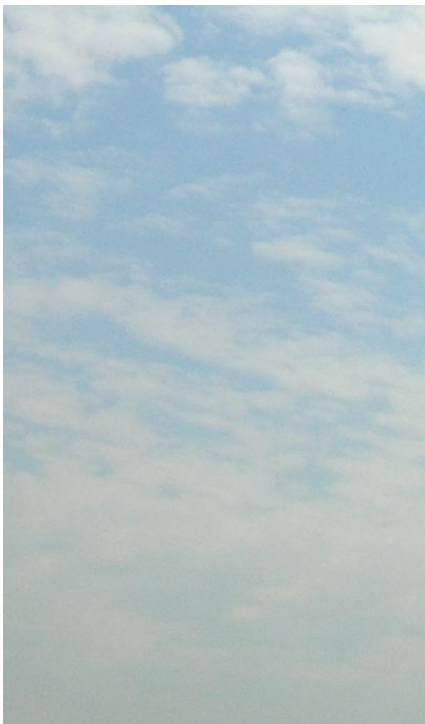
Approximation of marginal cost functions for waste prevention in Sweden -input data for modelling

2009-10-22

Profu



TOWARDS SUSTAINABLE WASTE MANAGEMENT

Summary

The aim of this project is to estimate marginal costs functions for waste prevention in some Swedish industrial sectors. The aim is to use the approximated functions as part of the input data for further modelling.

The work is conducted in three steps: a literature survey, telephone interviews, and finally calculations and analysis of results.

One result of the study was that little information was available on the costs of waste prevention and the effects of the preventive measures.

Thereby the result presented is to be seen as examples of costs of measures and its corresponding effects, rather than representative data for the industrial sectors. More comprehensive and trustworthy input data is needed, if reliable waste abatement cost functions for the Swedish industrial sectors are to be constructed.

From the empirical work, the overall impression is that the Swedish companies are aware of the necessity of waste prevention from a resource savings' perspective, but that it is a matter of business economics if measures are implemented or not.

Various measures have been taken to prevent waste in Swedish industries, but mainly from the perspective of saving raw material, i.e. from a cost perspective. Additionally, the awareness of the time and costs for handling packaging waste, has led to the companies putting pressure on suppliers to reduce these amounts.

The work presented here is a subproject to "Future waste quantities" a project within the Swedish research programme "Towards Sustainable Waste Management". The research programme is financed by the Swedish Environmental Protection Agency.

Contents

Foreword

The aim of this project is to estimate marginal costs functions for waste prevention in some Swedish industrial sectors. The aim is to use the approximated functions as part of the input data for further modelling.

The work presented in the current report is a subproject of the project “Future waste quantities” in the Swedish research programme “Towards Sustainable Waste Management”. The research programme is financed by the Swedish Environmental Protection Agency.

The work has been done by a project group at Profu AB.

The main work presented here was conducted in 2007-2008. The writing of the report is finalised in October 2009.

1 Introduction

1.1 What is waste prevention?

Waste prevention means measures taken before a substance material or product has become waste according to the Directive on waste (2008/98/EC). Waste prevention includes reducing the amount as well as its impacts on the environment and human health, as well as the content of harmful substances

Another term used in literature is *source reduction.* Thereby the reuse of a material within a production unit in order to substitute raw material is what we define as waste prevention. The reprocessing of a material for usage in another production process would not be waste prevention.

In literature, the distinction between *waste prevention* and *waste minimisation* can be complicated. Figure 1 shows the OECD's definition of waste minimisation. According to their definition waste minimisation is a broader term than prevention. Waste prevention in their case covers *prevention, reduction at source* and *re-use of products*. Waste minimisation however, also includes the waste management measures *quality improvements* and *recycling*. The term chronological orientation stands for the lifecycle of waste. Measures executed early or before waste is generated are preferred.

The EU definition of *waste prevention* that we use is similar to the OECD definition of *waste preventive measures* (Figure 1), but with one exception. By *reuse* we understand from the EU definition, the following meaning: **"**reuse means any operation ….are used again for the same purpose for which they were conceived" (Directive 2008/98/EC). OECD defines *reuse* as "the multiple use of a product in its original form for its originally intended purpose or an alternative purpose, with or without reconditioning" (OECD 1996).

According to the EU definition we thereby define the recirculation of processing waste within the production process as waste prevention, but the usage of processing waste for an alternative production process not as waste prevention. Particularly for the wood industry this would mean that the recirculation of chemicals or pulp waste for paper making is waste prevention according to our definition. On the other hand, the usage of saw dust from a saw mill as raw material for making wood particle boards is not waste prevention.

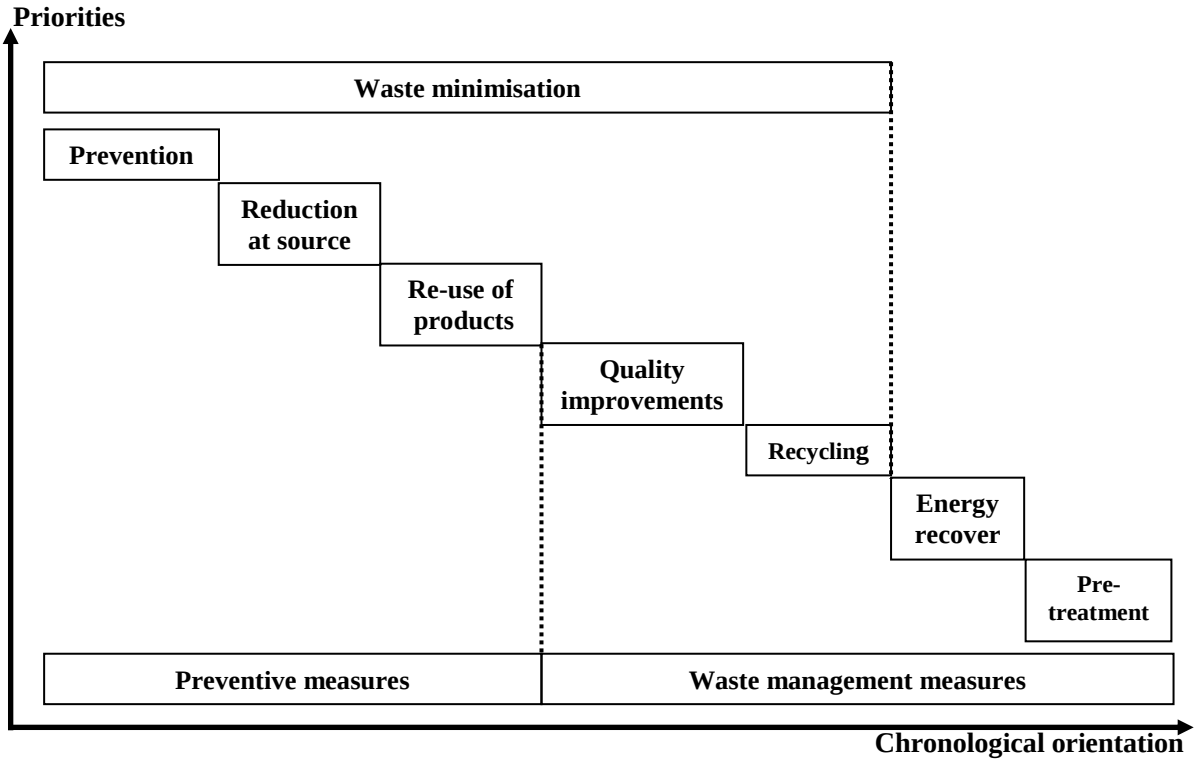


Figure 1 Waste prevention as part of waste minimisation measures according to OECD (1996).

The EU Thematic Strategy on Waste Prevention and Recycling (COM (2005) 666 final) aims to commit all Member States to developing waste prevention policies that result in better use of resources. It is pointed out that the policies must reach the individuals and businesses, whose decisions influence the generation of waste.

1.2 Purpose

The purpose of this project is to estimate marginal cost functions for waste prevention in some Swedish industrial sectors. The aim is to use the data as input data for further modelling of future waste quantities.
A secondary purpose is to increase the knowledge on measures for waste prevention, and to gather data on current waste preventive measures in Swedish industries.

2 Methodology

The work is conducted in three steps. First, a literature survey; second, telephone interviews; and third, calculations and analysis of results.

2.1 Literature survey

The literature survey aimed at finding data from previous case studies on costs for waste prevention. The data was compiled in a database. Starting from the database, a further selection was made from the data in order to decide on usable abatement cost data.

The following detailed information was needed, if the data was to be used:

1) cost for the waste preventing action,
2) amount of waste prevented (in tonnes),
3) effect of measure, compared to total, generated waste (%),
4) type of waste fraction,
5) type of action to prevent the waste,
6) type of industrial sector.

Some information was found through follow up-questions to authors of the documented case studies, as well as by further literature surveys.

In the database, the industry segments are divided by codes (Appendix A), agreed upon to be used in this project. The waste from all industry segments are further divided into fractions after EWC-Stat-code (Appendix B). The two dimensions form a matrix, but not all branches generate all types of waste.

2.2 Choice of industries for interviews

In order to get information on recent or ongoing waste prevention in Swedish industries, telephone interviews were made with representatives of Swedish industries and the producers' associations. The representatives were chosen from the two largest industrial sectors according to generated waste quantities, (the mining industry excluded), namely the forest industry, including paper and pulp industry and the iron and steel industry. Furthermore, five companies on the Swedish Environmental Protection Agency's list of "Good examples of waste management in companies" (Swedish Environmental Protection Agency, 2002) were chosen for interviews.

The questions asked are shown in Appendix C and D.

2.3 Analysis

In the analysis, the literature data and the findings from the interviews were brought together.

The methodology for introducing abatement opportunities in the EMEC model is described in Östblom (2002). The unit cost of abatement increases with the quantity abated as the less expensive measures of abatement are applied first. The methodology described by Östblom (2002) is applied for abating emissions of sulphur dioxide (SO_2) in industry, but the principle for the method is applicable also here. The method is briefly described in the following, but for details we recommend Östblom (2002).

The starting point is the unit cost values for abatement from the literature data. The unit cost is the cost per unit to reduce 1, 2, 3% of the waste, while the searched marginal cost for reducing waste from 1 to 2%, for example. The marginal cost function is expressed as the derivative of the total cost function with respect to quantity.

By using regression analysis (or the method of least squares)[1], the best fitting parameters for the unit cost function are determined and transferred to the corresponding marginal abatement cost function. This procedure is repeated for all sets of data for the industrial sectors. The parameters are then to be used in the further modelling by this project. In this study we assume one marginal cost curve applies for a whole industrial sector, independently of waste type.

Earlier studies pointed out the difficulty in finding abatement costs for Swedish industries (Lundmark, year unknown; Kristensson, 2001), as for industrial waste prevention in particular (Ecosys, 2007). Also in this project, lack of literature data on abatement costs was striking, both in the literature study and in the interviews. The identified abatement costs from the literature data cover only some sectors, and not the sectors selected for the interviews.

[1] The method of least squares is used to model numerical data from empirical or other observations, by altering the parameters of a model to get an optimal adjustment of the empirical data. The best fit is characterised by the sum of squared residuals have its least value, a residual being the difference between an observed value and the value given by the model.

3 Results

We want to stress that data on waste preventions costs and effects of measures appeared to be scarce. Thereby, the data presented is to be seen as examples of costs of measures and its corresponding effects, rather than being data representing the industrial sectors.

Correspondingly, the result of this study is an attempt to construct waste abatement cost functions. More comprehensive and trustworthy input data is needed, if reliable waste abatement cost functions for the Swedish industrial sectors are to be constructed.

3.1 Literature survey

The literature survey was conducted within the period of October 2007 to February 2008 and resulted in about 200 case studies on waste prevention, mainly European studies. In Appendix F the results of the literature survey are presented. The list is a gross list, meaning data on the various waste prevention case studies we found in the literature survey. Further studies identified had a lack of transparency and were not included in the gross list.

The case studies were sorted according to industry segment and further evaluated. It turned out that the majority of the data was not complete, according to the requirements of this study (section 2.1). Mainly the cost for the waste preventing action, and the waste reduction effect on an overall level, was missing.

Furthermore, the vocabulary was to some extent misleading; what was called waste prevention in many cases turned out to be alternation in waste handling (meaning reduced landfilling) and not waste prevention, according to the definition in Chapter 1. Thereby, after a further sorting of the input data a final net list was complied. **Table 1** contains the net list, which is the data we consider usable for this project.

Four industry segments were covered with data. The data was either the unit cost needed or data so that the unit cost could be calculated, as well as the effect on the total waste quantities at an overall industry plant level. The calculations and assumptions made are described in the following section.

Table 1 The results from the literature survey; unit waste abatement cost and the share removed of total waste amounts in the case study.

Code	Industry	Waste share reduced %	Unit cost SEK/tonne
15-16	Food and drink	4.5	7943
15-16	Food and drink	3	653
15-16	Food and drink	1.5	0
29-35	Machinery	47	214
26	Non-metal materials	10	0
26	Non-metal materials	20	0
26	Non-metal materials	30	102
26	Non-metal materials	40	2631
27-28	Steel, metal, metal products	23	379
27-28	Steel, metal, metal products	50	0
27-28	Steel, metal, metal products	10	245
27-28	Steel, metal, metal products	15	533

The plotted unit costs (SEK/tonne) of abatement for the share of waste reduced is shown for the three industrial sectors food and drink, non metal materials and steel metal and metal products (Figure 2). As can be seen the unit costs vary strongly between sectors.

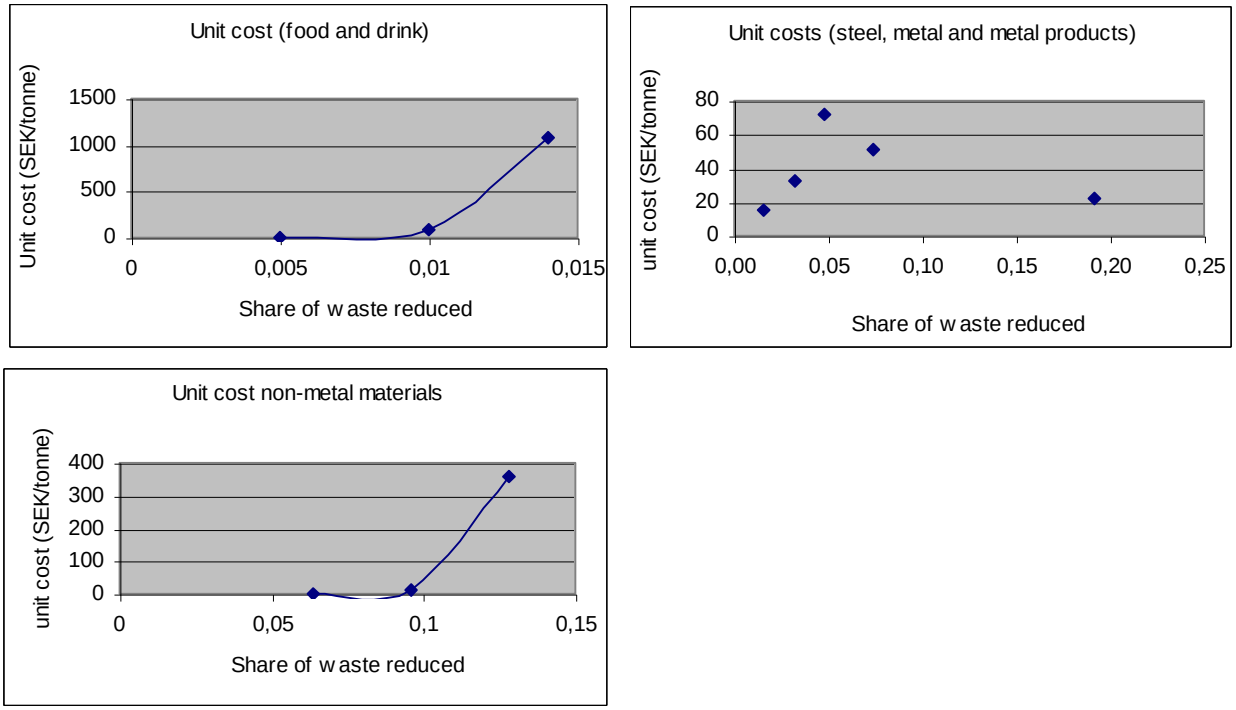


Figure 2 Plotted unit costs of abatement from the literature survey for the sectors food and drink and non-metal materials steel, metal and metal products.

With the unit costs above as starting point, the parameters for the unit cost function and the corresponding marginal abatement cost function are estimated. The method of least squares is used for approximate the equation and is described by Östblom (2002). By using a large number of values for the degree of abatement, also outside the range of values for the estimated function, and simulating the unit cost functions and the marginal cost functions give, the shapes of these functions shown in Figure 3 and Figure 4.

When comparing the data of the Figures 2-4 it is clear that the functions of the unit cost and the marginal cost vary widely between sectors. This is explained by the large variations in input data. The variations make the functions not being representative for the corresponding sectors. Thereby, no conclusions regarding the cost levels of the sectors can be drawn, due to lack of input data. The corresponding parameter estimates are shown in Table 2.

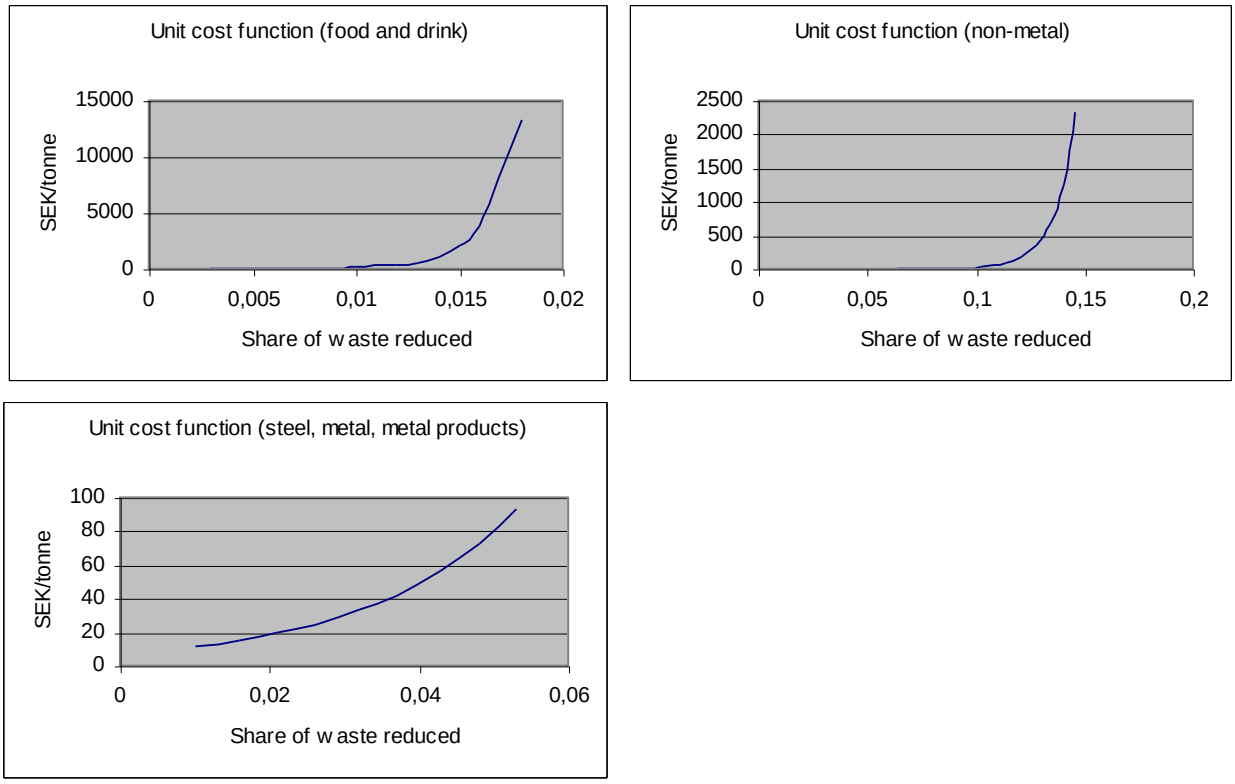


Figure 3 The unit cost function for industry sector sectors food and drink, non-metal materials and steel metal and metal products.

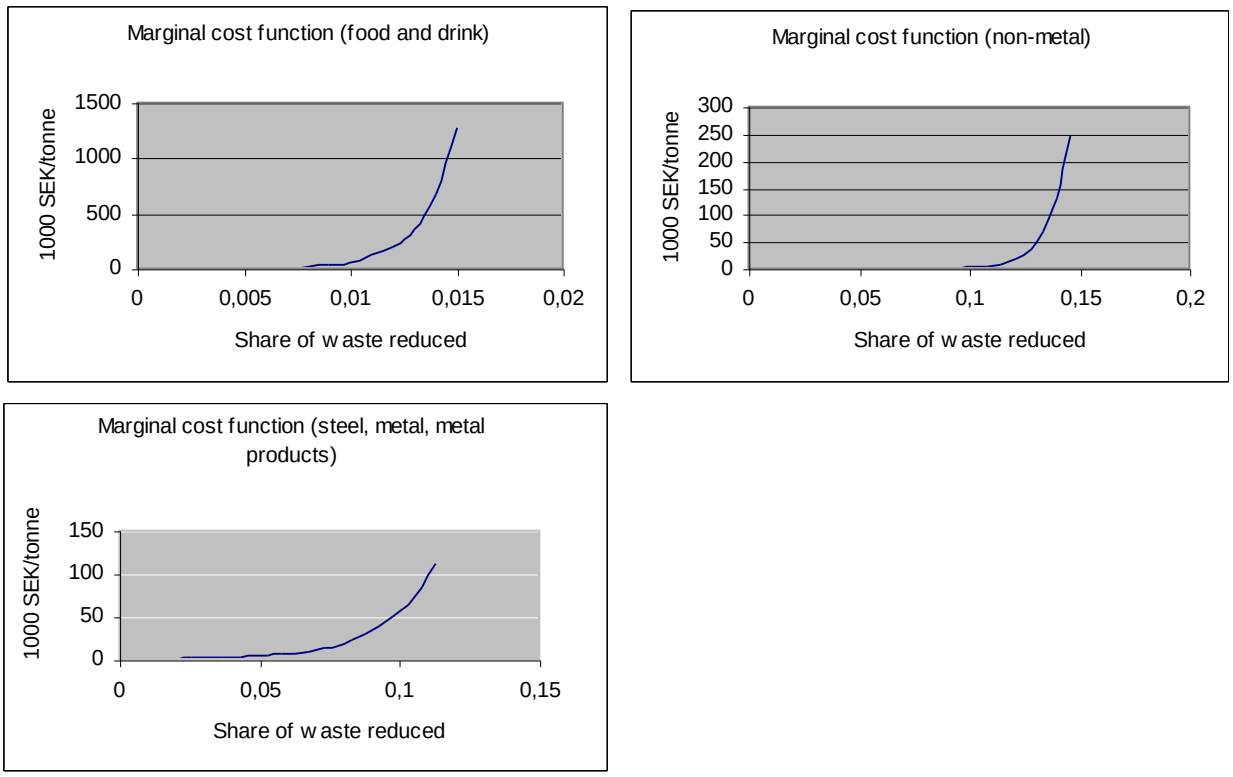


Figure 4 The marginal cost function for industry sector sectors food and drink, non-metal materials and steel metal and metal products.

Table 2 Estimation of parameters. The parameters (β,γ,K) are described by Östblom (2002).

Sector	β	γ	*K*
Food and drink	111	-618	0
Non-metal	0,14	-91	0
Steel, metal, metal products	332	-48	0

3.2 Interviews

The companies contacted represent the forest industry, including paper and pulp industry and the iron and steel industry. Furthermore, we also interviewed five companies on the Swedish Environmental Protection Agency's list of "Good examples of waste management in companies" (Swedish Environmental Protection Agency, 2002). Finally two representatives of Swedish producers' associations were made.
All interviews were via telephone during the period from December 2007 to January 2008.

The forest industry

Table 3 Results from the interviews with representatives of the forest industry.

Company, (Products)	**Measures for waste prevention**	**Cost**	**Other comments**
Finndomo, Hässleholm (Prefabricated wooden houses)	Since 5-10 years Finndomo buys pre-cut board and plasterboard in order to avoid saw dust and plaster waste.	No data	They source separate in 22 waste fractions. Polystyrene (Styrofoam/ frigolit) was earlier material recycled, now for incineration (with energy recovery)
Finndomo Hjältevad (Prefabricated wooden houses)	-	No data	They source separate in 15 fractions. The waste is mainly wood which goes to boilers for internal and external heating. Leftover insulation material is returned to the manufacturer, and equipment for compaction is installed to decrease transports.
Elitfönster, Vetlanda and Lendhova (Windows)	Elitfönster buys pre-cut aluminium profiles in order to avoid waste. Chips from drilling are sent back to the manufacturer for recycling.	No data	Their other waste is mainly wood and glass.
Kinnarps, Jönköping (Furniture)	Their transportation to customers reuse all packaging (blankets and paper board). This system has been used since the company started its business in the 1940s.	No data	Their other waste is mainly wood waste which is sold as fuel for district heating.
Tarkett, Ronneby (Floors)	Through the internal and external reuse system, 23% plastic material is reused per tonne produced plastic floor. The internal system both reuses waste from the production system and discarded material from the quality control. The internal reuse has been running for 30-40 years. The possibility for customers to return waste was introduced in the 1990s.	No data	They sort waste in 21 waste fractions, mainly for recycling. Since the 1996 waste to landfill has decreased from 350g to 50g/m2 floor, mainly through recycling.
Södra Cell, Värö (Pulp)	Ongoing work to prevent ashes, green liquor and lime mud.	No data	Mainly by-products which are not considered waste by the company are generated. Work is being done to find alternative handling than landfilling for the mentioned waste fractions.

The iron, steel and metal industries

Table 4 Results from the interviews within the iron and steel industry.

Company (Products)	Measures for waste prevention	Cost	Other comments
Pacwire (Galvanized baling wire)	A purification unit has enabled the reuse of hydrochloric acid waste for more than 10 years. The company also visits international trade fairs in order to learn from competitors' technical development. The zinc waste is sold for reprocessing.	No data	All companies using the same technology in the sector struggle with the costs of handling the hydrochloric acid waste.
SSAB Merox (Recycling of by-products)	There is an overall policy not to generate more waste than necessary. Recycling of steel slag to the blast furnaces and pelletized dust with iron contents is and recycled in the process.	No data	SSAB Merox (subsidiary of SSAB) is responsible for processing and sales of by-products from the steel making process

Other industries

Table 5 Results from the interviews with companies on the list of "Good examples" (Swedish Environmental Protection Agency, 2002).

Company (Products)	Measures for waste prevention	Cost	Other comments
Enics, (formerly Flextronic) Västerås (Printed circuit board)	Enix asks suppliers to reduce mainly corrugated board. If two suppliers offer equal products they choose the one with less waste.	No data	General awareness campaigns and education to raise the knowledge on waste handling and reduction.
ABB Service, Ludvika (Service, i.e. waste management)	ABB Service introduced a return system for packaging in which wood packaging replaced plastic. Also reduced packaging demanded at purchase. General waste reduction on a policy level.	No data	
IAC, (formerly Lear Corporation), Färgelanda (Plastic components)	Plastic is reused within the production process after grinding. The company has invested in small plastic mills at each production line, instead of one central mill used earlier. With the current decentralized system, the risk for contamination of the plastic is reduced with less storage and transport.	No data	
ICA, Västerås (Storage centre wholesaler, provision)	Reduced packaging demanded at purchase.	No data	Large quantities of corrugated board, soft plastic and biological waste for recycling.

Interviews with the producers' associations

Table 6 Contact details and data from the interviews with the producers' associations.

Organisation	Measures for waste prevention/Other comments
Skogs-industrierna, (Swedish Forest Industries Federation)	The federation is the trade and employers' organisation for the pulp, paper and wood mechanical industries. Effort is focusing on finding alternatives to landfilling of green liquid (200 000 ton) and lime sludge. Also ashes are being landfilled. Up to 95% of what is waste according to statistics finds an outlet, for reuse or energy purposes. Their opinion is that general waste reduction from the forest industries is not an end in itself, but focus should continue being on the wastes currently landfilled, according to the representative. Black liquor is an example of waste that has been used for 50 years for energy purposes.
Jernkontoret (the Swedish Steel Producers' Association)	Currently focus is on "Kriterieprojektet" with suggestions of new limits for contents of e.g. heavy metals in waste (what they regard being by-products) to be used. Thereby slag from blast furnaces cannot be used for road construction, a current market.

Comments to the interviews

The overall impression from the interviews is that the companies are aware of the need of waste prevention from a waste management and resource saving's perspective. However, it is a matter of cost if measures are implemented or not. Various measures have though been taken to prevent waste, but mainly from the perspective of saving raw material and thereby by saving costs. Additionally, the awareness of the time and costs for handling packaging waste, has led to the companies putting pressure on suppliers to reduce these amounts.

Little information was available on the costs of waste prevention and the effects of the measures taken.

Comments to the result of the interviews

The aim of the interview was to collect examples on costs of waste prevention case studies. As no data on costs was available, this aim was not fulfilled. This means that for various types of waste and industrial sectors, waste prevention will not be estimated.

A secondary aim was to increase the knowledge on measures for waste prevention, and to gather data on current waste preventive measures in Swedish industries. This aim was fulfilled to some extent, and additionally some attitudes towards waste management and waste prevention was compiled.

4 Conclusions

The work carried out within this subproject is an attempt to construct waste abatement cost functions for some Swedish industrial sectors. However, little information was available on the costs of waste prevention and the effects of the preventive measures.

Thereby the result presented in this study is to be seen as examples of costs of measures and its corresponding effects, rather than representative data for the industrial sectors. More comprehensive and trustworthy input data is needed, if reliable waste abatement cost functions for the Swedish industrial sectors are to be constructed.

From the empirical work, the overall impression is that the companies are aware of the need of waste prevention from a waste perspective, but that it is a matter of cost if measures are implemented or not. Various measures have been taken to prevent waste, but mainly from the perspective of saving raw material i.e. from a cost perspective. Additionally, the awareness of the time and costs for handling packaging waste, has led to the companies putting pressure on suppliers to reduce these amounts.

5 References

For references of the case studies, see Appendix G

Chapple W., Harris, R., and Morrison Paul, C.J., 2006. The cost implications of waste reduction: factor demand, competitiveness and policy implications. J Prod Anal (2006) 26:245-258. DOI 10.1007/s11123-006-0014-6.

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Lundmark R., (year unknown). Utbudet av biobränslen på kort och lång sikt, Luleå tekniska universitet, Enheten för Nationalekonomi.

OECD, 1996. Considerations for Evaluating Waste Minimisation in OECD Member Countries

Swedish Environmental Protection Agency, 2002. Bra avfallshantering hos företag (Good examples of waste management in industries) (in Swedish).

Östblom, G., 2002. Introducing costs of sulphur abatement in the EMEC model, Konjunkturinstitutet, Stockholm, Sweden.

Appendix A

The codes for the industry segments included in the study.

Sector	Code
Agriculture and forestry	01-02
Fishing	05
Mining and quarrying	10-14
Food, beverage and tobacco	15-16
Textile and leather industry	17-19
Wood manufacture	20
Pulp and paper manufacture	21-22
Oil refineries, manufact. of coke	23
Chemical, rubber and plastic manufact.	24-25
Non-metallic mineral prod. manufact.	26
Manufacture of basic metals	27-28
Manufacture of machinery and equipment	29-35
Other manufacturing	36
Electricity, gas and water supply	40-41
Construction	45
Services	60-95
Sewage and refuse disposal, sanitation and similar activities	90
Waste generation from households	-

Appendix B

The EWC-stat-codes used in the project.

	Non-hazardous waste
EWC-Stat-kod	***Avfallsfraktion***
01.2, 01.4, 02, 03.1	Acid, alkaline or saline wastes, Spent chemical catalysts , Chemical preparation wastes, Chemical deposits and residues
03.2, 11	Industrial effluent sludges (wet weight), Common sludges
6	Metallic wastes
07.1	Glass wastes
07.2	Paper and cardboard wastes
07.3	Rubber wastes
07.4	Plastic wastes
07.5	Wood wastes
8	Discarded equipment
08.1	Discarded vehicles
08.41	Batteries and accumulators
9	Animal and vegetal wastes
10.1	Household and similar wastes
10.2	Mixed and undifferentiated materials
10.3	Sorting residues
12	Mineral wastes excl. 12.4 and 12.6
12.4	Combustion wastes
	Sum
	Unspecified fractions from Waste in Sweden 2004
	Total according to SMED
EWC-Stat-kod	**Hazardous waste**
01.1	Spent solvents
01.3	Used oils
01.2, 01.4, 02, 03.1	Acid, alkaline or saline wastes, Spent chemical catalysts , Chemical preparation wastes, Chemical deposits and residues
03.2, 11	Industrial effluent sludges (wet weight), Common sludges
6	Metallic wastes
07.1	Glass wastes
07.5	Wood wastes
07.7	Waste containing PCB
8	Discarded equipment
08.1	Discarded vehicles
08.41	Batteries and accumulators
10.2	Mixed and undifferentiated materials
10.3	Sorting residues
12	Mineral wastes excl. 12.4 and 12.6
12.4	Combustion wastes
12.6	Förorenade jord- och muddermassor
	Sum
	Unspecified fractions from Waste in Sweden 2004
	Total according to SMED

Appendix C

071204

Questionnaire to companies- Questions regarding waste prevention at industries
1) Please describe how your company is working with waste management today

- What fractions are regarded?
- What fraction dominates?
- How are these fractions taken care of? Are they treated externally or internally?
- Is there a market for the sorted waste?

2) What kind of waste is mainly generated within your company?

3) Have you implemented measures to reduce material use/waste amounts?

- Within the production?
- At purchase?
- At sub delivery?

Please describe how the work with the measures are being done.

4) Have you done or are you planning to implement any changes (such as changes within the production, education of the staff, material change etc.)?

5) Have you met any obstacles in the attempt to decrease the amount of waste? If so, how did you overcome these obstacles?

6) What are the costs for the measures? (SEK/a, SEK/tonne)

7) What is the outcome of the measures? (cost savings, savings in tonnes)

8) Can we include your name in our research study?

Supplement:

S1) How large it the costs for waste management compared to raw material costs, process costs, labour costs?

S2) If the waste handling costs would double, what measures would you take?

S3) If there was an ideal situation of "zero waste", which waste fraction do you think would be easiest to reduce? Which would be the hardest to reduce?

S4) Is there anyone else at your company you recommend me to talk to?

Appendix D

080110

Questionnaire to producers' organisations
1) What questions within the waste management area are of current interest within your sector?

2) What residual or waste fractions do you consider being waste in your sector?

3) What current work is there on waste prevention? Vilket arbete pågår inom avfallsprevention?

3) What doe waste prevention cost and what are the effects in your sector.

Appendix E

Companies contacted, person and date.

Company	**Date and person**
The forest industry	
Finndomo, Hässleholm	20071205, Greger Jonsson
Hjältevadshus, Hjältevad	20071205, Lars Ekdal
Elitfönster, Vetlanda och Lendhova	20071205, Line Nilsson
Kinnarps, Jönköping	20071206, Tomas Ekström
Tarkett, Ronneby	20071206, Peter Okmark, Leif Göthammar
Södra Cell, Värö	20071214, Roine Myrin
The steel industry	
Pacwire	20080114, Gunnar Bohlin
SSAB Merox	20080114, Hanna Friberg
"Good examples" (Swedish EPA, 2002)	
Enics, Västerås (formerly Flextronix)	20071214, Tomas Rågeberger
ABB Service, Ludvika	20071217, Stefan Wik
IAC, Färgelanda (formerly Lear Corporation)	20071214, Jimmy Kleibrant
ICA, Västerås	20071214, Lennart Östman
Organisation	
Skogsindustrierna (Swedish Forest Industries Federation)	20071214, Kristina Wicklund
Jernkontoret (the Swedish Steel Producers' Association)	20071215, Hélène Axelsson

Appendix F

The gross list of input data on waste prevention case studies of the literature survey. The references are listed in appendix G

Nr	Ref	Name	Reduced amount of waste [ktonne]	Cost/tonne	Cost [kSEK]	Year	Sector	Code	Measure	Of total [%]	Saving [k£]	Unit
1	1	Aire&Calder	4,8	1 246	5 983	92-'93					3 350	£
2	1	Catalyst	12	1 189	14 265	93-'94					2 300	£
3	1	Dee Catchment	87	35	3 020						4 550	£
4	1	Don Rother Dearne	(5 100 m3)		3 259						565	£
5	1	Hereford and Worcester	-		367						250	£
6	1	Humber Forum	18	163	2 935						1	£
7	1	Knowsley	-		226						95	£
8	1	LWMI	13,7	214	2 935	94-'95	Machinery	29-35		47	1 300	£
9	1	Medway and Swale	116	1	141						2 155	£
10	1	Merseyside	-		0						5 300	
11	1	Tayside Food	-		536						291	£
12	1	WEFT	0,023	7 362	169		Textile				371	£
13	1	WMWM	1,3	228	296						895	£
14	14	Pilkington	1,3	1 520	1 975		Glass (England)				53	£
15	15	Agrochemical	2	1 185	2 370		Chemestry					€
16	16	Joseph and Jesse Siddons Ltd. 1999.	0,3	56	17	99	Foundry (England)	27-28		23	8	£
17	17	Armatide Shank, glace use	0,023	307	7		Sanitaryware manufacturer	26	Process modification reduced virgin glace use	30	6	£
18	17	Armatide Shank, glace use	0,435	3 406	1 482		Sanitaryware manufacturer	26	Process modification reduced virgin glace use	40	102	£
19	17	Armatide Shank, glace use	0,462	0	0		Sanitaryware manufacturer	26	Process modification reduced virgin glace use	20	126	£
20	17	Armatide Shank, glace use	0,462	0	0		Sanitaryware manufacturer	28	Installation of robotic sprayers to increase production flexibility gave also reduced virgin glace use	10	126	£

21	18	Food										
22	18								Largest saving potential for raw material, other input and electricity. Main "possibilities" for savings through technology change 60% see table 3.5. 30% "procedural change"			
23	18	Total of entire study	1,4	7 317	10 244	97-'00	Food	15-16	30-40% (up to 50%) reduction in raw material wastage	5		
24	18	of which	1,400									
25	18	technology change	0,860	11 261	9 679	97-'00	Food	15-16	Division between savings in tonne from table 3.5 are assumed to be the same as the division between savings in pound	5		
26	18	procedural change	0,432	1 306	564	97-'00	Food	15-16		3		
27	18	other without capital cost	0,108	0	0	97-'00	Food	15-16	Good housekeeping, input change, product modification, other	2		
28	19	Food										
29	19	Total of entire study	1,4			97-'00	Food	15-16	30-40% (up to 50%) reduction in raw material wastage			
30	22					03-'05	Mix					
31	23	WREP, mean					Manufacturing				8 733	£
32	23	WREP, total									148 459	£
33	23	KARE, mean					Manufacuring and transport/ warehouse				6 180	£
34	23	KARE, total									86 528	£
35	24											
36	25	Phillips 2004										
37	26	Phillips 2006										
38	27	NREP									346 793	£
39	30	East Sussex betre rural, only waste	176			05-'06	Farming, hotel				32 280	
40	30	East Sussex betre rural				05-'06	Farming, hotel				272 000	
41	31	Cosby waste not					Mix					
42	32	Carletti A/S				99	Food	15-16	Slimeline production		100 000	DKR/yr
43	32	Bent brandt A/S	80%			99	Wholesale trade with glass, porcelain, wallpaper and cleaning agent	5 144	Packaging adjustment and reduced repackaging			DKR/yr
44	33	Large-scale kitchen	50			02	Large-scale kitchen operation	555	Adjustment of portioner regarding number of persons		500 000	DKR/yr
45	34	Roulund	99			04	Rubber	25	Reuse within production, reduced raw material			

46	35	Foundry	200			04	Foundry (Denmark)		Reuse within production, reduced raw material		2,5milj/år	DKR/yr
47	36	Wood products	25%			99	Wood furniture		Automatic cutting-out			DK
48	36	Ifölge Graco Industriudstyr	20%			99			Introduced adjustable spray mouthpiece for spray painting, air mixture intake, education of the spray painters.			
49	37	Rubber industry	36						Better internal sorting, relocation of containers. Rubber went to inciniration before. Now it is used to replace raw material			
50	37	Hempel Manufacture of paint, varnish, ink						24	Slimline production when products are changed		120 000	DKR/yr
51	38	Kitchen and bathroom modules	-50%						Factory assembly of kitchen and bathroom modules that are put together, transported and installed at serial production (hotel, apartments)			
52	39	General Mills	290,56			06	Food, baking	15-16	Became aware of a large loss due to rests that got burnt and stuck. Changed production and recipe.		760 000	USD/yr
53	40	Custome foams	34						Cutting-out, formation of plastic foam skum blocks due to customers wishes. For sound isolation, packaging etc. An increased quality controll of incoming material, an increased accurancy in the production process and product specifications. Less careless mistakes.			
54	41	Scandiadam	-50%				Car repair shop		Recycling system for spray cans. Reduces the amount of packaging waste and the amount of oil spillage			
55	41	HMC Bauer	26				Metal industry		Manifacures metal products such as tool clips, fans etc. A smaller production assortment and better production organisation reduced the spill.			UK
56	41	Spillers Speciality Feeds	88				Animal food		Better process control			UK
57												
58	42	Food, drink and Tobacco			379		Food, drink and tobacco		Reduced raw material use due to process improvements.	Summary of 65 project within Waste Minimisation Clubs in England	0	£
59	42	Textiles, leather and clothing			101		Textiles, leather and clothing		Reduced raw material use due to process improvements.	Summary of 65 project within Waste Minimisation Clubs in England	0	£
60	42	Coke, petrol and nuclear fuels			3		Coke, petrol and nuclear fuels		Reduced raw material use due to process improvements.	Summary of 65 project within Waste Minimisation Clubs in England	0	£

61	42	Chemicals and man-made fibres			545		Chemicals and man-made fibres		Reduced raw material use due to process improvements.	Summary of 65 project within Waste Minimisation Clubs in England	0	£
62	42	Basic metal and metal products			128		Basic metal and metal products		Reduced raw material use due to process improvements.	Summary of 65 project within Waste Minimisation Clubs in England	0	£
63	42	Engineering and allied industries			145		Engineering and allied industries		Reduced raw material use due to process improvements.	Summary of 65 project within Waste Minimisation Clubs in England	0	£
64	42	Other manufacturing			177		Other manufacturing		Reduced raw material use due to process improvements.	Summary of 65 project within Waste Minimisation Clubs in England	0	£
65	43	Defra										
66	44	Cfab	100%=37 tonnes			99	Metal industry		Cleaner production alternatives gave reduction in cyanide waste	Ireland, the total programme expenditure was 3 million € for various types of actions		EURO
67	44	Hitech Planting	60%			99	Metal industry		Cleaner production alternatives gave reduction in hazardous waste	Ireland, the total programme expenditure was 3 million € for various types of actions	-	EURO
68	44	SIFCO turbine components	25%			99	Metal industry		Cleaner production alternatives gave reduction in chemicals use	Ireland, the total programme expenditure was 3 million € for various types of actions	91 000	EURO
69	44	Coates Lorilleux	74 tonnes			99	Metal industry		Reduction in packaging waste (plastic and metal)	Ireland, the total programme expenditure was 3 million € for various types of actions	28 000	EURO
70	44	Yves Rocher	67%			99	Printing ink		Cleaner production alternatives gave reduction in raw material	Ireland, the total programme expenditure was 3 million € for various types of actions	75 000	EURO

Appendix G

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7 See [1], Case study Humber Forum

8 See [1], Case study Knowsley

9 See [1], Case study LWMI

10 See [1], Case study Medway and Swale

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