

Possibilities to change to other transport modes etc.

Questions about rail, sea and intermodal transport have been asked in the interviews of ODAL and LRF. LRF has in a recent interview (Hogfors, pers. comm., 2000) indicated that historically it has been difficult to transfer more goods from road to rail due to the e.g. the higher costs for rail transport. Generally, ODAL does not consider that there are any real limitations in how much they could transport on sea or railway other than that they need to have ports or railways close to the silos. The economic conditions must also be beneficial. Historically, ODAL has only used rail to a small extent. The incentives to use more rail transport have been small. SJ hasn't offered tracks but has rather removed tracks unless ODAL has paid to let the tracks remain. The new necessary rail infrastructure has not been built regarding goods transports. Only about 5 of the 80 silos of ODAL have railway tracks today. If ODAL hadn't financed the tracks close to these 5 silos they would not have any tracks left. Another problem is that there must also be tracks to the customers. ODAL has negotiated with SJ a couple of times and one of them (about 10 years ago) led to some transferral of goods to rail. However, this co-operation has ended. The decision about who should pay the cost for these tracks is always a difficult task. A problem for the railway is that side-tracks have more often been removed instead of being reinvested in. Some of the few railway-tracks that was close to the silos in ODAL have been taken away by the local railway companies (SJ etc.). If the tracks was to be remained ODAL would have to pay a price that was too high for ODAL. So the removing of tracks seems to be a cost matter for railway companies.

For ODAL and the agriculture industry it seems difficult to transfer much more goods from road to rail, especially if the transport is to be loaded on rail directly at the silos. A possibility is to load first on a lorry and then on railway. The average distances are, however, generally probably too small. About 70-110 km is an average distance from silo to silo or customer (according to previous energy analysis). LRF indicated that 150 km could be a reasonable distance to transfer to rail from road. It could be less if you have rational reloading stations.

Another difficulty is that SJ has not offered any grain wagons. Instead, these have been rented from other countries by ODAL. Anyway, the informant does think that it seems likely that the government wants to benefit the railway and not the road and refers to the tax situation. The informant concludes that it is odd that the railway has to be so expensive and thinks that, in the long run, is it possible that there will not be any goods transport on rail.

Regarding sea transport, there have been discussions about digging more canals for example between the two seas Siljan and Mälaren. However, nothing has been done so far. The ports (mostly owned by municipalities) have also been increasing their charges and fees. This makes sea transport on distances currently below about 100 km uninteresting. Regarding sea transport, the reloading is also considered expensive. Otherwise, ship is used as much as possible above 100 km.

The shipping companies pricing level is dependent on their costs. The costs for the ship-owners are fees for piloting (a relatively new fee for ships over 70 meters), ports, loading etc. Mats Mattson, shipmaster on Rederi AB Uman (who ships grain for ODAL), replies that a problem is that the road transport does not have to pay the same fees when going to a terminal. In a port, with railway tracks, sea transport is the mode responsible for the costs for the tracks. Another problem is that the port fee varies a lot between different ports. The owners of the ports, which mostly are municipalities, set the fees for the ports. ODAL points out that an advantage with ship is that it is efficient and carries huge volumes, which can decrease the work (and associated time and cost). Another advantage with transporting more on rail or sea is that it reduces the number of lorries at the public roads. This can for example increase the traffic safety and be more energy efficient. A disadvantage is NMA’s demand for extra pilots on certain types of transport. ODAL thinks that this is an unnecessary cost for ships which have been going in the same fairways for 20 years. The possibilities for a transferral of more goods to sea transport are accordingly limited. Crucial for the use of sea transport is the distance and the proximity of the fairways to the silos and customers. In addition, the cost is important.

LRF’s comment on intermodality is that it generally is very expensive to reload. A reload can cost the same as a transport of 50-100 km or even more. A lorry that has loaded full load with wood takes at least 0,5 hour to unload (if the driver does it himself with a crane). It is also common that the drivers have to wait at the reloading stations. If a certain type of big cranes is used the reloading can go much faster. On the other hand these cranes are very costly. No revolutionary new technical development is expected so it seems difficult to make this process much cheaper. In the ordinary business they invest in ship loading equipment, but no revolutionary development of those are expected or invested in as an action.

The informant at ODAL considers that the use of intermodal transports is reduced due to the cost increase. Another problem is that when you transfer from road to rail the cost rises so there are no actual economical incitements to use railway transports today. Even if the railway would be cheaper, the problem remains that the tracks are not in the same place as the customers are. The intermodal transports would, however, increase if the cost for railway transports were reduced. But if not more infrastructure is built (side-tracks) the increase in railway transports would be still be marginal. Intermodal transport is of course possible but the costs for reloading is high. LRF indicates that the costs have made the involved companies to in great extent get rid of storage places and reloading locations. The aim today is to go direct to the target using lorry transport. It should also be noted that each reload is wearing the grain so that 2-4% of the grain could be lost in a transport chain including reloading at 3-4 silos.

The intermodality regarding grain is efficient where there are special plants in the port that are efficient. For example when the grain goes form silos in pipelines to ships. These should be easier to handle than the intermodal systems in the forest industry, lifting with cranes and maybe some with truck. The costs are important for the possibility to create special pipelines etc.

The Swedish State Railways (SJ) and the Swedish National Rail Administration have high costs for the infrastructure. The cost for the maintenance seems to be the main problem. The expansion of fast passenger trains can also be explanation, since SJ might not want goods transport to compete with passenger transport. Cost issues and where the financing, necessary for the building of the infrastructure, should be taken from, is an obvious problem.

The chances for a change of choice in transport mode might increase if the rail could be proved to be better and cheaper than the alternatives and that the control of the goods can be maintained. To make the reloading more efficient it is maybe in this area where the biggest potential to improve intermodal transport lies. The old cranes at reloading sites are very expensive and this makes the reloading expensive. When reloading everything has to be rational, no one should have to wait and no extra trucks should have to go there for the reloading (they should be there all the time).

In the future, lighter load carriers for lorries, e.g. in fibreglass, could reduce the weight with about 3 tons. The intermodality between lorries and ship does sometimes not include other load carriers than the lorry itself (RoRo-ships), this is of course a fast and inexpensive way to reload. A mean to increase the transfer of goods from tractors to lorries is to enhance the compensation from companies like ODAL when the farmers are using lorries. A conclusion drawn from the interviews is that lorries will probably expand more in the future than other transport modes at least in the short run.

Please also note that common criteria for transferral of goods between transport modes for Sweden, Finland and Norway etc. will be studied in the next phase of the project (Phase 3). Therefore, more information about the possibilities for changing between transport modes will be further developed in Phase 3.

Potential effect of more drying at the farms

An increase in the drying of grain at the farms instead of at the silos, is more or less a prerequisite for the closing of silos. Closing silos can also be advantageous if more farmers chose to dry the grain at the farms. A study of the effect of more drying at the farms is therefore of interest. If the grain is dried at the farm, the water content in the grain is reduced and the transport volume (tonnes) is reduced correspondingly. This should also lead to a potential for energy saving. To find out the size of this energy saving potential is the main objective in this chapter.

Background

Today, ODAL have different reception plants for different qualities of grain. The system today is mainly that the farmer sells whenever and to whom he wishes. ODAL seldom has the knowledge of the quality of the grain until it is delivered. A problem with not knowing the quality of the grain is that some silos, intended for certain qualities, will be full while others are more or less empty. This means that many lorries may have to travel a long distance before they can deliver the grain to a silo which is not full (generally, the farmer can always deliver to the nearest silo. Further transports are carried out by ODAL).

The quality of the grain determines the use of the grain (low quality is used as fodder, high quality is used as e.g. flour etc.). Accordingly, after the different qualities have been stored they are sold for some of these different purposes. The system today makes it somewhat difficult to plan the activities (including transports). To solve this problem, ODAL tries to make more contracts with the farmers in advance so that they know approximately how much grain of a certain quality they will receive.

About 40% of the grain are presently purchased through contracts. ODAL also wants to encourage the farmers to dry and store the grain until it is delivered. If the farmer stores and dries at home, and conduct tests of the quality at the farms, ODAL can more easily keep record of the different qualities and directly transport them to a suitable receiver. It also means that ODAL gets a lower storage cost. The farmer who gets a higher storage and drying cost is compensated for this. The compensation is paid as an increment on the price for the grain. The increment is 1/11 –2000 around two SEK/dt. This is under the condition that the grain is dried to a water content of 14 %. The farmer can also plan his activities better and knows where to put the grain and could speculate in prices for the grain more effectively as well.

If you are going to load a larger fraction of the harvest on lorries, instead of tractors (the effect of closing silos), without drying some difficulties, appear. For example, you have to transport it fast so that you can dry the harvest fast (at least within three days otherwise there might arise some toxins in the grain). Therefore, you also have to have a large capacity of lorries available, since many farmers harvest at the same time, due to the short harvest season in Sweden. This is of course costly if the lorries can’t be effectively used for other purposes in the off season. The peak in grain deliveries in the autumn also makes it difficult to find products for return trips (Ljungberg, pers. comm., 1999, regarding silo in Norrköping). The peak in grain deliveries in ODAL is illustrated in the figure below.

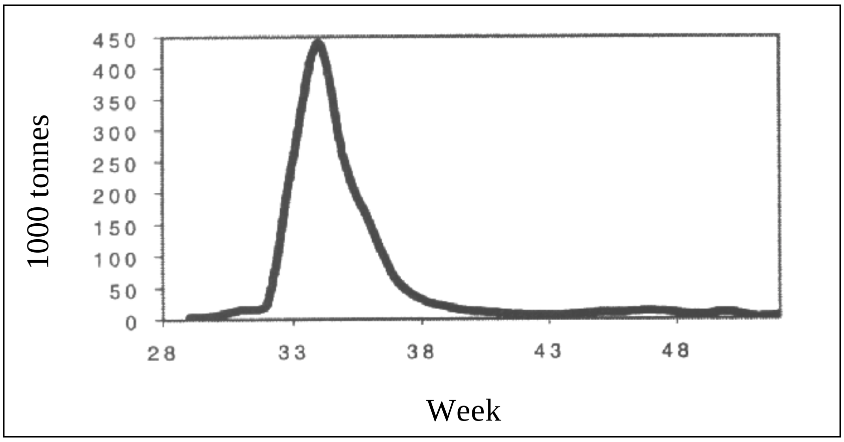


Figure 40 Deliveries of grain per week to ODAL, tonnes (Annual report ODAL, 1997)

A normal year about 60% of the grain is delivered during the harvest season, although the climate can change this figure quite significantly between years (in 1997 was about 80% delivered during the harvest season). If the grain is dried and stored on the farm, transports with return trips can be easier to organise. If the grain is dried at the farmers, the emissions from the transport can be reduced. On the other hand, the emissions from the farmers drier might be higher than from ODAL's drier. Generally if the traditional type of hot air dryer, with oil as fuel, is used, the difference is marginal. The energy use for drying grain with these types of drier is approximately 1,85 litres of oil per %-unit and ton of dried grain, regardless of size of the drier (Regnér, pers. comm., 1999). The figures include an efficiency loss of 15-20%. If the grain is dried from a water content of 21% to 13,5%, the fuel consumption in this type of drier is about <u>13,9 litres of oil per ton dried product.</u> This corresponds to an energy use of about 139 kWh/tonne, which can be compared with the energy use for a transport from Söderköping to Terragona in Spain using about 140 kWh/tonne (se Figure 39 above).

However, the large dryers sometimes have a possibility to use other energy sources instead of oil since they are often localised closer to larger cities. For example, they might be able to use waste heat, steam, district heat or natural gas. The cost for investing in a pipeline for, e.g. natural gas, to the farmers is too large, due to the distance[18].

In ODAL's case, mostly hot air dryers with oil as fuel are used. The possibility to use other fuels than oil is dependent of location and no general assumption can be made in this case. Therefore, the difference between different sizes of dryers will not considerably effect the energy use and emissions in this general analysis.

<u>The pilot action</u>

The pilot action is to approximately assess how much energy ODAL could save by buying more through contracts and how logistics and planning could improve through these means. The pilot action will be based partly on the special case in Söderköping, where the difference using tractors or lorries, with an assumed energy use, e.g. is described. In this pilot action, it is illustrated what happens with the energy use with a change in the amount of dried grain at the farmers (leading to less transport volume).

The pilot action includes a study with three alternatives.

- The basic alternative (0-alt.) is to mainly use tractors (see mix in the table below) with undried grain to Söderköping and lorries to Norrköping/Djurön.
- The 1- alternative is to deliver undried grain with lorries to Söderköping and to Norrköping/Djurön.
- The 2-alternative is to deliver <u>dried</u> grain to Söderköping and undried to Norrköping/Djurön with lorries (this case is hypothetical since it is more logical to also transport dried grain between Söderköping and Djurön/Norrköping).
- The 3- alternative is to deliver dried grain to Söderköping and to dried grain to Norrköping/Djurön (dried at the farm) with lorries.

Previously in this chapter, we analysed different cases from transport of grain in a route. A similar study is made with different cases. In the chapters 7.5, 7.6 and 7.7, the focus is on describing the flows and energy use in ODAL given a certain transport volume. The transport

[18] It should be recognised that the Swedish natural gas pipeline grid is undeveloped (due to the lack of domestic natural gas sources) and covers only a small portion of the populated areas in Sweden.

volume (in tonnes) can however be changed in different parts of the transport chain depending on where the grain is dried. The different cases are illustrated in the table below.

Table 69 Transport mean mix and drying point of the grain in different alternatives

	Case 0	Case 1	Case 2	Case 3
Farmer to Söderköping	Lorry: 8% Tractor: 92% (undried grain)	Lorry: 100% (undried grain)	Lorry: 100% (dried grain)	Lorry: 100% (dried grain)
Söderköping-Norrköping/Djurön	Lorry: 100% (undried grain)	Lorry: 100% (undried grain)	Lorry: 100% (undried grain)	Lorry: 100% (dried grain)

The method and the energy efficiency factors in the Chapter 7.7 for lorries and tractors are also used as a base in this chapter. To simplify the study, we are assuming that the cases 0 and 1 and energy use previously calculated are identical with the cases 0 and 1 in the table above. It is assumed that he grain to be dried from a water-content of 21% to 13,5%. A factor is used to calculate the transport volume of dried grain based on the undried grain. The factor is 0,9133 (0,79(1+0,135/0,865)). The energy use based on these prerequisites in the different alternatives is illustrated in the table below.

Table 70 Energy use in transport in the different alternatives (kWh)

		Case 0	Case 1	Diff.	Case 2	Diff.	Case 3	Diff.
Farmer to Söderköping	Per delivery	137	69,1	-50%	63,1	-54%	63,1	-54%
	Total	64 300	32 400	-50%	29 600	-54%	29 600	-54%
Söderköping -Norrköping/ Djurön	Per delivery	60,1	60,1	0%	60,1	0%	54,9	-9%
	Total	7 500	7 500	0%	7 500	0%	6 850	-9%
Farmer to Norrköping/ Djurön	Per delivery	197	129	-35%	123	-38%	118	-40%
	Total	71 800	39 900	-44%	37 100	-48%	36 400	-49%

In the table above, the figures in the step "Söderköping-Norrköping/Djurön" are an average of the energy use in transport to Norrköping and Djurön. It could be noted that Case 2 and 3 would reduce the energy use in “Farmer to Söderköping” with 54% compared to case 0. The energy use in “Söderköping to Norrköping/Djurön” can, as an effect of more drying, be reduced by about 9% in case 3. The total reduction of the route (Farmer to Norrköping/Djurön) is 38%/delivery and 48% as a total in case 2 compared to case 0. The reduction of the route in case 3 comparing with case 0 is 40% per delivery and about 49% as a total.

Accordingly, the table above shows the increase in energy saving potential as an effect of more drying of the grain before transportation. Note however that case 0 shows a situation where no grain is dried before transportation (with the exception of the return trip goods). This can not generally be considered as the situation in ODAL. The potential is therefore changing between silos and the potential illustrated here should be seen more as an example rather than the actual potential in ODAL or the Söderköping route.

Case 3 farmer to Söderköping compared with case 1 shows *the probable effect of the drying* on the energy use in the whole route. The energy saving potential of drying per delivery and total is about 9% farmer to Söderköping. The effect of more drying at the farm also increases the possibility to go directly to the final reception plant or the customer. This can also reduce the time used for reloading.

<u>Possibilities for drying more at the farms</u>

As mentioned earlier, ODAL stimulates the farmers economically to dry more at the farms. The constraints are often that the farmers in some cases have to purchase special equipment and/or improve the road to the farm so that a lorry can collect the harvest. There is also a demand from ODAL that the height beneath the loading equipment must be at least 3,60 m (Johansson, pers., comm., 2000). However, if the economical incitements are strong enough this should not be a problem.

A potential problem is also that the quality of the grain is somewhat uncertain, as described earlier. However ODAL is working to solve this problem and is nowadays selling special equipment for measurement of grain quality. The farmer who dries the grain can send a sample with mail to ODAL. The analysis of the sample is, to a great extent, automatic. The analysis of the grain samples takes about one day (can take longer if many arrive at the same time) and can be used by ODAL's sales chapter to e.g. estimate the quality of the grain and transport need in different areas. This system has been in use in ODAL for about half a year (June 2000) and is an important prerequisite of more use of IT for e.g. route planning and transfer to more energy efficient transport modes. The introduction of MOVEX, which is a business system (computer software), will also help to follow-up the transport flows in ODAL. To be assured of the quality, ODAL visits the farmers traditionally and conduct quality tests of the grain to be delivered. ODAL also perform tests when the grain is delivered and makes controls of the farmers dryers. ODAL also informs the farmers about methods for how the farmer should measure the quality of the grain.

An assessment of how improved logistics can facilitate transferral of goods to rail and sea; and an investigation into possibilities of increased use of combined transport modes is carried out in the phase 3 of the project.

Pilot action 2: Effect of use of IT based systems

The second action is a study of how changes in information flow and route planning could affect the energy use". This includes an investigation of to what degree improved logistics can optimise the use of most energy-efficient route choices and how the load factor can be raised by improved return trips. The study has mainly been carried out in contact and co-operation with the Swedish University of Agricultural Sciences (SLU). Gebresenbet & Ljungberg (2000) have in a pilot study equipped a number of lorries with Global Positioning Systems (GPS). GPS is a satellite based navigation system primarily developed for military use but is now accessible for civilians. The system provides latitude and longitude positions and altitude over sea level. Using signals from at least three satellites and a GPS portable receiver, the position and speed of moving vehicles can be determined. Route-planning program has been used to analyse the data in the pilot action.

Background

The use of IT based systems is a new area which could be used in a larger extent by transport planners to save energy. GPS and GIS (Geographical Information System) in combination with mobile telecommunication can e.g. make it possible for transport planners to keep record of the position of different vehicles. With traffic information systems, disturbances in the traffic can be reported, new assignment can be divided to the closest vehicle and routes can be changed due to new circumstances. In general, transport companies are not using IT-systems like this (e.g. route programs and GPS-systems). Therefore, a question is if such equipment can reduce the energy use.

In our previous calculations, the return trips with the used vehicles have been assumed to vary depending on vehicles. With our calculated transport mode mix, the transport volume of the return trips amounted about 1/5 of the weight of grain deliveries generally in ODAL. The return trips to the farms generally include seeds for sowing, fertiliser and fodder. However as described above these transports are often carried out with other vehicles than the ones delivering grain.

The total use of production and flows of grain to “grain and supply co-operatives” and private traders (about 4 million tonnes) was illustrated in Figure 31. The figure showed that there is a possibility for use of return trips. However, the return trips are clearly lower so there is no potential to reach full load on the return trips for all the deliveries to the farms. It is, to a large extent, the same actors who sell fertiliser, fodder and seeds for sowing and the ones who buy the grain. A problem is that the terminals for fertiliser and factories for fodder and seeds for sowing and reception plants for grain are spread in a large area. For example, seeds for sowing is mainly transported from a central storage in Västerås and fertiliser is mainly transported from Köping. About 90% of the deliveries are delivered by lorries and about 10% are delivered by tractors from ODAL’s shops by the customers. It is also a problem that many farms today are so specialised so that not many farms buy fodder and sells grain in any significant extent.

The increasing of load factor can be achieved by using the same type or different types of goods in both delivery and return trips and it must not necessary be the type of goods described in Figure 31. Besides the possibility of increasing the return trips, the organisation form and possible co-operation with other producers are also important factors, which could influence the energy use.

Today, ODAL are using hauliers for their transports. The hauliers are organised in three haulier associations. These are “Sveaåkarna, Vestab, and ÖMT and they have the responsibility for the transports and transport planning. ODAL receive the orders and forwards these to the hauliers. A certain haulier association has the main responsibility for transports in particular geographical area, although this association sometimes is operating in others areas. The transport planners have the responsibility to allocate the orders between the different hauliers, which then allocate them between their vehicles/drivers. There is a certain competition between the hauliers and this could be a problem in the co-ordination of goods and return transports. Some information can be difficult to get for the transport planners. The transport planners do e.g. seldom know of transport orders and routes arranged by others than themselves.

The access to information is important for the possibility to co-ordinate the flow of goods and the distribution system. Based on the design of information flow, distribution systems can be organised in different ways. A direct distribution system is illustrated in the figure below.

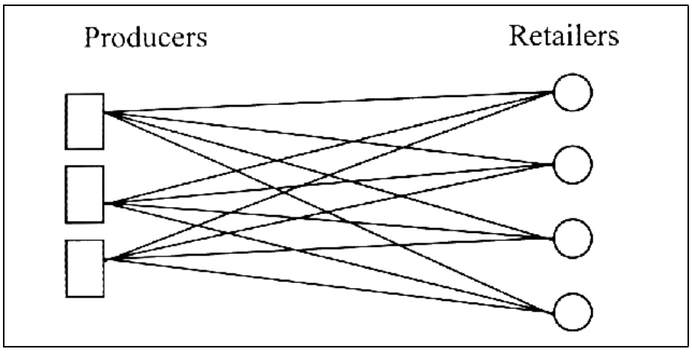


Figure 41 A direct distribution system with multiple transactions between different actors (Source: Gebresenbet, 2000)

If a third party is involved which co-ordinates the transports with IT-equipment. The transports could be organised according to the figure below.

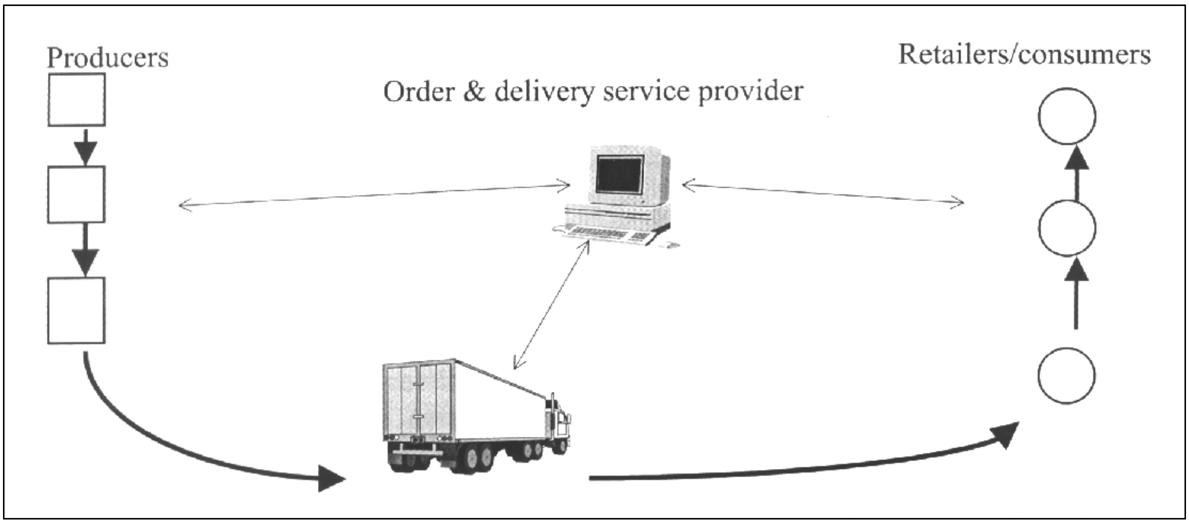


Figure 42 A distribution system in which a third party is used to co-ordinate the transports (Source: Gebresenbet, 2000)

The thick and thin arrows in Figure 42 illustrate the material and information flows between the actors respectively. The practical organisation can be an obstacle or an advantage for co-ordination of goods. Even if there are no competition between different haulier organisations, there can be other reasons for choosing own vehicles rather than other hauliers vehicles. In this aspect, it could be an advantage to use a large independent company such as ASG and similar companies as a third party to handle the distribution and logistics.

However, even if there are available flows of goods in both directions and/or flows of goods that could be loaded together at all times, there can still be obstacles for co-operating these transports. Examples of such obstacles are:

- The shape of the goods; bulk goods is difficult to load together with other types of goods
- Technical limits; for example the demand for temperature etc
- Competition
- Regulations for handling certain types of goods; e.g. provisions and animals
- Resistance against change and factors of uncertainty

The flows of grain in opposite directions are mainly found in the step “silo to silo” and return trips are found here to some extent and in the surrounding area. In some periods other type of transports can be prioritised for example during the harvest period. The main goal is often during this period to transport grain from the farms to the silos. Some loading via different types of goods is occurring when lorries are used for deliveries of goods in sacks and on pallets to the farms. These lorries can also be used to collect grain from the farms. However the problem is that the flows in opposite directions not is available at the same time of the year. The majority of the grain is delivered in the early autumn during a few weeks (see figure 7), while fertiliser is delivered mainly during the autumn and the winter. The fodder is as previously mentioned delivered all year (Gebresenbet, 1999).

The collecting of grain can be combined with deliveries of fodder in bulk. In addition, some other types of goods like building materials are in some extent used for return trips. As mention earlier, a large part of the grain is delivered with tractors, which makes it more difficult to load or combine with other types of goods. The most common scenario today is, according to The Federation of Swedish farmers, LRF, (Hogfors, pers. comm., 2000) that the transporting company uses different lorries when collecting the grain and when delivering fertiliser and fodder to the farmers. Fodder is often delivered with a lorry using a number of boxes, which are unloaded pneumatically. Grain transport is mainly delivered with lorries that are “high limbed” (so they can tip over the platform body).

In a fusion in the agriculture industry between different farmer organisations some years ago, the main aim was to be able make the transports more effective. In the beginning after the fusion the common transport company delivered fertiliser and fodder and picked up the grain harvest from the farmers. In the county of Jämtland, there were also unattended stations out in the countryside where the farmers were able to pick up for example fertilisers themselves. Nevertheless, they co-ordinations of the transports to the same place were soon shut down. The main reason was probably according to Hogfors (pers. comm., 2000) that they transporting company found that the rhythm between in and out transport was too diverse and that the gain in co-ordination was too small. Hogfors points out that the same lorry could be used for both receiving (grain) and delivering (fertiliser/fodder) transportation if the grain (bulk cargo) is loaded in sacks and the fertiliser/fodder is loaded in sacks on pallets (general cargo).

A conclusion is that it is important to make more farmers dry and store at the farms so that the peak in deliveries of grain can be reduced. It is also an advantage if more lorries can be used if the size of the return trips is to be increased and the energy use (kWh/tonnekm) is to be reduced. Accordingly, an increase of the load factor is also achieved in the organisation and route system of the transports. The potential in using IT based systems will be examined in the following pilot action.

<u>Pilot action</u>

A pilot action was carried out in the regions around Norrköping and Uppsala in 2000 by Gebresenbet & Ljungberg, SLU. Both these regions are within the ODAL area. Measurements were made of grain transports and distribution of goods. Gebresenbet & Ljungberg did also some other studies of other types of goods like distribution of meat and milk. Our interest and report will, however, only concern the relevant results for the grain deliveries and return trips. Places for deliveries and collecting were registered with GPS-equipment. Quantity and type of goods were also noted. The project also included a mapping of flows of goods. In Uppsala was also noted the use of time for loading and unloading and waiting in queues was also recorded. The study included 19 lorries, 4 tractors and 34 routes. Six of the routes where carried out with continuous route registration.

The evaluation of the results was made by software for route optimisation. DPS WinLogiX was used for total optimisation of systems with several routes were also the numbers of vehicles are optimised and DPS RouteLogiX Pro was used for optimisation of separate specific routes.

<u>Possibilities to save energy by using IT based systems</u>

The pilot actions showed that there is a large potential to save energy in some cases. Some examples that have showed a large potential for energy saving are:

- Route optimisation have a large potential and can shorten routes and transport distances by up to 29%. Long routes with many stops for load and reload has the largest potential.
- Co-ordination of distribution of goods (e.g. fodder) and grain collection at the farms.
- A possibility to reduce the number of vehicles by optimising many routes together.
- Use of appropriate and in some cases flexible vehicles that can carry many types of different goods.

Route optimisation has, as mentioned above, different effects depending on the distance and number of stops. On more simple routes the driver can generally decide which route is the shortest and fastest. The routes regarding grain deliveries are generally often only between one location for collecting and one for delivery. Many routes were studied in the pilot action. In one example, a possibility to reduce the distance with generally about 6-7% was identified. However, the total distance of some routes could be reduced by about 23% or by up to 28% of the driving time. However, although most routes in the pilot action could not be reduced at all it is observed that also simple routes can sometimes be optimised and reduced. The important factors for the size of the reduction is the total distance and number of stops. It is also clear that the potential for reduction is larger if more vehicles and transports are involved in the optimisation for example during the harvest season.

In another study by Gebresenbet (2000) in the same area, both distance and time could be reduced by about 34% in some routes if optimisation was made before the distribution. This report also showed that about 20% of the drivers planned their route perfectly without extra IT based systems. The results also indicated that it seemed easier to plan the route well in suburbs or regions/rural areas than in towns. The total optimisation of the transports involved in the study reduced the routes, the total distances and the number of vehicles with 58%, 39% and 42% respectively.

However, the high reduction results described above generally concern transports of provisions in general e.g. transports of bread and meat. The possibilities for return trips for grain transports will probably not always reach this potential for example depending on what vehicle that is used. The lowest possibilities are probably between farmer and silo. It would be desirable to be able to load grain at every delivery of return trips so that the load factor could be maintained high. An obstacle today is that sanitary problems must be solved e.g. via some kind of sacks, plastic containers or some other new technique.

Other areas where IT based systems could be of use are in the identifying goods e.g. with bar codes. Two-dimensional bar codes can be used to reduce the time for loading and reloading and to improve the possibilities for co-ordination and transport planning etc. However, it is important to standardise protocols and to increase the security to be able to use these techniques. The Swedish transport industry is using electronic business communication to high extent and it is working more and more with standardisation of electronic documents for invoices and other similar information exchange. About 70% of the larger transport companies have declared that they already have or will have bar codes on their goods within a year. More research needs to be done in this area to clarify the benefits in reduced energy use due to more use of bar codes (Gebresenbet, & Ljungberg, 2000).

Pilot action 3: Effect of a changed driving style

The designation “ecodriving”, i.e. an economical driving style, has the objective of changing the driving behaviour in order to decrease the fuel consumption and exhaust emission. Ecodriving could be beneficial for the transportation company or owner-operator, since the fuel cost is a major portion of the expenses that could be influenced.

Background and introduction to ecodriving

The concept of economical driving style was originally conceived in the USA but much of the present work in Europe emanates from several countries such as Belgium, Finland, the Netherlands, Switzerland and United Kingdom. The concept of “ecodriving” was introduced in Sweden using the basic ideas and education package that had already been developed in Finland. Several Swedish Governmental Authorities and organisations teamed up with their counterparts in Finland and the concept was thereafter introduced in Sweden as well.

Ecotraffic (Ahlvik, 1999) has carried out an inception study for the Swedish National Road Administration (SNRA) on the potential decrease in energy use by changing the drivers behaviour (i.e. driving style). The study has also listed some of the activities in this area in Europe. Some of the material cited here is from the literature survey in that study.

Theoretical potential and limitations

First, it is of interest to highlight some issues of the energy flow in the driveline of a heavy goods vehicle. Palmer has made a comprehensive investigation about the energy balance of the driveline of such a vehicle. The overview is shown in the figure below.

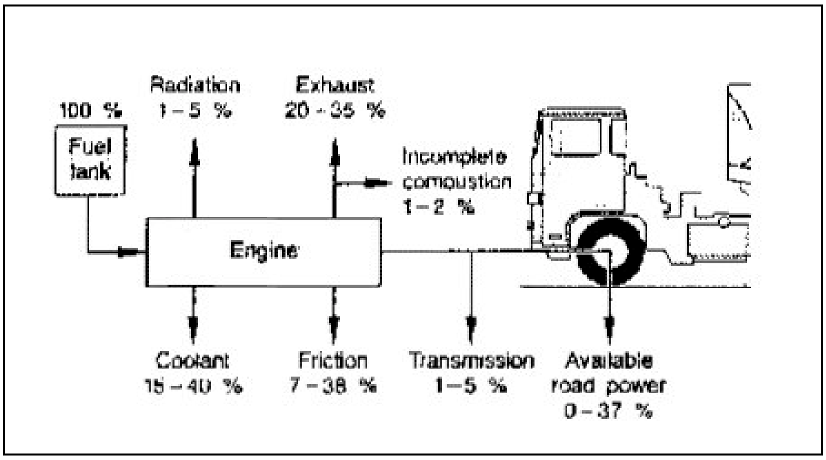


Figure 43 Energy use in a truck (source: Palmer, 1993)

As can be seen in the figure, the maximum available road power corresponds to an efficiency of 37%. The minimum efficiency corresponds to situations as, for example, curb idle. Engine friction, cooling losses and exhaust are the major losses. Transmission losses are of less importance. Therefore, for a certain power, the most favourable strategy to reduce the fuel consumption is to run the engine in the optimum load and (engine) speed range. Other methods to reduce the fuel consumption include alteration in the driving pattern. This could be achieved by changing the acceleration scheme and reducing the losses of inertia in braking. The potential of alteration of the driving pattern is somewhat reduced in congested traffic compared to less dense traffic. In the former case, there is not much option for the driver but to follow the traffic flow. Likewise, the potential for reducing the fuel consumption is also less in highway driving.

In order to gain some understanding about the theoretical potential of improvement in fuel consumption by changing the driving style, the specific fuel consumption in the engine load and speed range is shown in the figure below. This figure is an adapted and modified version of figure from a reference by Moser et al., 1994. Originally, the figure showed the specific fuel consumption (in g/kWh, ranging from 193 to 300) and the smoke (in Bosch units, ranging from 0,5 to 3,0). Some modifications to the diagram have been made by the authors of this report. The first modification is the addition of isolines showing constant power. The second modification is the addition of a line representing the optimum fuel consumption for a certain power.

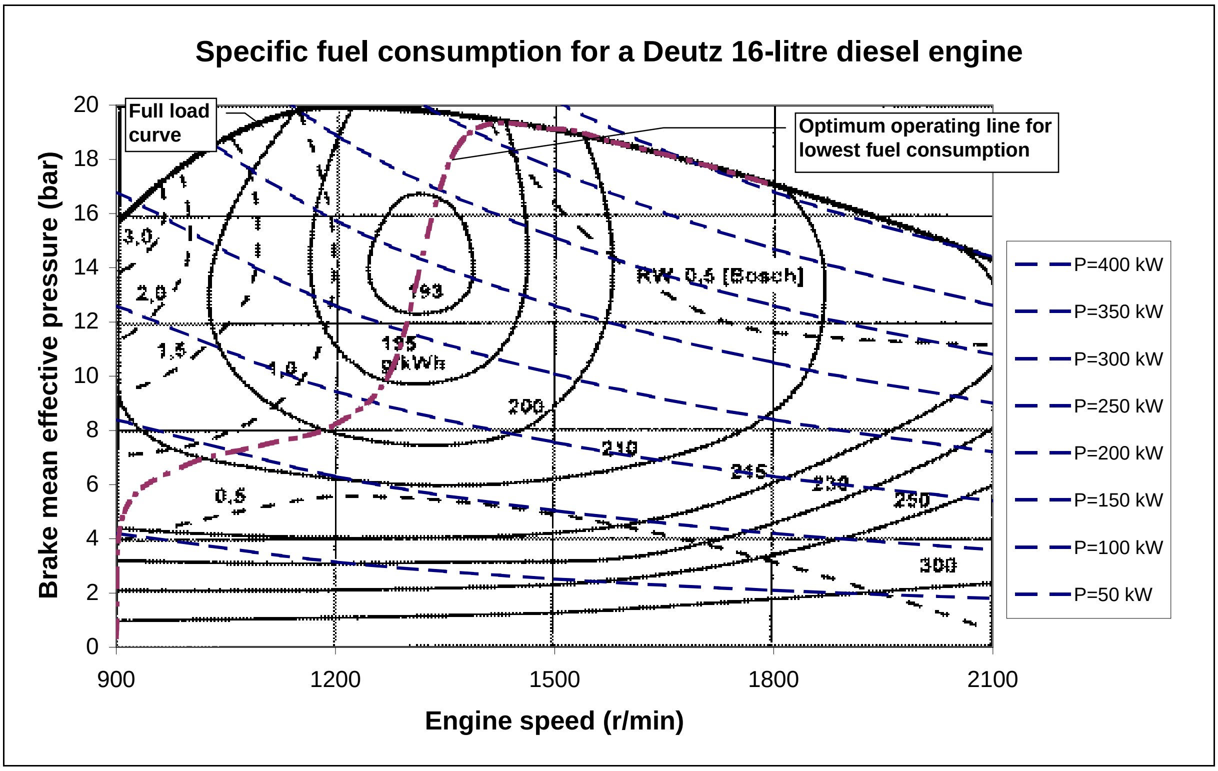


Figure 44 Specific fuel consumption and optimum operation (for a certain power) in the engine load and speed area

In general, the figure shows that the lowest possible fuel consumption could be achieved by running on low engine speed when the required engine power is below 350 kW. It should be noted that the road load power needed on a flat road is far less than this level. The reason why a reduced engine speed and increased load (for constant power) is not beneficial in the power range between 150 and 350 kW is twofold. First, the engine is probably optimised for about 1 200 r/min (camshaft design, injection advance, turbocharger, etc.). Second, since the engine is turbocharged (the standard feature of all modern heavy-duty engines), the air-fuel ratio is rather low (lower than optimum) at high load below 1 200 r/min and this increases the fuel consumption. This can also be seen on the smoke emissions that increase considerably in this area of the load and speed map (up to 3 Bosch units). The impact on the fuel consumption is considerably less, and in general, the optimum engine speed falls into the range of 1 000 to 1 600 r/min. Within the mentioned area is generally beneficial to reduce the engine speed as much as possible and to increase the load as much as possible for any given power. The exception is the area of high load below 1 200 r/min mentioned above, where the speed should not be reduced to 1 000 r/min.

The conditions shown in the description of the driveline above clarifies that a gearshift strategy can be found that minimises the fuel consumption. A strategy that maximises the engine load and keeps the engine speed within the range of 1 000 to 1 600 r/min (preferably 1 200 to 1 400) is beneficial. Another important factor, as mentioned above, is the alteration of the driving pattern in order to accelerate as efficiently as possible and to reduce the braking losses as much as possible. Some examples of results will be given below that highlight the potential of these means.

Methodology in the study

In the project planning of this project, it was decided to carry out some practical pilot actions in co-operation with the case companies. After some discussions, an investigation of the potential for ecodriving was chosen as one of the pilot action. Ecodriving for drivers of light-duty vehicles was first introduced in Sweden based on a concept from Finland. The organisation for the driving schools in Sweden (STR) has been the principal organisation involved in the education of teachers and organizing the courses for the drivers. A subsidiary company of STR, EcoDriving International, was founded to handle this business.

Some activities on ecodriving have also been carried out in Finland to educate drivers of heavy-duty vehicles. However, it was felt in Sweden that a more comprehensive education material was needed for the drivers of heavy-duty vehicles. Considerable work was invested in this task by EcoDriving international and TYA, an organisation dealing with working environment (and education in this area) within the framework of the transport workers unions. Therefore, the possibility of initiating an education of these drivers was considerably delayed from the timeframe (about one year) originally anticipated. In the winter of 2000, the programme for the education was more or less ready and the education of the teachers started. Discussions were then initiated in the spring of 2000 between Ecotraffic, EcoDriving International and the case company SJ/Svelast in order to investigate the possibilities for running a pilot test for some selected drivers of Svelast. However, due to several reasons, the decision of the participation of SJ/Svelast in such a programme was delayed until the fall of 2000. Therefore, it was not possible any more to carry out this programme within the timeframe of our project. It was also thought that the fall and winter with varying weather conditions was not an ideal time of the year to carry out such a programme.

Since the opportunity to carry out a practical demonstration within one of the case companies was not possible, an alternative approach was taken. It was decided to collect and assess some of the preliminary and principal investigations carried out by EcoDriving International during the spring and summer of 2000. These data were kindly made available to the project team by EcoDriving International. Some of the results already collected in the previously mentioned study by Ecotraffic are also reported here.

Results

DaimlerChrysler and its subsidiary Mercedes Benz (light and heavy-duty vehicles) has carried out an extensive investigation about the potential of changing the driving style. Some of these results were reported by Renner (1998) at a conference organised by SNRA in the fall of 1998. Tests were carried out by using Mercedes Actros, a heavy lorry, which is quite representative of long-distance lorries used. Although the driving pattern may differ from the driving pattern in the Nordic case companies, the results should be possible to generalise to these conditions as well.

To motivate the driver to save fuel, a man-machine interface (MMI) is needed to provide the relevant information. Three major categories of driving situations have been identified where the fuel saving potential is significant. These are cruising (at constant speed), downgrade driving and acceleration. Mercedes has noted that the information to the driver at cruising speed is an indication that the driver should make the most efficient gear selection. This could be made by using a gear indicator. In downgrade driving, it is important to select the right gear and to use the service brake in order to avoid wasting any fuel (using the fuel cut-off for a motored engine). The driver should waste as little inertia as possible in entering the levelled chapter again. Making the driver aware of the vehicle inertia, the topological characteristics and traffic flow pattern is important in order to utilise this insight for fuel saving. During acceleration, it is important to reach the constant velocity with high acceleration. This is definitely against common sense about economical driving, where the recommendation has been to drive "as if you had an egg between your foot and the accelerator pedal". Heavy-duty vehicles often have many gears and, therefore, it is usually beneficial to pass some of the lower gears. The importance of the strategy in acceleration has been shown by Renner in the previously mentioned publication. The following four different strategies have been investigated.

- Strategy 1: shifting too late, too high engine speed
- Strategy 2: optimal shifting
- Strategy 3: too frequent shifting in low gears
- Strategy 4: engine speed is too high

The recording of engine speed, throttle position and gear selection for the four strategies in the acceleration from 0 to 59 km/h are shown in Figure 45. Although the figure is complex and probably not easily understood[19], the main conclusions are interesting. It is striking to note that strategy 2 has both the lowest fuel consumption and the highest average velocity. This indicates that the driver has been able to use the maximum torque of the engine in the range of the engine speed where the specific fuel consumption is at its lowest level.

[19] Arrows indicating the legend for the curves have been added in case 1 by the authors of this report.

Acceleration strategies for trucks (0 -

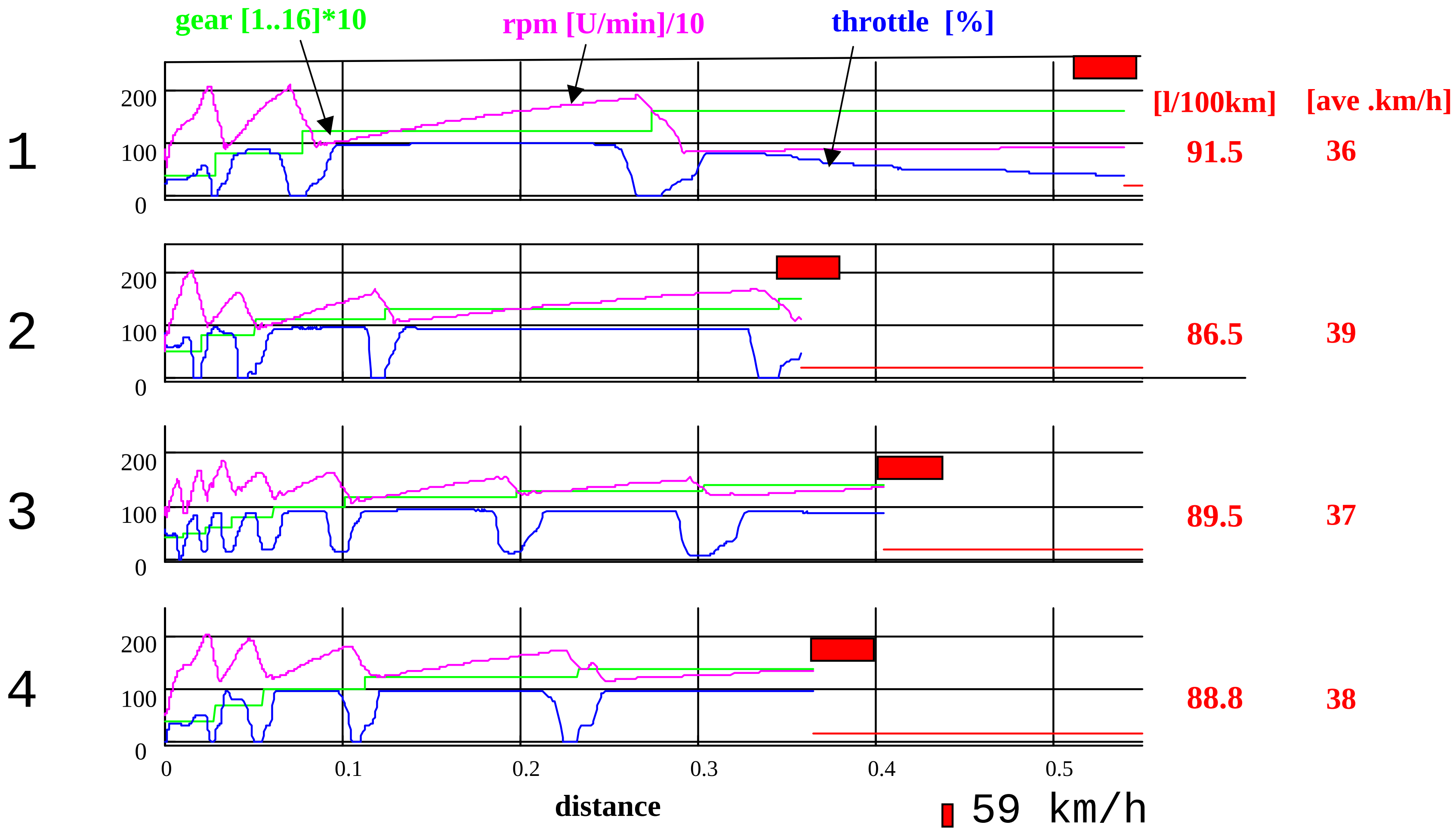


Figure 45 Impact of different acceleration strategies

In the next figure, an illustration is shown of the results from a series of tests carried out by Mercedes. A number of drivers from Mercedes and some miscellaneous other drivers participated. In the tests, the average saving of fuel was 22% although the average vehicle speed was almost identical.

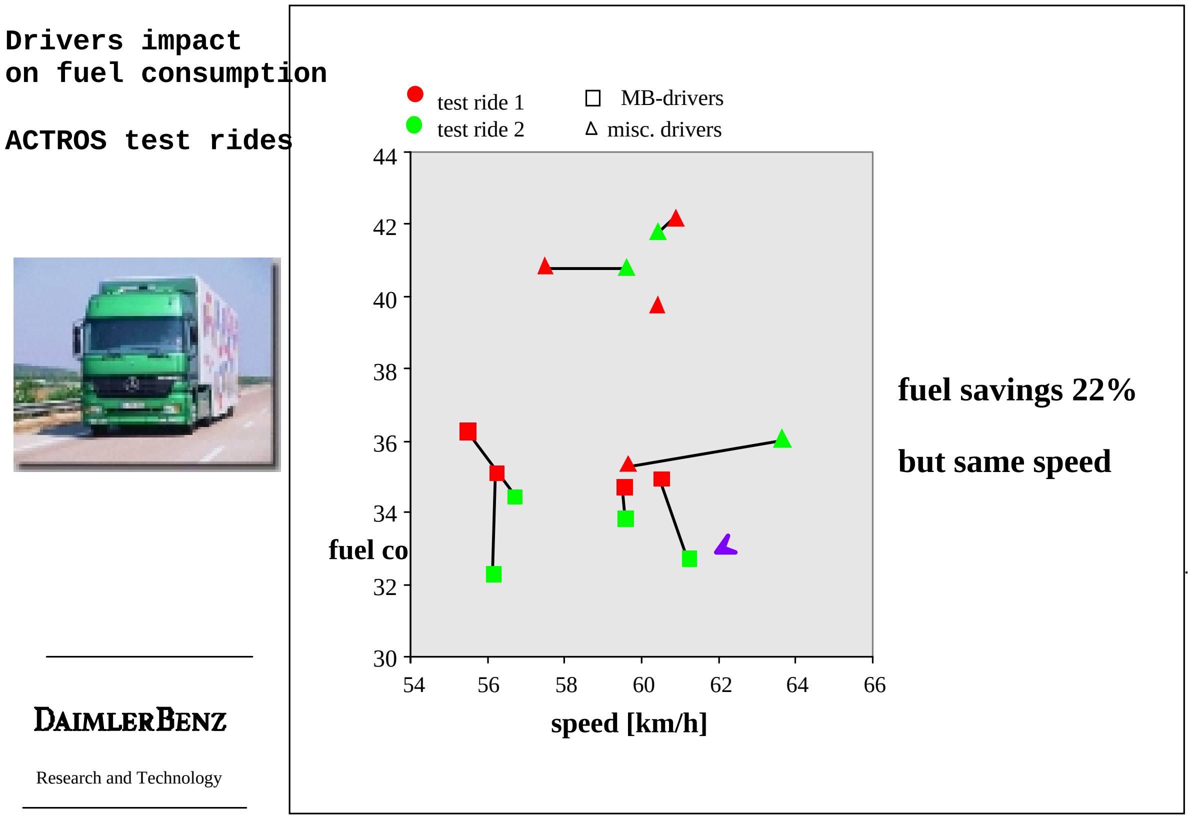


Figure 46 Data on fuel consumption savings in tests by DaimlerChrysler (formerly DaimlerBenz)

Future potential

Today, training of the drivers is a mean that has been found effective in order to change the driver's behaviour. The experience from Sweden is that theoretical education only is not sufficient to achieve the full potential of ecodriving (Alexandersson, pers. comm., 2000). Drivers are often sceptical and it is necessary to add a complementary practical course in a vehicle. During this part of the education, it is also necessary to utilise some kind of IT support, MMI and/or an on-line measurement of the fuel consumption. An example of such a device is shown

Figure 47 On-board device for fuel consumption measurement and training (Source: EcoDriving, 1999)

in Figure 47. In this case, the device has been installed in a passenger car but recently it has been used with success in heavy-duty vehicles as well.

Figure 48 Optimum engine speed range (source: DaimlerChrysler)

The need for MMI support does not end with the devices necessary for the education of the drivers. Until recently, the tachometer (rev counter) has been the only support available with the purpose of providing the driver with an aid of this kind in the vehicle. The rev counters usually have a green field as indicated in Figure 48 to show the optimum engine speed range. The range in Figure 48 is well in line with the optimum speed range previously shown in the diagram in Figure 44, except that the range is somewhat wider in Figure 48.

In the future, more "intelligent" on-board computers could have several functions integrated in the system that may serve the driver with the necessary information. It is also conceivable that this data could be sent from the on-board computer to a host computer at the operator's office to further analyse the data. In this assessment, a continuous improvement of the driving style could be initiated based on this analysis. A potential problem that cannot be neglected in this respect is that the drivers might feel uncomfortable with the supervision from the office. In summary, technology will not be the limitation in the future, provided that the MMI can be handled in a smooth way.

4.10. Discussion and Conclusions

The principal purpose of the study of energy use in ODAL was to provide an overall idea of the approximate amount of energy used in different parts of the transport chain. The transport chain has been divided into the steps “farmer-to-silo”, ”silo-to-silo”, “to export”, and, in the special case, also “from export harbour to import harbour”. The figures in different parts of the chain are partly uncertain and can differ up to 20% or more, especially since the transport volumes differ considerably between years and regions in ODAL. However, the data could be used to show, which the areas of main energy use are, and the potential for energy-saving activities. The important factors in energy saving, such as the choice of transport mode and distance between producer and consumer, etc., are also highlighted via the study of energy use and pilot actions.

Energy use in ODAL

It can be noted that about 30 % more energy is used in the “silo-to-silo” step (11,3 GWh/year) compared with the “farmer-to-silo step” (7,41 GWh/year). The distance is also longer in the “silo-to-silo” step. The average energy efficiency in “silo-to-silo” is however larger, about 0,15 kWh/tonnekm, compared to 0,67 kWh/tonnekm for “farmer to silo”. The “farmer-to-silo” step includes more use of tractors, which are also assumed to have a lower load factor than lorries. About 65% of the grain in ODAL is exported and the energy use for transport to export harbours in Sweden is about 12,2 GWh/year.

The special case study called “Söderköping” illustrates the great effect of a short transport distance and high-energy efficiency of the transport mode/mean. The special case has more than 50% higher energy use per delivery (about 136 kWh compared to 84) compared to the average for the general farmer-to-silo transport case. The main explanation for this is the more frequent use of tractors as the transport mean and a longer average distance to the silo (about 18,9 km compared to 11,4 km). The average energy efficiency in the special case is about 0,77 kWh/tonnekm.

The importance of short transport distance and high-energy efficiency is also illustrated in the examined special route from a farmer delivering to Söderköping and further to Djurön and Terragona in Spain. The calculations showed that almost 90% of the energy use is attributed to the sea-route segment from Djurön to Terragona, even though ships have the highest energy efficiency. Therefore, efforts undertaken to improve the energy efficiency of ships could be interesting. In the transport for export by ship in ODAL, the employment of ships of increasing size from 25 000 tons to 50-55 000 tons is occurring. The constraint is, however, in ports were it is not always possible to receive ships larger than those presently used.

The calculations in the special case also showed that there was a large potential for energy savings in the farmer-to-silo step. The study revealed that although the distance in this step was only about 0,4% of the total transport distance, the energy used was almost 10% of the total energy use for transport (kWh/tonne).

Pilot actions

There is a potential to reduce energy use by replacing tractors with lorries in the first “farmer-to-silo”step according to our calculations and assumptions. The special case study showed a potential for about a 50% reduction by using only lorries. However, it should also be noted that the use of tractors as the transport mean is somewhat larger in the special case (about 92% compared to about 88% generally in ODAL). Consequently the potential for energy saving in the farmer-to-silo step might be slightly lower generally in ODAL. On the other hand, there might also be some potential to save energy in some routes in the silo-to-silo leg if tractors are used to a larger extent than in the special case Söderköping to Norrköping/Djurön.

Using only lorries is not realistic in the short run. It is clear that it is necessary to get more farmers to dry on the farm. Sometimes road conditions are also too bad for lorries to be able to reach the farms. Another factor is the availability of lorries, which cannot be taken for granted, since there can be a shortage during the peak harvesting time. To achieve the potential, ODAL provides incentives to farmers who transport their grain with lorries by giving them a higher price for the harvest if it is dried at the farm and collected by lorries. During the last four years, the amount of tractor use for transport has, as a result of this, been more than halved. So there is a relevant area for transferral of goods between these transport means. Even though 100% use of lorries is not a realistic goal in the short term, perhaps about an 80% use factor can be possible within 10 years.

In the “silo-to-silo” step, the share of tractor transport is already so low, 0,1%, (in tonnekm) that there is limited potential in this step to further reduce the energy use by substituting tractors with lorries. A relevant question, therefore, is: Can more energy efficient sea or rail transport be used instead of lorry transport? For ODAL and the agriculture industry it seems difficult to transfer many more shipments of goods from road to rail, especially if shipments are to be loaded directly on rail at the silos. One alternative is to load first on a lorry and then on railway. The average distances are however generally too short to suit railway transportation. About 70-110 km is an average distance from silo to silo or customer (according to the previous energy analysis). The study indicates that 150 km could be a reasonable distance to transfer from road to rail. However, it could be less if the reloading systems are highly efficient.

The opportunities to transfer more goods to sea transport are also limited. Crucial for the use of sea transport is the distance and the nearness of the harbours to the silos and customers. In addition, the cost is important. This makes sea transport for distances under about 100 km currently uninteresting. Also regarding sea transport, reloading is considered expensive. Ships are already used as much as possible for routes greater than about 100 km. A general problem with intermodal transport is that reloading is often very expensive. Reloading alone can involve as much cost as a shipment of 50-100 km or even more.

For the fraction of grain that is aimed for export there is also a potential for realising energy savings. There is, for example, a potential to reduce the amount of tractors used for transport that come directly from the farmer (which accounts for about 40% of the total energy used in the transportation chain from farm to export harbours). The potential for energy saving by using lorries instead of tractors partly depends on the higher energy efficiency for lorries compared with tractors and partly on the assumed higher average load factor for lorries.

There is also a potential for energy saving with more drying at the farms according to one of the pilot actions. The energy saving effect of drying at the farms can be about 9-10% in a route in ODAL. Drying at the farm mainly favours switching from tractor to lorry transportation, which is more energy efficient, and also gives the farmer better opportunities to sell when the price is high, among other things. ODAL generally encourages drying by giving better prices for grain, which is delivered during the off-harvest season by lorries.

Another effect of doing more drying at the farm is that it also increases the possibility to go directly to the final receiving plant or the customer. Drying and storage at the farms is also necessary to be able to increase the load factor, reduce empty return trips and improve transport planning and co-ordination possibilities.

The potential effect of using more IT-based systems to reduce energy use in the agricultural industry is also interesting. In studies, route optimisation has been shown to have a large potential and can shorten routes and transport distances by almost 30%. Long routes with many stops for loading and reloading have the largest potential. Routes involving grain deliveries are generally only between one collection and delivery location. Studies indicate that it could be possible to reduce the distance in such routes by about 6-7%. However, other routes could be shortened by more than 20% of the distance or up to 28% of the driving time. There is also a possibility to reduce the number of vehicles by making a total route optimisation. Co-ordination of the distribution of goods (e.g. fodder) and grain collection at the farms is also possible and can reduce the energy use. However, there are some obstacles, e.g., there is a need for vehicles that can carry different types of goods in a sanitary way. The part of the transport chain that has the best chance for an increased load factor and co-ordination with the shipments of other types of goods is probably from silo to silo.

The transport organisation can be important for the co-ordination of diverse goods shipments. Today different haulier organisations are used by ODAL. It could be easier to increase load factors and shipment co-ordination if a large independent company such as ASG or similar companies were used as a third party to handle the distribution and logistics in ODAL. When using many haulier organisations there can be competition between the haulier organisations or other reasons for choosing your own vehicles rather than other hauliers' vehicles, all of which diminishe the opportunities for optimal shipment co-ordination.

It is important that the transport company used has IT-support for transport planning, e.g., GIS, GPS and programmes for route planning, to support operational efficiency and good communication with the drivers. Good communication between the transport planner and the driver also improves the possibility for more efficient loading and reloading.

A change in the driving style, i.e., ecodriving, could have a significant impact on fuel consumption. Tests on a limited number of drivers indicate that the potential in this area is about 10% for cars and slightly less for lorries. The National Swedish Road Administration support research in this area and the organisation for driving schools in Sweden (STR) has been the principal organisation involved in the education of teachers and organising the courses for drivers. Some limited experience is already available from the first groups of educated drivers. The development of IT and MMI support in vehicles will enable further improvement in this area in the future.

Generally, the results in this report show the importance of high load factors if energy efficiency (kWh/tonnekm) is to be improved. Discussions about the possibility of increasing the load factor in ODAL and the use of improved load carriers will be undertaken in the next report from this project (phase 3-report). To obtain more precise figures than presented in this study, the focus should be on finding more exact fuel consumption and load factor data on delivery and return transports. Larger samples divided into specific different regions could also improve the precision of the results. Distances could be more exactly measured, e.g., by finding the co-ordinates for all the farmers and customers and by using this data in advanced map programs.

5. Final conclusions

In Norway the results from the pilot actions indicated that fish transport from Western Norway to the continent has an average energy use for down-trip and return trip of about 0,22 kWh per tonnekm. The return trips give lower energy efficiency. This is caused by low load factor. If the load capacity had been fully utilised on return trips, the energy efficiency could be improved to about 0,18 kWh per tonnekm.

Different driving style could have a great influence on fuel use and thereby energy efficiency. Our cases show that non-economic driving could increase fuel consumption with 25 percent. The energy saving potential in today's lorry transport is greatest in mountain and hilly areas.

Two pilot actions to increase energy efficiency have been carried out:

- actions to reduce energy consumption and to increase the load factor in today's lorry transport
- actions to achieve a transferral of goods from lorries to more energy effective rail- and ship transport.

The result shows that it is possible to reach 5 % reduction in the energy use in the lorry transport at company level. Actions containing information and motivations measures among the drivers is carried out: energy saving course for all drivers, examinations and motivation and competence developing processes. The work has been obligatory for all drivers. An important element is to organise the drivers into groups and set fuel reduction aims for the group and not individually. This gives a constructive competition between the groups to reduce fuel consumption, and focus on teamwork.

For the whole fish export from Norway transported on lorry a 5 % reduction in fuel consumption would give an energy saving effect of about 12.000 tonne fuel or about 115 mill kWh a year. This assumes that our four fish cases to be representative for Norwegian fish export.

Generally commercial companies need an economical motivation to reduce the energy use more than to a level required by public laws and regulations. Such motivation could be from an increase in income or reduction in costs. Reduction in energy use could also be a strategy for developing other competitive advantages (e.g. positive image) to keep their position in the market without particular possibilities to increase income or to reduce costs.

The following additional conditions for reduction of fuel consumption can be identified in today's lorry transport:

- actions and strategies has to be suitable with other main processes going on in the company
- the hard competition in the transport sector makes it difficult to spend much time on developing processes as information and motivation of drivers
- the increasing demand for "just in time" deliveries makes it difficult to use the most energy efficient driving style.

During the project period transferral from road to rail and ferry were done for two of the four case routes. Rail based transport with dried cod to Italy reach a reduction in energy use at 60 % compared with lorry based transport. The effect comes from the more energy efficiency train transport used on the whole distance from Western Norway to Verona in Italy. The transport is similar in time efficiency (5% difference) to the lorry-based transport in 1999.

The other implemented action frozen fish to Boulogne-sur-Mer in France, is based on ferry and train transport. Here the reduction in energy use is “only” about 20 percentage, caused by the train from Åndalsnes to Oslo. The energy saving effect is limited due to the long ferry distance Oslo-Rotterdam. Ferry is less energy efficient than lorry transport.

The other potential transferable alternatives give lager reduction in energy use. Transferrals of goods from road to rail transport in three cases (from Western Norway to Poznan, Bremerhaven and Boulogne-sur-Mer) gives an average reduction in energy use at about 70 %. This calculation assumes bridge across the Fehmarn Belt (Rödby- Puttgarden).

For the ship alternative the reduction is at the same level for the transport to Bremerhaven and BSM, when the ship transport to Italy use nearly as much energy as the lorry transport due to the long sea distance. It is important to state that these calculations are based on the assumption of using large ships today used overseas between Europe and America and Europe and Asia.

If all the fish export from Norway to the European continent where transported by train the total reduction in energy use could be about 70.000 ton fuel or nearly 700 mill kWh. This calculation is based on the assumption that our four cases give a representative picture of transport distance and transport mode in the today’s fish export.

Specific necessary conditions for transferral of goods to rail in the case company Waagan Transport was the possibilities for reducing costs for wages. Another motivation was to develop a more flexible transport system with road, rail and sea. Rail transport makes it also possible to improve the public acceptance. Positive environmental image might bring new customers to the company.

Another necessary condition is investment in new trailers with the huckepack system adaptable for different transport modes. In autumn 2000 fresh salmon was difficult to include in this system due to non-optimised logistic chain. When the punctuality is improved WT is going to include fresh fish in these intermodal transport chain.

Also Norwegian Railways (NSB) and The Norwegian National Rail Administration have done preparations to established a transferral to train transport by enlarging tunnels and investment in intermodal rail equipment. There is a potential conflict between Cargo trains and public trains in the future. With steady faster public trains there would bee a need for passing lines for trains in same direction.

In year 2000 Waagan Transport was the only transport company using the Åndalsnes-Oslo line for fish transport. When the intermodal transport co-operation between WT and NSB Cargo was published in august 2000, NSB got many inquiries from other transport companies. In 2001 therefore two new large transport companies are going to transfer goods from road to rail using this line. Our case company has apparently started a process among the transport companies resulting a substantial reduce in energy use in transport of goods. In NSB Cargo this process is mentioned as “the Waagan effect”.

In Finland the energy use in the case transport chain, from Voikkaa paper mill to the customer in Cologne, Germany is analysed. The energy use is calculated for transporting 8 800 tonnes paper. The amount of raw materials is estimated from their yearly volumes in proportion to yearly production of paper. The energy use includes loading, unloading and other handling of goods except for the possible handling in Germany, which differs from the handling in Finland. The total energy use of the transport chain amounts to 2 971 MWh, which is 0,34 MWh per paper tonne. From the energy efficiency, kWh/tonne-km, it is evident that the train transport in Germany is more energy efficient than the train transport in Finland. This is probably due to the fact that transport distances in this case are shorter in Finland than selected distance in Germany, and that the share of electric locomotives is larger in Germany than in Finland.

According to the calculations in Finland, the most important energy saving actions are:

- Further utilization of return loads
- The use of electric locomotives instead of diesel ones in rail transport
- Transport of large volumes in long distances by rail

Utilization of return loads is an important energy saving action. When looking for further potential for them, all material flows coming to the mill must be taken into account. Owing to nature of timber transport, it is almost impossible to imagine any return loads for them. However, for other raw materials and materials that are used, for example for production of energy at the mill, potential return loads can be identified.

Electric trains are less energy demanding than diesel trains. However, the use of diesel locomotives cannot always be avoided in Finland. Rail transport is essentially more energy efficient than road transport when the volumes are large and the transport distance are long. Advantages of rail transport are smaller when small lots are transported short distances. Nevertheless, the paper mill of Voikkaa produces paper in such amounts in one day in average that train can economically transport it. In Voikkaa's case, there are two ports in almost the same distance from the mill. At the moment, separate trains are going to each port. There could be a possibility to combine trains when the volumes are not energy-economically sufficient.

Due to the geographical location of Finland, the share of sea transport is already large in export chain. Thus, the waterborne transport cannot be increased more since the use of inland waterways is limited during winter. Consequently, a more likely mode change is from road transport to rail transport. However, the transport by lorry cannot always be seen as a most energy-consuming alternative. In train transport the energy use of handlings (e.g. shunting) is often considerable.

The effect of the speed of the ship on the energy use is the most significant factor when the sea transport is in question. Owing to the large share of the sea transport in the chain, the small reductions in fuel consumption can generate remarkable savings when considering the whole chain.

The export chain of the paper is a complex transport chain where responsibility is shared for many partners. The optimisation of selected phases of the chain must be done with care; increase in energy use in one phase can decrease it in another and vice versa. In addition to energy use, other effects of energy saving actions on transport chain must be taken into account. Costs of different transport chains can't be excluded when the chains are compared to each other. Investments needed for changes have to be taken into consideration, too.

In addition, the communication has an important role in efficient transport chain. The great amount of partners and subcontractors create high requirements for data, information and knowledge transfer in the chain. However, the various information systems cause problems and difficulties that have to be solved.

The study of energy use in the Swedish case company ODAL provided an overall idea of the approximate amount of energy used in different parts of the transport chain. The transport chain has been divided into the steps “farmer-to-silo”, ”silo-to-silo”, “to export”, and, in the special case, also “from export harbour to import harbour”. The figures in different parts of the chain are partly uncertain and can differ up to 20% or more, especially since the transport volumes differ considerably between years and regions in ODAL. However, the data could be used to show, which the areas of main energy use are, and the potential for energy-saving activities. The important factors in energy saving, such as the choice of transport mode and distance between producer and consumer, etc., are also highlighted via the study of energy use and pilot actions.

It can be noted that about 30 % more energy is used in the “silo-to-silo” step (11,3 GWh/year) compared with the “farmer-to-silo step” (7,41 GWh/year). The distance is also longer in the “silo-to-silo” step. The average energy efficiency in “silo-to-silo” is however larger, about 0,15 kWh/tonnekm, compared to 0,67 kWh/tonnekm for “farmer to silo”. The “farmer-to-silo” step includes more use of tractors, which are also assumed to have a lower load factor than lorries. About 65% of the grain in ODAL is exported and the energy use for transport to export harbours in Sweden is about 12,2 GWh/year.

The special case study called “Söderköping” illustrates the great effect of a short transport distance and high-energy efficiency of the transport mode. The special case has more than 50% higher energy use per delivery (about 136 kWh compared to 84) compared to the average for the general farmer-to-silo transport case. The main explanation for this is the more frequent use of tractors as the transport mode and a longer average distance to the silo (about 18,9 km compared to 11,4 km). The average energy efficiency in the special case is about 0,77 kWh/tonnekm.

6. References

Ahlvik P. (1999): *Impact of driving style on fuel consumption and exhaust emissions – A literature survey*. The Swedish National Road Administration.

Andersen, O., Uusitalo, O., Ahlvik, P., Hjortsberg, H., Groven, K., Brendehaug, E. (1999): *Energy in transport of goods. Nordic examples.* VF-rapport 6/99. Sogndal: Western Norway Research Institute.

Finnlines (1999): *Main particulars of ships*. Finnlines.

Gebresenbet, G., & Ljungberg, D. (1999): *SATRA: Co-ordinated goods transport within the agriculture industry to benefit a sustainable transport system- Summary progress report*. Swedish University of Agriculture Sciences, Uppsala (In Swedish).

Gebresenbet, G., & Ljungberg, D. (2000): *SATRA: Co-ordinated goods transport within the agriculture industry to benefit a sustainable transport system- Final report*. Swedish University of Agriculture Sciences, Uppsala (In Swedish).

Gebresenbet, G. (2000): *Promoting effective goods distribution through route optimization and coordination to attenuate environmental impact – the case of Uppsala*. Swedish University of Agriculture Sciences, Uppsala

Hansen, C. J., Høyer, K.G. and Tengström, E. (2000): *Nordic transportation in the future. Demand of sustainability and efficiency.* Nordic Transportpolitical Network (NTN) Interreg-IIC. VF-rapport 8/00. Sogndal: Western Norway Research Institute.

Hjortsberg, H. and Ahlvik, P. (2001): *Energy saving potential in the agriculture industry in Sweden. A report from Phase 2 of the European Commission SAVE -project "Energy saving in transport of goods – a pilot project in rural natural resource based industries*." Ecotraffic. Stockholm.

Kauppalehti (2000): Kauppalehti (Finnish daily business and financial newspaper) 19.10.2000.

KFB (1994:49): *Emissions- och energivärderingsprinciper för transportsystem*. Stockholm (In Swedish).

Ministry of Transport and Communication Finland (1999): *Environmental competitiveness of port operators - definition and tool*. (In Finnish:Ympäristökilpailukyvyn määrittäminen ja mittaaminen satamatoiminnassa.). Publications of the Ministry of Transport and Communications 30/99. 48 p.(in Finnish).

Moser F. and Flotho A. (1994): *Die neuen wassergekühlten Deutz-Dieselmotoren BMF 1015, MTZ 55 7/8* (in German).

ODAL (1997): *Annual report* (in Swedish).

ODAL (1997): *Let us present ODAL*. Brochure, Enköping (In Swedish).

Oijala T. (1995): *Calculation of Metsäteho for the energy use of transport of timber.*

Palmer F. (1993): *Environmental Challenges facing Road Transport Fuels and Vehicles Outside the USA*. SAE Paper 932682,.

Hansson, P.A. et al. (1998): *Engine emissions from agriculture tractors and forestry machines*. Swedish University of Agriculture Sciences, Department of Agriculture Engineering, Report 232, Uppsala (In Swedish).

Pussinen, J. (1997): *Railway traffic energy consumption and emissions in Finland*. (In Finnish: Rautatieliikenteen energiankulutus ja päästöt Suomessa.) Tampere University of Technology, Transportation Engineering. MOBILE programme - 001T-4 (in Finnish).

Renner G. (1998): *Driver behavior, fuel consumption and a fuel economy system*. TransportMiljö 98, Seminar in Borlänge, Sweden, 8 – 10 September 1998.

Säteri, L. & Väkevä, J.& Örn, J. (1999): *Puunkorjuun ja puutavaran kaukokuljetuksen kustannukset vuonna 1998*. Metsäteho. 4 p. (Tilastoliite.)

SIKA (1997): *Prerequisites for calculations. New line of policy in traffic* – Appendixes, SOU: 1997:35, ISBN 91-38-20538-6, ISSN 0375-250X, Stockholm (In Swedish).

Statistics Finland (1998): *Energy Statistics 1997*. Energia 1998:1.

Swedish Environmental Protection Agency (1997): *Att äta för en bättre miljö – slutrapport från systemstudie livsmedel*. ISBN 91-620-4830-9, Rapport 4830, Naturvårdsverket, Stockholm (In Swedish).

VR (2000): *Environmental report 1998-1999.*

Yin, R. (1994): *Case study research, design and methods*. Sage Publications, Beverly Hills

Personal information:

Bertnes, Trude, Norwegian Railways, Narvik, 2001.

Brunstad, Knut, Norwegian Railways, Oslo, 2000.

Dahle, Anne Berit, Statistics Norway, Oslo 2001.

Kleppe, Asle Jon, Waagan Transport, Ålesund, 1998-2000.

Nedland, Lars, DFDS Tor Line, Oslo, 2001.

Nistad, Arne, Nistad Transport, Sandane, 2000.

Nordvik, Dag, Volvo, Kolbotn, 1999-2000.

Owrehagen, Kjell, Norwegian Railways, Oslo, 2001.

Strand, Oddmund, DFDS Tor Line, Oslo, 2001.

Waagan, Per, Waagan Transport, Ålesund, 1998-2000.

Waagan, Kjersti, Waagan Transport, Ålesund, 2000.
Ahonen. Transport company, 1999

Arminen, Lassi. The Port of Kotka, 1999

Gunnar, Ilpo. Steveco, 1999-2000

Karsio, Hanna. UPM-Kymmene, 1999-2000

Marttinen, Heikki. VR Cargo, Kouvola, 2000

Metsola, Erkki. UPM-Kymmene Forest, 1999

Miettinen, Pekka. VR Cargo, Kouvola, 2000

Mölsä, Juha. UPM-Kymmene, Voikkaa, 1999-2000

Ora,Seppo. ORPE-kuljetus (a transport company, especially timber), 1999

Schacht, Silke. UPM-Kymmene Distribution Gmbh, 2000

Peltonen, Aila. UPM-Kymmene, Voikkaa, 1999

Pik, Martti. UPM-Kymmene, Kymi, 2000

Puranen, Seppo. VR Cargo, Kouvola, 1999-2000

Rämä, Vesa-Matti. UPM-Kymmene, 1999

Sihvonen, Martti. VR Cargo, Kouvola,1999-2000

Suutari, Jari J. UPM-Kymmene, Voikkaa, 1999-2000

Tapaninen Ulla. Finncarriers, 2000

Tuuri, Jari. Kuljetusliike Jari Tuuri Ky (transport company), 1999

Vuorenpää ,Tuomo. Metsäteho, 2000

Alexandersson Jan, EcoDriving International, 2000

Berglin, Per O., ODAL, 1998.

Carlsson, Bengt, ODAL, 1999

Eriksson Erik, Svelast, 2000

Gebresenbet, Girma, SLU, 2000

Hogfors, Sven, LRF, Feb. 2000

Jakobsson, Guy, Uner och Jönsson, 2000

Johansson, Olle, ODAL, 2000

Karlsson, Roger, Swedish Shipowners Association, 2000

Ljungberg, David, SLU, 1999

Mattson, Mats Rederi AB Uman, 2000

Regnér, Sigurd, SLU, 1999

Sjöö, Pernilla, ODAL, 1999

Swahn Magnus, SJ, 2000

Söderström, Mats, ODAL, 1999

Thorn, Ronny, ODAL, 2000

Vilhemsson, Lennart, ODAL, 1999

Internet

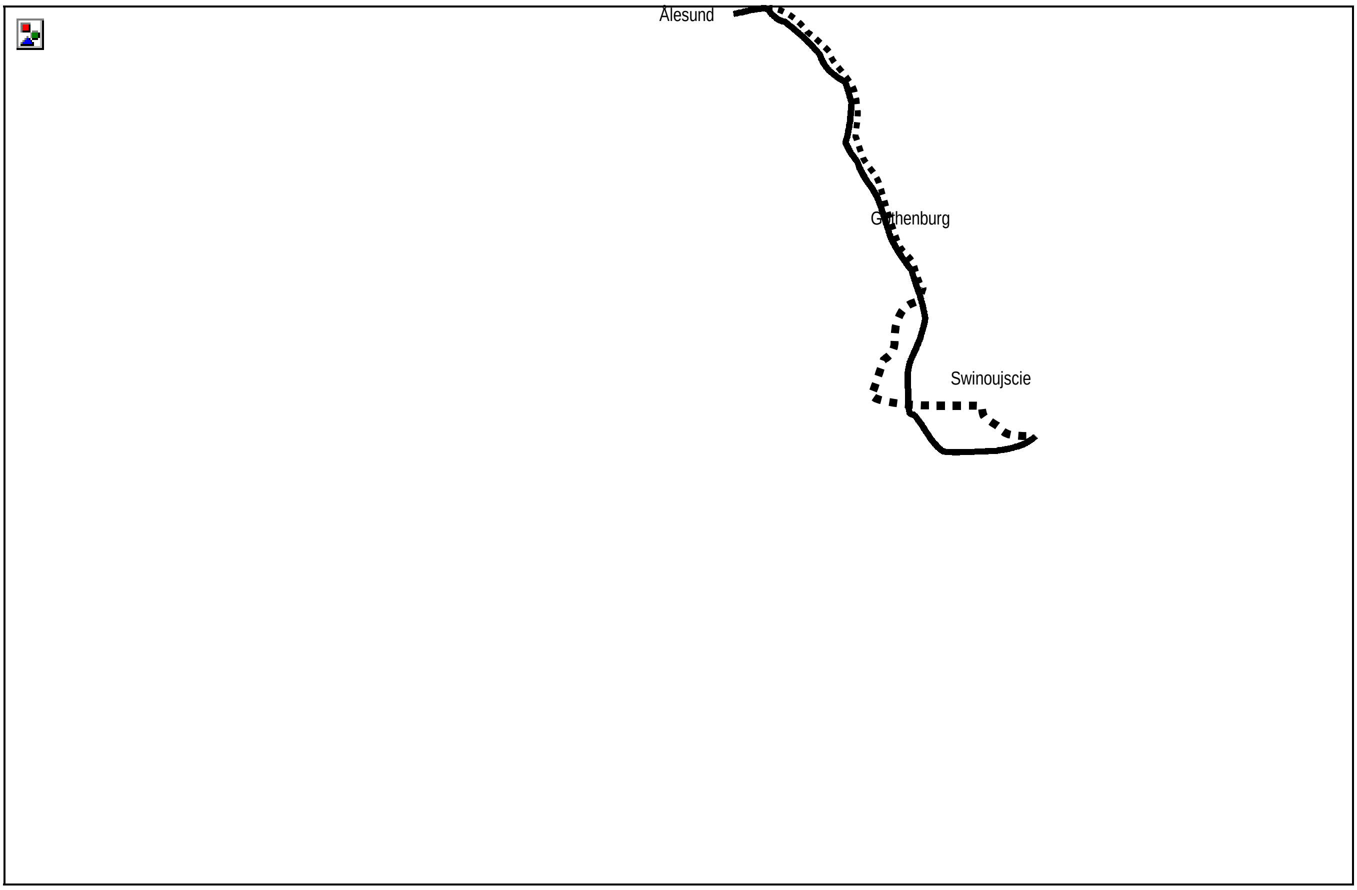
Forestindustries 1999. http://www.forestindustries.fi/fi/metsa/pkorjuu.htm
SKAL (Finnish Trucking Association) 2000. www.skal.fi/
VTT Communities and Infrastructure 2000. www.vtt.fi/yki/lipasto/yksikkopaastot/index.htm
www.ecodriving.com/
www.ecodriving.se/
www.nsb.no
www.ntm.a.se/ “NTM - Nätverket för Transporter och Miljön”
www.sjv.se/ “Jordbruksverket”
www.tya.se/

Attachment 1: Case routes described on map, including alternative routes by rail and ship

CASE A:

Fresh (and frozen) herring to Poland (Poznan) with lorry from Ålesund via Gothenburg to Trelleborg, ferry to Rostock and lorry on the last distance to Poznan. This route is marked with a whole line on the map.

The alternative route by train is marked with a dotted line: Lorry from Ålesund to Åndalsnes (110 km), train from Åndalsnes to Poznan. This assumes railway bridge across the Fehmarn Belt (Rødby-Puttgarden).

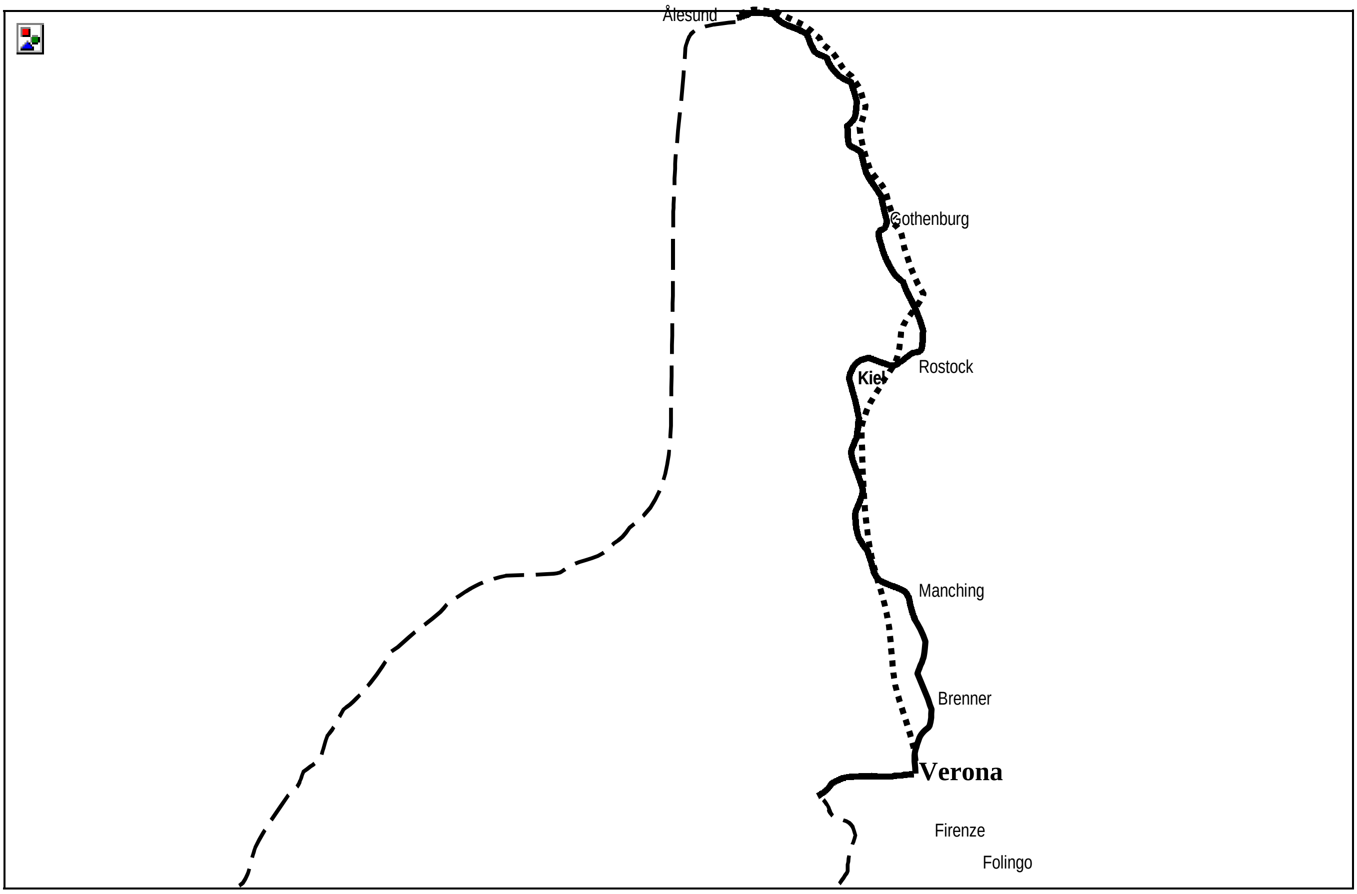


CASE B:

Dried cod from Western Norway to Torino, Italy. The route with lorry is from Ålesund to Gothenburg, ferry from Gothenburg to Kiel, lorry transport from Kiel to Manching, rail transport (lorry on rail) from Manching to Brenner, and lorry transport on the last distance to Torino. On this map this a marked with a whole line.

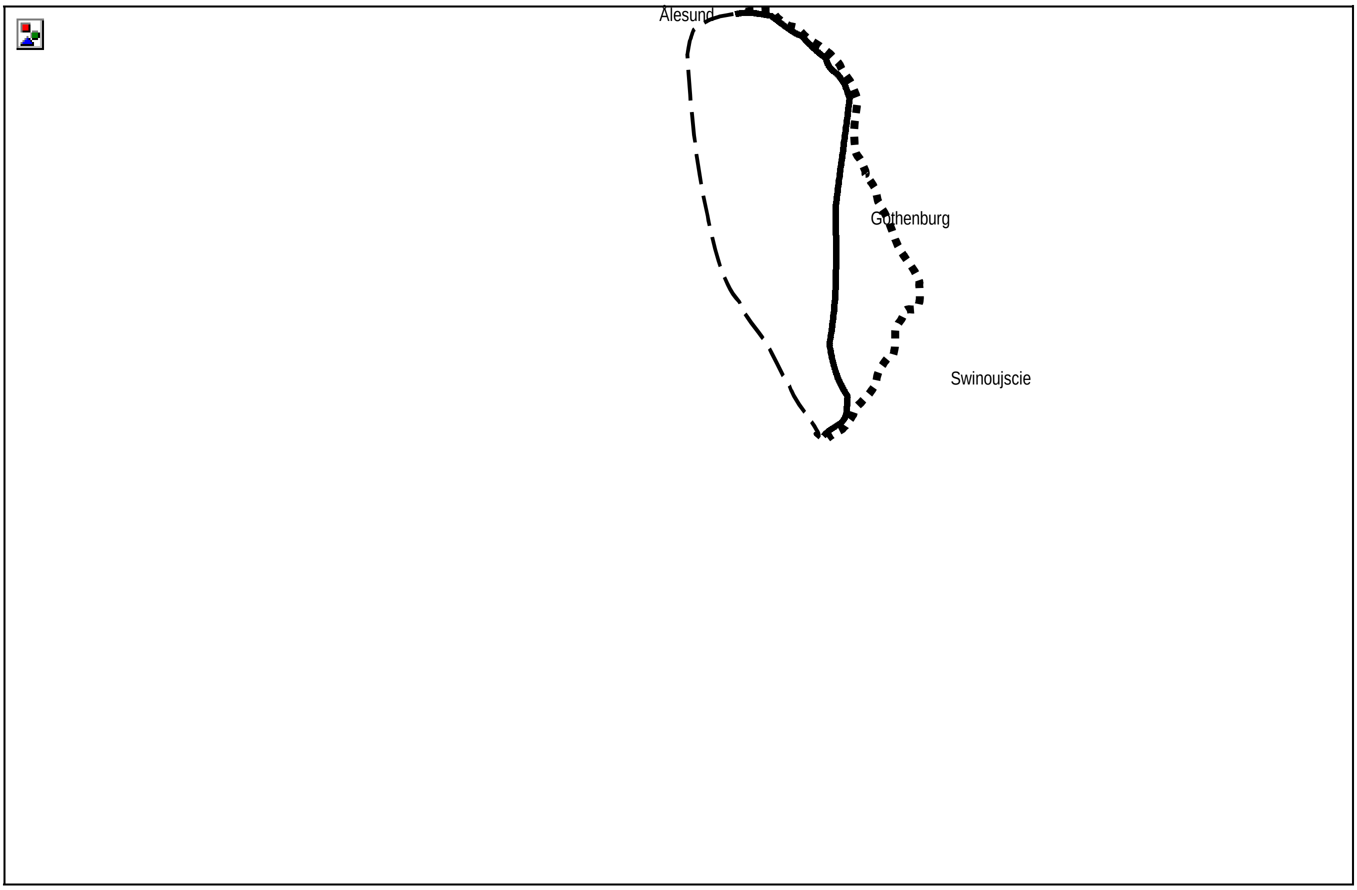
The alternative route by rail is train transport the whole distance from Åndalsnes to Verona. Lorry is used in both ends, from Ålesund to Åndalsnes, and from Verona to Torino. This route is implemented during the project period, and is marked with a dotted line on the map.

The sea alternative is ship from Ålesund harbour to Genova, and lorry the last distance to Torino.



CASE C:
Fresh saith fileet from Western Norway to Bremerhaven. The route is lorry transport from Ålesund to Moss (south-eastern Norway), ferry from Moss to Hirtshals (Denmark), and lorry transport from Hirtshals to Bremerhaven. This route is marked with a whole line on the map.

The alternative route by rail goes from Ålesund to Bremerhaven with lorry transport in both ends. This is marked with a dotted line on the map. The sea alternative assumes ship the whole distance from Ålesund harbour to Bremerhaven.



CASE D:

Fresh (and frozen) white fish from Western Norway to Boulogne-sur-Mer, France. The route is lorry transport from Ålesund to Oslo, ferry to Kiel, and lorry transport on the last distance. This route is marked with a whole line on the map.

The implemented alternative route is marked with a dotted line: Train from Ålesund to Oslo, cargo-ferry from Oslo to Rotterdam, and lorry on the last distance to Boulogne-sur-Mer.

The alternative sea route is by ship the whole distance from Ålesund harbour to Boulogne-sur-Mer.