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Pulp Fiction

- effects of climate control policies on the Swedish pulp and paper industry

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Abstract

Title: Pulp Fiction - effects of climate control policies on the Swedish pulp and paper industry.

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Issues: One reasonable effect of emissions trading is arising incentives for cutting fossil fuel usage. One effect of the Swedish tradable green certificates is revenues for electricity producers using renewable energy sources. The two instruments can be supposed to affect electricity prices. All these three matters are important to the pulp and paper industry. In order to adjust, a number of energy related technological changes can be carried out in the pulp and paper mills.

Purpose: The purpose is to estimate changes in costs and revenues of an integrated sulphate paper mill and a TMP mill followed by new climate control policies and energy related improvements in the mills.

Methodology: Literature studies and interviews were used to shape two plausible but extreme scenarios for prices on emission allowances, green certificates, electricity and raw material. Literature studies and interviews were also used to create two typical Swedish pulp and paper mills and a list of possible energy related improvements. The analysis was done through applying the two scenarios on the two case mills and the possible improvements.

Conclusions: The pulp and paper industry is affected by climate control policies, directly via revenues from green certificates and partly by potential selling of emission allowances, but mainly indirectly through higher electricity price and under one scenario by higher prices of raw material. Threats as well as opportunities were found. The positive cash flow of a number of analyzed possible measures could alter the profit largely, compared to present profit and to profit/loss under the scenarios.

Keywords: Climate control policy instruments, emissions trading, tradable green certificates, thermo mechanical paper production, integrated sulphate paper production, pulp, energy utilization, and electricity price.

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We also want to thank a large number of Vattenfall employees for their friendliness and willingness in answering our questions as well as the people in the forest industry we have been in touch with.

Lund and Stockholm, June 2004

Carl-Johan Andersson Pontus Löfstrand

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1 Introduction

This chapter tells the background, issues, purpose, structure and scope of the master thesis.

1.1 Background

1.1.1 Major Swedish export industry

The forest industry is one of the most important industries in Sweden with a share of Swedish export corresponding to almost 15per cent. The largest part of the forest industry is the pulp and paper industry regarding turnover as well as number of employees.[1] The pulp and paper industry is energy-intensive and is utilizing about one half of the total energy used in the Swedish industry. The pulp and paper industry is also a large producer of energy in the form of biofuel from wood and electricity. [2]
There are two different ways of making pulp, either in a chemical process or in a mechanical process. The chemical process is mostly based on energy produced from wood but fossil fuel is also used.
The mechanical process of making pulp is much more electricity-intensive but fossil fuel is an important ingredient also in the mechanical process.
The demand for pulp and paper products is still rising and therefore the production of pulp and paper is also growing. Since the middle of 1970 the electricity and biofuel utilization in the pulp and paper industry has increased at expense of fossil fuel utilization that has decreased and has stabilized over the last five years.[3]

1.1.2 Major climate policy changes

During the 1990´s global warming became one of the most important international environmental issues. Human beings seem to have influence on global climate through emissions of gases with greater heat capacity than ordinary air causing the so-called greenhouse effect. The greenhouse gas having the biggest influence on the greenhouse effect, due to volumes of emission, is carbon dioxide, CO_2. [4] This thesis will not investigate the existence and reasons of global warming any further.
Limiting the emission of greenhouse gases can generally be done in three ways:

1. Reduction of energy usage and thereby reduced emissions.
2. Switching energy sources.
3. Taking care of the emitted gases.

A switch from fossil fuels like oil and coal to biofuel like wood, bark, ethanol etc, would mean decreased net emissions of CO_2. This is due to the fact that firing biofuel, like wood, gives no net increment of CO_2 because growing forests are rebinding CO_2.

[1] Skogsindustrin 2002-En faktasamling (2003), Skogsindustrierna
[2] Energianvändningen inom industrin (2001), Energimyndigheten
[3] Skogsindustrin 2002-En faktasamling (2003), Skogsindustrierna
[4] Bernes, Claes (2003), En varmare värld –Växthuseffekten och klimatets förändringar

Due to the interest for climate policy the Kyoto protocol was agreed on in Kyoto 1997, aiming to limit and reduce the emissions of the most significant gases. The Kyoto protocol constitutes maximum emissions of the major greenhouse gases for the industrialized countries during the time period 2008-2012. Sweden was allowed by the EU to increase emissions by four per cent for the time 2008-2012 but has voluntarily chosen to decrease emissions by four per cent, compared to the emissions in 1990.
One outcome of the Kyoto protocol is the tradable emissions allowances, that CO_2-emitters are obligated to posses to cover their actual amount of emissions.
Emissions trading between companies within the European Union (EU) will start 2005.[5]

A parallel climate policy instrument is the system with green certificates, introduced in Sweden and a number of additional EU-countries in order to increase the incentives for using renewable energy sources. The green certificates are given free of charge to producers of renewable electricity and electricity users have an obligation to buy a certain amount of certificates.[6] Since the owner of green certificates has the possibility to sell the certificates, a new opportunity of earning money has arisen for biofuel producers, such as the pulp industry[7].

1.1.3 Major Vattenfall customers

Vattenfall is the largest electricity company in the Nordic region and the fifth largest in Europe. Vattenfall has got over 34 000 employees, had a net sale about 100 000 MSEK in the year 2002, and is fully owned by the Swedish government.[8]
The pulp and paper industry is an important sector for Vattenfall, because it demands both large amounts of electricity and other kinds of energy solutions. Consequently Vattenfall is interested in the changed market conditions for their customers and how they could handle the new situation caused by climate policies.

[5] Bernes, Claes (2003), En varmare värld –Växthuseffekten och klimatets förändringar
[6] Larsson, Erik et al (2003), Ekonomiska styrmedel inom energiområdet
[7] Lindvall, Per (2004-01-29) Dagens industri
[8] Vattenfall (2002),Vattenfall Annual Report

1.2 Issues

The environmental policy instruments, i.e. green certificates, emissions trading, taxes and subsidies have effects on manufacturing industries, the energy system and the energy producing companies. As a consequence also the business environment of energy producers and energy consumers is affected. The energy usage of the pulp and paper industry is complex and therefore, business solutions of energy producing companies for pulp and paper producing firms are also complex.

The effects of the new climate control policy instruments, green certificates and emissions trading system[9], are unknown to a large extent. The certificates give substantial incomes for electricity producers using renewable energy sources. The emissions trading system is intended to give incentives to cut fossil fuel usage and is expected to raise electricity prices. Prices and effects of emissions allowances and green certificates are important factors for the paper- and pulp making industry and need further analyzing.

Very long-term investments are common in the pulp and paper industry; in some cases the expected technical lifetime is longer than 40 years. For an old mill there are possibilities to make major improvements in the energy utilization according to the best available technology today. But because of the size and the long term of investments a large share of certainty is desirable when investing. Describing possible energy related improvements in the pulp- and papermaking processes is an important issue in this thesis.

The pulp and paper industry is highly energy intensive and uses fossil fuel, electricity as well as biofuel. Depending on the produced product in the mill, the kind of energy utilization differs. The sulphate pulp making process uses a lot of steam while the thermo mechanic pulp making process uses a lot of electricity. This situation makes every little increase in purchase price of energy a huge amount for the mills to handle.

Lots of heat is involved in the pulp making process. Thanks to the recovery of heat it is possible to use the steam in backpressure turbines and the outcome is environmental friendly electricity. The large amount of produced heat makes the pulp and paper industry a major producer of green electricity and is therefore both a supplier as well as a competitor to Vattenfall.

Up to today extensive theoretical and practical studies have been done in the field of energy optimization, substitution of energy sources, heat, steam and waste recovery in the pulp and paper industry. Some recent macroeconomic studies[10] analyze the impacts of climate policy on gross domestic product (GDP), electricity prices and the

[9] Note that the term emissions trading or emission allowances are used as a simplification at this point, further information about it and other flexible mechanisms is described in the chapter “Flexible mechanisms”.

[10] For example Econ on emissions allowances and electricity trading, ITPS and CPB on GDP and others

pulp and paper industry in general. The two fields of studies described leave a gap on the subject how costs and revenues are affected, with and without changed energy utilization, of pulp and paper mills, by climate policies. The general industry level is reached through specific cases, unlike existing macroeconomic studies that are applied on the industry without examining energy technology and energy usage on the mill-level.

1.3 Purpose

The purpose is to estimate changes in costs and revenues of an integrated sulphate paper mill and a TMP mill followed by new climate control policies and energy related improvements in the mills.

1.4 Structure of the thesis

This thesis is not sharply divided into theory, empirics and analysis, instead a series of analyses that are combining theory and empirics are used. Also the different types of work like reading, interviewing, analyzing and writing are done in an iterative mode, rather than separated operations.
The scenarios are created by the thesis workers and audited in a seminar consisting of a group of specialists at Vattenfall. The description of case mills, reference mill and energy technology improvements are also done first by the students and then audited by specialists at Vattenfall. The different parts of the thesis and their connections are described in figure 1-1:

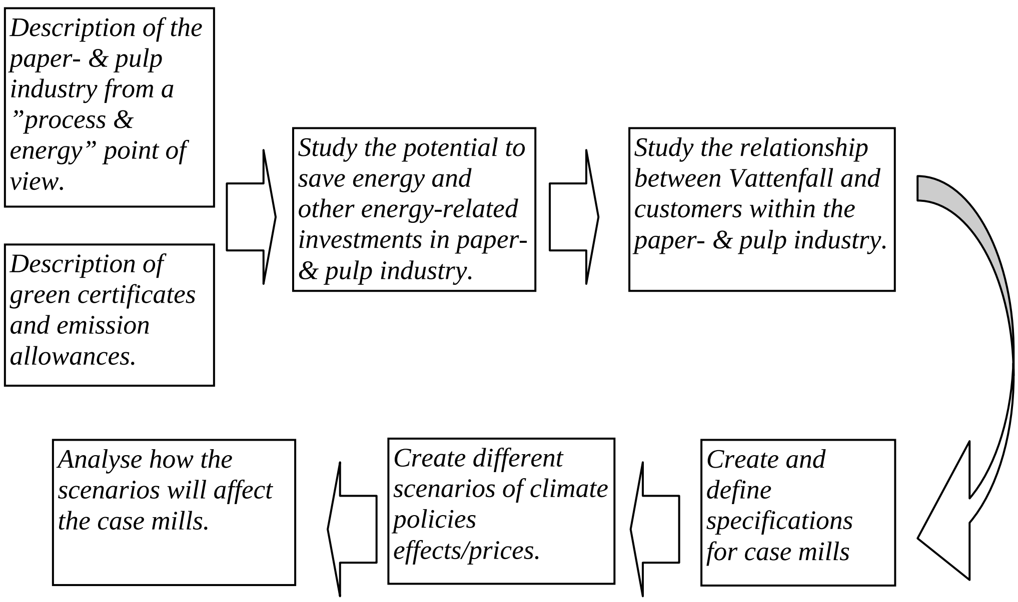

Figure 1-1. The components of the thesis and the chosen sequence of work.

1.5 Scope and delimitations of the thesis

Two scenarios are being built from one set of input and intermediate parameters with different values, the thesis focuses on the outcome of the scenarios applied on case mills, giving the output parameters. The input parameters are the new climate control policies and the intermediate parameters are such parameters largely affected by climate control policies. Setting a value on these input parameters and intermediate parameters includes some analyzing, however it is impossible to undertake all analyzing necessary to give a perfect estimation of for example electricity prices within the frames of this thesis. Electricity prices will be analyzed from an emission trading and a green certificates point of view, using a ceteris paribus-approach, everything else hold equal. This means that all other mechanisms affecting the electricity price are neglected, due to the large number and complexity of the factors. The thesis only comments CO_2-taxes and subsidies on environmental friendly power production shortly and does not analyze changes of CO_2 taxes and subsidies.

The used time horizon is 2012, which is a very short time when considering energy investments. However nothing specific is constituted by the Kyoto protocol beyond 2012.

Basically all Swedish pulp and paper mills are unique, in order to be able to express some kind of general conclusions without examining everyone of the 59 mills, two case mills are used and compared to the best technology available. The two case mills have the most common production technology, size and age. Many of the companies operating pulp or paper mills in Sweden also operate mills in other countries, these are not considered in this thesis.

This study considers some variables as input, intermediate output. Electricity price is for example affected by emission allowances and also affecting the energy usage.
The *input parameters* are:

- Price of emissions allowances
- Price of green certificates

The *intermediate parameters* are:

- Electricity price
- Price of raw material

The *output parameters* are:

- Specific energy usage
- Electricity production
- Energy-mix
- Changed production; process and/or product
- Energy investments

2 Methodology

The methodology chapter describes in what way the study is undertaken in order to fulfill the purpose, described in the previous chapter. The authors have tried to write this chapter in an accessible and straightforward way.

2.1 Choice of practical methods

2.1.1 The using of scenarios and case mills

Two plausible future developments are being set up through giving the input parameters and intermediate parameters different values. These developments will be called scenarios from this point. The two scenarios used in this thesis are extreme rather than being the most likely, in order to make some kind of results deviating from the present situation. The scenarios will be applied to the two case mills of the thesis, giving a set of output parameters. Parameters are not totally defined on forehand, but have been added, excluded and modified in order not to exclude any possible outcomes.

The causality of the parameters, or variables can be displayed in figure 2-1:

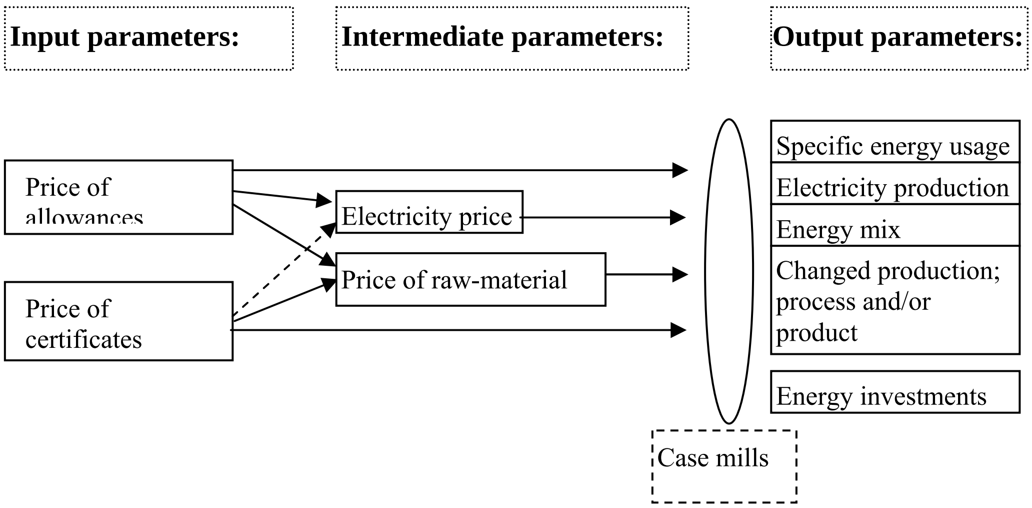

Figure 2-1. The causality of the parameters of the thesis.

2.1.2 The creation and auditing of scenarios

The two scenarios of the thesis have been created through analyzing interviews, reports, articles and academic literature. After finishing the scenarios an auditing meeting with experts of different fields from Vattenfall was carried out in order to grant validity of the scenarios. The meeting verified some parameter values and proposed some changed values, probably resulting in more reasonable values of the input- and intermediate parameters and thereby improving validity of the scenarios.

2.1.3 The selection of manufacturing technology

There are several different ways of making pulp and paper, some more popular than others. This master thesis has chosen to select the two most frequently used processes of producing paper in each segment: an integrated sulphate mill and a thermo mechanical mill. Thanks to this selection the majority of Swedish mills is represented.

2.1.4 The case mills

In each selected segment of making pulp and paper a mill is made up to apply the scenarios upon. The technical data specifications are taken from different existing mills in Sweden and mixed into an illustrative "typical" Swedish mill with the intention of representing a general Swedish mill in each segment. The interested parties of the thesis thereafter confirm the relevance and probability. Through creating very typical mills, the results of these mills can be said to be relevant, to a large extent, also for the pulp and paper industry in general.

2.1.5 The reference mills

The case mills are compared with best available technology in order to demonstrate possible improvements in each segment. In one case a reference mill illustrates the potential improvements of energy savings and in the other case the improvements are exemplified by manufacturers most up-to-date research and development as well as through recent university studies.

2.1.6 Influences of having an orderer

This thesis is ordered and paid for by Vattenfall, this fact has a number of consequences, for example:

- A rich supply of information and contacts, supplied by Vattenfall. Of course this causes a risk of biasing the study.
- The purpose was partly handed over to the thesis worker, however the authors consider themselves to have the amount of liberty desired.
- Resources have been available for e.g. travels, photocopies and phone calls.
- The validity and relevance of the purpose might be supported by the fact that someone is willing to pay for the actual issue. However the validity and reliability of the result of the study can be detoriated.

2.2 Information gathering

In order to gather background information as well as analyzed data, interviews, company reports, scientific reports and academic study books have been used. The background information is mainly based on secondary data. The interviews give primary data[11] but are mainly aimed at bringing inputs for analyzes.

[11] Darmer, P & Freytag, v. F (1995), Företagsekonomisk undersökningsmetodik

2.2.1 Interviews

Interviews are used for information gathering on specific issues, for overall conclusions of the topic of the thesis as well as for comparing and verifying data. The interviewees have different backgrounds, such as Vattenfall employees in different fields, scientists, process engineers of the pulp and paper industry, lobbyists of the pulp and paper industry, etc. Some of the interviewees are specialists in one field and some have understanding of the many different fields concerned in this thesis. Suggestions upon whom to interview are collected from supervisors both on Vattenfall and Lund University as well as from interviewees. The interviews are conducted in a semi-structured way, a list of subjects and quite open questions were used in order to start discussions on the topics of the thesis. The interview answers were gathered in a spreadsheet, giving an overview of the answers and a handy possibility to compare different answers.

2.2.2 Literature studies

On the topic climate control policies only sparse academic study literature could be found, when literature retrieval was made, probably because the topic is very young. To gather information on this topic reports of different kinds and governmental directives have been used. On the topic pulp and paper technology and energy technology academic books exists, on this topic also consultant reports have been used. Of course also interviews have brought information on these subjects.

2.3 Criticism of the study

2.3.1 Criticism of the sources

Lots of readings and suggestions for interviews have been handed over by Vattenfall, this has been comfortable for the thesis workers, but also exposed the thesis to the risk of biasing the study. The thesis workers have hold in mind to compare answers of different interest groups. The spreadsheet displaying all interview answers improves possibilities to compare opinions and to reveal biased answers.
Some of the reports used are analyzing reports, which can cause a bias compared to using non-analyzing and non-valuating reports.

A number of risks are connected to using interviews as source. One is the risk that the interviewee answers in a way he or she thinks is desired by the interviewer. The statements of the interviewees might also be miss-interpreted.[12] Both thesis workers have taken part of virtually all interviews, which reduces the risk of miss-interpretations. When combining questions on specific matters and on conclusions about effects about the same matters the interviewer faces a significant risk to influence and steer the interviewees' answers. The interviewers have been aware of these risks and have sometimes told the interviewee to try to answer as neutral to earlier discussions as possible.

[12] Eriksson, L.T. & Wiedersheim, P.F. (1997), Att utreda, forska och rapportera
Holme, I M & Solvang, B K (1997), Forskningsmetodik Om kvalitativa och kvantitativa metoder

2.3.2 The KAM 2-mill is not an integrated mill

The reference mill KAM 2 used as reference mill for the integrated sulphate paper mill, has no paper production, it produces only market pulp. KAM 2 can be used as a reference for the sulphate producing process of the integrated sulphate paper case mill, but a reference for the paper producing processes has not been used. This gives two risks:

1.Using the same pace for improvements in the paper producing part of the mill as in the pulp producing part of the mill might be unrealistic.

2. Converting facts for market pulp production to pulp production in integrated mills might be hazardous since the pulp producing processes are partly different.

2.3.3 Weak connection between some parameters

There are connections between most of the parameters of the used scenarios, but no strong connection between prices on green certificates and emissions allowances could be found. The chosen combinations of levels of emissions allowances and green certificates are therefore somewhat stochastic. This may cause unrealistic situations, as well as realistic situations, which alters the analysis.

2.4 Aspects on theory of science

2.4.1 Combining qualitative and quantitative methods

The thesis is based both on qualitative and quantitative data, the lion share consists of qualitative data in the form of description of climate instruments and pulp and paper making technology. The technical data and price data on e.g. electricity are of course also partly of a quantitative nature. The according descriptions written in the thesis reflect almost the same mixture of text respectively numerical data, where the numerical descriptions has got somewhat less room.

The analyses are quantitative to a higher extent than the information gathering, however parts of the analyses are only commentating on the subjects.

The analyses are undertaken in a more quantitative way since it improves possibilities to generalize more[13] upon effects on the Swedish pulp and paper industry. Generalizing might sound unpleasant in an everyday context, however a generalization is the first step on the road to understanding a complicated relation[14].

Qualitative methods are used in the initial information gathering in order to increase validity[15], i.e. to secure that the right matters are collected, which is extra important to care about since this thesis deals with a quite unexplored field. Combining qualitative and quantitative methods in attempt to illuminate the problem from different points means improving validity[16].

[13] Holme, I M & Solvang, B K (1997), Forskningsmetodik Om kvalitativa och kvantitativa metoder

[14] Darmer, P & Freytag, v. F (1995), Företagsekonomisk undersökningsmetodik

[15] Holme, I M & Solvang, B K (1997), Forskningsmetodik Om kvalitativa och kvantitativa metoder

[16] Darmer, P & Freytag, v. F (1995), Företagsekonomisk undersökningsmetodik

2.4.2 Validity and reliability

Whether a study really describes the subject can be examined through analyzing validity and reliability. The following model, figure 2-2, shows the relationship: Reliability of information is about whether we really measure what was said to be measured, which is important to consider when undertaking quantitative studies. Reliability of a study exists when collected information is reliable. A threat to reliability is the problems of testing for example price analysis, the perfect test of reliability can be said to be real life testing.

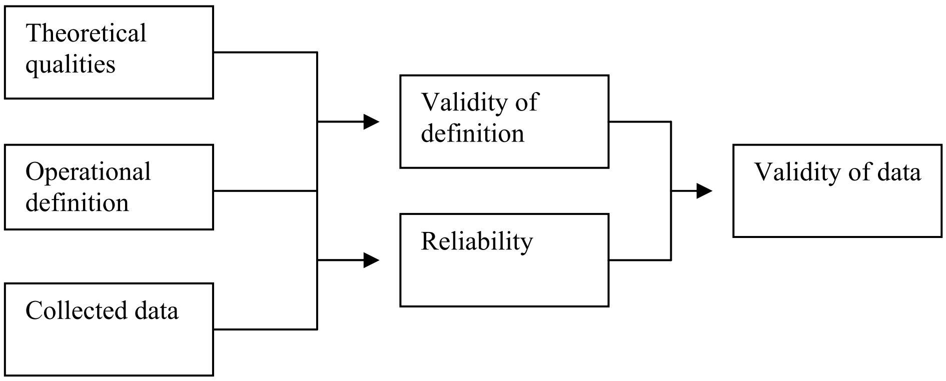

Figure 2-2. The connections behind valid data.

Using secondary data can be a threat to validity[17]. The scenarios have been audited by practioners of the fields, which grant both some reliability and validity. The interview-guide has also continuously been refined to increase reliability and hopefully also validity of the results.

[17] Holme, I M & Solvang, B K (1997), Forskningsmetodik Om kvalitativa och kvantitativa metoder

3 Description of climate control policy instruments

This chapter describes the climate control policy instruments dealt with in this thesis. The main instruments are the flexible mechanisms being a consequence of the Kyoto protocol and other international summits, the second being the green certificates constituted by the Swedish government.

3.1 Flexible mechanisms

3.1.1 Description of the Kyoto protocol and its components

The Kyoto protocol of 1997 contains limitations of emissions of greenhouse gases for the greater part of industrialized countries that have ratified the protocol. The greenhouse gases defined in the protocol are:

Carbon dioxide (CO_2)
Methane (CH_4)
Nitrous Oxide (N_2O)
Hydrofluorcarbons (HFCs)
Perfluorcarbons (PCFs)
Sulphur Hexafluoride ($SF_{6)}$

Carbon dioxide is the main contributor and the one upon most emphasis will lie.
The Kyoto protocol contains four kinds of mechanisms, called *flexible mechanisms*, intended to reach cost effective measures independent of national states, these are:

- *Joint implementation, JI;* constituting possibilities of reducing emissions through projects in other countries with emission obligations and get Emission Reduction Units, ERU, as compensation. This alternative is interesting for companies with hardly reducible emissions.
- *Clean development mechanism, CDM;* constituting possibilities of reducing emissions through projects in countries without emission obligations, i.e. developing countries. This also renders emission credits for the company financing measurements, called Certified Emission Rights, CER.[18]
- *Emissions trading,* is a system for trading emission allowances between companies within specified regions, for example the EU. The exact name is Assigned Amount Units, AAU.
- *Coal sinks* Carbon dioxide storages like wood generates Removal Units, RMU, which also equals emissions allowances[19].

It is a national issue how the national limitations set by the Kyoto protocol shall be met. Within the EU there will be trading of emissions allowances between companies in industries with high emissions of greenhouse gas, with exception for the transport industry. The national governments will divide the national commitment between the sectors trading emissions allowances and sectors of society that do not have to possess emissions allowances and therefore also do not trade emissions allowances.

[18] Larsson, Erik et al (2003), Ekonomiska styrmedel inom energiområdet
[19] Ibid.

From this point of the master thesis these sectors will be called trading sectors and non-trading sectors. This dividing makes the base for the total national amount of emission allowances allocated to companies in industries obligated to possess emissions allowances.[20] Hence, the total amount of emissions allowances allocated to the trading sectors is a quite national matter.

Initially, under the Kyoto-protocol, Sweden was committed decrease greenhouse gas emissions by four per cent until 2012 compared to 1990. The first period of the Kyoto-protocol is 2008-2012, emission levels are constituted for industrialized countries ratifying the protocol, called Annex A countries. Non-industrialized countries signing the protocol without being obligated to certain emission volumes are called Annex B countries. It is possible for Annex A countries to take emission reducing actions in Annex B countries through the Clean Development Mechanism, CDM.

3.1.2 EU level and Swedish level of emission policy

In addition to the Kyoto-protocol EU has reallocated the national amounts between its member states, called *"The burden sharing agreement"*, and decided to run a testing period during 2005-2007. No absolute maximum levels are decided for the EU testing period, the only restriction is that the national allocations must align with the constituted levels for 2008-2012. The EU-reallocation gives Sweden the right to increase carbon dioxide emissions by four per cent up to 2012, as opposed to guidelines of Kyoto constituting a decrease by four per cent. However Sweden has in addition to EU-regulations decided to decrease emissions by four per cent.[21] [22] It is unclear how this burden is to be shared between trading and non-trading sectors in Sweden.

3.1.3 How and when the emission allowances will be allocated

An emitter initially needs *permits* to have the right to emit CO_2, additionally the emitter needs *allowances* to cover the actual amount of emissions.

The amount of emission allowances allocated to the individual emitting company will in Sweden be based on historical emission data, although some emitters have the possibility to apply for allowances including an extension of production and emissions. Only plants with an effect of 20 MW (input power) or more will be part of the allocation. This makes about 300 plants in Sweden of which 59 are pulp and paper mills. Initially allowances will include no other greenhouse gases than carbon dioxide. For the time period of 2005-2007 the EU-directive constitutes that the member states shall distribute at least 95 per cent of the allowances free of cost, for the time period 2008-2012 at least 90 per cent shall be distributed freely.[23] Hence 5 respectively 10 per cent can for example be sold by auction. The goal for EU is eight per cent less carbon dioxide emissions in the year 2012 compared to 1990. This

[20] Burström von Malmborg, Fredrik et al (2002), Företagsperspektiv på "Joint implementation"

[2121] Bernes, Claes (2003), En varmare värld –Växthuseffekten och klimatets förändringar

[22] Europaparlamentets och rådets direktiv 96/61/EG (2003), 2003/87/EG

[23] Ibid.

probably concludes smaller amounts of allowances for the time period of 2008-2012 than 2005-2007.
A new allocation of allowances should take place every fifth year. The first period of emission allowances is however only three years, 2005-2007. For the time period 2008-2012 limitations might be valid for more greenhouse gases than carbon dioxide. The term carbon dioxide equivalents are used for an amount of the actual gas causing the same effect on global warming as one ton of carbon dioxide. [24]

3.1.4 The Swedish implementation of flexible mechanisms

Näringsdepartementet, the Swedish ministry of industry and trade, has planned the Swedish implementation of the EU-directive mentioned above. At the point of writing it is unclear how adjustment of the Swedish environmental legislation will be done, which is mainly an issue for the ministry of environment, miljödepartementet. Important issues are for example taxes on carbon dioxide and how emission limitations shall be divided between trading and non-trading sectors.
The Swedish allocation of emission allowances to individual firms will be based on their emissions during 1998 – 2001, however the emitters will have the opportunity to apply for extended allowances. Emission reducing actions done before 1998 will not be taken into account. The allocation of allowances to the individual plants will be done no later than October 2004. The Swedish National allocation plan allocates 22,9 mega ton carbon dioxide per year for the period 2005-2007 to the trading sectors, the national allocation plan is now to be ratified by the EU.

3.1.5 The economical mechanisms followed by emissions trading means cost effective emissions reduction

The cheapest greenhouse gas reduction will be done first since the one who can reduce emissions in the cheapest way will make the greatest profit of selling allowances. This makes emissions trading an economically efficient way of reducing emissions.[25] This can be expressed as, the greatest possible emission reduction of greenhouse gases for the money can be achieved. An international market with perfect functionality would mean that the price of emission allowance would reflect the marginal cost of reducing emissions[26].

3.1.6 Joint implementation and Clean Development Mechanism can limit prices in the long run

Joint Implementations (JI) undertaken in other annex A countries or Clean Development Mechanism (CDM) measures undertaken in annex B countries can be used when cheaper emission reductions are possible abroad than at domestic sites. This is likely to appear especially when it comes to modernizing plants in developing countries. A study of implementations done in order to reduce carbon dioxide emissions in India made by German companies shows possibilities to reduce cost of

[24] Europaparlamentets och rådets direktiv 96/61/EG (2003), 2003/87/EG
[25] Burström von Malmborg et al (2002), Företagsperspektiv på ”Joint implementation”
[26] Johansson, B (2003), Nationella mål och flexibla mekanismer

the German carbon dioxide handling[27]. If the amount of cheap possible measure in developing countries is substantial it also means a limiting effect on prices of emission allowances. CDM and JI are parts of the Kyoto protocol but the European directive that links the different mechanisms is not ready at the point of writing. Hence it is unclear when JI and CDM can be credited and when effects can appear.

3.1.7 International prizing

It should be stressed that there will not be different prices of emissions allowances in different EU countries, as a consequence of trading. This means that the effects of the Swedish decision to voluntarily reduce carbon dioxide emission more than constituted by the EU indeed mean a need to buy emission allowances but will only influence European allowance prices very slightly.

3.1.8 Penalty system

According to the directive on emissions trading from the European parliament and council, the penalty fee of exceeding emissions allowances possessed will be 40€/ton carbon dioxide during 2005-2007 and 100€/ton carbon dioxide during 2008-2012. These fees are to be paid in addition to emission allowances, because being fined still means you have to buy emission allowances.[28]

3.2 The green certificates system

Behind the Swedish green certificates system there is another EU-directive, a directive about renewable energy. Some member states have chosen to use guaranteed feed-in systems to promote renewable energy, for example France, Germany and Spain and others have chosen systems for tradable green electricity certificates, for example Sweden. Beside these systems subsidies are also used.[29]

The Swedish system for green certificates introduced in 2003, states that a certain part of energy usage should be produced with renewable energy sources.

The system has two main parts; the right for electricity producers using renewable energy sources to receive an amount of certificates corresponding to the number of MWh produced from renewable energy sources, issued by the government, and the obligation for electricity users to possess certificates. The certificates are tradable and are principally sold from electricity producers using renewable energy sources to electricity users. Energy intensive industries, like pulp and paper, are however excepted from the obligation.

Energy sources considered as renewable and therefore giving the electricity producer green certificates are:

- wind power
- solar energy
- wave energy
- geothermal energy

[27] Böhringer, Cristoph et al (2003), Environmental and resource economics 24
[28] Europaparlamentets och rådets direktiv 96/61/EG (2003), 2003/87/EG
[29] Unger, Thomas (2003), Common energy and climate strategies for the Nordic countries – A model analysis, doctors thesis

- some hydro power
- biofuel

In addition to renewable energy sources, green certificates will also be given to combined heating and power plants firing peat.

Electricity users are obligated to use a steadily growing quota of renewable energy sources, which is done through possession of green certificates corresponding to 7,4 per cent of electricity usage in the first year, 2003. The term quota obligation will be used from this point of the thesis. The quota obligation will increase each year, giving the following quotas:

Year:	Quota of certificated energy usage:
2003	7,4 %
2004	8,1 %
2005	10,4 %
2006	12,6 %
2007	14,1 %
2008	15,3 %
2009	16,0 %
2010	16,9 %

The relative increase above is equivalent to an increase by 10 TWh until the year 2010.[30] About 1500 plants are entitled to receive green certificates; their output is altogether 6 TWh.[31]

Estimations predict that biofuel will represent about 80 per cent of the future additional renewable energy sources, i.e. 8 TWh of foreseen expansion until 2010 of renewable energy sources comprise biofuel[32].

3.2.1 Price ceiling for the first two years

A virtual price ceiling for green certificates is caused by the way the system is constructed. The fine for reluctance to possess certificates, called non-compliance fee, was 175 SEK/MWh for 2003 and 240 SEK for 2004. In future the fine will correspond to 150 per cent of average certificate price of the past year[33]. Hence, 175 respectively 240 SEK plus tax is the maximum price anyone would be willing to pay for certificates, that is the price ceiling for the first two years, 2003 and 2004. The price ceilings including company tax of 28 per cent are 243 SEK and 333 SEK.

3.2.2 The pulp and paper industry and green certificates

As mentioned above energy intensive Swedish industry will be excluded from the quota obligation, i.e. the obligation to possess certificates covering a certain quota of energy usage. Nevertheless the plants producing electricity, using biofuel will receive certificates, this turns some plants into large net sellers of certificates. Many pulp and paper producers gain substantial revenues from green certificates. For example

[30] Regeringens proposition 2003/04:42, Torv och elcertifikat
[31] Eriksson, Lars (2003) Ny Teknik 03-06-17
[32] Eriksson, Lars (2003) Ny Teknik 03-05-14
[33] Regeringskansliet (2003), Frågor och svar om elcertifikat

Rottneros sold green certificates for 7,7 MSEK during the fourth quarter of 2003, which can be compared to an operating profit of 60 MSEK, giving 13 per cent of the operating profit.[34] The Swedish forestry industry has an electricity producing capacity of 4-4,5 TWh multiplied with the certificate price of 249 SEK[35] gives a theoretical value of more than one billion SEK.

3.2.3 The administration and trading of green certificates

The Swedish green certificates are mainly administrated by Svenska Kraftnät, the power grid authority, and by Statens Energimyndighet, the energy authority. Svenska Kraftnät keeps the register of certificate owners, distribute information on prices and do the formal issue of certificates. Energimyndigheten on the other hand approves the sites applying for certificates, register those obligated to possess certificates and approve that they fulfil the quotas.[36]

The Nordic electricity market place, Nordpool has started trading green certificates. Deals are also closed bilaterally and through brokers.

3.2.4 International certificate trade

Beside Sweden, national green certificates also exists in a number of other countries, for example Holland, Belgium, Austria, Italy, Great Britain and Denmark[37]. Renewable Energy Certificate System, RECS, is an additional international voluntary trading system for green certificates with 100 members, of which 70 are trading, in 18 countries. Totally 32,5 TWh RECS-certificates have been issued of which 13 TWh have been used to guarantee consumers renewable energy usage.[38]

The supply side of this market is represented in Sweden through a number of energy plants and industrial plants, demand seems however mainly to exist in Holland because of Dutch national tax relieves connected to possession of certificates[39].

3.3 Taxes and subsidies

The Swedish carbon dioxide emission tax during 2003 was 760 SEK/ton for heating purposes, 180 SEK for the industry and zero for electricity production[40]. Governmental investigation about tax changes as a consequence of emission allowances and green certificates is being performed[41].

This thesis will not investigate the political situation of tax on CO_2 emissions, but assumes unchanged CO_2 taxes. Unchanged CO_2-taxes means increased incentives to cut CO_2 emissions when allowances are introduced, which could be viewed as being in line with ambitious Swedish climate policy targets.

[34] Nyhetsbyrån direkt (2004) Dagens Industri 04-02-05
[35] Certificate price for march according to Vattenfall Supply & Trading newsletter, Traded Markets 1/2004
[36] Svenska Kraftnät Marknad (2003), Elcertifikat- vad är det?
[37] http://www.svk.se/upload/3359/Elcertifikat.pdf , 2004-02-17
[38] http://www.recs.org/, 2004-03-02
[39] Andersson, Nils, Interview, 2004-03-02
[40] Larsson, Erik et al (2003), Ekonomiska styrmedel inom energiområdet
[41] http://www.stem.se, 2004-03-05

Today subsidies exist for e.g. wind power, probably these can be cut when the green certificates proves giving stable revenue for electricity producers using renewable energy sources.

4 The input- and intermediate parameters

In this chapter the input parameters and the intermediate parameters, i.e. certificates prices, prices on emissions allowances, electricity price and price on raw material are analyzed. Later on in this chapter the mentioned parameters are given values and formulated as two scenarios.

4.1 Supply of allowances

At the point of writing some national allocation plans are ready and some are still not finished. During the beginning of this autumn (2004) EU is to audit the national allocation plans. Generous national allocation plans means large supply of allowances and a small need to buy allowances, resulting in low prices on allowances. Primarily caused through lying heavy burdens on the non-trading sectors, in order to still fulfil the EU or Kyoto commitment. Insufficient audits of whether emitters' emissions exceed possessed allowances can also cause excess supply. Probably even more important to supply of allowances are the policies towards the EU-entrants countries. These countries have a lot lower CO_2 emissions than constituted by Kyoto and the EU burden sharing agreement. Ukraine has for example a surplus of 1000 Mton today compared to the Kyoto goal[42], Ukraine is not an EU-entrant but can serve as an example. The emissions reductions are due to the collapse of eastern European heavy industries in the early nineties. The question is whether and how the excess amount of CO_2 will hit the market. Calculations done by Vattenfall show that if all EU-entrants excess CO_2 would be sold, prices on the European market for emissions allowances would be zero[43]. However governments are prohibited by EU competition legislation, to allocate more allowances to companies than needed since it would mean a subsidy. Possibly governments can trade emissions bilaterally, which still probably would alter the emission allowances market powerfully.[44]

4.1.1 Costs for reducing CO_2 emissions

Emissions reductions can be undertaken in a lot of ways and under a lot of different costs. No one would undertake reductions at higher costs than prices of allowances and those who can do reductions at lower costs than existing price level of allowances would do so and sell their allowances, concluding that reduction costs sets allowance prices. Emissions reductions can be carried out in the new EU-countries at costs about 7-10 €/ton[45]. The quantity of these reductions will influence prices on allowances, extensive possible reductions at costs of 7-10 € would give allowance prices at corresponding levels. Figure 4-1 is meant to illustrate the market for CO_2 –reductions.

[42] Point Carbon, Carbon Market Europe April 15 – 2004
[43] Lundgren, Göran, Interview, 2002-03-26
[44] Nelson, Bo, Interview, 2004-03-05
[45] Andersson, Nils, Interview, 2004-03-02

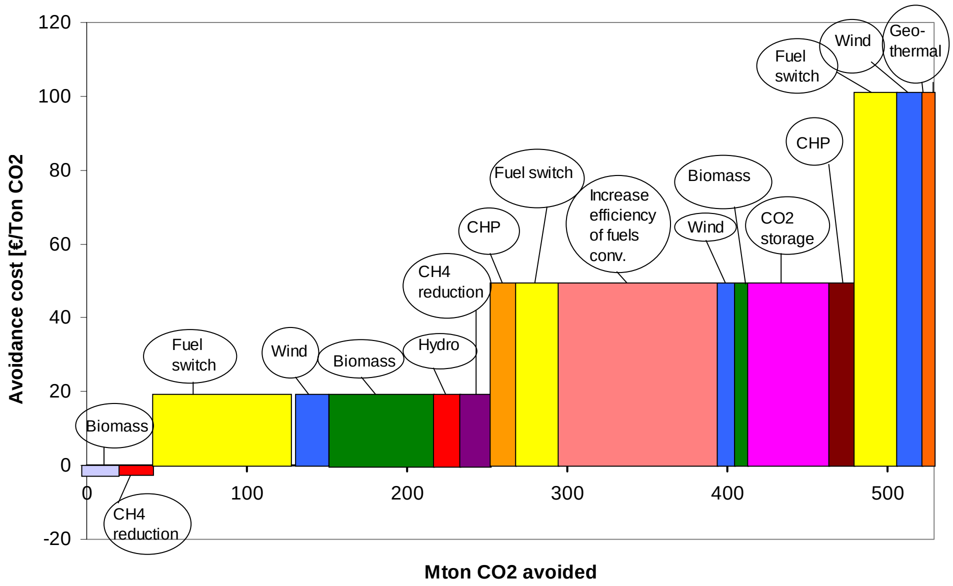

Figure 4-1. Costs for reducing CO_2-emissions.

Note that this figure is intended to show different costs and potentials in illustrative way rather than being an exact source for cost information.[46]

4.1.2 Current experiences of emissions trading

Emission allowances have been traded as highest at prices of 13€/ton, during February, but are now traded at 7,30 €/ton, reported by the analyst company Point Carbon that gathers price data from brokers, deals closed bilaterally remain unknown to Point Carbon[47]. This price drop can be explained by recent publishing of generous national allocation plans in for example Germany. However the total known generosity of allocation plans is to be considered moderate, according to analyst institute Point Carbon[48]. The allocations conclude a slight reduction of emissions, of about 0,5 to five per cent. These quantities are assumed to result in a liquid and functioning market. Over-allocation would lead to prices close to zero and therefore low interest in selling allowances. Normally, financial theory talks about high prices as a cause for low liquidity[49], but it seems logical that extreme prices, both extremely low and extremely high, restrain trade.
The hitherto trade volumes are rather small compared to expected volumes next year, when the EU Emissions Trading Scheme (ETS) starts. The reasons for trading CO_2 already are to learn trading from testing it or because suspecting prices to be better now than when the ETS is started in January. The current prices are a hint about expectations on future prices of ETS.[50]

[46] Figure based on European Climate Change Programme long report June 2001
[47] Point Carbon, Carbon Market Europe April 15 – 2004
[48]Ibid.
[49] Arnold, Glen (2002), Corporate financial management, 2:ed
[50] Carnö, Johanna, Interview, 2004-04-19

If the market will be sound and not struck by over-allocation, fundamental drivers such as weather and economic growth will be most important for prices, according to Point carbon[51]. Other drivers may be more reasonable, such as:

1. In the long run costs for emissions reductions will set prices on a functioning market and
2. Quantity of allocated allowances will set prices in the short run. Figure 4-2 illustrates price statistics for emission allowances during September 2003 and April 2004.

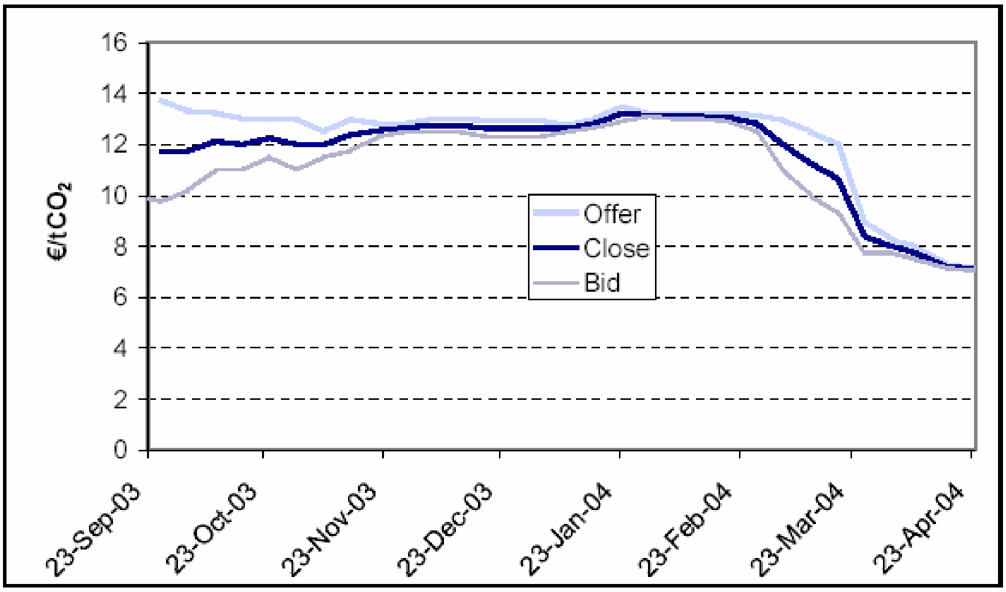

Figure 4-2. Price statistics for emission allowances.

4.2 Prices of green certificates

During 2003 the price of certificates reached the price ceiling of 243 SEK, described in chapter 3.2.1, a driving force behind high prices at the end of the year was the possibility to store certificates over the turn of the year combined with expectations of rising prices due to high fines for 2004. Prices rose to 249 SEK during March but have sank below 200 SEK during April. The reason for falling prices can be caused by less insecurity about the immature market, but most important is probably that the production has been under estimated, there is excess supply of renewal electricity production sources enough for an unknown period of time, which postpones new power plants. Figure 4-3[52] illustrates the price statistics of green certificates in Sweden during January 2003 and March 2004.

[51] Point Carbon, Carbon Market Europe April 15 – 2004

[52] Traded Markets, 4/2004, newsletter Vattenfall Supply & Trading

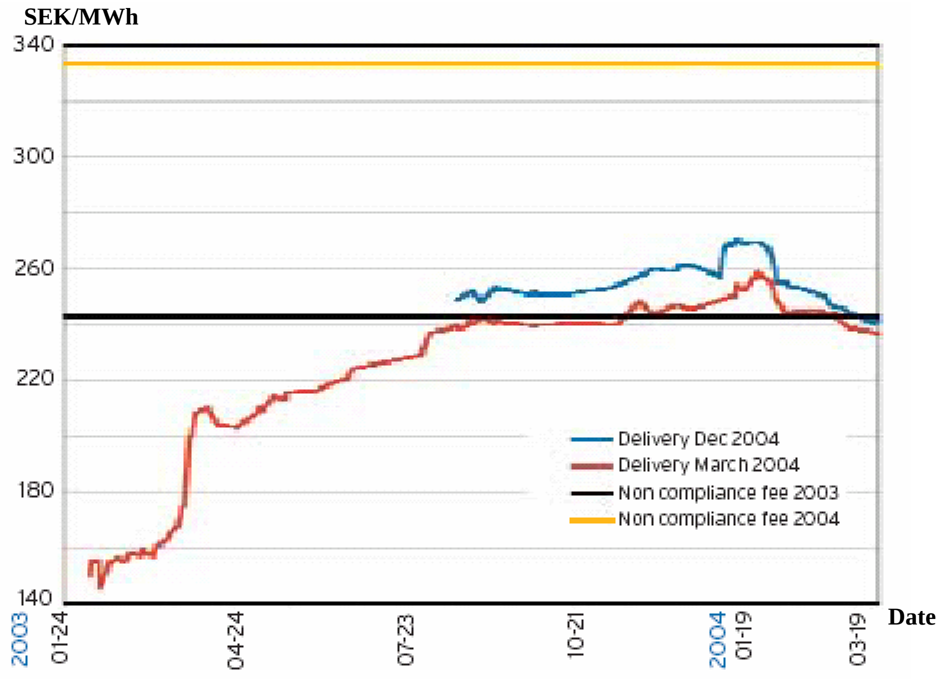

Figure 4-3. Price statistics for Swedish green certificates.

Prices will have to rise up to 300-350 SEK to make power plants, with the available technology of today using renewable energy sources, profitable. Since the quota obligation rises each year it is only a matter of time when these price-levels will be reached, unless new renewable energy sources with cheaper production cost enters the market. However it might take some years until all capacity is used. The green certificates system is being audited at the point of writing and the time period of the system will most likely include ten additional years, covering the time up to 2020. [53] This makes that investors have to deal with a lot less uncertainty, making investments in renewable energy production more attractive, which gives expectations on lower certificates prices.

4.2.1 Emissions trading might lower certificates prices

Increased electricity price due to emissions trading affects electricity demand downwards and therefore also causes less demand for certificates in absolute numbers since the quota is defined as a share of total electricity usage.[54]

4.3 The electricity price

The electricity market is rather complex and therefore is there a brief introduction below to the different mechanisms affecting the electricity price.

[53] Hedenström, Claes, interview, 04-04-16
[54] Unger, Thomas (2003), *Common energy and climate strategies for the Nordic countries – A model analysis*

4.3.1 Price formation

The price formation on the electricity market is complex. There are several factors like the weather conditions, the availability of the power- and transmission plants, the import/export of electricity, etc. affecting the price mechanism. A distinguishing feature for the Nordic market is the dependency on power from hydro plants and in turn the weather conditions. Since 1996 the Nordic electricity market is deregulated and the price volatility is in general larger than traditional raw-material exchange.
On the Nordic power exchange, NordPool, there is an opportunity to buy and sell electricity on the spot market where fluctuations in price are common. On a cold winter's day when the power capacity is reaching maximum there are special power plants with very high marginal cost taken into production and the electricity price increases.[55] The last traded KWh gives the actual market price and the producers are willing to sell when prices meet marginal (variable) production cost of the actual power source. The equilibrium price (market price) is the price at which the quantity demanded equals the quantity supplied. The equilibrium quantity is the quantity bought and sold at the equilibrium price. Markets move towards equilibrium because prices regulate buying and selling plans and because prices adjust when plans do not match.[56] The mechanisms are illustrated in figure 4-4.
When all capacity is used, the price shortly can exceed the marginal cost and this in turn gives even higher electricity prices than the marginal cost motivates[57].

4.3.2 The supply and demand situation of electricity

The demand for electricity changes over the day and night, between weekends and working days, and over the year. The demand is preferably depending on electrically heated households and energy intensive industries like pulp and paper, iron and steel industry, etc. The energy users are often very price-insensitive, the demand is inelastic, and therefore is the amount of the usage in the short term almost constant even though fluctuations of the price. Ever since 1970, with a few exceptions, the electricity utilization in Sweden has increased and this is a trend expected to continue.[58]

The demand of electricity is satisfied with different electricity production procedures like hydropower, nuclear power, wind power, powerplants, etc. The supply of electricity is considered to be more price-sensitive than the demand as a result of the producers' possibility to adjust the production after the actual demand.[59]

The market price, i.e. the spot price, is determined to be the intersection between the marginal cost of the most expensive way of producing electricity and the line describing the electricity demand. This relation is illustrated in figure 4-4:

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[55] Econ-analys (2004), Rapport 29/03 Konsekvenser på elpriset av införande av handel med utsläppsrätter
[56] Parkin, M, Powell, M & Matthews, K (2000), Economics 5th ed
[57] Econ-analys (2004), Rapport 29/03 Konsekvenser på elpriset av införande av handel med utsläppsrätter
[58] Ibid.
[59] Ibid.

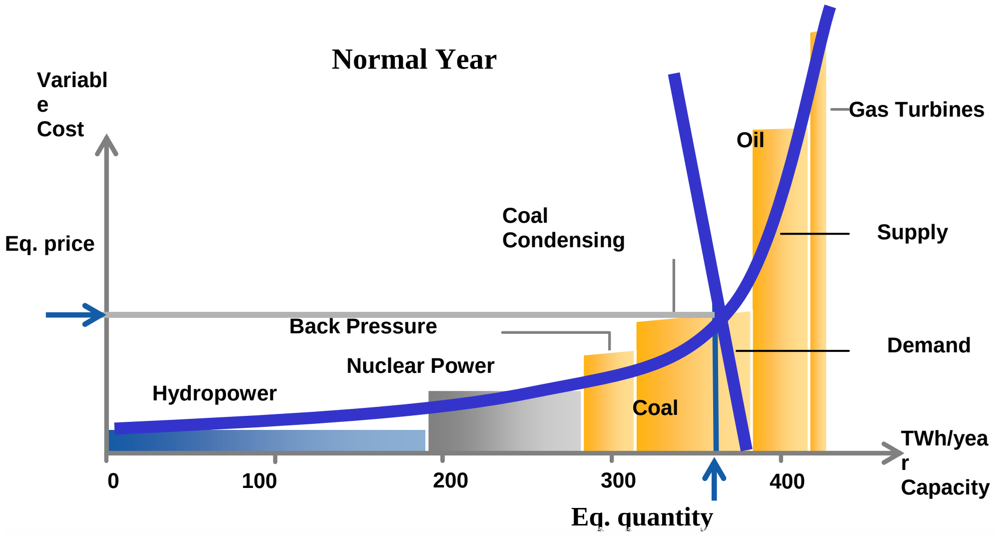

Figure 4-4. The electricity demand and supply in the Nordic region.

4.3.3 The connection between electricity price and emission allowances

As figure 4-4 can tell the wholesale electricity price (market price) is basically set by the marginal generation cost of the last running unit in the order of merit, i.e. the running power plant with the highest marginal generation plant. This marginal cost includes the value of the allowance. The last running unit is almost always a fossil-fired plant in either Germany, Poland or in the Nordic countries, except at times of low demand and very good supply of hydropower. The allowance cost is therefore always a part of the price setting marginal cost. Consequently, the wholesale market price of electricity will increase at the same time as when the price of allowances increases.[60] This is shown in the figure below.

The observant reader remembers the allocation free of cost described in the chapter 3.1 (Flexible mechanisms) and therefore rejects the described cost increase. This is due to the opportunity cost. The opportunity cost of an action is the best forgone alternative[61]. Increasing prices on electricity due to emissions trading has been analyzed by the Dutch economists group named CPB, and the conclusion were that when a coal power plant uses its allowances to cover emissions, the cost of using an allowance is the opportunity cost of not selling the allowance on the allowance market[62]. The conclusion is that prices requested by coal power producers will include allowance prices.

[60] Vattenfall (2003), Electricity market report 2003 part 1: General key themes and issues
[61] Parkin, M, Powell, M & Matthews, K (2000), Economics 5th ed
[62] Mannaerts, Hein & Mulder, Machiel (2003), Emissions trading and the European electricity market

The importance of CO_2 to electricity prices is dependent on how often the demand curve intercepts the supply curve within in the CO_2-generating part of the supply curve. This explains how often CO_2 generating electricity production determines the price. According to the interviewees of the thesis the CO_2 generating electricity production is price determining between 40 – 60 per cent of the year, most likely 60 per cent of the year. The relationship between the marginal price of electricity and the introduction of emission allowances is illustrated in figure 4-5:

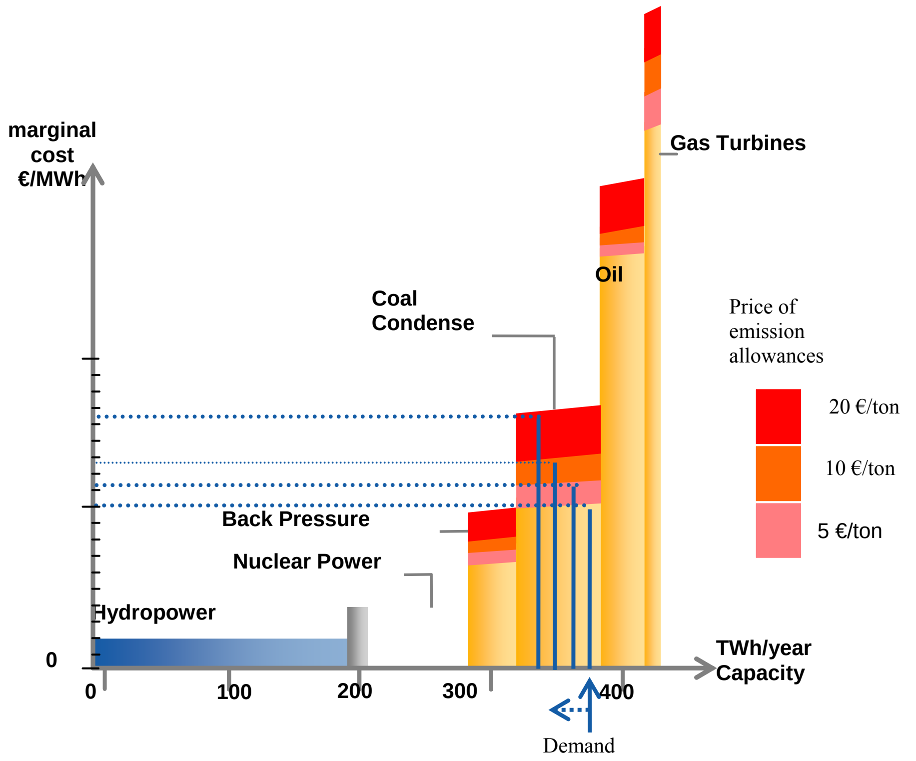

Figure 4-5. The electricity supply in the Nordic region with added costs for emission allowances.

4.3.4 Renewable electricity vs. the electricity- and emission allowance price

Assuming green certificates quotas all over the Nordic countries Thomas Unger finds negative correlation between sizes of green certificates quotas and electricity prices as well as prices of emission allowances. This conclusion also assumes a Nordic market for emission allowances.[63] However both assumptions does not meet over the next years. Certificates quotas do not exist in all the countries making out the common Nordic electricity market, only Sweden has a system of importance and emission allowances will be traded on a European market, giving one price all over Europe. The Swedish green certificates system alone adds 10 TWh new renewable electricity

[63] Unger, Thomas (2003), Common energy and climate strategies for the Nordic countries – A model analysis, Paper V

to the Nordic electricity market. (Please see the chapter 3.2 for further details) This means 2,5 per cent increase in supply on the Nordic electricity market, which has a total size of about 400 TWh. Marginal costs of the renewable energy sources are lower than marginal coasts of coal condensing, which stretches this part in figure 4-4 above that comes before coal condensing and in turn moves coal condensing to the right, which will have a suppressing effect on electricity prices.
The sensitivity for electricity prices of producers of renewable electricity is lower than of other producers because the prior interest for renewable energy producers is to sell as much electricity to render incomes from certificates, rather than selling electricity when prices are high. The possibility to store power is also much lower than compared to e.g. hydropower. The suppressing effect on electricity prices during times of really high electricity prices, e.g. in the mornings and during cold winter days, will not be as important as if selling electricity was the only revenue.[64]

The CO_2-reductions followed by the Swedish green certificates system will be very small in a European context, and therefore not influencing European prices on emissions allowances. The Swedish CO_2 emissions are relatively small, totally 48 Mton where about 24 Mton allowances is likely to be allocated in Sweden to the trading sectors.[65] The Swedish CO_2 emissions are about 1 per cent of the total EU-25 emissions.

4.3.5 Increased use of fossil fuel for electricity production in Sweden

Fossil fuelled power production will increase sharply in Sweden when the oil-fired power plants in Karlshamn and Stenungsund are started after the present modernizing. Alone Stenungsund will emit 2,6 Mton CO_2 in one year[66], making out ten per cent of total CO_2 allocation. These plants have two effects:

1. More fierce competition in the next allocation of allowances, in 2008, the other emitters will receive a smaller allocation and will therefore be forced to pay for a larger part of their allowances.

2. The bar called “Oil” in figure 4-4 will get lower, due to modernizing, but will get wider due to extended running times. This makes CO_2-emitting electricity production price determining more often, depending on prices of emissions allowances, the result will be a raising effect on electricity prizes, although the oil-fired plants will cause less CO_2-emissions per KWh thanks to modernizations.

It should be remembered however that Stenungsund would have lower costs including costs for emissions allowances than Danish coal condense power plants[67].

[64] Bittén, André, interview, 2004-04-04
[65] http://www.pointcarbon.com/wimages/CME_23_April_2004.pdf, 2004-04-26
[66] Kindlund, Göran, E-mail conversation, 2004-04-20
[67] Andersson, Nils, Interview, 2004-03-02

4.3.6 Replacing coal with gas

Producing electricity by firing gas emits about 440 grams CO_2 per KWh compared to hard coal, which gives about 800 grams per KWh[68]. It is a common opinion that gas usage will increase in the Nordic countries. The analyst company Econ states that the gas expansion will be large enough to cause sinking electricity prices, after the initial increase caused by emissions trading.[69] The world supply of gas is large, the proven reserves are calculated to last 60-70 years and lots of prospecting remains[70].

4.3.7 Influences on electricity prices by the pulp and paper industry

This is not an accidental inversion of the thesis title. Since the pulp and paper industry are both large electricity users and producers, changes in the industry have significant effects on the electricity market. Higher electricity prices stimulate industries to save electricity and production may eventually be shut down, which decreases aggregated demand and thereby also prices. The pulp and paper industry is unusual in the sense that higher electricity prices may not only decrease their demand, this industry may also increase the domestic production of electricity. Large parts of the electricity production from biofuel reside in the pulp and paper industry.

4.3.8 Further equalization between the Nordic and European electricity market

The Nordic electricity market is less dependent on fossil fuels than most others. Poland is supplied by nearly 100 per cent coal and coal is also the dominant energy source in Germany. Emissions' trading is thus going to raise German and Polish electricity prices more than the Nordic prices. The continental European price increases can hardly be carried over to the Nordic electricity market due to limited transmission capacity, instead the price gap will grow.[71]

4.4 Biomass fuel vs. pulp wood

The biomass fuel mentioned in this thesis is branch, wastage and wood not passing the quality requirement for pulp production and is therefore burned in a power plant producing heat and electricity. Pulpwood on the other hand is the raw material in pulp and later on in paper as well. Since biomass fuel and pulpwood contains the same burnable raw material it is possible to exchange biomass to pulp wood in the power plant.

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68 Statistiska centralbyrån, Emissionsfaktorer
http://www.scb.se/templates/tableOrChart____24672.asp, 2004-03-16
69 Econ-analys (2004), Rapport 29/03 Konsekvenser på elpriset av införande av handel med utsläppsrätter
70 Nilsson, Lars J., Interview, 2004-03-30
71 Bittén, André, interview, 2004-04-04

4.4.1 The price competition between biomass fuel and pulp wood

The last 50 years most of the Swedish wood has been used for pulp and papermaking and if pulpwood is to be used as fuel in biomass power plants two requirements has to been fulfilled:[72]

1. The cost of using biomass-fuel has to be lower than the price for fossil-based fuel in order to secure the competitiveness of biomass based energy production.
2. The second requirement for profitable biomass-based power production is the importance of better economical return for the forest owner when selling to the energy sector instead of to the pulp and paper industry.

As in the cases with electricity, green certificates and emission allowances, price of biomass is set by the supply and demand, or in other words, by the market. The possible supply of biomass fuel in the Swedish forests is large and it is possible to take care of another 30 TWh wood without hurting the long-term production possibility of the forest[73]. The price is depending on whether it is complex or not to find it due to costs of collecting, transportation, etc. There are several prognoses done on this topic, where there is an estimated cost for using the different wastage in the forest for biomass power production, but no forecast includes the introduction of green certificates or emission allowances and is therefore not presented in this thesis. The authors expect a relationship between the price of biofuel and the price of pulpwood but the extent is hard to tell. Patrik Söderholm, Associate Professor of Economics, supports the assumption made in scenario two.

4.4.2 The connection between green certificates and the biomass price

Green certificates are a support for renewable sources of energy and since biomass-fuel is qualified into this segment it is affected by fluctuations in the price of green certificates. The authors assume that the present price of green certificates at 200 SEK/MWh has no effect on the price for pulpwood. Increasing prices and the introduction of emissions allowances, could increase the demand for biofuel and, as a consequence, for pulpwood as well.

It is also important to notice that there is a law implemented in Sweden 2005, where the local authorities are responsible for the waste and this in turn will probably lead to increasing burning of rubbish, which is qualified for green certificates. This fact will probably reduce a possible price rise. There is also a possibility to import biomass fuel from other countries and this is done at present time as well.

4.4.3 The relationship between emission allowances and the price for biofuel

The primary effect of the introduction of emission allowances is the increased marginal cost for the users of fossil fuel. This makes it more profitable to convert to biomass-based production and in turn there is a growing demand for biomass fuel

[72]Lundmark, & Söderholm, P (2003), Optimal användning av den svenska skogsråvaran
[73] Ekström, Clas et. al (2001), Biobränslen från skogen

growing. It is the author's opinion that the relationship between the biomass price and the price of emission allowances is not as clear as daylight but there is one, if the price on emission allowances is high this will probably lead to increasing prices of biomass.
It is important to observe that, due to a European Union directive, 300 TWh of renewable energy is supposed to be introduced before the end of 2010 and this in turn could affect the Swedish price of biomass[74].

[74] Hedenström, Claes, Scenario meeting, 2004-04-23

5 Scenarios for input parameters and intermediate parameters

The thesis applies two scenarios for emission allowance prices, certificates prices, electricity prices and raw material prices on the two case mills described in a later chapter. First the parameters are described and then the scenarios with the different outcomes of the parameters are described. Experts within Vattenfall have verified the scenarios.

Figure 5-1 illustrates the model describing the relationship between the parameters repeated in order to remind the reader.

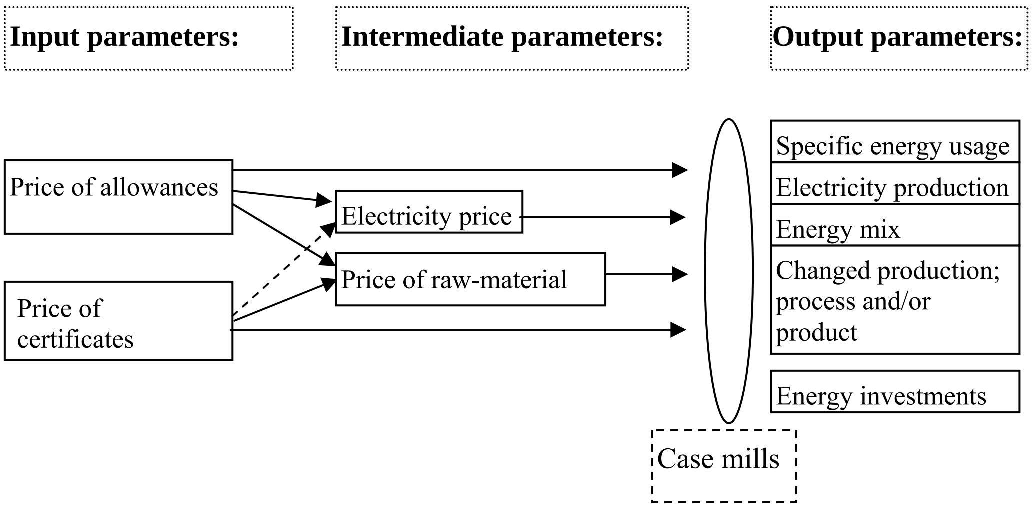

Figure 5-1.The causality of parameters of the thesis.

5.1 General facts and assumptions about the scenarios

This chapter is about to introduce the scenarios of this thesis, though there are some facts and assumptions equal to both scenarios. These are presented below:

- The Swedish CO_2-tax remains unchanged due high Swedish political ambitions in climate issues, which means adding allowance costs to the existing tax-costs.
- The scenarios are concentrated at the four parameters and avoiding concerns about other factors. The overall attempt of the study is to use a ceteris paribus, all else hold equal, approach on how climate policies affect the Swedish pulp and paper industry.
- The scenarios are extreme rather than highly likely in order to concentrate on studying the causality.
- The time horizon used is 2012, since nothing is constituted by the Kyoto protocol for the time thereafter.

5.1.1 Parameter 1: Price of emission allowances

The emissions trading part of the scenarios is based on aggregated supply of emissions allowances, i.e. whether the excess amounts of CO_2 in some of the new EU-entrants countries will slip into the market or not. Further details on this subject can be found in the chapter Supply of allowances.

5.1.2 Parameter 2: Green certificates

In this thesis there are two scenarios for the price of green certificates made up, one price is to be seen as a low estimation while the other one is a rather generous approximation. A price prognostication is made at the beginning (2005) and in the end (2012) of the period and the price trend is estimated to be linear between these moments, i.e. the same percentage share for changes is used.
The primary cause of the two different price estimations is the uncertainty whether the system of green certificates is to be continued after 2010 or not. As mentioned in chapter 4.2 this means a lot of uncertainties for the possible investors in new green certificate qualified electricity but in this thesis the authors presume that the system will continue after 2010. The important factor for the continuous price of green certificates is *when* the directive comes. Depending on when the decision is taken the possible green certificate investors will be able to invest in green certificate qualified electricity plants or not, and this is what finally decides the price formation of green certificates.
With a hesitating decision the investors are waiting with their investment decision, hence there is a less supply of green certificates rising and in turn more expensive production is used. A late decision increases the uncertainty and the investment risk, resulting in a production with low fixed cost and a high variable cost, a high marginal cost means higher prices under market pricing.
If there is a distinct directive taken in the immediate future that the system with green certificates will continue, with a rising quote of green certificates, there is most likely investments to be done with a larger production of certificates as a consequence of this and in turn a lower price on green certificates.

5.1.3 Parameter 3: Electricity price

Both demand and supply of electricity will change until 2012. Historically electricity demand has been correlated to GDP growth. Electricity supply will be altered through e.g. a new large nuclear reactor in Finland, closed reactors in Sweden, increased usage of natural gas and trough the fact that the Swedish green certificates system adds 10 TWh new renewable electricity. It is very hard to predict new equilibriums on the electricity market, therefore is the supplied and demanded quantity of electricity unchanged in the scenarios. Other causes for change, except for effects of certificates and emission allowances, are simply neglected.

The increased electricity price caused by emissions allowances is calculated by the equation below. The parameters involved in the calculations are presented below:

Emission factor of used fuel	(Kg CO_2/KWh)	*(1)*
Price for emission allowances:	(€/ton CO_2)	*(2)*
Exchange rate:	(SEK/€)	*(3)*

Part of year when coal is price setting: (%) *(4)*

In order to estimate the emission allowances effect upon the electricity price the following equation is used:
Electricity price mark up = (*1) * (2) * (3) * (4)* *(Eq. 5-1)*

As mentioned in chapter 4.3.4 there is no strong correlation between green certificates and the electricity price and therefore are no considerations taken whether green certificates affect the electricity price or not.

5.1.4 Parameter 4: Raw material

High certificates prices increase the willingness to pay for wood-fuel, concluding large demand for biofuel. High prices on emissions allowances could make it profitable to switch from fossil fuel to biofuel for electricity and heat production in a number of European countries. An increased pan-European demand for biofuel, would rise prices on Nordic biofuel significantly.
Increased demand for biofuel due to high prices on certificates and allowances may also make it profitable to use the best part of the tree, the pulpwood, in combined heat and power plants. The price on biofuel is an important part of the costs, or a opportunity-cost, in heat production in pulp mills. The price of pulpwood, on the other hand, is of-course also crucial.

5.2 Scenario 1

5.2.1 Parameter 1: Eastern European surplus of CO_2 hits the market

In this scenario a large supply of emission allowances is assumed. This can be caused by for example generous allocations both in old and new EU-member states, through agreements about transfer between nations, or through CDM-projects with e.g. Ukraine. The basic cause for this scenario is that the CO_2 surplus of the EU-entrants slips into the market. An extensive supply gives prices moving towards zero. Fundamental price drivers like reduction cost turns irrelevant since excess supply sets prices.
Price estimation for 2005 - 2012: 5 €/ton CO_2.

5.2.2 Parameter 2: Cheap green certificates

There **is a** decision taken in the immediate future about a continued green certificate system, with a rising quote of green certificates, and as a consequence there is major investments done and the price of green certificates is therefore presumed to be low.

Price estimation 2005:	**Price estimation 2012:**
150 SEK/MWh	**200 SEK/MWh**

5.2.3 Parameter 3: Electricity price faces a small mark-up due to emission allowances

Allowance costs of 5 €/ ton CO_2 gives an electricity price mark-up of 22 SEK/MWh on average until 2012 when using the equation 5-1. This mark-up is added to the existing price of 230 SEK/MWh.

Price estimation for 2005-2012: 252 SEK/MWh

5.2.4 Parameter 4: Price on raw material remains unchanged

Low prices on certificates and allowances cause the demand and prices on pulpwood to remain at the same level as today, i.e. 170 SEK/MWh.
Price estimation for 2005-2012: 170 SEK/MWh

5.3 Scenario 2

5.3.1 Parameter 1: Small supply of emissions allowances and expensive reductions

In this scenario the national allocation plans are not too generous or the EU is tough on the generous ones. The CO_2 surplus of the EU-entrants does also not slip into the market through agreements on transfer between the nations. A small or moderate supply gives a functioning market where cost of CO_2 reductions gives the prices. It is also assumed that only a small number of reductions are possible at as low costs as 7-10 €/ton and the effects of CDM are rather small. Costly reductions give emission allowance prices of 20 €/ton CO_2 in the year 2012.
Price estimation for 2005 - 2012: 20 €/ton CO_2.

5.3.2 Parameter 2: Expensive green certificates

There **is no** decision taken in the immediate future about continued green certificate system and the investors is therefore hesitant whether invest or not and as a consequence of this the price of green certificates is increasing.

Price estimation 2005:	**Price estimation 2012:**
300 SEK/MWh	**350 SEK/MWh**

5.3.3 Parameter 3: Electricity price faces a large mark-up due to emission allowances

Allowance costs of 20 €/ ton CO_2 gives an electricity price mark-up of 88 SEK/MWh on average until 2012.
Price estimation for 2005-2012: 318 SEK/MWh

5.3.4 Parameter 4: The price on raw material increases

High price for green certificates and emission allowances increase the willingness to pay for pulpwood, concluding large demand for biofuel. High prices on biofuel-wood also make pulpwood profitable for burning. The actual rise in price for biofuel-wood in 2012 is estimated to be 20 per cent (140 SEK/MWh * 1,2 = 164 SEK/MWh) thus the subsequent price increase for pulpwood in the year 2012 is estimated to be 5per cent, i.e. 178,5 SEK/MWh.
Price estimation for 2005-2012: 178,5 SEK/MWh

6 The pulp and paper industry

This chapter introduces the reader to the pulp and paper industry and to the manufacturing process of pulp and paper. A complete account of the manufacturing process is offered in appendix A.

6.1 The Swedish pulp and paper industry

In global terms, Sweden is “a major power” in the forest industry, ranking fourth among the world’s paper and pulp exporters and second in exports of sawn softwood timber and the exports stands for almost 15 per cent of Sweden’s exports of goods.[75]
The total Swedish production of pulp in 2002 was 11 400 kton with a total capacity of 11 900 kton and the paper production was in 2002 approximately 10 700 kton with a capacity of 11 400 kton paper[76].
The total Swedish energy application was in 2003 401 TWh where the industry sector uses 152 TWh[77]. The largest energy user in the Swedish industry is by far the pulp and paper industry with an annual energy application of approximately 75 TWh (1999)[78].

6.2 How to make pulp and paper

Every tree consists of cellulose fibres and lignin. The lignin bonds the fibres together and the combination between lignin and fibres gives the characteristics of the pulp and later on the characteristics of the paper. The main process in chemical pulp production is, in contrast to the mechanical process where almost all the wood becomes pulp, to separate the fibres and lignin. [79] There are in basically two different ways release the fibres:

- Chemical dissolution of lignin. The process proceeds from cooking wood chips in a large boiler with cooking liquor and chemical pulp is distinguished. The chemical in the liquid dissolves the lignin, so that the fibres are liberated.[80] The most common chemical way of making pulp is the sulphate pulp process[81].
- Mechanical process. The mechanical pulp is produced in a process where the fibres are torn away from one another mechanically. In the process where the trees are grinded, mechanical forces are used to separate the fibres.[82] The most popular mechanical process is called TMP (thermo mechanical pulp)[83].

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[75]Swedish Forest Industries Federation (2003),The Swedish forest industries – 2002 Facts and figures
[76]Ibid.
[77]Energimyndigheten (2004), Energiläget i siffror 2003
[78]Energimyndigheten (2001), Energianvändningen inom industrin
[79] Borg, Olov F (1989), Papper och Pappersmassa – en grundbok
[80] http://www.skogssverige.se/MassaPapper/Faktaom/swe/massaopapptillv/kemassa.cfm, 2004-02-26
[81] Energimyndigheten (2001), Energianvändningen inom industrin
[82] http://www.skogssverige.se/MassaPapper/Faktaom/swe/massaopapptillv/mekmassa.cfm, 2004-02-26
[83] Energimyndigheten (2001), Energianvändningen inom industrin

Paper consists of cellulose fibres that are tightly bounded one to another in a network so they can form sheet[84]. Paper is made in a process where pulp is mixed with water. The mix is once again grinded and the beating material is passing through different steps of drying in order to increase the dryness.[85]

It is also possible to use waste paper as a raw material for paper products, especially when there is no great demand in strength, hence the recycled fibre is less strong and pliable than the fresh fibres. The waste paper arrives to the mill in bales where the paper is unlaced in water. The diluted solution is then grinded whereupon it is cleaned from printer's ink and impurities before it returns to the paper machine.[86]

[84] http://www.skogssverige.se/MassaPapper/Faktaom/swe/massaopapptillv/paptillv.cfm, 2004-02-26
[85] Borg, Olov F (1989), Papper och Pappersmassa – en grundbok
[86] http://www.skogssverige.se/MassaPapper/Faktaom/swe/massaopapptillv/retur.cfm, 2004-02-26

7 The Anderslöf and Carlstrand case mills

In this chapter the two case mills, which later on are analyzed together with the two scenarios created in chapter 9,10 and 11, are described.

7.1 Introduction

Anderslöf and Carlstrand are two small towns made up for this master thesis in order to represent regular Swedish industrial communities situated at the Gulf of Bothnia and Lake Vänern. Anderslöf and Carlstrand are similar to each other since both of them have a major mill within the community. Anderslöf is an integrated sulphate paper mill that could represent a typical Swedish integrated sulphate paper mill and Carlstrand is a TMP mill also comparable with its competitors in Sweden. More information as well as technical data is to be described below.

7.2 The selecting process of mills for this master thesis

In Appendix A there is a discussion about the selection of describing one integrated sulphate paper mill process and a TMP mill process. A similar discussion is also represented here in order to state reasons for the selection of the technical data for the made up mills Anderslöf and Carlstrand.

The selection process has sort of crystallized during the first months of this master thesis where the authors have met a lot of people with a solid knowledge about the pulp and paper industry.
There have been several official interviews, as well as unofficial, with people with different backgrounds, intentions and employers, etc.
As the reference list can tell a lot of different reports, articles, theses, technical books etc. have been read and studied and the authors have also been visiting a sulphate mill and a TMP mill as well in order to have as much knowledge as possible before making the decision.
With the knowledge picked up during the studies mentioned above several discussions were held with the different interested parties in the thesis and stress was laid on the accessibility to reasonable data.

Since the purpose is to do a general study of an integrated sulphate paper mill and a TMP mill where the case mills could represent a typical Swedish mill in each segment, instead of a specific mill, the technical data for the mill is a mix between different Swedish mills and general data presented in "Energiförbrukningen i massa- och pappersindustrin 2000". The data and the mixture have been carefully selected to be as correct as possible and the selected data have been discussed with people familiar with the actual topic.
Through this process the authors believes the data presented below is representative for the majority of Swedish mills in the chosen segments, and consequently relevant for the purpose of this master thesis.
In order to not expose where the different data is taken from, there are no references mentioned below.

7.3 The Anderslöf mill

The Anderslöf is an integrated sulphate paper mill producing sack paper preferably used in refuses sacks, paper carriers etc. The sack paper producing process is one of the most energy intensive one per produced ton compared to other types of paper like fine paper, kraftliner or paper board. Anderslöf is a mill in the middle ages, about 30 years old, with a technology comparable to the average Swedish integrated sulphate paper mill.

Anderslöf mill has a constant annual production of 200 000 ton sack paper and a total energy application of 1,1 TWh including heat and electricity. The amount of pulp needed for producing 1 ton sack paper at Anderslöf is 960 kg and the pulp is bleached.

Anderslöf mill uses a bark boiler working together with the ordinary black liquor recovery boiler. There is oil used in the lime burner, for start-ups of the digester house and for temporary enlargements in the production. (For explanations of the pulp- and paper making, please see appendix A) Anderslöf uses 11 000 m^3 (50 oil equivalents/ton paper) of oil every year in the different processes and this is to be seen as a rather low amount of fossil fuel dependency. The minimal oil utilization is supposed to be 5000 m^3. The specific electricity utilization of sack paper produced at Anderslöf is 1,6 MWh. The data of Anderslöf presented below is taken from information produced in 2002.

7.3.1 The allocation of costs at Anderslöf mill

The market price for one ton sack paper produced at Anderslöf is 4400 SEK, the production cost of one ton sack paper at Anderslöf is ca 4 000 SEK and the allocation of costs is illustrated in figure 7-1. It is important to notice that the energy cost at Anderslöf, amounting to 9 per cent of the total distribution of costs, have reference to the purchased energy and is not including the energy produced in-house. Anderslöfs estimated cost for biofuel is 140 SEK/MWh and the cost for oil is 180 SEK/MWh. At Anderslöf the steam producing factor is about 0,90 due to losses, hence it takes 1,1 MWh biofuel or oil to produce 1,0 MWh steam.

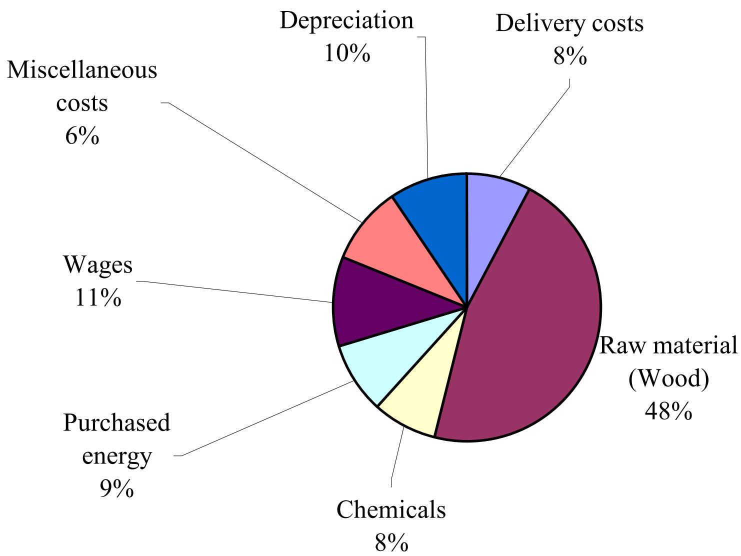

Figure 7-1. The allocation of costs at Anderslöf mill.

7.3.2 Simulated steam demand in the Anderslöf mill

In table 7-1 the steam demand of Anderslöf is presented and also the data used in the simulation. Since Anderslöf is an integrated mill the drying process (described in Appendix A) is unnecessary and is therefore excluded in the data below.

Unit	**Specific heat uilization (GJ/Adt)**
Digester house	2,8
Oxygen delignification	0,4
Bleaching	0,5
Miscellaneous processes	0,9
Summary: fibre line	**4,5**
Evaporation	4,4
Pulpdryer	-
Soot blowing	1,6
Summary: recovery line	**6,0**
Paper machine	6,8
Summary: paper machine	**6,8**
Back-pressure power	1,2
Losses	0,9
Total	**19,3**

Table 7-1.The simulated steam demand at Anderslöf mill.

7.3.3 The steam balance at Anderslöf mill

The simulated steam balance of Anderslöf mill is presented in table 7-2 in GJ per ton paper, since Anderslöf has no condensate turbine there is no electricity produced other than in the back-pressure turbines.

Unit	**GJ/ton paper**
Production	
Black liquor + NCG	15,2
Secondary heat	0,1
Bark+oil	4,0
Total	**19,3**

Consumption	
Pulp processes (incl. soot blowing)	10,5
Paper machine	6,8
Back-pressure power	1,2
Condensing power	0,0
Losses	0,9
Total	**19,3**

Table 7-2.The steam balance at Anderslöf mill.

7.3.4 CO_2-emmisions at Anderslöf mill

The annual CO_2-emission from the oil utilization at Anderslöf is estimated to be (11 000*0,94*3,15 ton CO_2/ton oil) 32 500 ton.

7.4 The Carlstrand mill

The Carlstrand mill is a TMP mill where 500 000 ton advanced newspaper, is produced every year. The advanced paper is used for appendixes, special papers and direct mail advertising. The paper produced for these categories is a mix of different kinds of pulp and the present mix used at Carlstrand mill is offered in 7-3.

Kind of pulp	**Share (%)**
Groundwood pulp	10
TMP	75
Waste paper	15
Total	**100**

Table 7-3.The pulp mix at Carlstrand mill.

The different pulp demands different amount of energy during the manufacturing process. Using waste paper is a rational utilization of energy because the demand is less than 25 per cent of the demand for TMP, but the need for bleaching increases when the share of waste paper is growing. The paper quality is to a high extent independent of the chosen raw-material mixture, hence there is a possibility to increase the amount of waste paper on behalf of the amount of thermo mechanical pulp.

7.4.1 The allocation of costs at Carlstrand mill

The market price for advanced paper is ca 3800 SEK/ ton paper and production cost at Carlstrand is ca 3 700 SEK/ton paper, thus the allocation of costs is illustrated in figure 7-2. The electricity cost at Carlstrand amount to 18 per cent of the total distribution of cost.

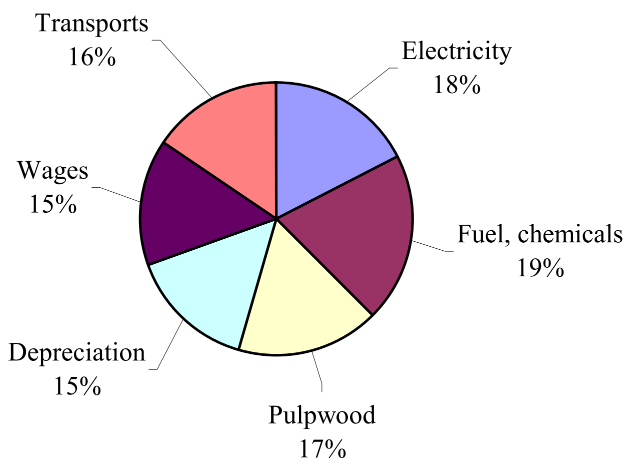

Figure 7-2.The allocation of costs at Carlstrand mill.

7.4.2 Electricity utilization at Carlstrand mill

The annual electricity consumption at Carlstrand is very extensive, almost 1,4 TWh and the own production of electricity made in back-pressure turbines is small or 0,08 MWh per ton paper. Carlstrand uses a bark boiler and an oil burner as well to get the required steam for especially the paper machines. The total use of oil is 27 000 m^3 and the estimated least possible amount of oil usage is 5 500 m^3 annual. The mill is not self-supplied with biofuel and is therefore forced to import about 120 000 m^3 biofuel.

Since the TMP process is very energy intensive, especially electricity intensive, table 7.4-1 is made to present the electricity usage per ton paper at the Carlstrand mill.

Process	**Share (%)**	**MWh/ton type of pulp**	**Contribute to the final product MWh/ton type of paper**
TMP (refinery)	75	2,5	1,9
Groundwood pulp	10	2,15	0,2

Waste paper	15	0,55	0,1
Summary			**2,2**
		MWh/ton paper	
Paper machine		0,65	0,7
Total utilization			**2,8**

Table 7-4.The electricity utilization at Carlstrand mill.

7.4.3 CO_2-emmisions at Carlstrand mill

The annual CO_2-emission from the oil utilization at Carlstrand is estimated to be (27 000*0,94*3,15) 80 000 ton.

8 Energy related improvements in the pulp and paper industry.

In the text below a brief description of the proposed improvements of the energy application in the pulp and paper industry is done. This report is made with the intention to let the reader get a view of what can be done in the processes mentioned earlier in Appendix A.

8.1 Proposed energy improvements at a sulphate mill and a TMP mill

To be able to discover and understand the improvements that can be done in a sulphate pulp mill a reference mill (a description of KAM 2 is given below) is made up which is later on compared with the case mill.
To be able to discover and understand the improvements that can be done in a TMP mill the different improvements are exemplified by information and studies from manufacturer and universities.
The reference mill and the possible improvements in energy utilization are later on to be compared with the Anderslöf and Carlstrand mills.

8.2 The sulphate mill improvements

There is a lot written about different theoretical improvements for the energy applications in a sulphate pulp mill, especially in Sweden where this kind of chemical pulp is the dominating one and the Swedish pulp production probably is the worlds most environmental-conscious[87]. In this master thesis KAM 2 is used as a reference mill in order to illustrate the improvements possibilities.

8.2.1 The KAM 2-mill

In 1996 MISTRA (The foundation for strategic Environmental Research) started a programme with the purpose to make "*A completely ecocyclic system for high-quality paper products which efficiently utilise the energy potential of the biomass*"[88].
To meet the purpose a sulphate pulp mill KAM (Kretsloppsanpassad massafabrik) with the best available technology in the late 1990:s was simulated. The first KAM-mill was presented 1998 and an audited mill, KAM 2, was presented in the year of 2000. The differences between the mills were small but KAM 2 is more detailed than the forerunner and is therefore decided to be the reference mill in this thesis.[89] It is important to remind the reader that there is no corresponding mill in Sweden like KAM 2 and it is a project made to show how to utilize the energy in the best way.

8.2.2 KAM 2 facts

KAM 2 has an annular production of 720 000 tons of pulp and consumes 4,97 m^3 of wood for every ton produced pulp. The annual overall energy application is 2,2 TWh

[87] MISTRA (1998), Programförklaring av KAM
[88] http://www.stfi.se/mistra/kamprog.htm, 2004-03-23
[89] Ledung, Lars et al (2001), KAM 2-programmets referensfabrik version 2000

and the surplus of the produced heat is 0,94 TWh. All steam is produced in the black liquor recovery boiler and in the limekiln, thus there is no need for a bark boiler. The bark from the wood is removed and gasified and the surplus is sold to the market. There is no fossil fuel used in KAM 2 and therefore is there no net contribution of CO_2.[90]

8.2.3 The pulp making process in KAM 2

Since almost every little step in KAM 2 is enhanced it is an extensive task to describe them all and therefore is only the major changes that really makes the difference, mentioned below. The simulated data is showed in table 8.2-1 and in 8.2-2.

The digester house in KAM 2 uses a continuous boiler where the wood is impregnated with black liquor and the black liquor is subsequently transported to the evaporator in only one step. The cooking time is shorter since the cooking process is interrupted when the kappa number reaches 26-28 and thru oxygen delignification the kappa number is further decreased down to 10.[91] The washing, screening and bleaching process is relatively conventional therefore is these processes not further explained.

The evaporation plant contains 6 steps where the thickwaste liquor has an outcome dryness of 80 per cent and all the condensate is recycled. The recovery of tall oil is estimated to be ca 35 kg/t_{90} (t_{90} = Adt (one ton air dryed pulp) = pulp with a dryness of 90 per cent).[92]

The black liquor recovery boiler is a conventional one producing steam with a pressure of 80 bars and is working with the limekiln burner. The evaporation process of black liquor is very efficient, hence is the steam production from the black liquor recovery boiler enough to support the steam demand and therefore is the unnecessary bark (102kg/t_{90}) sold to the market. The limekiln burner uses evaporated bark as fuel and consumes about 90 kg bark/t_{90}. The mills back pressure turbines take care of the steam produced in the black liquor recovery boiler and the limekiln before it enters the processes, and the residual steam is used in a condensing turbine in order to produce even more electricity.[93]

It is important to notice that KAM 2 is a mill simulated to make *sulphate pulp for the market* instead of *supplying an integrated paper mill.*

8.2.4 The steam demand of KAM 2

In 8-1 is the simulated steam demand for KAM 2 illustrated in GJ/Adt.[94]

Note: The high consumption in the bleaching step is depending on the high temperature that this process (Chlorine dioxide) demands. The advantages with this process is the tiny wastage of pulp and fibres and that the short and hot cycle facilitates less bleaching investments.[95]

[90] Ledung, Lars et al (2001), KAM 2-programmets referensfabrik version 2000
[91] Ibid.
[92] Ibid.
[93] Ibid.
[94] Backlund, Birgit, 2004-03-23
[95] Backlund, Birgit, 2004-03-29

Unit	GJ/Adt
Digester house	1,6
Oxygen delignification	0,14
Bleaching	1,37
Summary: fibre line	**3,11**
Evaporation	4,01
Soot blowing	1,01
Summary: recovery line	**5,02**
Losses	0,37
Total	**8,5**

Table 8-1. The steam demand of KAM 2.

8.2.5 Steam balance of KAM 2

Table 8-2 presents the steam balance of KAM 2 and the electricity produced in the back-pressure and condensing turbines.[96]

In order to get as correct simulation and comparison to Anderslöf as possible, the made up integrated sulphate paper mill used in this thesis, the drying step in KAM 2 is excluded and the steam is therefore used for producing electricity in the existing back-pressure and condensate turbines.

Unit	GJ/ADt
Production	
Black liquor + NCG	17,9
Secondary heat	0,6
Bark+oil	0
Total	**18,5**
Consumption	
Pulp processes (incl. soot blowing)	8,5
Back-pressure power	3,7
Condensing power	2,2
- Ditto, condenser	4,1
Total	**18,5**

Table 8-2. The steam balance and produced electricity at KAM 2

[96] Backlund, Birgit, 2004-03-23

Of the total electricity production of almost 1300 kWh/ADt is 712 kWh/ADt used within the mill in the different processes and the rest (588 kWh/Adt) is sold to the market but it is important to notice that KAM 2 is given green certificates for all electricity produced (1300 kWh/ton pulp).

8.2.6 CO_2-emmisions at KAM 2

There is no usage of fossil fuel within the KAM 2 mill and therefore is the *direct* emission of CO_2 completely defeated. In the direct emissions is the energy usage in transport, chemical manufacturing, etc. excluded.[97]

8.2.7 The paper machine used together with KAM 2

The paper machine used together with the KAM 2 mill, in order to get an integrated sulphate mill, has an energy utilization of 80 per cent of the averaged paper machine of today. Considering the low energy utilization in KAM 2 it is the authors opinion that it is possible to decrease the steam requirements with 20 per cent when using the latest available technology, hence is the specific steam utilization for the paper machine in KAM 2 5,8 GJ/ton paper.
All together the KAM 2 mill in this thesis has got a specific steam utilization of 14,4 GJ per ton sack paper.

8.2.8 The relationship between Anderslöf and KAM 2

The authors estimate KAM 2 to be about 25 years ahead of Anderslöf concerning the technology used in the pulp and paper production. This means that it will take about 25 years before every process, especially the energy utilization, is as good as in KAM 2 and before every machine uses the best available technology of today (2004). Or put it in other words, in the year of 2029 Anderslöf will have the same specific energy utilization as KAM 2 got today. Figure 8-1 illustrates Anderslöf moving towards the energy utilization of KAM 2.

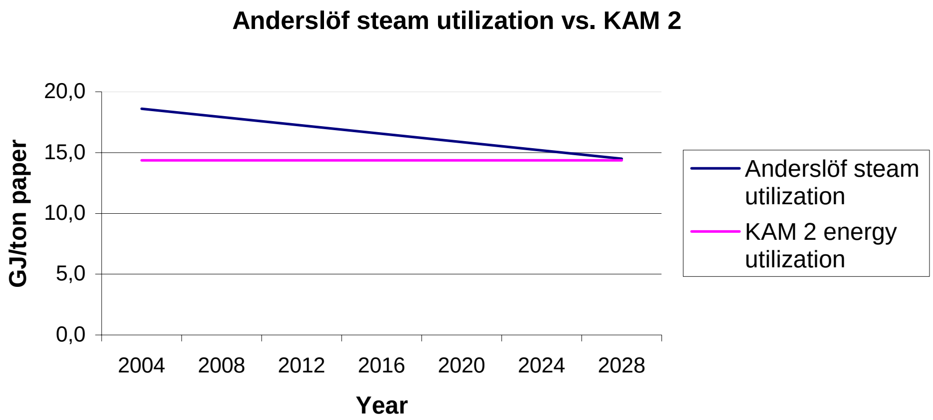

Figure 8-1. Predicted steam utilization at Anderslöf versus the steam utilization at KAM 2.

[97] Ledung, Lars et al (2001), KAM 2-programmets referensfabrik version 2000

The authors assume that Anderslöf got a conventional investment programme, where there are new investments done in machineries, mostly when the old has broken down and no investments are done with the intention to save energy. The scopes of the investments done at Anderslöf are strictly product related, the energy saving factor is secondary and just seen as a positive detail. The investments are made with the purpose of guarantee the sack paper production will continue.
In order to facilitate the calculations the improvements/investments are to be seen as linear throughout the years and further discussions concerning exactly *where* the investments in the mill are done is not included in the thesis.
The focus of the thesis is until 2012 and during these 8 years until 2012 there is investments done that can respond to that Anderslöf has approached the steam utilization of KAM 2 with about 32 per cent (8 years/25 years). This means that Anderslöf has moved 32 per cent or 1,4 GJ/ ton paper towards the same energy application as KAM 2 has got today.

The saved steam due to the natural improvements done at Anderslöf is possible to use in a condensing turbine not existing at the mill right now. Due to the large demand of cooling water for a possible condensing turbine the electrical efficiency is about 20 per cent, hence for every saved GJ of steam it is possible to make about 0,06 MWh electricity at Anderslöf. The Swedish pulp and paper mills are also large electricity users and are therefore affected by the rising electricity prices, though the specific electricity usage at Anderslöf is constant during the selected period due to energy improvements neutralizing increasing electricity demand as a consequence of improving quality[98]. Inflation, risk premium, capital cost etc are not taken into consideration in the calculations made in the forthcoming analysis. As pointed out before, the accumulated positive cash flows are expressed as “accumulated savings”.

8.3 The TMP mill improvements

The TMP mills are not as well documented as the chemical mills and as a result of this no reference mill has been found that suits this thesis. The improvements possibilities are therefore exemplified by manufacturers information and through recent done studies at Swedish universities.

8.3.1 Measure one: 10% off

The refinery process (extensively described in appendix A), where the chips are grinded and the fibres are released, is by far the most energy intensive process (approx. 70 per cent of total energy usage in the pulp producing process) in the thermo mechanical way of making pulp, consequently is this the process where most effort is put in and where the most of the research and development is spent on[99].

Metso Paper is a division of Metso Corporation from Finland manufacturing refiners and other tools used in the TMP process. “*Metso Paper is one of the world’s leading*

[98] Wiberg, Rolf (2001), Energiförbrukningen i massa- och pappersindustrin 2000
[99] Borg, Olov F (1989), Papper och Pappersmassa – en grundbok

suppliers of equipment and machinery for the pulp and paper industries”[100]. Metso Paper has developed a TMP concept of new energy reducing instruments called LE™ and according to their own research it is possible to save at least 5-10 per cent in the first refinery step compared to standard segments, this means also that the specific energy usage will decrease with 5-10 per cent[101]. The operating principle of this development is that the radial position of the refiner forces the pulp to flow faster into the plate gap. This shortens the fibre residence time in the refiner and makes refining more efficient. More efficient refining, a higher refining intensity and a less turbulent flow leads to reduced energy consumption.

Another study by Möllersten tells that it is possible to save up to 0.7 TWh (approx. 10 per cent) of the total Swedish TMP-mills electricity application through electricity conservation[102]. This statement is based on three different studies and is to be seen as a general valuation of the possible energy improvements compared with the technologies used in the mill nowadays. Common improvements of the electricity application are speed control of pumps and fans[103].

It is vital for the quality and the energy utilization that the pulp enters the refiner in a continuous flow with as small variance as possible. The fluctuation depends on the density of the pulp that in turn is in some part depending on the time of the storage. In 1990 ABB introduced at system called TERMAP in order to get better control of the flow. The new optical control system decreases the electricity utilization in the refiners with 7 per cent in contrast to ordinary refineries.[104]

Another possibility to decrease the electricity is to use the process that former Sunds Defibrator and SCA developed where the fibres are released in low temperature and the lignin is therefore not soften up as usual. When the pulp enters the second refinery it is exposed to higher pressure and temperature than in regular refineries for 10 seconds, this gives the same result as the usual process but have a stated potential of saving energy up to 20 per cent compared with the ordinary process.[105]

The outcome of the different possibilities mentioned above is that there are opportunities for saving energy and especially electricity, the most value-added and expensive kind of energy. According to the different solutions the authors makes the estimation that it is possible to save about 10 per cent of the electricity utilization at a TMP mill and this measure is therefore named 10% off.

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[100] Metso Corporation, (2004), Annual report - 2003
[101] Bergqvist, Peter & Vuorio, Petteri, Finding a more environmental friendly approach to refiner mechanical pulp production
[102] Möllersten, Kenneth (2001), Potential and cost-effectiveness of CO_2 reductions through energy measures in Swedish pulp and paper mills
[103] Wiberg, Rolf (2001), Energiförbrukningen i massa- och pappersindustrin 2000
[104] Gavelin, Gunnar (1996), Mekaniska massor – framställning och användning
[105] Ibid.

8.3.2 Measure two: Changed mix

Measure two is about changing the raw material mixture in a TMP mill, increasing the share of recycling paper and decreasing the share of fresh TMP reduces energy usage substantially. A greater share of recycled paper is used in the analysis as a measure to reduce the electricity utilization since the production of pulp from recycled paper uses far less energy than thermo mechanical pulp production. A much larger share of recycled paper, De-inked Paper, DIP, is possible and would result in even lower electricity consumption. Table 8-3 presents the present and new mixture.

Kind of pulp	**Present Mixture (%)**	**New mixture (%)**
Groundwood pulp	10	10
TMP	75	60
Waste paper	15	30
Total	**100**	**100**

Table 8-3. The present and altered pulp mix at Carlstrand TMP mill.

8.3.3 Measure three: Biofuel

Measure three considers replacing oil with biofuel as far as possible. Oil can however not be fully substituted under present technology, thus there is a least possible amount of oil utilization at the case mill of this thesis. The main incentive for this measure is to gain revenues from selling excess emission allowances. The downside of increased usage of biofuel is that costs for maintenance and replacing worn material are higher for biofuel burning than oil burning.

8.4 The paper machine

Throughout this master thesis where a lot of theses, reports and studies have been read it has been more and more obvious that the energy utilization when making paper is a less important cost and there is not much effort put into energy improvements. This opinion is supported by one of the largest paper machine manufacturers, Metso Paper. The most important with paper manufacturing is to get the right quality and a process without interruption and this is what the research & development departments are focussing on. The energy utilization is only a secondary process and is therefore in some cases neglected even if Metso Paper thinks that there is possible improvements, but since the customers demand is focusing in other improvements there is less research done.[106]

In a study by Lindell there are several different techniques for drying paper presented and explained. Cylinder drying with hot steam is the most broadly used drying technique and as a consequence of this these are the most interesting improvements for this thesis. For every per cent of increasing dryness from the press rolls, 4 per cent of thermal energy is saved and therefore is it important to remove as much water as

[106] Lindén, Anders, 2004-04-02

possible in the press roll[107]. With the drying technology of today it is possible to decrease the amount steam used for remove water from 3,5 KJ/ kg H_2O down to 3,0 KJ/ kg H_2O.[108]
Another possible improvement is to recover the steam used to remove condensate water from the inside of the drying cylinders instead of just let the saturated steam condensate like today[109].

Due to conversations with different people familiar with paper production and the improvements mentioned above the authors consider it reasonable to estimate the possible energy savings to at least 10 per cent in steam demand without any larger investments in new machineries.

8.5 Offensive electricity strategies: Potential for increasing electricity production

There are opportunities for the Swedish pulp and paper industry to produce more electricity than the amount produced today in all types of mills. The average electrical efficiency of the combined heat and power production systems in the Swedish pulp and paper industry is about 9 per cent. This means that the existing turbines has got a rather low operating capacity factor, probably due to the low electricity price in the past. There are two main improvements presented below:

1. An increased utilization of the installed steam turbine capacity, due to increasing time that existing steam turbines are operated, etc., is estimated to increase the total Swedish electricity production in the pulp and paper sector with about 0,7-1,0 TWh. This possibility for electricity production increases the demand of steam, but since the marginal electricity efficiency for this extra steam is very high (≈0,90) the steam demand is only 1,1 $MW_{biofuel}$ /$1{,}0_{electricity}$ MW, consequently there is a need for another 0,8-1,1 TWh biofuel.[110]

2. When the production capacity of the mills has increased the turbines has been by-passed in production capacity in order to enable the processes with sufficient steam. If the steam system is optimized for the mill's present process steam demand and if the old turbines are replaced with newer ones that generate more power with the same steam flow the estimated potential of increased electricity production is another 1-1,7 TWh. This possibility for electricity production increases the demand of steam, but since the marginal electricity efficiency for this extra steam is very high (≈0,90) the steam demand is only 1,1 $MW_{biofuel}$ /$1{,}0_{electricity}$ MW, consequently there is a need for another 1,1-1,9 TWh biofuel.[111]

[107] Lindell, Kristian (2002) A survey of energy Aspects for different paper drying Processes
[108] Lindell, Kristian, 2004-04-06
[109] Ibid
[110] Möllersten, Kenneth (2001), Potential and cost-effectiveness of CO_2 reductions through energy measures in Swedish pulp and paper mills
[111]Ibid.

With the offensive electricity strategy step one and step two mentioned above taken into action the estimated average electrical efficiency of the combined heat and power production systems in the Swedish pulp and paper industry reaches about 14-15 per cent.[112]

[112] Möllersten, Kenneth (2001), Potential and cost-effectiveness of CO_2 reductions through energy measures in Swedish pulp and paper mills.

9 Analysis

This chapter and the two following chapters describe the outcomes of the scenarios applied on the Anderslöf sulphate mill and Carlstrand TMP mill, i.e. the output parameters are given a value. Also outcomes after taking improving measures are presented and discussed. First facts common to both mills are presented, and then two separate chapters, analyses and discussions of the two mills are undertaken.

The authors remind the readers about the input- and output parameters of the thesis and recommend a brief rehearsal of figure 2-1 describing the causality of the used parameters:

9.1 A rehearsal of parameters common to both analyses

A brief rehearsal of the scenarios made up in chapter 5 is presented in the tables below as well as the most important data of the case mills. Table 9-1 illustrates the existing (April-2004) prices of several parameters used further in the analysis.

Parameter	**Unit**	**Amount**
Electricity price	SEK/MWh	230
Existing green certficates	SEK/MWh	200
Exchange rate	SEK/€	9,2
Price of oil	SEK/MWh	180

Table 9-1. Data common to both analyses.

Table 9-2 illustrates the chosen levels of the different parameters in each scenario and is a concise rehearsal of the scenarios presented in chapter 5.2 and 5.3:

Parameter	**Unit**	**Ref 2012**	**Scenario 1**	**Scenario 2**
Emission allowances	€/ton CO_2	0	5	20
Green certificate price in 2005	SEK	200	150	300
Green certificate price in 2012	SEK	200	200	350
Emission allowances effect on the electricity price	SEK/MWh	0	22	88
Total electricity price	SEK/MWh	230	252	318
Price of biofuel	SEK/MWh	140	140	164
Price of pulpwood	SEK/MWh	170	170	178,5

Table 9-2. The data of Ref 2012 and the made up scenarios.

9.2 Comments on figures used in both analyses

9.2.1 Used price level

In the calculi the price level of 2004 is used, hence real values are used and no further consideration of inflation is undertaken. Neither real rate of interest is considered when cash flows are summed up over the period 2005-2012 and presented in the column “Accumulated savings”. Hence, these values are not discounted. One consequence of this is that non-linear changes in cash flows are not made visible.

9.2.2 Revenues from selling emissions allowances might be limited in time

Gaining revenues from selling emissions allowances is a possibility followed by reduced oil usage, used in the analyses. For example replacing oil with biofuel and selling the allowances allocated for 2005-2008, means revenues for those years. But less emissions also means a smaller need for allowances in the next period of 2008-2012 and therefore probably less allowances will be allocated by the government, making a repeated selling impossible over the coming period. This depends on future governmental choice of allocation methods and the authors make an assumption about future allocations to be based on emissions over the last couple of years. Thus reducing CO_2 emissions means a stream of revenues limited to last only three or five years depending on whether the mill will undertake the action during 2005-2008 or 2008-2012. In the analyses of the two case mills reductions are undertaken in the later period in order to gain revenues from selling allowances five times instead of three times. The risk of getting a reduced allocation in the later period than the earlier is neglected.

9.2.3 Pulp and paper companies as price takers

Many pulp and paper products are mainly globally, competition is in those cases global and price differences can therefore not exceed cost of transportation between continents. As a consequence increased costs on one continent cannot be passed on to customers through raised prices; instead producers facing increased costs must cut other costs, alter their production or take a loss. The authors of the thesis make no further investigation but assume this to be the case also for the products produced by Anderslöf and Carlstrand. Therefore is the market price in the calculi in the analyses never changed.

9.2.4 The way the term profit is used

The term profit is used in the calculi both when it describes a loss or a “true” profit. The sign in front of the figures tells whom of the two it is. The term profit is used in a general way in the calculi, and cannot be defined as “gross profit/loss”, “operating profit” or “profit of the year”. The closest definition to the way profit is used in the calculi is probably operating profit. No clear definition is available because the profit/loss statement used in the calculi is a simplification made up by the authors under supervising of authorities at Vattenfall in order to give a fast, simple and plausible picture of operations. Besides some of the figures, such as “other specific variable and fixed costs”, are given by producers and it is unknown to the authors exactly what is concluded.

9.2.5 Accumulated savings as room for capital cost

The calculi presented in the analysis do not include capital cost changes, followed by investments required for some of the actions. The authors found it very hard to estimate the size of investment in equipment for increased prduction of pulp from recycled paper. Economic lifetime and discount rate are also decisions of the individual firm that affects capital cost, hence no estimations of these subjects are undertaken. The possible room for investments is however expressed for the different actions in the column “Accumulated savings”. This column sums up the positive cash flows, i.e. increased revenues or cost decrease, caused by the prevailing action. Hence, the possibility is given to the reader who is familiar with the required investment amounts, to calculate the investments with his individual investment horizon and discount rate; the accumulated positive cash flows are given in the calculi.

The maximum annual room for negative cash flows followed by investments required for the actions in this analysis can be calculated by finding a present value of the annual positive cash flows. An average annual value can be used since the distribution of cash flows is fairly even over the years. Room for investments can be expressed in the following way:

$$\frac{Acc.savings}{8years} * \frac{1-(1+r)^{-N}}{r}$$

Where:
r = Discount rate of the individual firm or project
N = Economic lifetime expected for the investment

9.2.6 The meaning of Ref 2012

Ref 2012 reflects the situation in the year 2012 when no one of the made up scenarios are applied, thus is the circumstances concerning green certificates, emission allowances, pulp wood, biofuel and electricity price like the ones existing today. The Ref 2012 is made to be able to make a comparison of the effects from the input parameters when the actual scenario is applied or when different measures and offensive strategies are taken and when they are not. The existing data of today used in Ref 2012 is illustrated in table 9-2 as well as a rehearsal of the made up scenarios.

10 The Anderslöf analysis

This chapter describes the outcomes of the scenarios applied to the Anderslöf integrated sulphate paper mill, i.e. the output parameters are given a value. Outcome after taken improving measures are also presented and discussed.

10.1 Background information

To facilitate the reading of the analysis some background information is presented below. The made up integrated sulphate paper mill used in this thesis is presented in chapter 7, nevertheless is a brief rehearsal of the most important data at Anderslöf presented in table 10-1:

Anderslöf, 2004	**Unit**	**Amount**
Annual paper production	Ton/year	200 000
Annual profit	MSEK/year	80
Specific cost	SEK/ ton paper	4000
Sales price	SEK/ ton paper	4400
Existing specific steam usage	GJ/ton paper	18,7
Existing specific electricity prod.	MWh/year	0,3
Specific steam utilization at Anderslöf without improvements	GJ/ton paper	18,7
Specific steam utilization at KAM 2	GJ/ton paper	14
Specific steam utilization at Anderslöf with the forecasted (0,14 GJ/ton paper & year) energy improvements	GJ/ ton paper	17
Specific saved steam at Anderslöf due to the forecasted improvements	GJ/ ton paper	1,38
Specific saved steam at Anderslöf due to the forecasted improvements	MWh/ton paper	0
Annual saved steam counted as bio-fuel/oil with a steam producing factor of 0,9	MWh/year	84 938
Annual amount of saved oil	m^3	6 000
Specific saved steam converted into electricity in a condensate turbine with a electrical efficiency = 0,2	MWh/ton paper	0,08
Annual saved steam converted into electricity in a condensate turbine with a electrical efficiency = 0,2	MWh/year	15 289

Table 10-1. The data of Anderslöf mill.

10.2 Scenario 1 applied to Anderslöf

When applying scenario one to Anderslöf the different parameters hit the mill in different areas. A complete table of calculations is presented in appendix B, hence is only the highlights presented in table 10-2.

How to read the table: *The column "Ref 2012" illustrates the outcome of actions taken at Anderslöf in 2012 when Ref 2012 is applied, i.e. the circumstances is like the existing ones, hence the proposed measures are taken but the estimations excludes the effects from climate policies.*

"2012" shows the outcome of the different measures taken when scenario one is applied to Anderslöf in 2012.
"Acc. savings" illustrates the total savings or total costs during the period 2005-2012 due to the taken measure and this is likewise the maximum cost considering new investments without losses when using a very simplified capital investment valuation, with an eight year term where the discount rate is excluded.
Note: Savings in raw material for the boilers, due to energy improvements, is showed as possible net revenues instead of saved costs.

Estimation	**Unit**	**Ref 2012**	**2012**	**Acc. Savings (kSEK)**
The green certificate price	SEK/MWh	200	200	
Annual increased gross electricity costs	kSEK/year	-	7 066	**56 525**
Annual changed value of existing own electricity production	kSEK/year	-	1 325	- **1 894**
Total increased net cost	**kSEK/year**	**-**	**5 741**	**58 419**
The saved steam converted into electricity and sold to the market, including green certificates	kSEK/year	6 574	6 912	**29 885**
Cost savings for less biofuel demand	kSEK/year	11 891	11 891	**53 511**
Cost savings for less oil demand including emission allowances	kSEK/year	15 115	16 209	**73 376**
Summary: Changed revenues, cost savings for less oil demand	kSEK/year	**15 115**	**10 469**	**14 957**
Increased pulpwood cost	**kSEK/year**	**0**	**-**	
Profit	**kSEK/year**	**95 115**	**90 469**	
Changed profit	**%**	**19**	**13,1**	

Table 10-2. Scenario 1 applied to Anderslöf.

10.2.1 The specific energy usage at Anderslöf

The specific steam usage at Anderslöf is decreasing since the steam consumption moves towards the steam consumption at KAM 2. During the period 2005-2012 the specific steam demand has decreased with approx. 7 per cent or 1,4 GJ/ton paper compared to if there was no development at all.

10.2.2 The electricity production at Anderslöf

The revenue from the present electricity production decreases due to the low prices on green certificates.
The decreased low-pressure steam demand in the different processes due to improvements done in order to guarantee the production of sack paper can be used in a condensing turbine in order to produce electricity. With the given amount of steam it is possible to produce 15 GWh in 2012 and according to scenario one the estimated

value of the produced electricity is 7 MSEK. The difference between scenario one and a situation with the present circumstances (Ref 2012) in the estimated value of the electricity production is 0,3 MSEK in 2012.

10.2.3 The energy mix at Anderslöf

The bark boiler and oil boiler at Anderslöf are producing steam with 10 per cent losses in heat, hot flue gases etc. The saved steam thanks to the energy improvements can be translated into the raw material used in the bark/oil boiler at Anderslöf.
The saved amount of steam in 2012 85 GWh; hence the reduced steam demand could be transformed into amount of saved money for reduced use of biofuel or oil in respectively boiler.
If the saved steam is produced in a bark boiler firing biofuel the estimated value of the improvements is 12 MSEK in 2012 and during the entire period 2005-2012 the estimated value is 54 MSEK.
As a comparison the estimated value of steam produced in an oil boiler is worth 16 MSEK in 2012 and finally 73 MSEK over the present period. A comparison between scenario one and the non-scenario case gives that the cost saving from the exchanging oil is 1,1 MSEK larger when scenario one is applied.

10.2.4 The changed allocation of costs at Anderslöf and the competition for pulpwood

The increased electricity price, caused by emission allowances, enlarges the costs for electricity with 7 MSEK annually under scenario one.
In this scenario the price of biofuel remains the same and therefore no competition exist concerning the pulp fuel from the biofuel energy sector. Since the specific amount of purchased energy at integrated sulphate mills is low, the increased electricity price and saved steam do not affect the allocation of costs noticeably and the price of pulpwood remains the same as well.

10.2.5 Offensive electricity strategy

The proposed improvements in chapter 8.5 aims to show the potential of enlarged electricity production an offensive electricity strategy could bring. In table 10-1 is the result of the two offensive strategies applied to Anderslöf for 2012 and the total period of 2005-2012 presented, the complete estimation is presented in appendix B. The mark-up percentage for the electricity production used in the calculations below is the same as the total mark-up estimated for the total Swedish mills.
How to read the table: *The electricity production at Anderslöv increases and due to the present circumstances the estimated value of the production differs. In "2012" is the amount of electricity and estimated value when scenario one is applied presented. "Ref 2012" presents the same amount of produced energy as "2012" though the estimated value differs since Ref 2012 is applied, i.e. the circumstances is like the existing ones. The column "Acc. savings" aims to illustrate the total savings during the period 2005-2012 due to the taken measure and this is likewise the maximum cost considering new turbines etc. without losses when using a very simplified capital investment valuation, with a eight year term where the discount rate is excluded.*

Optimize operating time	**Unit**	**Ref 2012**	**2012**	**Acc. Savings (kSEK)**
Potential for increased electricity production	MWh/year	12 750	12 750	
Sell the increased electricity production to the market	kSEK/year	5 483	5 764	
Increased cost for biofuel	kSEK/year	1 964	1 964	
Net revenue = Sold electricity - biofuel cost	**kSEK/year**	**3 519**	**3 801**	**27 750**

New turbines				
Potential for increased electricity production	MWh/year	20 250	20 250	
Sell the increased electricity production to the market	kSEK/year	8 708	9 155	
Increased cost for biofuel	kSEK/year	3 119	3 119	
Net revenue = Sold electricity - biofuel cost	**kSEK/year**	**5 589**	**6 036**	**44 073**

Optimize operating time + new turbines				
Potential for increased electricity production, step 1	MWh/year	33 000	33 000	
Sell the increased electricity production to the market	kSEK/year	14 190	14 919	
Increased cost for biofuel	kSEK/year	5 082	5 082	
Net revenue = Sold electricity - biofuel cost	**kSEK/year**	**9 108**	**9 837**	**71 822**

Table 10-3. Offensive strategies applied to Anderslöf.

10.2.6 The outcome of the offensive strategies

In the table above the possible revenues from the different steps are listed. In step one when the present turbines are optimized for the current production and the operating time is increased, there is an annual potential for producing another 12 GWh electricity. The total revenue for this operation, considering the growing purchased quantity of biofuel, is estimated to be 4 MSEK in 2012 and during the entire period the estimated revenue is 28 MSEK.
If the measurement mentioned in step two, additional optimization and replacements of turbines, is taken into action it is possible to produce 20 GWh annually. If this electricity is sold to the market the estimated revenue is 6 MSEK in 2012 and the total revenue of the period is 44 MSEK.

When combining the improvements in electricity production in step one and step two the total electricity outcome is 33,0 GWh annually. When converting this amount into

MSEK the total revenue of 9,8 MSEK in 2012 and the amount of 2005-2012 is 71,8 MSEK.

Due to the higher price of green certificates and electricity the estimated value of the electricity differs whether scenario one is applied or not. The net revenue is 0,7 MSEK larger when scenario one is applied compare to a situation like today.

10.3 Discussion scenario 1

The different input parameters gives in turn different output parameters and with the aim to facilitate the results of the different measures taken into action figure 10-1 is offered. Figure 10-1 compares the total profit at Anderslöf during 2012 with Ref 2012 applied as well as when scenario one is applied, thus the difference in profit comes from the introduction of emission allowances and the comparatively low price for green certificates as a consequence of less oil demand.
Note: No consideration is taken to offensive strategies in figure 1.

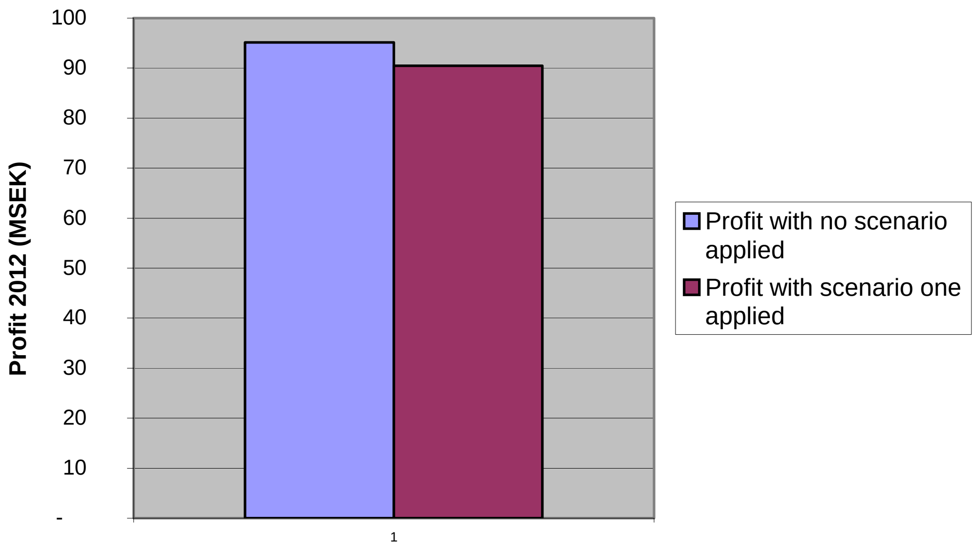

Figure 10-1. The profit at Anderslöf in 2012 with and without scenario one applied.

As figure 10-1 can tell the profit for Anderslöv in 2012 compared to Ref 2012 decreases with 4,6 MSEK preferably due to the increasing cost for electricity.

First of all, the value of existing internal electricity production is increased with about 1,3 MSEK in 2012. The revenue from selling green certificate is the same as the present one but the value of internal electricity production rises because of the CO_2 price mark-up on electricity, thus in overall the estimated monetary value grows.

When applying scenario one to Anderslöf it is possible to see the different outcome whether the saved steam is transformed into a reduced cost for less demand of steam

in paper manufacturing or if the steam is used in electricity production. The steam at Anderslöf produced in boilers using biofuel or oil as raw material. In the calculations above it is showed, due to the oil price and price of emission allowances, that decreasing the oil utilization is most profitable. When using less oil the costs decrease with over 4 MSEK in 2012 compared to using less biofuel.
The possibility to use steam in a condensing turbine in order to produce electricity is not a rather good solution since the revenue is substantially lower than of decreasing the use of fuel even though the revenues is 0,3 MSEK larger when scenario one is applied than in the reference case. The calculations shows that the cost savings of less demand for biofuel instead of producing electricity are 70 per cent greater in 2012 and the cost savings of less need for oil in turn gives up to 135 per cent greater revenues. The huge difference is in part depending on the low electrical efficiency, and this in turn depends on the characteristics (low pressure and temperature) of the saved steam and the energy consumption for water-cooling. The estimations above tells that an investment in a condensing turbine, with a seven year term, where inflation, risk premium, capital cost etc are excluded may not exceed 30 MSEK in order to be profitable. The authors estimate it to be hard to find a condensing turbine for this price.

When combining advantages and disadvantages of scenario one a trend concerning the revenues is identified. In the beginning of the period the disadvantages from increasing electricity price strikes Anderslöf fairly hard (8,7 MSEK) or –11 per cent less profit, but the increasing revenues from the decreased oil purchase altogether with the growing price on green certificates makes the effect die away and in the end of the period the revenues exceed the costs by far (5,7 MSEK) or a rising profit with 7 per cent compared to today. Regarding the amount of saved oil, it exceeds the limit of required oil at Anderslöf (minimum level: 5 000 m^3/year) and therefore is the surplus of saved oil converted into sold biofuel in year 2011 and 2012. This in turn gives that further reductions of steam demand have to be translated into less biofuel demand or increased electricity production.

A comparison between a situation in 2012 with the existing conditions and the conditions when scenario one is applied gives that cost savings in a less demand for oil is even more tempting in scenario one due to the rising price for electricity. The savings of cost is 1,1 MSEK larger compared to no applied scenario at all.

Anderslöf has an opportunity to increase revenues from electricity production in backpressure turbines through considering the proposed measures for enlarged production of electricity.
With the given circumstances it is possible to produce electricity with an estimated value in 2012 of 4 MSEK when step one is taken into action, 6 MSEK with step two and when both of them are taken into operation the estimated value is 10 MSEK. The aggregated increase of revenues thanks to these improvements during 2005-2012 is 72 MSEK and a very simplified capital investment valuation, with an eight year term where the discount rate is excluded, tells that likewise is 72 MSEK the maximum cost considering new turbines, optimizations, etc. without losses.

When scenario one is applied to Anderslöf and the offensive strategies is taken the net revenues is 0,7 MSEK larger in 2012 compared to the existing situation but in total during 2005-2012 the net revenues is 1,0 MSEK less due to the low price for certificates in the beginning of the period. The monetary room for investments is therefore smaller in scenario one compared to Ref 2012.
The growing demand for fuel, due to the enlarged electricity production, is fulfilled with biofuel since this is most profitable solution, due to emission allowances, as well as being the most environmental friendly solution.

10.4 Scenario 2 applied to Anderslöf

Table 10.4 presents the high lights of the comparison of scenario two and Ref 2012 applied to Anderslöf. The complete calculations and estimations are presented in appendix C.
For instructions in how to read the table below, please turn to chapter 10.2.

Estimation	**Unit**	**Ref 2012**	**2012**	**Acc. savings (kSEK)**
The green certificate price	SEK/MWh	200	350	
Annual increased gross electricity costs	kSEK/year	-	28 262	**226 099**
Annual changed value of existing own electricity production	kSEK/year	-	14 299	**102 129**
Total increased net cost	**kSEK/year**	**-**	**13 963**	**123 970**
The saved steam converted into electricity and sold to the market, including green certificates	kSEK/year	6 574	10 218	**44 796**
Cost savings for less biofuel demand	kSEK/year	11 891	13 930	**62 684**
Cost savings for less oil demand including emission allowances	kSEK/year	15 115	19 596	**88 353**
Summary: Changed revenues, cost savings for less oil demand	**kSEK/year**	**15 115**	**5 632**	**- 35 616**
				-
Increased pulpwood cost	**kSEK/year**	**-**	**19 200**	**- 153 600**
Profit	**kSEK/year**	**95 115**	**66 432**	
Changed profit	**%**	**18,9**	**- 17,0**	

Table 10-4. Scenario 2 applied to Anderslöf.

10.4.1 The specific energy usage at Anderslöf

Like in the scenario 1 the steam demand at Anderslöf is decreasing and likewise is the saved specific amount of steam about 1,4 GJ/ ton paper, hence the input parameters, like green certificates and emission allowances, do not affect the specific energy usage. The reduction in specific energy usage stems entirely from moving towards the smaller specific electricity utilization of KAM 2.

10.4.2 The electricity production at Anderslöf

The estimated value of the existing electricity production is rising with, 14 MSEK in 2012 and in total during 2005-2012 with 102 MSEK.
The conditions given in scenario two and the amount of saved steam make it possible to annually produce another 15,3 GWh electricity in 2012 and totally 69 GWh during 2005-2012. This amount of electricity produced in condensate turbines have an estimated value of 10,2 MSEK and 44,8 MSEK respectively. If the electricity was produced under the conditions of today the estimated value would be 6,6 MSEK, almost 3,6 MSEK less than in scenario two.

10.4.3 The energy mix at Anderslöf

The saved amount of steam in 2012 76,4 GWh in 2012 since the boilers at Anderslöf have a steam-producing factor of 0,9 the amount of saved raw material is about 11 per cent greater. The valuation of this reduction depends on whether the steam stems from oil or biofuel.
If the saved steam is produced in a bark boiler with biofuel the estimated value of the improvements is 14 MSEK in 2012 and during the total period 2005-2012 the estimated value is 63 MSEK.
As a comparison the estimated value of steam produced in an oil boiler is worth 20 MSEK in 2012 and finally 88 MSEK over the present period.
When Ref 2012 is applied to Anderslöf the estimated value of the saved steam is 15 MSEK when translated into oil and 12 MSEK when translated into biofuel.

10.4.4 The changed allocation of costs at Anderslöf and the competition for pulpwood

The present costs for electricity increases dramatically with almost 40 per cent up to 510 SEK/ ton paper when the electricity prises increases likewise. With the production of today at Anderslöf the costs increases with 28,3 MSEK annually due to increasing electricity prices.

The 20 per cent price increase for biofuel because of rising demand for biofuel makes the price of pulpwood rise as well. This relationship between the pulpwood and biofuel hits Anderslöf in two ways, the raw material is getting more costly and in turn a higher opportunity cost for steam. The opportunity cost for steam rises in pair with the increasing price for biofuel, though the opportunity cost is hard to handle since the internal price increases the revenues for one department and increases the costs for another one within the mill. Anderslöf has in this case no potential customer of the produced steam and the opportunity to sell steam is therefore very limited and as a consequence of this is the opportunity cost not taken into consideration.
The increased price for pulpwood, due to rising price for biofuel, makes the annual costs at Anderslöf grow with 19,2 MSEK with the present production.
In total the levels for green certificates and emission allowances used in scenario 2 gives Anderslöf rising cost with 6 per cent or 47 MSEK every year during 2005-2012.

10.4.5 Offensive electricity strategy

Likewise in scenario one there is a remarkable increase in electricity production when the two offensive strategies presented are applied to Anderslöf. There is no opportunity to produce more electricity in scenario number two compared to scenario number one therefore are the amount of produced electricity the same, but the estimated value differs.

In table 10.4 are the results of the two offensive strategies applied at Anderslöf in 2012 using the circumstances of scenario two and using the same circumstances as today. *The complete estimation is presented in appendix C and for instructions how to read the table below, please turn to chapter 9.2.5.*

Optimize operating time	**Unit**	**Ref 2012**	**2012**	**Acc. savings (kSEK)**
Potential for increased electricity production	MWh/year	12 750	12 750	
Sell the increased electricity production to the market	kSEK/year	5 483	8 521	
Increased cost for biofuel	kSEK/year	1 964	2 300	
Net revenue = Sold electricity - biofuel cost	**kSEK/year**	**3 519**	**6 221**	**47 162**

New turbines				
Potential for increased electricity production	MWh/year	20 250	20 250	
Sell the increased electricity production to the market	kSEK/year	8 708	13 533	
Increased cost for biofuel	kSEK/year	3 119	3 653	
Net revenue = Sold electricity - biofuel cost	**kSEK/year**	**5 589**	**9 880**	**74 904**

Optimize operating time + new turbines				
Potential for increased electricity production, step 1	MWh/year	33 000	33 000	
Sell the increased electricity production to the market	kSEK/year	14 190	22 055	
Increased cost for biofuel	kSEK/year	5 082	5 953	
Net revenue = Sold electricity - biofuel cost	**kSEK/year**	**9 108**	**16 101**	**122 066**

Table 10-5. Offensive strategies applied to Anderslöf.

According to the actual price of green certificates and electricity in scenario two the monetary outcome increases further up to 6 MSEK and 47 MSEK for the year 2012 and the total period 2005-2012 when the measures proposed in step 1 is taken into action.

In step 2, where new turbines are proposed, the revenues are estimated to be 10 MSEK in 2012 and in aggregation 75 MSEK.

Altogether the two proposed steps give a total monetary output of 16 MSEK and 122 MSEK for each period of time. The estimated value of the electricity produced with the present prices is 9 MSEK when both offensive strategies are taken into action.

10.5 Discussion scenario 2

Scenario two with the subsequent growth in prices for green certificates, electricity, biofuel, pulpwood and emission allowances affect the profit of today at Anderslöf remarkably. Figure 10-2 is illustrating the profit at Anderslöf in 2012 when Ref 2012 respectively scenario two are applied and when the less steam demand is translated into less utilization of oil.

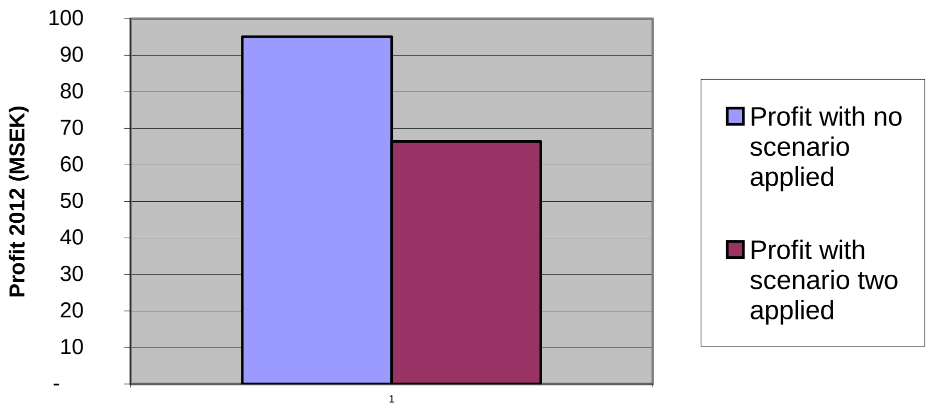

Figure 10-2. The profit at Anderslöf in 2012 with and without scenario two applied.

Likewise in scenario one the increasing price of electricity strikes Anderslöf noticeably, the annual cost for electricity increase with over 40 per cent or 28 MSEK. The estimated value of the present electricity production increases as well but the rise in increased revenues of 14 MSEK in 2012 is rather modest compared to the growing costs. In total the high electricity price decrease the profit at Anderslöf with more than 12 per cent in compared to if there was no system with emission trading and if the price for green certificates would stay at the present level.

When Anderslöf is moving towards the specific energy utilization of KAM 2 the savings in steam can be estimated in terms of saved raw material for steam production as well as an expanded electricity production in condensing turbines. Using these savings for producing more electricity would increases the total profit with 13 per cent (10,2 MSEK) in 2012. Over the whole period of 2005-2012 the total increased revenues from electricity production is 44 MSEK and this is also the maximum possible financial room for an investment in a condensing turbine with a eight year investment horizon where the inflation, risk premium, capital cost etc are excluded before losses will appear.

A large share of the difference in profit in Ref 2012 compared to scenario two comes from the increasing price in pulpwood. During scenario two the annual cost for pulpwood grows with approximately 19 MSEK or 5 per cent as a consequence of the rising price for biofuel.

Due to the increased biofuel price, converting the saved steam into a less demand for biofuel instead of producing electricity is getting more attempting. The estimations above illustrates that a total growth in revenues during 2005-2012 of 63 MSEK when transforming the steam into unused biofuel is possible. Still, irrespective of the increased prices for biofuel, the most profitable solution is to convert the unused steam into less demand for oil. The revenues increase concurrently with the saved amount of steam and amount to 88 MSEK during 2005-2012, compared to producing electricity or less demand for biofuel the revenue is 95 per cent respectively 40 per cent greater with less oil demand. Like in scenario number one Anderslöf reaches the minimal level of oil usage and the surplus of unused oil has to be translated into less biofuel demand or increased electricity production. The estimated value of the translated steam is considerably higher when scenario two is applied compared to Ref 2012. When using the existing level in electricity price, green certificates and no emission allowances the cost savings is much less than using scenario two. The effects from scenario two increases the revenues with 30 per cent when translating into oil compared to the levels of today.

When considering whether to use an offensive electricity production or not at Anderslöf there are strong monetary incentives for taking both step one and step two into action. With the levels for green certificates and electricity in scenario number two there is an opportunity to increase the profit. Already in the first year the revenue grows with 6 MSEK and 10 MSEK in 2012 when step 1 resp. step 2 are introduced at Anderslöf. In step 1, where larger investments are unnecessary, the annual profit increases with 77 per cent in scenario two compared to the present level.
The total cost for a turbine investment with an eight year investment horizon, where the inflation, risk premium, capital cost etc is excluded, without risking losses can be maximum 122 MSEK. When using Ref 2012 the room for an increased electricity production-related investment is only 73 MSEK, 49 MSEK less than when scenario two is applied.

In this scenario it is almost necessary to use the offensive strategies in order to compensate and reduce the substantially increased costs for purchased electricity and pulpwood. When making a comparison between the outcome of scenario two applied to Anderslöf and Ref 2012 it is obvious what effect the risen price for green certificates and emission allowances has.

11 The Carlstrand analysis

This chapter describes the outcomes of the scenarios applied to the Carlstrand TMP mill, i.e. the output parameters are given a value. Outcome after taken improving measures are also presented and discussed.

11.1 Background information

To facilitate the reading of the analysis some background information is presented below. The made TMP mill used in this thesis is presented in chapter 7, yet is a brief rehearsal of the most important data at Carlstrand presented in table 11-1.

Carlstrand, 2004	Unit	Amount
Annual paper production	Ton/year	500 000
Annual profit	MSEK/year	50
Specific cost	SEK/ ton paper	3700
Sales price	SEK/ ton paper	3800
Existing specific electricy usage	MWh/ton paper	2,82
Existing specific electricity production	MWh/ton paper	0,08

Table 11-1. The data of Carlstrand.

11.1.1 Present production at Carlstrand

First of all is the present production at Carlstrand presented without any scenario applied, thus table 11-2 presents the actual production at Carlstrand.

How to read the table: *The column "Ref 2012" illustrates the outcome of each action taken at Carlstrand in 2012 when Ref 2012 is applied, i.e. the circumstances is like the existing ones without effects from emission allowances, etc..*

"2012" illustrates the outcome of the different measures taken when scenario one is applied to Carlstrand in 2012.

"Acc. savings" illustrates the total savings or total costs during the period 2005-2012 due to the taken measure and this is likewise the maximum cost considering new investments without losses when using a very simplified capital investment valuation, with an eight-year term where the discount rate is excluded.

In the text below there are several tables presenting the outcomes of the different measures taken into action. Though there are only highlights presented underneath, since the complete calculus is presented in appendix D. The unit used in the estimations is of the specific kind with the aim to increase the understandings of the different measures taken into action.

Data	Unit	2005
The green certificate price	SEK/MWh	200
Specific revenue	SEK/ton paper	100

Present production		

Specific cost for electricity	SEK/ ton paper	649
Specific cost for pulpwood	SEK/ ton paper	620
Other specific variable and fixed costs	SEK/ ton paper	2 431
Specific changed value of existing own electricity production	SEK/ ton paper	-
Increased cost for biofuel	SEK/ ton paper	-
Total specific cost	SEK/ ton paper	3 700
Specific profit	**SEK/ ton paper**	**100**
Changed cost compared to existing cost	%	-

Table 11-2. Present production at Carlstrand.

As the table can tell, the present specific profit is estimated to be 100 SEK.

As in the case of Anderslöf continuous improvements in specific energy usage exist in the Carlstrand mill as well, however improvements in specific energy usage are compensated to a large extent by energy consuming improvements in paper quality[113]. The increased energy efficiency of ten per cent simulated below is an additional effect described in chapter 8.3.

11.2 Scenario 1 applied to Carlstrand

When applying scenario one to Anderslöf and later on compare it to a situation with Ref 2012 the different parameters hits the mill in different areas. A complete table of calculations is presented in appendix D, hence is only the highlights presented in the tables below.

11.2.1 Scenario 1 applied to Carlstrand without any measures taken

Table 11-3 is illustrating how Carlstrand is affected by the prices for green certificates and emission allowances simulated in scenario one and shows the outcome of scenario 1 applied to Carlstrand as well as when Ref 2012 is applied.

For instructions about how to interpret the table, please turn to part 11.1.1.

No measures taken	**Unit**	**Ref 2012**	**2 012**
Specific cost for electricity	SEK/ ton paper	649	711
Specific cost for pulpwood	SEK/ ton paper	620	620
Other specific variable and fixed costs	SEK/ ton paper	2 431	2 431
Specific changed value of existing own electricity production	SEK/ ton paper	-	2
Increased cost for biofuel	SEK/ ton paper	-	-
Total specific cost	SEK/ ton paper	3 700	3 760
Specific profit	**SEK/ ton paper**	**100**	**40**
Changed cost compared to existing cost	%	-	1,6

Table 11-3. Scenario 1 applied to Carlstrand without any measures taken.

The rising electricity price makes the specific cost for electricity increase up to 711 SEK while rest of the costs are constant. The increased cost for electricity decreases the profit with 60 per cent or down to 40 SEK/ ton paper.

11.2.2 Scenario 1 applied to Carlstrand with measure “10% off” taken

Measure 1, as explained in chapter 8.3.1, contains an electricity conservation of ten per cent in different processes at Carlstrand. The outcome of this measure is presented in table 11-4.

How to read the table: *The column “Ref 2012” illustrates the outcome of actions taken at Carlstrand in 2012 when Ref 2012 is applied, i.e. the circumstances is like the existing ones, hence the proposed measures are taken but the estimations excludes the effects from climate policies.*

“2012” shows the outcome of the different measures taken when scenario one is applied to Carlstrand in 2012.

“Acc. Savings due to inv. 2005-2012” illustrates the total savings or total costs during the period 2005-2012 due to the taken measure. The accumulated savings in the actual scenario is to be compared to the same scenario but no measures taken. The accumulated savings can also be seen as the maximum cost considering new investments without losses when using a very simplified capital investment valuation, with an eight-year term where the discount rate is excluded.

10% off	**Unit**	**Ref 2012**	**2 012**	**Accumulated savings due to inv. (kSEK)**
Specific cost for electricity	SEK/ ton paper	584	640	284 346
Specific cost for pulpwood	SEK/ ton paper	620	620	
Other specific variable and fixed costs	SEK/ ton paper	2 431	2 431	
Specific changed value of existing own electricity production	SEK/ ton paper	-	2	
Increased cost for biofuel	SEK/ ton paper	-	-	
Total specific cost	SEK/ ton paper	3 635	3 689	
Specific profit	**SEK/ ton paper**	**165**	**111**	
Changed cost compared to existing cost	%	- 1,8	- 0,3	

Table 11-4. Scenario 1 applied to Carlstrand with measure “10% off” taken.

When measure 1 is taken into action the specific cost for electricity decreases to an amount that compensates the rising electricity prices of the scenario. Due to the lower price of green certificates, compared to the existing one, the value of the existing electricity production reduces in the beginning but is concurrently rising with the price for green certificates. Overall, the profit shows a little growth during the period compared to today’s profit. The large difference in electricity price due to emission

[113] Wiberg, Rolf (2001), Energiförbrukningen i massa- och pappersindustrin 2000

allowances decreases the specific profit with approx 50 per cent compared to when Ref 2012 is applied.

11.2.3 Scenario 1 applied to Carlstrand with measure "changed mix" taken

Measure 2 contains the changing raw material mix at Carlstrand. The amount of waste paper increases on behalf of the thermomechanical pulp and as a consequence the specific electricity demand is decreasing. In table 11-5 scenario one is applied to Carlstrand with measure 2 taken into action.

Changed mix	**Unit**	**Ref 2012**	**2 012**	**Accumulated savings due to inv. (kSEK)**
Specific cost for electricity	SEK/ ton paper	524	574	547 518
Specific cost for pulpwood	SEK/ ton paper	620	620	
Other specific variable and fixed costs	SEK/ ton paper	2 431	2 431	
Specific changed value of existing own electricity production	SEK/ ton paper	-	2	
Increased cost for biofuel	SEK/ ton paper	-	-	
Total specific cost	SEK/ ton paper	3 575	3 624	
Specific profit	**SEK/ ton paper**	**225**	**176**	
Changed cost compared to existing cost	%	- 3,4	- 2,1	

Table 11-5. Scenario 1 applied to Carlstrand with measure "changed mix" taken.

When changing the raw material mix of the advanced paper produced at Carlstrand there is a large change in electricity demand. The specific electricity cost is reduced with 137 SEK, thus the total value of the reduced cost during 2005-2012 amount to 550 MSEK. This sum is also the maximum capital to invest in changed processes, due to the changed raw material mix, without risking losses. The specific profit grows with 76 per cent and as a consequence Carlstrands' annual profit come up to 88 MSEK. The specific profit with Ref 2012 applied to Carlstrand is 49 SEK larger in contrast to when scenario two is applied.

11.2.4 Scenario 1 applied to Carlstrand with measure "biofuel" taken

When taking measure 3 into action the dependency upon fossil fuel decrease and in turn the utilization of biofuel enhances. This measure taken into action at Carlstrand in scenario one, as well as Ref 2012, is presented in table 11-6

Biofuel	**Unit**	**Ref 2012**	**2 012**	**Accumulated savings due to inv. (kSEK)**
Specific production cost	SEK/ ton paper	3 700	3 760	
Specific net revenue from replacing oil with biofuel and sell allowances	SEK/ ton paper	19	25	93 752

Increased cost for biofuel	SEK/ ton paper	-	-	
Total specific cost	SEK/ ton paper	3 681	3 735	
Specific profit	**SEK/ ton paper**	**119**	**65**	
Changed cost compared to existing cost	%	- 0,5	1,0	

Table 11-6. Scenario 1 applied to Carlstrand with measure "biofuel" taken.

When exchanging the use of oil with biofuel the specific profit increases. Thanks to the revenues from selling emission allowances and the lower price per MWh for biofuel compared to oil, the total profit amounts to 65 SEK in 2012. It should be pointed out that the exchange in fuel occurs in 2008 and the revenue from emission allowances comes annually during 2008-2012, the limited time is based on the assumption in chapter 9.2.2 about future allocation being based on emissions of last couple of years.

11.2.5 Offensive electricity strategy

In chapter 8.5 there are two different strategies presented to show the potential of enlarged electricity production an offensive electricity strategy could bring. In table 11-7 the result of the two offensive strategies applied to Carlstrand with and without (Ref 2012) scenario is offered. The complete table is attached in appendix E.
The mark-up percentage for the electricity production used in the calculations below is the same as the total mark-up estimated for the total Swedish mills.

Optimize operating time	**Unit**	**Ref 2012**	**2 012**	**Accumulated savings due to inv. (kSEK)**
Potential for increased electricity production	MWh/year	8 500	8 500	
Sell the increased electricity production to the market	kSEK/year	3 655	3 843	
Increased cost for biofuel	kSEK/year	1 309	1 309	
Net revenue = Sold electricity - cost for biofuel	**kSEK/year**	**2 346**	**2 534**	**18 500**

New turbines				
Potential for increased electricity production	MWh/year	13 500	13 500	
Sell the increased electricity production to the market	kSEK/year	5 805	6 103	
Increased cost for biofuel	kSEK/year	2 079	2 079	
Net revenue = Sold electricity - cost for biofuel	**kSEK/year**	**3 726**	**4 024**	**29 382**

Optimize operating time + new turbines				
Potential for increased electricity production	MWh/year	22 000	22 000	
Sell the increased electricity production to the market	kSEK/year	9 460	9 946	
Increased cost for biofuel	kSEK/year	3 388	3 388	
Net revenue = Sold electricity - cost for biofuel	**kSEK/year**	**6 072**	**6 558**	**47 882**

Table 11-7 Offensive strategies applied to Carlstrand.

Through implementing the proposed measures for increased production, the net revenues can grow as well. The first step is to optimize the operating time, etc. and this could enlarge the annual electricity production with 8 500 MWh and in turn 18,5 MSEK during the entire period 2005-2012. In step two where the park of turbines are optimized or even exchanged, the annual electricity production increases with 34 per cent up to 13 500 MWh or an estimated value of 29 MSEK during 2005-2012. Altogether there is room for investments of 48 MSEK in offensive energy measures at Carlstrand when scenario on is applied. The green certificates and emission allowances of scenario one increases the revenues from offensive strategies with 0,5 MSEK in 2012 compared to Ref 2012.

11.3 Discussion scenario 1

Applying scenario one to Carlstrand, possible measures and offensive strategies gives a rather bright picture of the future. The different outcomes from the proposed measures at Carlstrand where no investments cost are taken into consideration compared to the present profit of 50 MSEK annually are illustrated in figure 11-1. *Note:* ***The first bar (No measures taken) illustrates the actual profit under scenario two while the rest of the bars illustrate the profit when the actual investment cost for each measure taken is excluded*** *The profit for the offensive strategies below is to be seen as an addition to an already existing profit except in the two last alternatives.*

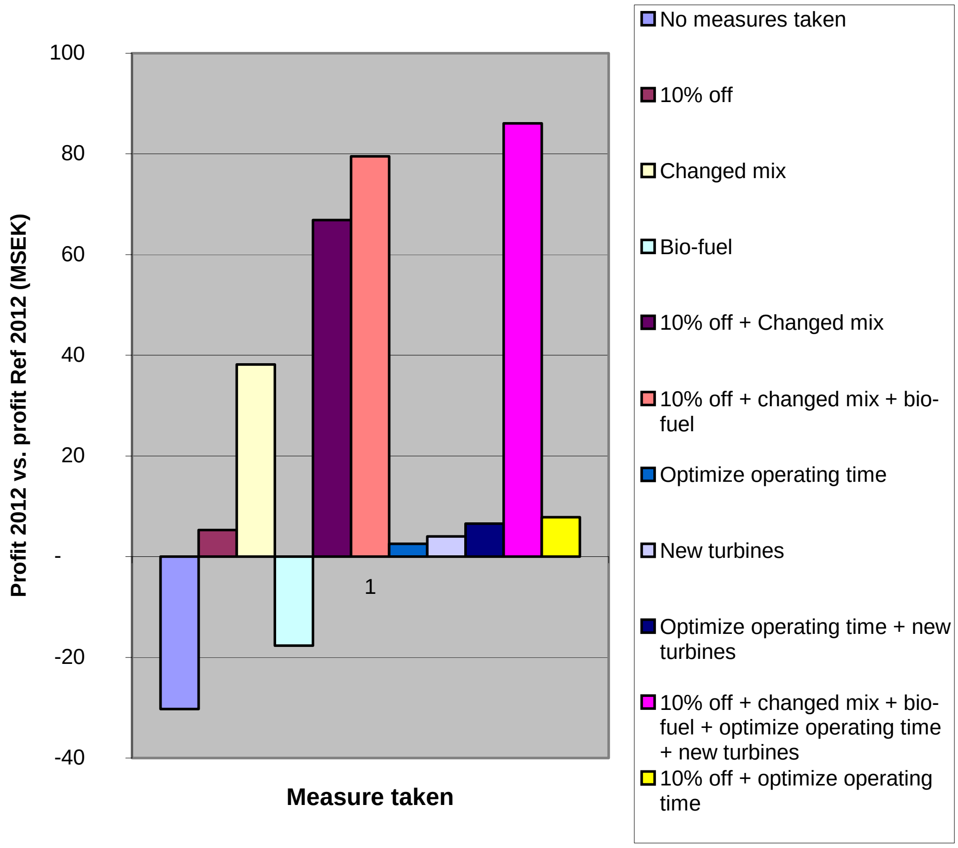

Figure 11-1. The profit at Carlstrand in 2012 under scenario one with different measures taken.

The mill has a number of opportunities for improving the profit and only two lines of action results in a smaller profit than today, these are; doing nothing and only changing fuel mixture and in turn selling emission allowances.

As figure 11-1 can tell, the decreased profit due to the price level for green certificates and emission allowances is approx. 30 MSEK and as a consequence Carlstrand is moving towards a nil return. Even though the price level of emission allowances could be seen as rather modest the economical effect on a TMP mill is obvious and the authors recommend Carlstrand to take measures.

The poor outcome of the last mentioned alternative is of course caused by the low prices of emission allowances in this scenario. Only switching from oil to biofuel seems to be a bad idea under scenario one, the profit improvement is not only small it is also time limited, since the same amount of allowances not will be allocated when emissions are reduced. Another argument against increased usage of biofuel is that costs for maintenance and replacing worn material are higher when burning biofuel than when burning oil.

In order to illustrate the potential power in cutting costs when combining the different measures, some simulations are added in figure 11-1. The modest line of changes, only undertaking measure one and offensive strategy one, gives an improved result of 16 per cent compared to today. The ambitious line of changes, undertaking all measures and both offensive strategies improves the result with 122 (cost for investments are excluded) compared to today.

When comparing the different outcomes in the analysis one must remember that capital cost not is considered and that other kinds of additional costs followed by the changes not are considered. The accumulated profits of the different measures are substantially bigger than the accumulated profits of the offensive strategies, but the unknown costs can also be suspected to be substantially different. The nature of paper production (as in the case of the measures) and the nature of investments in electricity production (as in the case of the offensive strategies) are different and hard to compare.

The largest individual profit change under scenario one is available through changing the raw material mixture, i.e. measure two. However this is also the most fundamental change to production. This measure has a giant potential since the raw material mixture could be altered far more than proposed. The share of recycled paper could be up to 100 per cent, therefore the suggested mixture change from 15 per cent to 30 per cent recycled paper could definitely be considered as modest. In the long run it should also be remembered that the pulp producing machinery needed for recycling paper is cheaper than for TMP[114].

A sensationally small difference in outcome between the two offensive strategies to produce more electricity appears, when considering that the first strategy requires only cost for controlling and does not require any investments. The relatively small increase in electricity price of scenario one gives an accumulated profit change from new turbines of 29 MSEK and 18 MSEK during 2005-2012 from optimized running times with existing turbines. It is more profitable to invest in rising electricity production under scenario one compared to Ref 2012.

11.4 Scenario 2 applied to Carlstrand

Scenario two means high prices on emission allowances, electricity and green certificate and raised prices on raw material. All of these are significant parts of the Carlstrand calculus except for prices on emissions allowances. Prices on emissions allowances are only considered in the calculus indirectly trough the impact on electricity price. In the text below is the highlights of the calculus done presented, the complete calculations is attached in appendix F. The unit used in the estimations is of the specific kind with the aim to increase the understandings of the different measures taken into action.

For instructions in how to read the table below, please turn to chapter 11.1.1.

[114] Eidensten, Lars 2004-05-07

11.4.1 Scenario 2 applied to Carlstrand without measures taken

Scenario 2 is applied to Carlstrand and the result is presented in table 11-8.

No measures taken	**Unit**	**Ref 2012**	**2 012**
Specific cost for electricity	SEK/ ton paper	649	898
Specific cost for pulpwood	SEK/ ton paper	620	651
Other specific variable and fixed costs	SEK/ ton paper	2 431	2 431
Specific changed value of existing own electricity production	SEK/ ton paper	-	19
Increased cost for biofuel	SEK/ ton paper	-	11
Total specific cost	SEK/ ton paper	3 700	3 972
Specific profit	**SEK/ ton paper**	**100**	**- 161**
Changed cost compared to existing cost	%	-	7,1

Table 11-8. Scenario 2 applied to Carlstrand with no measure taken.

The electricity price, due to emission allowances, increases with 40 per cent and this fact strikes Carlstrand very hard. The specific cost for electricity is rising with 249 SEK and in turn the former profit turns into a loss of 161 SEK per ton paper compared to when Ref 2012 is applied. The value of the existing electricity is indeed rising but this cannot compensate the electricity mark-up at all. Due to the rising price for biofuel, the overall specific cost increases as well as the price on the raw material for paper, pulpwood.

11.4.2 Scenario 2 applied to Carlstrand with measure “10% off” taken

Table 11-9 represents the outcome of scenario 2 and the reference scenario applied to Carlstrand with electricity conservation taken into action.

10% off	**Unit**	**Ref 2012**	**2 012**	**Accumulated savings due to inv. (kSEK)**
Specific cost for electricity	SEK/ ton paper	584	808	359 065
Specific cost for pulpwood	SEK/ ton paper	620	651	
Other specific variable and fixed costs	SEK/ ton paper	2 431	2 431	
Specific changed value of existing own electricity production	SEK/ ton paper	-	19	
Increased cost for biofuel	SEK/ ton paper	-	11	
Total specific cost	SEK/ ton paper	3 635	3 882	
Specific profit	**SEK/ ton paper**	**165**	**- 71**	
Changed cost compared to existing cost	%	- 1,8	4,6	

Table 11-9. Scenario 2 applied to Carlstrand with measure “10% off” taken.

Using electricity conservation as a counteraction against the rising costs is a powerful measure, but as table 11-9 can tell it is not enough to turn the loss into profit. The specific costs decrease with 90 SEK per ton paper but still there is a specific loss of 71 SEK. An even worse identification than the specific loss is the decreasing trend of the profit (loss) during the period 2005-2012. Even though the specific profit is rather depressing the accumulated savings of measure 1 is the gleam of light, hence is the estimated value of the electricity conservation almost 360 MSEK. A comparison to Ref 2012 crystallizes the effects from especially emission allowances.

11.4.3 Scenario 2 applied to Carlstrand with measure "changed mix" taken

Measure two contains changing raw material mix at Carlstrand, the amount of waste paper increases and the thermo mechanical pulp is in turn decreasing with a lower electricity utilization per ton paper as a consequence. The highlights from scenario two and reference scenario in 2012 and the accumulated savings between 2005-2012 due to investment are displayed in table 11-10.

Changed mix	**Unit**	**Ref 2012**	**2 012**	**Accumulated savings due to inv. (kSEK)**
Specific cost for electricity	SEK/ ton paper	524	725	691 391
Specific cost for pulpwood	SEK/ ton paper	620	651	
Other specific variable and fixed costs	SEK/ ton paper	2 431	2 431	
Specific changed value of existing own electricity production	SEK/ ton paper	-	19	
Increased cost for biofuel	SEK/ ton paper	-	11	
Total specific cost	SEK/ ton paper	3 575	3 799	
Specific profit	**SEK/ ton paper**	**225**	**12**	
Changed cost compared to existing cost	%	- 3,4	2,4	

Table 11-10. Scenario 2 applied to Carlstrand with measure "changed mix" taken.

Likewise in scenario 1 is measure 2 a powerful electricity saving tool. The estimated value of the savings done in measure 2 during 2005-2012 is 690 MSEK and likewise is this the potential maximum amount worth risking when investing without increasing losses. The specific loss during these conditions is estimated to be about 12 SEK/ ton paper. The difference in specific cost for electricity depending on the scenario applied is 201 SEK in favour to the reference scenario.

11.4.4 Scenario 2 applied to Carlstrand with measure "biofuel" taken

With measure 3 Carlstrand decreases the dependency of oil noticeably when converting into an increasing demand and utilization of biofuel. The effects on Carlstrand are displayed in table 11-11.

Biofuel	**Unit**	**Ref 2012**	**2 012**	**Accumulated savings due to inv. (kSEK)**

Specific production cost	SEK/ ton paper	3 700	3 961	
Specific net revenue from replacing oil with biofuel and sell allowances	SEK/ ton paper	19	34	59 514
Increased cost for biofuel	SEK/ ton paper	-	11	
Total specific cost	SEK/ ton paper	3 681	3 948	
Specific profit	**SEK/ ton paper**	**119**	**- 138**	
Changed cost compared to existing cost	%	- 0,5	6,4	

Table 11-11. Scenario 2 applied to Carlstrand with measure "biofuel" taken.

Revenues from selling the emission allowances are limited in time, based on the assumption done in chapter 9 about allocations being based on emissions done over the last couple of years. The next allocation period Carlstrand would be given less allowances, due to less CO_2-emission, than the period before. In this thesis, Carlstrand renders revenues from emission allowances between 2008-2012 of an estimated value of 60 MSEK compared to no exchange at all. Since the price of electricity is continuously high, the specific loss is large and the effect from selling emission allowances is rather modest. Due to emission allowances the net revenues is 15 SEK/ton paper larger in when scenario two is applied on behalf of the reference scenario.

11.4.5 Offensive electricity strategy

Likewise in scenario one there is a remarkable increase in electricity production when the two presented offensive strategies are applied to Carlstrand. Since the electricity output accords to the possibility of producing more electricity rather than the variation in the input parameters, the amount of produced electricity is the same as in scenario one, but the estimated value of the production differs.
In table 11-12 is the results of the two offensive strategies applied to Carlstrand for 2012 and the total period of 2005-2012 presented, the complete estimation is presented in appendix G.
For instructions in how to read the table below, please turn to chapter 11.2.5.

Optimize operating time	**Unit**	**Ref 2012**	**2 012**	**Accumulated savings due to inv. (kSEK)**
Potential for increased electricity production	MWh/year	8 500	8 500	
Sell the increased electricity production to the market	kSEK/year	3 655	5 681	
Increased cost for biofuel	kSEK/year	1 309	1 533	
Net revenue = Sold electricity - cost for biofuel	**kSEK/year**	**2 346**	**4 147**	**31 441**

New turbines				
Potential for increased	MWh/year	13 500	13 500	

electricity production				
Sell the increased electricity production to the market	kSEK/year	5 805	9 022	
Increased cost for biofuel	kSEK/year	2 079	2 435	
Net revenue = Sold electricity - cost for biofuel	**kSEK/year**	**3 726**	**6 587**	**49 936**

Optimize operating time + new turbines				
Potential for increased electricity production	MWh/year	22 000	22 000	
Sell the increased electricity production to the market	kSEK/year	9 460	14 703	
Increased cost for biofuel	kSEK/year	3 388	3 969	
Net revenue = Sold electricity - cost for biofuel	**kSEK/year**	**6 072**	**10 734**	**81 377**

Table 11-12.Offensive strategies applied to Carlstrand.

Carlstrand has a great opportunity to derive advantages from the electricity production when implementing offensive strategies mentioned above. The estimated value is about 4,2 MSEK in 2012 and 31 MSEK in total when the operating time in the existing turbine park is optimized. Through realising step two, another 6,6 MSEK in 2012 is added. The total net revenue from the two steps is 81 MSEK throughout the period and an investment in increased electricity production, with a eight-year investment horizon, where the inflation, risk premium, capital cost etc are excluded, can amount up to maximum 81 MSEK without risking increasing losses.

11.5 Discussion scenario 2

Scenario two has a worse outcome than scenario one, mainly due to the higher electricity price. The different outcomes from the proposed measures at Carlstrand compared to the present profit of 50 MSEK annually are illustrated in figure 11-2. *Note:* ***The first bar (No measures taken) illustrates the actual profit under scenario two while the rest of the bars illustrate the profit when the actual investment cost for each measure taken is excluded.*** *The profit for the offensive strategies below is to be seen as an addition to an already existing profit except in the two last alternatives.*

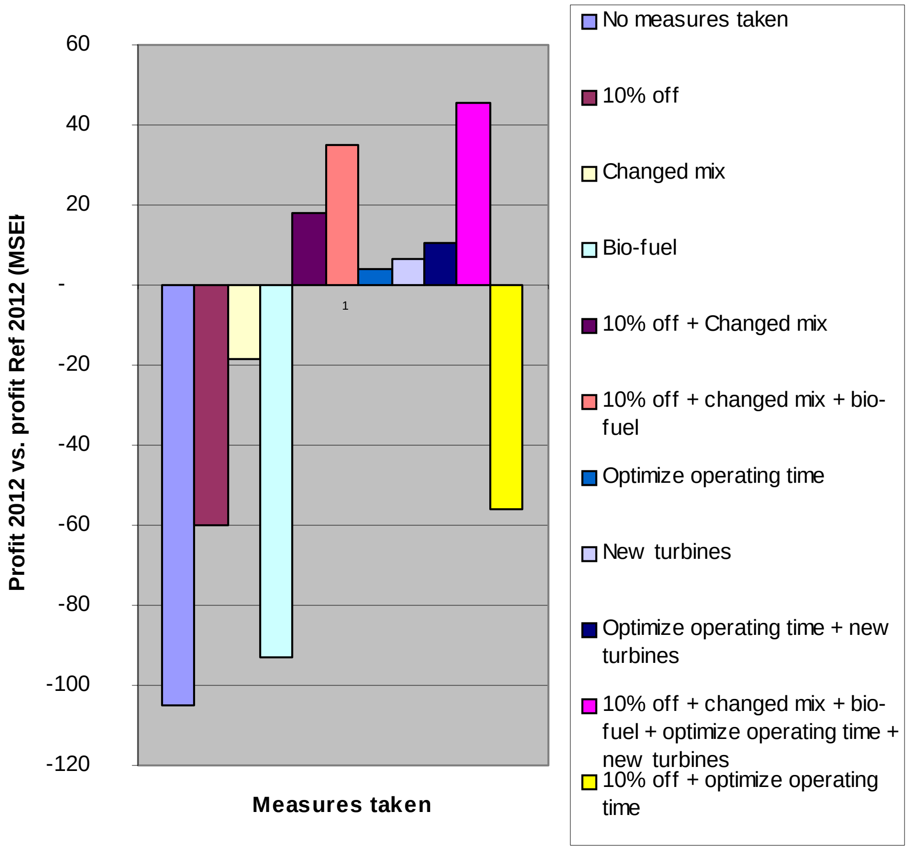

Figure 11-2. The profit at Carlstrand in 2012 under scenario two with different measures taken

When scenario two is applied Carlstrand faces a loss of 105 MSEK if no measures or offensive strategies at all are taken. The changed in profit is even bigger; 155 MSEK when comparing to Ref 2012. Mainly the electricity price strikes Carlstrand really hard and it takes two or more measures to turn the loss into a profit. Again, the changed raw material mixture is the most powerful measure, in respect of altering the result. Figure 11-2 illustrates some selected combinations of the proposed measures as well, still taking all measures and realizing all strategies gives a lower profit compared to today. Considering that the profit level of today is pretty low, the future for Carlstrand under scenario 2 is dark. A further change in raw material mixture could however improve the result radically. Increasing the share of recycling paper from 15 per cent to 30 per cent improves the accumulated profit over eight years with 691 MSEK, another increase from 30 per cent to 45 per cent would probably give another 691 MSEK. As said before, the pulp producing machinery needed for recycling paper is cheaper than the one needed for TMP, hence a time horizon long enough to include a switch of machinery would make machinery for DIP more profitable than for TMP.

Due to the high electricity intensity of the TMP-technology, the electricity price is by far the most important parameter for Carlstrand. High prices on green certificates of scenario two yields only small revenues from electricity production at Carlstrand, also when considering the offensive strategies for increased electricity production. The net revenue from selling emission allowances, which are expensive in scenario two, and replace oil with biofuel does not have as nice consequences for Carlstrand as could be expected. This is partly explained by higher prices on the biofuel necessary for replacing oil. Another disadvantage of increased usage of biofuel, which is not considered, is that costs for maintenance and replacing worn material are higher for biofuel burning than oil burning.

An even smaller relative difference in scenario two than in scenario one appears between the two offensive strategies to produce more electricity. The relatively large electricity price increase of scenario two gives an accumulated profit change from new turbines of 50 MSEK and 31 MSEK from optimized running times with existing turbines.

The cost for pulpwood increases with 5 per cent or 16 MSEK annually for Carlstrand and is just another tough condition to add to the others. This thesis presents no raw material improvement hence is Carlstrand omitted to just face the fact of the scenario.

This analysis concludes some changes to the output parameters of the thesis. Specific energy usage is decreased by 20 per cent, when measure one and two are undertaken. Production volume would be zero in scenario two without any taken measures, due to heavy losses, and unchanged in the other cases, of course depending on patience toward losses of the management.
Once again, compared to Ref 2012 the profit decreases noticeably due to scenario two and the high price for green certificates and emission allowances.

12 Conclusions

Through applying two rather extreme scenarios for prices of emission allowances, green certificates, electricity and wood on two typical Swedish integrated pulp- and paper mills with possible energy related improvements, interesting effects on costs and revenues were calculated. A large number of conclusions were found, the highlights are presented in this chapter.

The new climate control policies, i.e. emissions trading and green certificates, can generally be said to have impacts on the Swedish pulp and paper industry, in some cases considerable effects. However the results are dependent on the kind of technology of the individual mill, the price level of green certificates and emission allowances and also by the line of action chosen by the companies.

The most important effects of allowances and certificates to TMP found in the thesis are not the direct effects but the indirect effects, i.e. the most important effects on the profit are caused by higher electricity price and raw material price.
Sulphate pulp, on the other hand, is affected directly by green certificates. The indirect effect on electricity price, calculated in this thesis, of emission allowances stems from raised marginal costs of CO_2-emitting electricity producers. Electricity prices thereby rise with 2 öre/KWh under allowance cost of 5€/ton CO_2 and 9 öre/KWh under allowances of 20 €/ton. High prices on certificates and allowances boost demand for biofuel, resulting in 20 per cent higher prices. The increasing demand for biofuel also affects demand for wood with higher quality, hence prices of pulp wood increases with 5 per cent. More expensive electricity, biofuel and pulpwood are serious threats to the pulp and paper industry since energy costs and raw material costs corresponds to about 50 per cent of all costs in the industry.

The future of TMP is darker than for sulphate pulp but both mills are still profitable under the scenario with low prices on certificates, allowances, electricity and wood. Under the expensive scenario, TMP turns unprofitable while the profit of sulphate paper mill shrinks with about 17 per cent. Figure 12-1 displays the profits of the two case mills under the two scenarios and without any scenario applied. It should be pointed out that the relative change in profit is big, largely because present profit in the TMP case is low. The cost increase under scenario two of TMP is 7 per cent compared to present costs, mainly due to the large dependency of the electricity price. The cost increase of TMP under scenario 1 is 1,6 per cent. Changes that might not be revolutionizing but are important to a business with low operating margins.

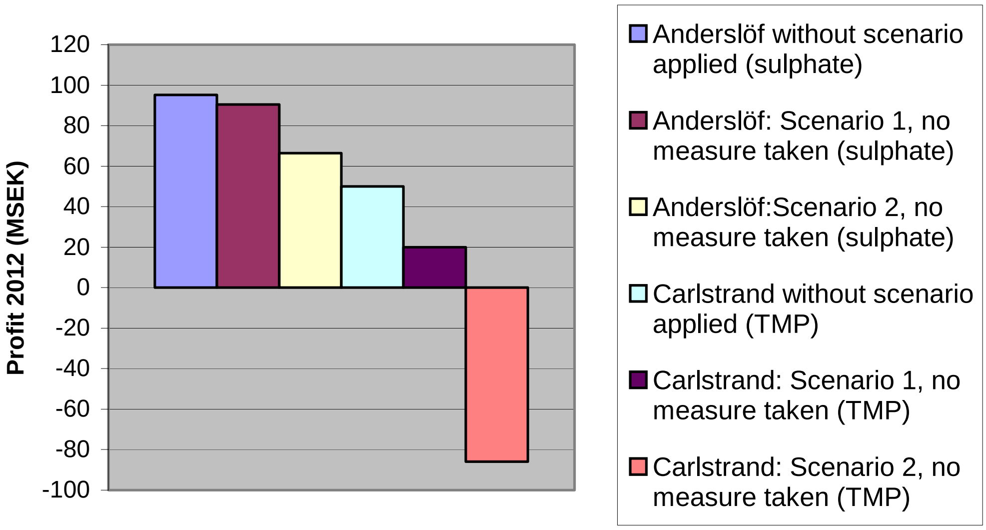

Figure 12-1. The profit at Anderslöf and Carlstrand in 2012 when the scenarios are applied.

A combination of powerful measures is necessary to create potential savings big enough to encumber the negative effects in the case of TMP. Some energy improvements have been evaluated and found to have potential for making TMP profitable also under the expensive scenario. The most powerful measures in combination shows a potential to turn TMP profitable again. However no chance to bring TMP back to the profitability of today was found under scenario two. The profitability of today is low, gross margin is for example only 2,6 %, so the future of the mill is a question of required return demanded by the owners. However the thesis does not include complete calculi of profits, only the positive cash flows, i.e. cost decreases and/or increases in revenues, and no costs for the actions were estimated. This means that potential for profit improvements and not the actual profit improvements were calculated.

The gross effect of switching from oil to biofuel, as far as possible, and selling emission allowances is surprisingly small in the case of TMP. Selling allowances according to an annual reduction of 21 500 m^3 oil gives a net profit improvement of the two scenarios of only 13 MSEK respectively 17 MSEK annually, without considering costs for adjusting the boiler.

The development of integrated sulphate paper mill towards the KAM 2-mill and thereby less steam demand can be used in a number of ways, all affected by climate policy instruments. The greatest value is given by reducing oil utilization and selling emission allowances. When oil usage has reached the lowest level technically possible, the saved steamed should be translated into decreased usage of biofuel. Using the saved low-pressure steam for electricity production in condensing turbines and gaining green certificates renders the smallest revenues, also under scenario two, where prices on green certificates are high.

The level of risk associated with investments in energy related improvements considered in the thesis is high since the value of cost reductions/revenue improvements varies drastically with the scenarios for allowances, certificates etc. For example the value of electricity and certificates of optimized electricity production at TMP varies between 48 MSEK and 81 MSEK during the period 2005-2012.

13 Suggestions for further research

The field of climate control policies is relatively young and unexplored so the number of potential subjects for research is high. The most needed next step for this thesis would be to develop a complete investment evaluation through estimating costs for the lines of actions dealt with in the thesis, find a reasonable economical life time and reasonable discount rate.

The relationship between biofuel prices and pulpwood prices could be of great importance to the pulp and paper industry, to the forestry industry and also for energy producers using biofuel. Alone translating prices to a common unit for biofuel and pulpwood required a lot of effort from the authors of this thesis.

A study of market functionality for pulp and paper products could be very useful to elucidate the degree of global prizing of different pulp and paper products. Pulp and paper companies are often said to be vulnerable to national or regional changes in business conditions. Are there for example different degrees of global respectively local prizing on different products? The relevance for this thesis is whether a part of increasing costs of the different products could be carried over to the customers through higher prices.

Applying the analysis of climate control policies on other industries could be of interest. Some industries are probably more affected by emissions trading and higher electricity price, than the pulp and paper industry is. Analysing effects of emissions trading on for example steel producing companies could probably give significant but maybe not so positive results. Applying an analysis of possible measures could be useful to the industries suspected to be struck worst by emissions trading.

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Appendix A

The pulp and paper industry

The text below introduces the reader into the energy usage in Sweden in general and in the pulp and paper industry in particular. Later on in this appendix the different processes of pulp and papermaking are described with focus on the most common ways of producing pulp and paper.

The Swedish energy application

Sweden has a large energy intensive industry, mainly based on raw materials like iron, wood and minerals. The total Swedish energy application was in 2003 401 TWh where the industry sector uses 152 TWh[115]. The largest energy user in the Swedish industry is by far the pulp and paper industry with an annual energy application of approximately 75 TWh (1999)[116]. This can e compared with the largest Swedish nuclear power station Ringhals, that produces about 25 TWh electricity annually[117].

The Swedish pulp and paper industry

In global terms, Sweden is “a major player” in the forest industry, ranking fourth among the world’s paper and pulp exporters and second in exports of sawn softwood timber. For the Swedish and Finnish economies the forest industry is an important part compared to other EU-countries. Forestry account for more than four per cent of Sweden’s GDP, twelve per cent of total value added in industry, eleven to twelve per cent of industrial employment and almost 15 per cent of Sweden’s exports of goods.[118] Some of the largest pulp and paper companies are Swedish, like StoraEnso, SCA, Holmen and Södra.

The production in the Swedish pulp and paper industry

A pulp and paper production plant is called mill and is often located close to sufficient water supply. The number of Swedish mills has steadily decreased during the 20th century and in 2000 were 59 mills operating, mainly in the northeast of Sweden but the size and production capacity of the remaining mills has increased[119]. The total Swedish production of pulp in 2002 was 11 400 kton with a total capacity of 11 900 kton, the paper production was in 2002 approximately 10 700 kton with a capacity of 11 400 kton paper[120].

[115]Energimyndigheten (2004), Energiläget i siffror 2003
[116]Energimyndigheten (2001), Energianvändningen inom industrin
[117] http://www.skgs.org/, 2004-02-25
[118]Swedish Forest Industries Federation (2003),The Swedish forest industries – 2002 Facts and figures

[119] Wiberg, Rolf (2001), Energiförbrukningen i massa- och pappersindustrin 2000
[120] Swedish Forest Industries Federation (2003); The Swedish forest industries – 2002 Facts and figures

The energy application in the pulp and paper industry

Pulp and paper is an important actor on the energy market. The cost of energy compared to the value added when producing pulp and paper is approximately 23 per cent[121].

The energy usage in the pulp and paper industry can be divided into several different categories. As mentioned above the total energy application in the pulp and paper industry is 75 TWh where the share of purchased quantity energy is ca 34 TWh. The difference between the application and the purchased quantity indicates the amount internal energy production. The lion's share of the generated energy at the mills is energy from internal processes amounting to 33 TWh, bark generated ca 7 TWh generated. The pulp and paper industry is energy intensive as well as electricity intensive, the electricity usage amount to 20 TWh of the total 75 TWh.[122] The pulp and paper industry is also a large producer of electricity, 35 of 59 mills got a turbine installed, with an annual production of 4 TWh mainly in back pressure power[123].

How to make pulp and paper

A tree consists of cellulose fibres and lignin. The lignin bonds the fibres together and the combination between lignin and fibres gives the characteristics of the pulp and later on the characteristics of the paper. The main process in chemical pulp production is, in contrast to the mechanical process where almost all the wood becomes pulp, to separate the fibres and lignin. [124] There are basically two different ways to release the fibres:

- Chemical dissolution of lignin. The process proceeds from cooking wood chips in a large boiler where cooking liquor and chemical pulp is distinguished. The chemicals in the liquid dissolves the lignin, so that the fibres are liberated.[125] The most common chemical way of making pulp is the sulphate pulp process[126].
- Mechanical process. The mechanical pulp is produced in a process where the fibres are torn apart mechanically. In the process where the trees are grinded, mechanical forces are used to separate the fibres.[127] The most popular mechanical process is called Thermo Mechanical Pulp (TMP)[128].

[121] Energimyndigheten (2001), Energianvändningen inom industrin
[122] Ibid.
[123] Wiberg, Rolf (2001), Energiförbrukningen i massa- och pappersindustrin 2000
[124] Borg, Olov F (1989), Papper och Pappersmassa – en grundbok
[125] http://www.skogssverige.se/MassaPapper/Faktaom/swe/massaopapptillv/kemassa.cfm, 2004-02-26
[126] Energimyndigheten (2001), Energianvändningen inom industrin
[127] http://www.skogssverige.se/MassaPapper/Faktaom/swe/massaopapptillv/mekmassa.cfm, 2004-02-26
[128] Energimyndigheten (2001), Energianvändningen inom industrin

Paper consists of cellulose fibres that are tightly bounded one to another in a network[129]. Paper is made in a process where pulp is mixed with water. The mix is once again grinded and the beating material passes through different steps of drying in order to increase the dryness.[130]

It is also possible to use waste/recycled paper as a raw material for paper products, especially when there is no great demand in strength, hence the recycled fibre is less strong and pliable than the fresh fibres. The waste paper arrives to the mill in bales where the paper is unlaced in water. The diluted solution is then grinded whereupon it is cleaned from printer's ink and impurities before it returns to the paper machine.[131]

Different kind of mills

There are a lot of different kinds of mills and no mill is exactly similar to another. Some mills only produce pulp while other mills only making paper. A mill that has the whole process from tree to the complete paper product is called an integrated mill. Table 1 describes the distribution of different types of mills in Sweden.

Type of mill	**Number of mills**
Pulp mills	13
Paper mills	13
Integrated pulp and paper mill	25
Waste paper mill	8
Total number of mill	**59**

[129] http://www.skogssverige.se/MassaPapper/Faktaom/swe/massaopapptillv/paptillv.cfm, 2004-02-26
[130] Borg, Olov F (1989), Papper och Pappersmassa – en grundbok
[131] http://www.skogssverige.se/MassaPapper/Faktaom/swe/massaopapptillv/retur.cfm, 2004-02-26

Table 1. The allocation of Swedish mills.

Figure 1 describes the pulp production in Sweden (1999), divided between the different production processes[132].

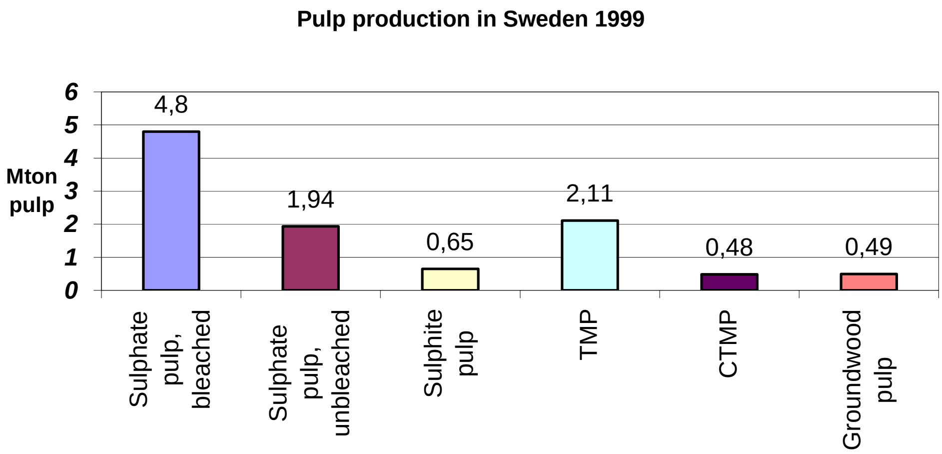

Figure 1. Pulp production in Sweden 1999 (TMP, CTMP and Groundwood pulp are mechanical processes, the other are chemical processes).

The selecting process of mills for this master thesis

When penetrating figure 1 it is obvious that the sulphate pulp process is the most common way of making chemical pulp with a total share of 91 per cent of the total Swedish output in this segment. In the mechanical segment of making pulp the dominating process is thermo mechanical pulp (TMP) with a production share of 69 per cent of the total Swedish mechanical pulp output.
The facts above makes it reasonable to describe the two processes mentioned more inherent than the others, as a result of their dominating position. Recent studies also indicate that the pulp produced with the sulphate process continues to increase at expense of the sulphite process, likewise is the popularity of the TMP process rising at expense of the groundwood pulp[133].

The purpose of this thesis is to estimate changes in costs and revenues of an integrated sulphate paper mill and a TMP mill followed by new climate control policies and energy related improvements in the mills. Since Vattenfall, in it's role as a major supplier to the Swedish pulp and paper industry, has a portfolio of key customers representing the total supply of the Swedish pulp and paper industry.
With the information furnished above in mind it seems to be rational to concentrate on a sulphate pulp mill and a TMP mill.
Depending on these circumstances the integrated sulphate and TMP making process is described in particular in the forthcoming chapters, later on is also a brief description about paper manufacturing made.

[132] Energimyndigheten (2001), Energianvändningen inom industrin
[133] Wiberg, Rolf (2001), Energiförbrukningen i massa- och pappersindustrin 2000

The sulphate pulp process

This chapter contains a description of making pulp in a sulphate pulp mill. In order to simplify the understanding of the different processes a flow-chart is being made (figure 2), the authors recommends the reader to have figure 2 in mind when reading the process explanation.
The main tasks in making chemical pulp are, as mentioned above, to separate the lignin from the cellulose fibres and, since the process demands a lot of expensive chemicals, to recover the used chemicals and to use the released energy in the process[134].

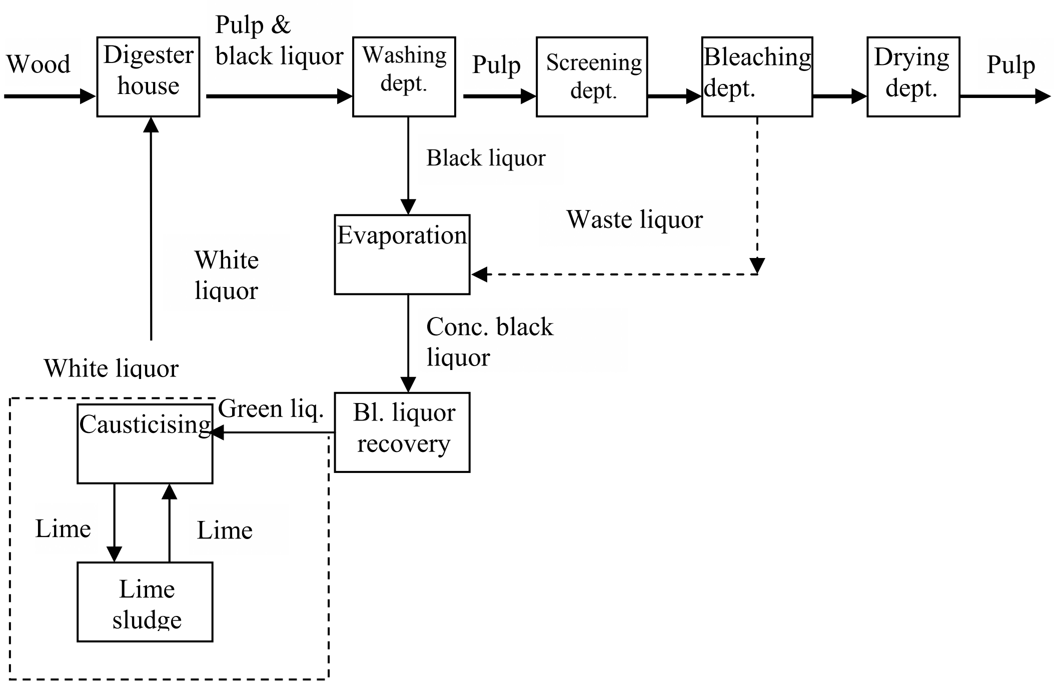

Figure 2. The sulphate pulp process.

The digester house

The first step in the chemical process is when grinded wood enters the digester house, the wood chips have a length of ca 30 mm and a thickness of 5 mm[135]. The pulp cooking can be done in two different ways: either in a batch or in a continuously cooking process. When cooking batches the digester is filled up with chips and when the process is completed the vessel is emptied and there is a new batch arriving, this is

[134] Kassberg, Mats (1998), Sulfatmassatillverkning
[135] Ibid.

the exact opposite of continuously cooking where there is a continuous flow of chips entering the digester.[136]
The different methods have almost the same output but continuously cooking is perceived as the most economic one and is therefore represented in most of the newly constructed mills[137].
Irrespective of whether batch or continuous cooking is used, the cooking process is almost the same. The digester is filled from the top with chips and white liquor. The active chemicals in white liquor are sodium hydroxide $(NaOH)$ and sodium sulphide (Na_2S) and the liquor is alkaline[138]. The white liquor is heated up and the cooking time is very dependent on the temperature. If the cooking temperature is lowered from 170°C down to 160°C the cooking time increases from 180 minutes up to 310 minutes.
The principal aim with the cooking process is to reach as low *kappa number* (a kappa number about 15-30 indicates lignin percentage of 2,25-4,5 per cent in the pulp) as possible. The kappa number indicates how much lignin there is left in the fibres and since lignin makes the pulp darker and less lignin makes the pulp brighter and therefore can the forthcoming bleaching process be reduced.[139] After the cooking process the raw material goes to the washing department and is separated into fibres and black liquor. The yield of fibres is about 40-60 per cent and the rest is black liquor (the name comes from the tint that the precipitated lignin gives the liquor)[140]. The kappa number also indicates the pulp exchange from the mix, low kappa number leads to a low pulp yield.

The washing department

After the digester house the pulp and black liquor enters the washing department in order to be separated from each other. The purpose with the washing process is to[141]:

- Separate the black liquor from the fibres.
- Recover the chemicals used in the digester house.
- Reject the released wood substance that contains combustible high-energy material.

It is extraordinary important for the pulp to be as clean as possible before it enters the screening department because the more soiled the pulp is, the higher consumption of chemicals in the bleaching department[142].

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136 http://www.skogssverige.se/MassaPapper/Faktaom/swe/massaopapptillv/sulfproc.cfm, 2004-03-01
137 Borg, Olov F (1989), Papper och Pappersmassa – en grundbok
138 Ibid.
139 Kassberg, Mats (1998), Sulfatmassatillverkning
140 Borg, Olov F (1989), Papper och Pappersmassa – en grundbok
141 Kassberg, Mats (1998), Sulfatmassatillverkning
142 http://www.skogssverige.se/MassaPapper/Faktaom/swe/massaopapptillv/sulfproc.cfm, 2004-03-01

The washing procedure of the mix is almost always a continuous process.[143] After the washing department the pulp enters the screening department and the black liquor, with a dry solid content of about 15 percent, enters the evaporation department[144].

The screening and the bleaching department

Generally the pulp contains particles like unbolted chips, bark or gravel that can disturb the forthcoming treatment of the pulp. The screening procedure separates the pulp, with a pulp concentration of about 1-3 per cent, in a large screen from the impurities. [145]

Since the pulp that leaves the screening department still have a brown shade it has to pass a process where the pulp is further bleached. With an aim to decrease the lignin percentage further bleaching procedures like oxygen gas bleaching, chlorine dioxide or ozone bleaching is used. Earlier it was common to use chlorine as a brightener but the environmental effect was harmful and therefore was increased development in different bleaching processes launched. The most efficient process is the oxygen gas bleaching with a lignin eliminate factor of 40-50 per cent wherein oxygen gas and sodium hydroxide is mixed with pulp after heating with steam to approximately 95°C. When bleaching with chlorine dioxide the mix is very acid (pH of 2-3) and heated up to about 50°C where the lignin is oxidized and converted in to water solvable matter and is therefore easy to separate.[146] Since the chemicals are both harmful and expensive almost every bleaching process is a closed system and the released lignin is restored and burned in the black liquor recovery boiler[147].

The drying department

When the clean and bleached pulp comes into the drying department the pulp is diluted to 1-1,5 per cent and if the mill is integrated the pulp enters the paper machine immediately or else the pulp is dried to a dryness of 90 per cent[148]. The water in the pulp is removed in a mechanical procedure to a dryness of about 50 per cent. To finally reach the level of a dryness of 90 per cent the pulp is pumped to a head box of drying. From the head box the pulp flows to a forming table with an endless wire for dewatering before it is stamped between rollers. The last step is the fan dryer where the pulp is finally dried and ready to be sliced up and put into bales.[149]

The pulp is now ready to be exported to a paper mill where it has to be dissolved in water before entering the paper machine.

[143] Kassberg, Mats (1998), Sulfatmassatillverkning
[144] http://www.skogssverige.se/MassaPapper/Faktaom/swe/massaopapptillv/sulfkemi.cfm, 2004-03-02
[145] Borg, Olov F (1989), Papper och Pappersmassa – en grundbok
[146] http://www.skogssverige.se/MassaPapper/Faktaom/swe/massaopapptillv/blekning.cfm, 2004-03-02
[147] Kassberg, Mats (1998), Sulfatmassatillverkning
[148] http://www.skogssverige.se/MassaPapper/Faktaom/swe/massaopapptillv/sulfproc.cfm, 2004-03-02
[149] Borg, Olov F (1989), Papper och Pappersmassa – en grundbok

The chemical and energy recovery

The chemical and energy recovery is an important step of the chemical pulp making process even though it is not involved in the immediate manufacturing procedure.

The evaporation plant

The black liquor and waste liquor enters the evaporation plant from the washing department and the bleaching department in order to be burnt in the black liquor recovery boiler but since the dryness of the black liquor only is 15 per cent the dryness has to be improved, higher dryness of the liquor gives better thermal economy and chemical recovery[150].

The black liquor is passing through a heat exchanger with several (5-6) stages and the pressure drops in each stage. This solution makes it possible to use the evaporated steam from the first step to heat up waste liquor in the next stage of the heat exchanger. In the heat exchanger's first step is fresh steam used and after that is the evaporated steam from the black liquor used to heat up the second step and so on. The principle is to use the steam evaporated from the cooking liquor from the step before to heat up the liquor in the next step and this is possible due to the decreasing pressure and this heat exchanging is also necessary to make the sulphate pulp making profitable.[151] When the former black and waste liquor leaves the evaporation plant it has changed name to thick waste liquor and has a dryness of about 68-72 per cent and is therefore burnable[152]. The evaporation procedure demands of course very much energy, for example 5 tones of water has to be evaporated from 6,67 tones of black liquor with a dryness of 15per cent in order to get 1, 67 tones of thick waste liquid with a dryness of 60per cent[153]. Another by-product when cooking pulp is sulphate soap that is used when manufacturing tall oil. The exchange of tall oil is about 20 kg per ton pulp (depending on kind of wood) is a raw material when producing paint, lacquer and soap.

The black liquor recovery boiler

The principal aim with the black liquor recovery boiler is to recycle the chemicals used in the digester house and to produce steam in order to make the mill self-supporting with heat, and in some mills is the steam also put into back pressure turbines to produce electricity to support the mill and/or to export electricity. The most common pressure in the soda recoveries in Sweden is 60 bar but abroad it is possible to confront as high pressure as 135 bar (Japan)[154]. This makes the black liquor recovery boiler an important economical element even though it is not included in the pulp making process and a very significant process for the environment.

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[150] http://www.skogssverige.se/MassaPapper/Faktaom/swe/massaopapptillv/sulfkemi.cfm, 2004-03-02

[151] Kassberg, Mats (1998), Sulfatmassatillverkning

[152] http://www.skogssverige.se/MassaPapper/Faktaom/swe/massaopapptillv/sulfkemi.cfm, 2004-03-02

[153] Kassberg, Mats (1998), Sulfatmassatillverkning

[154] Sodahus-konferensen ´03 (2003), ÅF-Celpap AB

The thick waste liquor is sprayed in finely divided drops into the boiler where the liquor dries and partly evaporates. The gas is burned and is heating up the tubes filled with boiler feed water into steam and through chemical reactions like deficiency of air and high temperature (800°C) becomes a deliquesce called green liquor at the bottom of the recovery boiler. When the green liquor enters the *white liquor preparation* (*causticising)* is the aim to separate and recover the chemical properties.[155]

White liquor preparation

The white liquor preparation is in popular parlance called the mixing department presumably because the main purpose with the preparation is to produce white liquor for the digester house and to decrease the proportion of polutions.
To make the process intelligible the chemical reaction are described below and to make it further understandable it is repeated that the chemicals needed in the digester house is sodium hydroxide $(NaOH)$ and sodium sulphide (Na_2S).
The green liquor contains two active ingredients and sodium sulphide is one of them and is therefore already prepared to be used again in the digester house. The procedure to get sodium hydroxide is more complicated and is divided into three steps:[156]

- *Slaking of lime*. The calcium oxide (burnt lime, CaO) reacts with the green liquor water (H_2O), becomes calcium hydroxide ($Ca(OH)_2$), a lot of heat is released through the reaction.
  $$CaO + H_2O \rightarrow Ca(OH)_2 + Heat$$

- *Causticising*. When the sodium carbonate (Na_2CO_3) in the green liquor reacts with calcium hydroxide ($Ca(OH)_2$) it is converted into sodium hydroxide $(NaOH)$ and calcium carbonate ($CaCO_3$). The sodium hydroxide goes to the digester house with the sodium sulphide and the calcium carbonate deposits as an unsolvable solution called lime sludge.
  $$Na_2CO_3 + Ca(OH)_2 \leftrightarrow (2NaOH) + CaCO_3$$

- *Lime sludge burning (calcinations)*. The lime sludge ($CaCO_3$) is burned in a lime sludge kiln at high temperature (1200°C) in order to get lime (CaO), used in the slaking of lime process mentioned above, and carbon dioxide (CO_2). The lime sludge kiln is a rotary kiln where the lime sludge is loaded in the upper end and in the lower end the burner is located. This is a very long construction, the world's longest is 135 m. Most of the lime sludge kilns uses a lot of oil as fuel but in recent years some of the kilns is using biofuel like bark and rind instead.
  $$CaCO_3 + Heat \rightarrow CaO + CO_2$$

[155] Borg, Olov F (1989), Papper och Pappersmassa – en grundbok
[156] Kassberg, Mats (1998), Sulfatmassatillverkning

The thermo mechanical pulp process

Thermo mechanical pulp is a mechanical and a refiner pulp and important characteristics of the manufacturing process are a large wood yield, about 85 per cent, and fewer and simpler process steps compared to the chemical process[157]. Since there are no chemicals involved in the production there is no need for recovery of the chemicals and therefore is the energy utilization low but almost all energy used is electricity, the most expensive kind of energy[158]. The most common range of application for TMP is where the demands for a light consistent paper are rather low like for newspapers and paperboard.

Other TMP characteristics are a low density, high stiffness, high opacity (a low opacity indicates that the paper is transparent) and that the paper turns yellow when it is exposed for ultraviolet radiation (sunlight). [159]

The refinery process

The process with the different stages is described in figure 3. It begins with the raw material, spruce, fir and sometimes asp, passes the washing department before it enters the preheating department. The chips is reaching a temperature of 90°C before they enter the grind with either a double disc refiner or a single disc refiner.[160] The refinery process often takes place in two refineries where the first one is pressurized[161].

The grind is run with electricity and the large engines are producing a lot of heat that is used in the washing and the preheating department. The chips are crushed in the grind and, due to the heat, the fibres are uncovered during their way from the centre of the disc up to the surface.[162]

[157] Borg, Olov F (1989), Papper och Pappersmassa – en grundbok
[158] http://www.skogssverige.se/MassaPapper/Faktaom/swe/massaopapptillv/mekmassa.cfm, 2004-03-04
[159] Borg, Olov F (1989), Papper och Pappersmassa – en grundbok
[160] Ibid.
[161] Gavelin, Gunnar (1996), Mekaniska massor – framställning och användning
[162] Borg, Olov F (1989), Papper och Pappersmassa – en grundbok

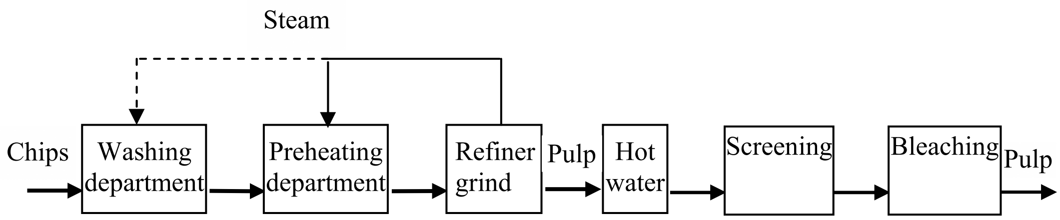

Figure 3. The TMP-process.

In the TMP process the lignin is not released from the fibres and this is why the paper turns into a shade of yellow after a while. Since lignin is sensitive to ultraviolet radiation exposure it is important to avoid it.
After the grinder the fibres enters a tub with hot water where the fibres are "resting" a couple of minutes to let the fibres unwind and recover its' natural elasticity with the intention of not increasing the freeness value.[163]

The screening and bleaching departments

The purpose with the screening of the pulp is to separate fibres with too much stiffness and therefore they are returning to the refiner grind for further treatment. The pulp exceeds several stages in the screening department and before it's ready to leave for the bleaching department it is almost cleaned from grind and gravel. Given that the lignin is left in the pulp the most important factors depends on the time the paper has been stored before utilization, the moisture content and the time the pulp spent in high temperature whereof a fresh, moist spruce is preferable.[164] If further paper brightness is needed it is common to make the pulp basic and to add sodium flame ($Na_2S_2O_2$), sometimes is hydroperoxide ion being used as well[165]. The bleaching procedure is getting more effective when the pulp is heated up to 75°C for less than one hour and no washing afterwards is necessary. In view of the fact that almost every TMP mill is a part of an integrated paper mill is not the dryness process described further and therefore is the pulp expected to go directly into the paper machines.

Paper manufacturing

In the text below is the paper manufacturing process briefly explained. The paper manufacturing process is almost the same for sulphate pulp and thermo mechanical pulp.

[163] Borg, Olov F (1989), Papper och Pappersmassa – en grundbok
[164] Ibid.
[165] http://www.skogssverige.se/MassaPapper/Faktaom/swe/massaopapptillv/mekmassa.cfm, 2004-03-04

The paper manufacturing process

When the pulp enters the paper machine its dryness depends on whether the pulp is a market pulp (90 per cent of dryness) or if the pulp is directly coming from the pulp mill, a.k.a. integrated mill (4 per cent). The paper manufacturing process is containing different steps viewed in figure nr. 4, where the drying process in its turn is divided into several steps.

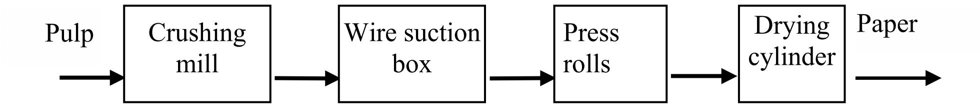

Figure 4. The paper manufacturing process.

The first step is to decrease the dryness down to 0,5-1 per cent into a mix with pulp and water and grind it once again into furnish[166]. The furnish is afterwards sprayed on a endless wire where it is possible for the water to flow off the pervious wire and the dryness increases up to ca 20 per cent. The strength of the paper depends on the distance between the fibre surfaces that allows hydrogen bindings. In order to further increase the dryness the wire passes rotating cylinders where the furnish is stamped by mechanical forces and reaches a dryness of 40-50 per cent. The water left in the furnish is eliminated and the furnish turns into paper and reaches the final target dryness of 90 per cent through passing a lot of steam heated cylinders in a drying apparatus. Dependent on the range of application different filling substances like chalk and China clay is added to get the best printing characteristics.[167]

[166] Nygaard, Johan (1986), Energikompendium för massa- och pappersindustrin
[167] Gavelin, Gunnar (1990), Papperstillverkning

Appendix B

Scenario one applied to Anderslöf

Estimation	**Unit**	**2000**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**Accumulated savings**
Specific steam utilization at Anderslöf without improvements	GJ/ton paper	19,3	18,7	18,7	18,7	18,7	18,7	18,7	18,7	18,7	
Specific steam utilization at KAM 2	GJ/ton paper	14,4	14,4	14,4	14,4	14,4	14,4	14,4	14,4	14,4	
Specific steam utilization at Anderslöf with the forecasted (0,17 GJ/ton paper & year) energy improvements	GJ/ ton paper	19,3	18,5	18,4	18,2	18,0	17,8	17,7	17,5	17,3	
Specific saved steam at Anderslöf due to the forecasted improvements	GJ/ ton paper	-	0,2	0,3	0,5	0,7	0,9	1,0	1,2	1,4	**6**
Specific saved steam at Anderslöf due to the forecasted improvements	MWh/ton paper	-	0,0	0,1	0,1	0,2	0,2	0,3	0,3	0,4	**1,7**
Annual saved steam counted as bio-fuel/oil with a steam producing factor of 0,9	MWh/year	-	10 617	21 235	31 852	42 469	53 086	63 704	74 321	84 938	**382 222**
Annual amount of saved oi	m3		983	1 966	2 949	3 932	4 915	5 898	6 000	6 000	**32 645**
Specific saved steam converted into electricity in a condensate turbine with a electrical efficiency = 0,2	MWh/ton paper	-	0,01	0,02	0,03	0,04	0,05	0,06	0,07	0,08	**0**
Annual saved steam converted into electricity in a condensate turbine with a electrical efficiency = 0,2	MWh/year	-	1 911	3 822	5 733	7 644	9 556	11 467	13 378	15 289	**68 800**
The green certificate price	SEK/MWh		150	156	163	170	177	184	192	200	
Annual increased gross electricity costs	kSEK/year		7 066	7 066	7 066	7 066	7 066	7 066	7 066	7 066	**56 525**
Annual changed value of existing own electricity production	kSEK/year		- 1 675	- 1 298	- 904	- 494	- 67	378	842	1 325	**- 1 894**
Total increased net cos	kSEK/year		8 741	8 363	7 970	7 560	7 133	6 688	6 224	5 741	**58 419**
The saved steam converted into electricity and sold to the market, including green certificates	kSEK/year	-	768	1 561	2 379	3 224	4 098	5 003	5 940	6 912	**29 885**
Cost savings for less bio-fuel	kSEK/year	-	1 486	2 973	4 459	5 946	7 432	8 919	10 405	11 891	**53 511**
Cost savings for less oil demand including emission allowances	kSEK/year	-	2 048	4 096	6 144	8 191	10 239	12 287	14 162	16 209	**73 376**
Summary: Changed revenues, cost savings for less oil demand	kSEK/year		- 6 693	- 4 267	- 1 826	632	3 107	5 599	7 938	10 469	**14 957**
Increased pulpwood cos	kSEK/year	-	-	-	-	-	-	-	-	-	
Profit	kSEK/year	80 000	73 307	75 733	78 174	80 632	83 107	85 599	87 938	90 469	**654 957**
Changed profit	%	-	- 8,4	- 5,3	- 2,3	0,8	3,9	7,0	9,9	13,1	
Offensive strategy, step 1											
Potential for increased electricity production	MWh/year		12 750	12 750	12 750	12 750	12 750	12 750	12 750	12 750	**102 000**
Sell the increased electricity production to the market	kSEK/year		5 127	5 207	5 290	5 377	5 468	5 563	5 661	5 764	43 458
Increased cost for biofue	kSEK/year		1 964	1 964	1 964	1 964	1 964	1 964	1 964	1 964	15 708
Net revenue = Sold electricity - biofuel cost	kSEK/year		3 163	3 243	3 327	3 414	3 505	3 599	3 698	3 801	**27 750**
Offensive strategy, step 2											
Potential for increased electricity production	MWh/year		20 250	20 250	20 250	20 250	20 250	20 250	20 250	20 250	**162 000**
Sell the increased electricity production to the market	kSEK/year		8 142	8 270	8 402	8 541	8 685	8 835	8 992	9 155	**69 021**
Increased cost for biofue	kSEK/year		3 119	3 119	3 119	3 119	3 119	3 119	3 119	3 119	**24 948**
Net revenue = Sold electricity - biofuel cost	kSEK/year		5 024	5 151	5 284	5 422	5 566	5 717	5 873	6 036	**44 073**
Offensive strategy 1+2											**9**
Potential for increased electricity production, step 1	MWh/year		33 000	33 000	33 000	33 000	33 000	33 000	33 000	33 000	**264 000**
Sell the increased electricity production to the market	kSEK/year		13 269	13 476	13 693	13 918	14 153	14 398	14 653	14 919	**112 478**
Increased cost for biofue	kSEK/year		5 082	5 082	5 082	5 082	5 082	5 082	5 082	5 082	**40 656**
Net revenue = Sold electricity - biofuel cost	kSEK/year		8 187	8 394	8 611	8 836	9 071	9 316	9 571	9 837	**71 822**
Profit offensive strategy 1+2 are taken into action	kSEK/year	80 000	88 187	88 394	88 611	88 836	89 071	89 316	89 571	89 837	**711 822**
Changed profit	%	-	10,2	10,5	10,8	11,0	11,3	11,6	12,0	12,3	

Appendix C

Scenario two applied to Anderslöf

Estimation	**Unit**	**2000**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**Accumulated savings**
Specific steam utilization at Anderslöf without improvements	GJ/ton paper	19,3	18,7	18,7	18,7	18,7	18,7	18,7	18,7	18,7	
Specific steam utilization at KAM 2	GJ/ton paper	14,4	14,4	14,4	14,4	14,4	14,4	14,4	14,4	14,4	
Specific steam utilization at Anderslöf with the forecasted (0,17 GJ/ton paper & year) energy improvements	GJ/ ton paper	19,3	18,5	18,4	18,2	18,0	17,8	17,7	17,5	17,3	
Specific saved steam at Anderslöf due to the forecasted improvements	GJ/ ton paper	-	0,2	0,3	0,5	0,7	0,9	1,0	1,2	1,4	**6**
Specific saved steam at Anderslöf due to the forecasted improvements	MWh/ton paper	-	0,0	0,1	0,1	0,2	0,2	0,3	0,3	0,4	**1,7**
Annual saved steam counted as bio-fuel/oil with a steam producing factor of 0,9	MWh/year	-	10 617	21 235	31 852	42 469	53 086	63 704	74 321	84 938	**382 222**
Annual amount of saved oi	m3		983	1 966	2 949	3 932	4 915	5 898	6 000	6 000	**32 645**
Specific saved steam converted into electricity in a condensate turbine with a electrical efficiency = 0,2	MWh/ton paper	-	0,01	0,02	0,03	0,04	0,05	0,06	0,07	0,08	**0**
Annual saved steam converted into electricity in a condensate turbine with a electrical efficiency = 0,2	MWh/year	-	1 911	3 822	5 733	7 644	9 556	11 467	13 378	15 289	**68 800**
The green certificate price	SEK/MWh		300	307	314	320	328	335	342	350	
Annual increased gross electricity costs	kSEK/year		28 262	28 262	28 262	28 262	28 262	28 262	28 262	28 262	**226 099**
Annual changed value of existing own electricity production	kSEK/year		11 299	11 700	12 110	12 529	12 957	13 394	13 842	14 299	**102 129**
Total increased net cos	kSEK/year		16 963	16 562	16 153	15 734	15 306	14 868	14 421	13 963	**123 970**
The saved steam converted into electricity and sold to the market, including green certificates	kSEK/year	-	1 182	2 389	3 622	4 883	6 172	7 490	8 839	10 218	**44 796**
Cost savings for less bio-fuel	kSEK/year	-	1 741	3 482	5 224	6 965	8 706	10 447	12 189	13 930	**62 684**
Cost savings for less oil demand including emission allowances	kSEK/year	-	2 458	4 916	7 374	9 832	12 291	14 749	17 137	19 596	**88 353**
Summary: Changed revenues, cost savings for less oil demand	kSEK/year		- 14 505	- 11 646	- 8 778	- 5 901	- 3 015	- 119	2 717	5 632	**- 35 616**
Increased pulpwood cos	kSEK/year		19 200	19 200	19 200	19 200	19 200	19 200	19 200	19 200	
Profit	kSEK/year	80 000	46 295	49 154	52 022	54 899	57 785	60 681	63 517	66 432	**450 784**
Changed profit	%	-	- 42,1	- 38,6	- 35,0	- 31,4	- 27,8	- 24,1	- 20,6	- 17,0	
Offensive strategy, step 1											
Potential for increased electricity production	MWh/year		12 750	12 750	12 750	12 750	12 750	12 750	12 750	12 750	**102 000**
Sell the increased electricity production to the market	kSEK/year		7 884	7 969	8 056	8 145	8 236	8 329	8 424	8 521	65 563
Increased cost for biofue	kSEK/year		2 300	2 300	2 300	2 300	2 300	2 300	2 300	2 300	18 401
Net revenue = Sold electricity - biofuel cost	kSEK/year		5 583	5 669	5 756	5 845	5 936	6 029	6 124	6 221	**47 162**
Offensive strategy, step 2											
Potential for increased electricity production	MWh/year		20 250	20 250	20 250	20 250	20 250	20 250	20 250	20 250	**162 000**
Sell the increased electricity production to the market	kSEK/year		12 521	12 656	12 795	12 936	13 080	13 228	13 379	13 533	**104 129**
Increased cost for biofue	kSEK/year		3 653	3 653	3 653	3 653	3 653	3 653	3 653	3 653	**29 225**
Net revenue = Sold electricity - biofuel cost	kSEK/year		8 868	9 003	9 141	9 283	9 427	9 575	9 726	9 880	**74 904**
Offensive strategy 1+2											**9**
Potential for increased electricity production, step 1	MWh/year		33 000	33 000	33 000	33 000	33 000	33 000	33 000	33 000	**264 000**
Sell the increased electricity production to the market	kSEK/year		20 405	20 625	20 850	21 081	21 316	21 557	21 803	22 055	**169 691**
Increased cost for biofue	kSEK/year		5 953	5 953	5 953	5 953	5 953	5 953	5 953	5 953	**47 626**
Net revenue = Sold electricity - biofuel cost	kSEK/year		14 451	14 672	14 897	15 127	15 363	15 604	15 850	16 101	**122 066**
Profit offensive strategy 1+2 are taken into action	kSEK/year	80 000	94 451	94 672	94 897	95 127	95 363	95 604	95 850	96 101	**762 066**
Changed profit	%	-	18,1	18,3	18,6	18,9	19,2	19,5	19,8	20,1	

Appendix D

Scenario one applied to Carlstrand

Measure taken	**Unit**	**2 005**	**2 006**	**2 007**	**2 008**	**2 009**	**2 010**	**2 011**	**2 012**	**Accumulated savings (kSEK)**
The green certificate price	SEK/MWh	150	156	163	170	177	184	192	200	
Specific revenue	SEK/MWh	100	100	100	100	100	100	100	100	
Present production										
Specific cost for electricity	SEK/ ton paper	649	649	649	649	649	649	649	649	
Specific cost for pulpwood	SEK/ ton paper	620	620	620	620	620	620	620	620	
Other specific variable and fixed costs	SEK/ ton paper	2 431	2 431	2 431	2 431	2 431	2 431	2 431	2 431	
Specific changed value of existing own electricity production	SEK/ ton paper	-	-	-	-	-	-	-	-	
Increased cost for bio-fuel	SEK/ ton paper	-	-	-	-	-	-	-	-	
Total specific cost	SEK/ ton paper	3 700	3 700	3 700	3 700	3 700	3 700	3 700	3 700	
Specific profit	SEK/ ton paper	100	100	100	100	100	100	100	100	-
Change compared to existing cost	%	-	-	-	-	-	-	-	-	
No measures taken										
Specific cost for electricity	SEK/ ton paper	711	711	711	711	711	711	711	711	
Specific cost for pulpwood	SEK/ ton paper	620	620	620	620	620	620	620	620	
Other specific variable and fixed costs	SEK/ ton paper	2 431	2 431	2 431	2 431	2 431	2 431	2 431	2 431	
Specific changed value of existing own electricity production	SEK/ ton paper	-2	-2	-1	-1	-0	1	1	2	
Increased cost for bio-fuel	SEK/ ton paper	-	-	-	-	-	-	-	-	
Total specific cost	SEK/ ton paper	3 764	3 764	3 763	3 763	3 762	3 762	3 761	3 760	
Specific profit	SEK/ ton paper	36	36	37	37	38	38	39	40	-250 325
Change compared to existing cost	%	1,7	1,7	1,7	1,7	1,7	1,7	1,7	1,6	
10% off										
Specific cost for electricity	SEK/ ton paper	640	640	640	640	640	640	640	640	284 346
Specific cost for pulpwood	SEK/ ton paper	620	620	620	620	620	620	620	620	
Other specific variable and fixed costs	SEK/ ton paper	2 431	2 431	2 431	2 431	2 431	2 431	2 431	2 431	
Specific changed value of existing own electricity production	SEK/ ton paper	-2	-2	-1	-1	-0	1	1	2	
Increased cost for bio-fuel	SEK/ ton paper	-	-	-	-	-	-	-	-	
Total specific cost	SEK/ ton paper	3 693	3 693	3 692	3 692	3 691	3 691	3 690	3 689	
Specific profit	SEK/ ton paper	107	107	108	108	109	109	110	111	34 021
Change compared to existing cost	%	-0,2	-0,2	-0,2	-0,2	-0,2	-0,3	-0,3	-0,3	
Changed mix										
Specific cost for electricity	SEK/ ton paper	574	574	574	574	574	574	574	574	547 518
Specific cost for pulpwood	SEK/ ton paper	620	620	620	620	620	620	620	620	
Other specific variable and fixed costs	SEK/ ton paper	2 431	2 431	2 431	2 431	2 431	2 431	2 431	2 431	
Specific changed value of existing own electricity production	SEK/ ton paper	-2	-2	-1	-1	-0	1	1	2	
Increased cost for bio-fuel	SEK/ ton paper	-	-	-	-	-	-	-	-	
Total specific cost	SEK/ ton paper	3 628	3 627	3 627	3 626	3 625	3 625	3 624	3 624	
Specific profit	SEK/ ton paper	172	173	173	174	175	175	176	176	297 193
Change compared to existing cost	%	-2,0	-2,0	-2,0	-2,0	-2,0	-2,0	-2,0	-2,1	
Bio-fuel										
Specific production cost	SEK/ ton paper	3 764	3 764	3 763	3 763	3 762	3 762	3 761	3 760	
Specific net revenue from replacing oil with biofuel and sell allowances	SEK/ ton paper				25	25	25	25	25	63 011
Increased cost for bio-fuel	SEK/ ton paper	-	-	-	-	-	-	-	-	
Total specific cost	SEK/ ton paper	3 764	3 764	3 763	3 738	3 737	3 737	3 736	3 735	
Specific profit	SEK/ ton paper	36	36	37	62	63	63	64	65	-187 314
Change compared to existing cost	%	1,7	1,7	1,7	1,0	1,0	1,0	1,0	1,0	
10% off + changed mix										
Specific cost for electricity	SEK/ ton paper	517	517	517	517	517	517	517	517	777 112
Specific cost for pulpwood	SEK/ ton paper	620	620	620	620	620	620	620	620	
Other specific variable and fixed costs	SEK/ ton paper	2 431	2 431	2 431	2 431	2 431	2 431	2 431	2 431	
Specific changed value of existing own electricity production	SEK/ ton paper	-2	-2	-1	-1	-0	1	1	2	
Increased cost for bio-fuel	SEK/ ton paper	-	-	-	-	-	-	-	-	
Total specific cost	SEK/ ton paper	3 570	3 570	3 569	3 569	3 568	3 567	3 567	3 566	
Specific profit	SEK/ ton paper	230	230	231	231	232	233	233	234	526 787
Change compared to existing cost	%	-3,5	-3,5	-3,5	-3,6	-3,6	-3,6	-3,6	-3,6	
10% off + changed mix + bio fuel										
Specific cost for electricity	SEK/ ton paper	517	517	517	517	517	517	517	517	777 112
Specific cost for pulpwood	SEK/ ton paper	620	620	620	620	620	620	620	620	
Other specific variable and fixed costs	SEK/ ton paper	2 431	2 431	2 431	2 431	2 431	2 431	2 431	2 431	
Specific changed value of existing own electricity production	SEK/ ton paper	-2	-2	-1	-1	-0	1	1	2	
Specific net revenue from replacing oil with biofuel and sell allowances	SEK/ ton paper	-	-	-	25	25	25	25	25	63 011
Increased cost for bio-fuel	SEK/ ton paper	-	-	-	-	-	-	-	-	
Total specific cost	SEK/ ton paper	3 570	3 570	3 569	3 543	3 543	3 542	3 542	3 541	
Specific profit	SEK/ ton paper	230	230	231	257	257	258	258	259	840 123
Change compared to existing cost	%	-3,5	-3,5	-3,5	-4,2	-4,2	-4,3	-4,3	-4,3	

Appendix E

Scenario one applied to Carlstrand

Optimize operating time	**Unit**	**2 005**	**2 006**	**2 007**	**2 008**	**2 009**	**2 010**	**2 011**	**2 012**	**Accumulated savings (kSEK)**
Potential for increased electricity production	MWh/year	8 500	8 500	8 500	8 500	8 500	8 500	8 500	8 500	
Sell the increased electricity production to the market	kSEK/year	3 418	3 471	3 527	3 585	3 645	3 709	3 774	3 843	
Increased cost for biofuel	kSEK/year	1 309	1 309	1 309	1 309	1 309	1 309	1 309	1 309	
Net revenue = Sold electricity - cost for biofuel	kSEK/year	2 109	2 162	2 218	2 276	2 336	2 400	2 465	2 534	**18 500**
New turbines										
Potential for increased electricity production	MWh/year	13 500	13 500	13 500	13 500	13 500	13 500	13 500	13 500	
Sell the increased electricity production to the market	kSEK/year	5 428	5 513	5 602	5 694	5 790	5 890	5 994	6 103	
Increased cost for biofuel	kSEK/year	2 079	2 079	2 079	2 079	2 079	2 079	2 079	2 079	
Net revenue = Sold electricity - cost for biofuel	kSEK/year	3 349	3 434	3 523	3 615	3 711	3 811	3 915	4 024	**29 382**
Optimize operating time + new turbines										
Potential for increased electricity production	MWh/year	22 000	22 000	22 000	22 000	22 000	22 000	22 000	22 000	
Sell the increased electricity production to the market	kSEK/year	8 846	8 984	9 128	9 279	9 435	9 599	9 769	9 946	
Increased cost for biofuel	kSEK/year	3 388	3 388	3 388	3 388	3 388	3 388	3 388	3 388	
Net revenue = Sold electricity - cost for biofuel	kSEK/year	5 458	5 596	5 740	5 891	6 047	6 211	6 381	6 558	**47 882**

Appendix F

Scenario two applied to Carlstrand

Measure taken	**Unit**	**2 005**	**2 006**	**2 007**	**2 008**	**2 009**	**2 010**	**2 011**	**2 012**	**Accumulated savings (kSEK)**
The green certificate price	SEK/MWh	300	307	314	320	328	335	342	350	
Specific revenue	SEK/MWh	100	100	100	100	100	100	100	100	
Present production										
Specific cost for electricity	SEK/ ton paper	649	649	649	649	649	649	649	649	
Specific cost for pulpwood	SEK/ ton paper	620	620	620	620	620	620	620	620	
Other specific variable and fixed costs	SEK/ ton paper	2 431	2 431	2 431	2 431	2 431	2 431	2 431	2 431	
Specific changed value of existing own electricity production	SEK/ ton paper	-	-	-	-	-	-	-	-	
Increased cost for bio-fuel	SEK/ ton paper	-	-	-	-	-	-	-	-	
Total specific cost	SEK/ ton paper	3 700	3 700	3 700	3 700	3 700	3 700	3 700	3 700	
Specific profit	SEK/ ton paper	100	100	100	100	100	100	100	100	-
Change compared to existing cost	%	-	-	-	-	-	-	-	-	
No measures taken										
Specific cost for electricity	SEK/ ton paper	898	898	898	898	898	898	898	898	
Specific cost for pulpwood	SEK/ ton paper	651	651	651	651	651	651	651	651	
Other specific variable and fixed costs	SEK/ ton paper	2 431	2 431	2 431	2 431	2 431	2 431	2 431	2 431	
Specific changed value of existing own electricity production	SEK/ ton paper	15	16	16	17	17	18	18	19	
Increased cost for bio-fuel	SEK/ ton paper	11	11	11	11	11	11	11	11	
Total specific cost	SEK/ ton paper	3 976	3 975	3 974	3 974	3 973	3 973	3 972	3 972	
Specific profit	SEK/ ton paper	-176	-175	-174	-174	-173	-173	-172	-172	-1 094 403
Change compared to existing cost	%	7,4	7,4	7,4	7,4	7,4	7,4	7,4	7,3	
10% off										
Specific cost for electricity	SEK/ ton paper	808	808	808	808	808	808	808	808	359 065
Specific cost for pulpwood	SEK/ ton paper	651	651	651	651	651	651	651	651	
Other specific variable and fixed costs	SEK/ ton paper	2 431	2 431	2 431	2 431	2 431	2 431	2 431	2 431	
Specific changed value of existing own electricity production	SEK/ ton paper	15	16	16	17	17	18	18	19	
Increased cost for bio-fuel	SEK/ ton paper	11	11	11	11	11	11	11	11	
Total specific cost	SEK/ ton paper	3 886	3 885	3 885	3 884	3 884	3 883	3 882	3 882	
Specific profit	SEK/ ton paper	-86	-85	-85	-84	-84	-83	-82	-82	-735 338
Change compared to existing cost	%	5,0	5,0	5,0	5,0	5,0	4,9	4,9	4,9	
Changed mix										
Specific cost for electricity	SEK/ ton paper	725	725	725	725	725	725	725	725	691 391
Specific cost for pulpwood	SEK/ ton paper	651	651	651	651	651	651	651	651	
Other specific variable and fixed costs	SEK/ ton paper	2 431	2 431	2 431	2 431	2 431	2 431	2 431	2 431	
Specific changed value of existing own electricity production	SEK/ ton paper	15	16	16	17	17	18	18	19	
Increased cost for bio-fuel	SEK/ ton paper	11	11	11	11	11	11	11	11	
Total specific cost	SEK/ ton paper	3 803	3 802	3 802	3 801	3 800	3 800	3 799	3 799	
Specific profit	SEK/ ton paper	-3	-2	-2	-1	-0	0	1	1	-403 012
Change compared to existing cost	%	2,8	2,8	2,7	2,7	2,7	2,7	2,7	2,7	
Bio-fuel										
Specific production cost	SEK/ ton paper	3 976	3 975	3 974	3 974	3 973	3 973	3 972	3 972	
Specific net revenue from replacing oil with biofuel and sell allowances	SEK/ ton paper				34	34	34	34	34	84 860
Increased cost for bio-fuel	SEK/ ton paper	11	11	11	11	11	11	11	11	
Total specific cost	SEK/ ton paper	3 986	3 986	3 985	3 951	3 950	3 949	3 949	3 948	
Specific profit	SEK/ ton paper	-186	-186	-185	-151	-150	-149	-149	-148	-1 051 783
Change compared to existing cost	%	7,7	7,7	7,7	6,8	6,8	6,7	6,7	6,7	
10% off + changed mix										
Specific cost for electricity	SEK/ ton paper	652	652	652	652	652	652	652	652	981 317
Specific cost for pulpwood	SEK/ ton paper	651	651	651	651	651	651	651	651	
Other specific variable and fixed costs	SEK/ ton paper	2 431	2 431	2 431	2 431	2 431	2 431	2 431	2 431	
Specific changed value of existing own electricity production	SEK/ ton paper	15	16	16	17	17	18	18	19	
Increased cost for bio-fuel	SEK/ ton paper	11	11	11	11	11	11	11	11	
Total specific cost	SEK/ ton paper	3 730	3 730	3 729	3 729	3 728	3 727	3 727	3 726	
Specific profit	SEK/ ton paper	70	70	71	71	72	73	73	74	-113 086
Change compared to existing cost	%	0,8	0,8	0,8	0,8	0,8	0,7	0,7	0,7	
10% off + changed mix + bio fuel										
Specific cost for electricity	SEK/ ton paper	652	652	652	652	652	652	652	652	981 317
Specific cost for pulpwood	SEK/ ton paper	651	651	651	651	651	651	651	651	
Other specific variable and fixed costs	SEK/ ton paper	2 431	2 431	2 431	2 431	2 431	2 431	2 431	2 431	
Specific changed value of existing own electricity production	SEK/ ton paper	15	16	16	17	17	18	18	19	
Specific net revenue from replacing oil with biofuel and sell allowances	SEK/ ton paper	-	-	-	34	34	34	34	34	84 860
Increased cost for bio-fuel	SEK/ ton paper	11	11	11	11	11	11	11	11	
Total specific cost	SEK/ ton paper	3 720	3 719	3 719	3 684	3 684	3 683	3 682	3 682	
Specific profit	SEK/ ton paper	80	81	81	116	116	117	118	118	1 066 177
Change compared to existing cost	%	0,5	0,5	0,5	-0,4	-0,4	-0,5	-0,5	-0,5	

Appendix G

Scenario two applied to Carlstrand

Optimize operating time	**Unit**	**2 005**	**2 006**	**2 007**	**2 008**	**2 009**	**2 010**	**2 011**	**2 012**	**Accumulated savings (kSEK)**
Potential for increased electricity production	MWh/year	8 500	8 500	8 500	8 500	8 500	8 500	8 500	8 500	
Sell the increased electricity production to the market	kSEK/year	5 256	5 312	5 371	5 430	5 491	5 553	5 616	5 681	
Increased cost for biofuel	kSEK/year	1 533	1 533	1 533	1 533	1 533	1 533	1 533	1 533	
Net revenue = Sold electricity - cost for biofuel	kSEK/year	3 722	3 779	3 837	3 896	3 957	4 019	4 083	4 147	**31 441**
New turbines										
Potential for increased electricity production	MWh/year	13 500	13 500	13 500	13 500	13 500	13 500	13 500	13 500	
Sell the increased electricity production to the market	kSEK/year	8 347	8 437	8 530	8 624	8 720	8 819	8 919	9 022	
Increased cost for biofuel	kSEK/year	2 435	2 435	2 435	2 435	2 435	2 435	2 435	2 435	
Net revenue = Sold electricity - cost for biofuel	kSEK/year	5 912	6 002	6 094	6 189	6 285	6 383	6 484	6 587	**49 936**
Optimize operating time + new turbines										
Potential for increased electricity production	MWh/year	22 000	22 000	22 000	22 000	22 000	22 000	22 000	22 000	
Sell the increased electricity production to the market	kSEK/year	13 603	13 750	13 900	14 054	14 211	14 371	14 535	14 703	
Increased cost for biofuel	kSEK/year	3 969	3 969	3 969	3 969	3 969	3 969	3 969	3 969	
Net revenue = Sold electricity - cost for biofuel	kSEK/year	9 634	9 781	9 931	10 085	10 242	10 402	10 567	10 734	**81 377**