

The Environmental Performance of Voluntary Agreements on Industrial Energy Efficiency Improvement

Martijn Rietbergen & Kornelis Blok
Department of Science, Technology and Society
Utrecht University, The Netherlands

NW&S 99068

The VAIE project was supported by the European Commission under the Joule Research Programme« (Contract No JOS3CT970021).
<http://www.akf.dk/vaie/index.html>

*The views and opinions expressed in this report are those of the authors only.
While this document is believed to contain correct information, no warranty is made or legal responsibility assumed, for the accuracy, completeness or usefulness of any information in this document.*

Environmental Performance of Voluntary Agreements on Industrial Energy Efficiency Improvement

M.G. Rietbergen & K. Blok
Department of Science, Technology and Society
Utrecht University, Utrecht 1999
NW&S Report No. 99068
ISBN 90-73958-54-7

Department of Science, Technology and Society
Utrecht University
Padualaan 14
3584 CH Utrecht
The Netherlands
Phone: +31-30-2537600
Fax: +31-30-2537601
<http://www.chem.uu.nl/nws/www/nws.html>

© Department of Science, Technology and Society

Preface

This report analyses the actual outcome of voluntary agreements on energy efficiency and CO₂ emission reduction. Several approaches to isolate the impact of the agreements are studied in the report. Furthermore the report includes a benchmark study on energy efficiency improvement in the pulp and paper industry in various countries. The report has been published in the series of the VAIE project.

The VAIE project is an EU project supported by »DG XII; Science, Research and Development« through »The Joule Research Programme« (Contract No JOS3CT970021). The VAIE-project studies the implementation and efficiency of voluntary agreements used as a policy instrument for energy conservation in the industry in the European Union.

The report was written by Martijn Rietbergen under supervision of Kornelis Blok.

Utrecht, 20 January 2000

Martijn Rietbergen

Summary

The VAIE research project studies the implementation and efficiency of (voluntary) agreements on industrial energy efficiency improvement in five European countries. The environmental performance of the agreements is one of the main issues studied within the VAIE project.

The *first chapter* defines the research issues and presents the research objectives and methods.

The aim of this research is to isolate the actual outcome of voluntary agreements on energy efficiency. The actual outcome is defined as the agreements' contribution to the overall impact on energy efficiency. Three different approaches were studied to assess the impact of the agreements.

The *second chapter* deals with the first approach to assess the actual outcome; the actual change in energy efficiency investment behaviour.

In this chapter we investigated to what extent firms' investments (and thus energy efficiency improvements) were promoted by the agreements. Either expert opinion or firms' own perceptions were used to judge the energy efficiency investment behaviour of the industry. The estimations based on expert opinions indicate that 31-48% of the total energy savings can be attributed to the implementation of the LTAs¹ in the Netherlands. The assessment of the actual outcome based on the response of a survey among firms shows similar results (29-44%).

The *third chapter* studies a different approach to assess the actual outcome; simulation of the energy efficiency investment behaviour in the business-as-usual case.

The overall monitored energy efficiency improvement was compared with the efficiency improvement in the business-as-usual (BaU) case. The BaU scenario reflects the energy efficiency improvement due to technological or operational changes that would have taken place anyway, also without the policy influence. The energy efficiency improvement in the BaU case was assessed by simulating the energy investment behaviour of industrial firms. Different models that describe the energy efficiency investment behaviour of firms were applied on a techno-economic database of energy efficiency improvement techniques to assess the energy efficiency improvement in the BaU case. We estimated that about 16-47% of the total energy savings can be attributed to the implementation of the LTAs in the Netherlands. The lower limit of 16% is however considered as an underestimated value.

¹ When we talk about the effectiveness of the LTAs we mean the complex of policies of which the LTA is the main part. However, also other elements, like subsidy schemes and fiscal incentives are involved.

Chapter four studies the possibility to use the historical development of process energy efficiency as a business-as-usual scenario.

In this chapter the actual outcome of agreements was assessed by comparing the current monitored energy efficiency improvements with the historical development of process energy efficiency. A decomposition analysis was applied to disentangle the impact of changes in product mix, the penetration of CHP and process efficiency improvement on the overall energy efficiency improvement on sector level. The results of this approach indicate a negative impact of the agreement. Based on the estimated actual outcome of the agreements in the previous chapters, we conclude that the impact of energy prices and other energy conservation policies, which were not taken into account in the decomposition analysis were probably larger than expected. Further elaboration of this method is required to isolate the real impact of the agreements.

Chapter five deals with the comparative analysis of the environmental performance of agreements with paper and board industries in the various countries involved in the project.

A benchmark study was carried out to compare the energy efficiency improvement in the paper and board industries over time. We vigorously addressed the quality and the comparability of the data used in the analysis. We conclude that the data availability and related uncertainties can be a limiting factor for the actual benchmarking operation as proposed in the Netherlands. We have also tried to evaluate the actual outcome of the agreements with paper and board manufacturers in other countries than the Netherlands by assessing the actual change in energy efficiency investment behaviour. However, due to a lack of detailed data a broader international comparison of the actual outcome of the agreements appeared to be difficult.

The final *chapter six* summarises the main conclusions of our research and gives recommendations for further research.

The main conclusion of this research is that, although an accurate assessment of the actual outcome is still lacking, a stimulating impact of the agreements on energy efficiency in the Netherlands can be observed. We conclude that on average about **one third to half** of the energy savings in the Dutch Manufacturing industry can be attributed to the agreements. Analysis of the actual outcome of the agreements in the other country indicates a stimulating impact of the agreements but the magnitude is highly uncertain.

There are three important routes for further research: the further elaboration of the method which analyses the actual change in energy efficiency investment behaviour is to our opinion the most promising route. We recommend to conduct more systematic surveys among firms and an 'on line' evaluation of the energy conservation projects to improve the understanding of the firms' energy investment behaviour. Another route

for further analysis of the actual outcome is the decomposition of the historical development of energy efficiency into more different long term trends, which also takes into account the impact of energy prices. A third promising alternative route, not taken into account in this study could be a micro-panel data analysis. Preliminary results from such type of analysis gives hope for improved evaluations of the actual outcome of voluntary agreements.

Table of Contents

1	Introduction.....	1
1.1	Definition of the research issue	1
1.2	Research objective	2
1.3	Approaches.....	2
1.4	Lay-out of the report.....	3
2	Actual change in energy efficiency investment behaviour.....	5
2.1	Method	5
2.2	Results	8
2.3	Discussion	11
2.4	Conclusion.....	13
2.5	Further elaboration of the assessment method	13
3	Simulation of energy efficiency investment behaviour in the business-as-usual case.....	15
3.1	Method	15
3.2	Results.....	16
3.3	Discussion	17
3.4	Conclusion.....	18
4	Monitoring of historical development of energy efficiency	19
4.1	Method	19
4.2	Data used in the analysis.....	21
4.3	Results and discussion	21
4.4	Conclusion.....	23
5	Comparative analysis of the environmental performance of agreements with paper and board industries.....	25
5.1	Manufacturing processes of pulp, paper and paper board	25
5.2	Voluntary agreements with paper and board industry	26
5.3	Benchmarking energy efficiency in paper and board industry.....	29
5.3.1	Method	29
5.3.2	Data used in the analysis	30
5.3.3	Results	33
5.3.4	Discussion.....	38
5.3.5	Conclusions and recommendations.....	43
5.4	International comparison of the actual outcome of agreements.....	44
5.4.1	Energy savings investments in paper and board industry	44
5.4.2	Concluding remarks	51
6	Conclusions and recommendations	53
6.1	Conclusions	53
6.2	Recommendations.....	54
	References.....	57
	Appendix I	63
	Contents of the VAIE Project.....	69

1 Introduction

In recent years, there has been growing interest by government and business in voluntary actions to meet greenhouse gas emission reduction objectives. The number of voluntary actions has been increasing considerably in the past few years [IEA 1997]. For so far, extensive studies on the implementation and efficiency of the agreements have however not been made. The VAIE-project² therefor explicitly studies the impact and efficiency of the agreements on the implementation of energy conservation technologies and behaviour. The overall aims of the VAIE-project are:

- To improve the understanding of voluntary agreements dealing with energy efficiency and CO₂ reduction;
- To discover under what conditions voluntary agreements can be expected to achieve environmental targets in an efficient way;
- Via the identification of best-practices of voluntary agreements, to give recommendations on how to improve the policy mix to be used to cope with energy efficiency and CO₂ reductions in industry.

An initial survey showed a variety of voluntary programs among countries participating in the project. Also large differences in objectives and achievements already made can be observed. One of the issues within the VAIE project is a quantitative study on the environmental performance of the agreements. This issue will be the topic of discussion in this report.

1.1 Definition of the research issue

The key research issue in this study is the quantitative analysis of the *environmental performance* of voluntary agreements on energy efficiency. The environmental performance of a policy mix or single policy instruments deals with on the one hand the *goal achievement* of the policy and on the other hand the *effectiveness* of the policy instrument(s), see Figure 1. The ‘goal achievement’ compares the total effect on energy efficiency since the reference situation with the policy targets. The reference situation reflects the level of energy efficiency prior to the introduction of the policy instrument(s). The ‘effectiveness’ compares the total effect on energy efficiency with a business-as-usual scenario. Regarding the effectiveness of policies we may distinguish the effect the VA and those of other policies. The ‘effectiveness’ is thus regarded as the policy’s contribution to the overall impact on energy efficiency. The business-as-usual (BaU) scenario represents the trend development of energy efficiency improvement due to technological or operational changes that would have taken place anyway, also without the policy influence. The issue of effectiveness is of main interest in this study.

² VAIE stands for Voluntary Agreements – Implementation and Efficiency. In the research project the following research institutes participate: AKF (Institute of Local Government Studies) from Denmark, the Department of STS (Science, Technology and Society) from the Utrecht University in the Netherlands, the Wuppertal Institute for Climate, Environment and Energy from Germany, CERNA/ECOLE DES MINES from France and the Department of Environmental and Energy Systems Studies from the Lund University in Sweden.

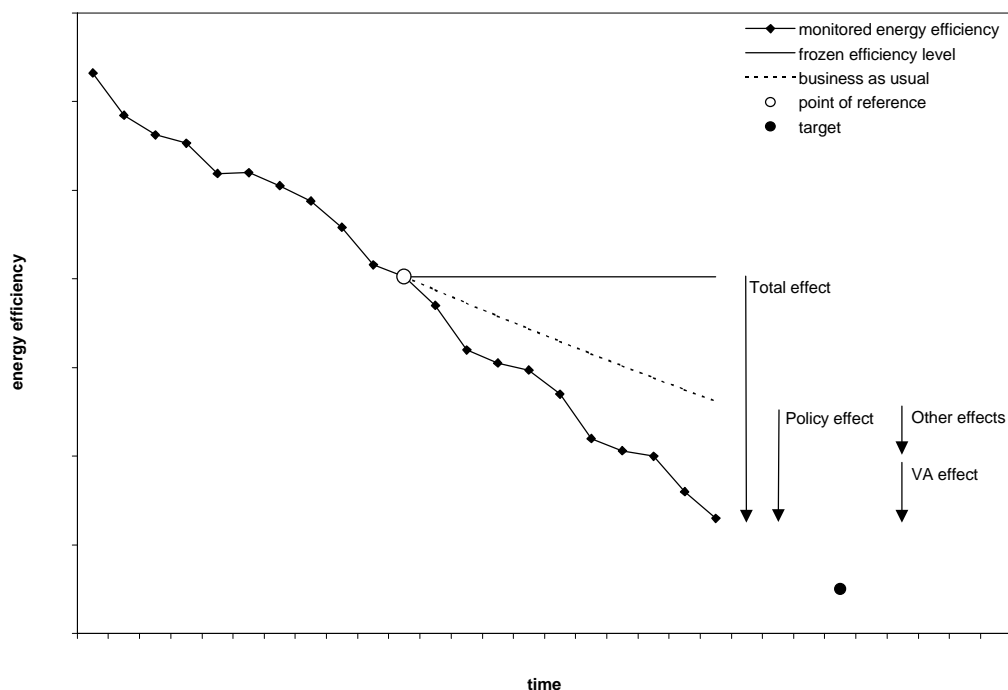
1.2 Research objective

A number of quantitative evaluations on the impact of voluntary agreements have been carried out, see e.g. [IEA 1997; Korevaar 1997; EZ 1998a; Johannsen and Togeby 1998; Togeby et al. 1998a]. Most of these studies have evaluated only the achievement of the agreements' targets. Less research experience has been gained with the agreements' contribution to the achievement of the policy targets or in other words the effectiveness of the agreements. The aim of this study is therefore to isolate the impact of the agreements and assess the actual outcome of voluntary agreements.

1.3 Approaches

The assessment of the actual outcome of agreements on energy efficiency improvement is however a complicated process. The following methodological problems can be observed, see also Figure 1. In the first place the impact of agreements can not easily be distinguished from the effects of the other instruments in the policy mix aimed at energy conservation. For example, energy price policy, taxes and subsidy schemes can heavily distort the impact assessment of voluntary agreements. Secondly, the energy efficiency improvement due to technological or operational changes in the absence of the agreements and other environmental policy instruments is difficult to determine [EEA 1997]. In other words a good and reliable BaU scenario is often lacking. Thirdly, energy efficiency improvement can often not easily be distinguished from structural changes in the economy, like de-materialisation as well as inter- and intrasectoral shifts [Farla and Blok forthcoming-a].

Figure 1: Schematic representation of the research issue and methodological problems



To tackle these methodological problems, three different approaches are followed to assess the actual outcome of the agreements:

1. *The actual change in energy efficiency investment behaviour.* We will investigate to what extent investments (and thus energy efficiency improvements) were promoted by the agreements. Either expert opinion or firms' own perceptions can be used to judge the energy efficiency investment behaviour of the industry. The actual outcome can subsequently be estimated on the basis of techno-economic analysis.
2. *Simulation of the energy efficiency investment behaviour in the BaU case.* Several models exist that describe the investment behaviour of firms regarding energy conservation measures. These models will be applied on a techno-economic database of energy efficiency improvement techniques to assess the energy efficiency improvement in the BaU case.
3. *Monitoring of the historical development of energy efficiency.* The actual outcome of agreements can be assessed by comparing the current monitored energy efficiency improvements with the historical development of process energy efficiency. In this approach, the historical development of the process energy efficiency is considered as the BaU case. A decomposition analysis will be applied to disentangle the impact of process efficiency improvement on the overall energy efficiency improvement on sector level.

1.4 Lay-out of the report

The lay out of the report is as follows. The *second* chapter deals with the assessment method that estimates the actual change in energy efficiency investment behaviour. This chapter discusses the assessment method and presents the results of a case study on the environmental effectiveness of the Dutch Long-Term Agreements (LTAs) on energy efficiency. The *third* chapter discusses the method to simulate energy efficiency investment behaviour in the BaU case. This chapter also presents the results of a study on the environmental effectiveness of the Dutch LTAs. The fourth *chapter* discusses the method to assess the actual outcome of the agreements by comparing the recent energy efficiency improvements with the historical development. The *fifth* chapter presents the results of a study that aims at the comparative analysis of the environmental performance of agreements on energy efficiency and CO₂ emission reduction with the paper and board industry in the various countries participating in the VAIE project. Chapter *six* summarises the conclusions of this study. Chapter *six* also presents recommendations for further research and policy recommendations to improve comparative analysis of the environmental performance of agreements.

2 Actual change in energy efficiency investment behaviour

The actual outcome of the voluntary agreements can be assessed by investigating the investments (and thus energy savings) made by the industry. Either expert opinion or firms' own perception can be used to judge whether or to what extent investments in energy conservation measures are encouraged by the agreements. The total effect can subsequently be estimated on the basis of techno-economic analysis. This chapter describes the assessment method in detail (section 2.1) and presents case study results for the Netherlands (section 2.2). This chapter also includes a discussion of the assessment method and the quality of the results (section 2.3). Section 2.4 summarises the main results, whereas section 2.5 deals with the further elaboration of this assessment method.

2.1 Method

The method to assess the impacts of the actual change in energy efficiency investment behaviour consists of three distinctive phases:

1. First, an inventory is made of all the energy savings measures taken in the specific sector. The energy savings measures are divided into different investment categories, which have been derived from the classification used in the Dutch annual LTA progress reports, see e.g. [Novem 1996a; Novem 1996d; VNP 1998]. The LTA progress reports generally distinguish the following investment categories:

1. Good housekeeping/energy management
2. Replacement investments
3. Energy-saving investments (retrofit)
4. Combined heat and power generation (CHP)
5. Other activities

The category 'good housekeeping' concerns energy saving measures that have a relatively short pay back period and do not require large investments. The second category concerns investments aimed at the replacement, maintenance or extension of industrial equipment. These investment are primarily made for strategic reasons. The profitability of these investments does in general not depend on the energy conservation potential. Energy conservation, related to these investments, has often a process integrated character. 'Energy-saving investments' concern projects aimed at the improvement of energy efficiency. Hence, the profitability of these investment depend largely on the conservation potential of the energy saving measure. Examples of such investments are insulation, adjustable speed drives and heat recovery. Investments in the combined heat and power installations (CHP) are considered as a separate conservation category, since a considerable saving on fuel can be made through CHP. Co-generation is presented as one of the most attractive options for meeting the energy conservation targets in the LTAs. Finally, we consider investments in the category 'other activities', like the close-down of firms and NO_x emission reduction, which also can improve energy efficiency.

2. In the second phase we assess to what degree the agreements have encouraged the investment in the various the energy saving measures. In our assessment model, we assume that investments in energy-saving measures can be been fully stimulated, largely stimulated, considerably stimulated, stimulated to a slight extent or not stimulated by the LTA. For this assessment procedure we have used *expert opinions* as well as *the firms' own judgement* on the energy efficiency investment behaviour of firms.

Expert opinions about energy efficiency investment behaviour of firms

The expert opinions about energy efficiency investment behaviour of firms, used in our study, are judgements of the research team tested against the judgement of the steering committee of the project 'Evaluatie Meerjarenaafspraken over energie-efficiency' by [Glasbergen et al. 1997]. In general, the following guidelines are observed for the assessment procedure, using expert opinions:

- Investments in energy saving measures in the category good housekeeping/energy management are assumed to be fully stimulated by an agreement, since these measures do not invoke excessive costs; the measures could have been taken anyway.
- Since replacement projects are not primarily implemented for the purpose of energy efficiency improvement, these investments are considered to be stimulated to a slight extent.
- We assume that investments in CHP are promoted to a slight extent, since CHP investment are to a considerable extent encouraged by other energy conservation policies, like the agreement between the Dutch government and the energy distribution companies and special subsidies directed towards the promotion of CHP investments.
- Since measures in the category retrofit investments are aimed at the improvement of energy efficiency and require considerable investments, we assume that they are largely stimulated by agreements.
- Investments in the category 'other activities' are assumed not to be stimulated by the agreements.

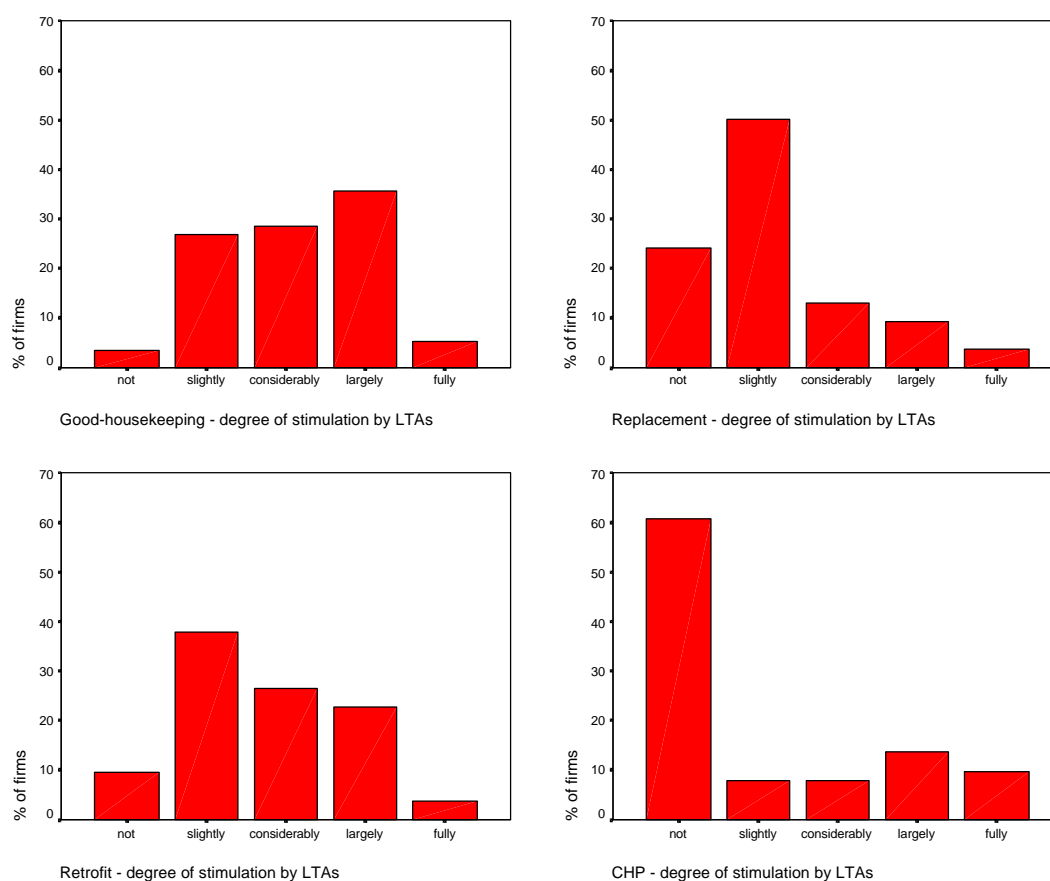
Energy-saving measures can also be 'considerably stimulated' by a VA. For more details on the application of this assessment procedure to specific sectors we refer to [Glasbergen et al. 1997].

Firms' own judgement about their energy efficiency investment behaviour

In a survey [Groot 1999], we have asked firms to assess to what degree agreements have promoted the investments in 'good-housekeeping measures', 'replacement projects', retrofit measures' and 'CHP-installations'. The firms were asked whether these investments were not stimulated, stimulated to a slight extent, considerably stimulated, largely stimulated or fully stimulated by the LTA. The survey resulted in a data set of about 60 Dutch firms with a LTA on energy efficiency. The data set includes firms in nine different industrial sectors. Figure 2 shows the survey response.

More than 90% of the respondents point out that energy saving measures in the category ‘Good-housekeeping’ are slightly to largely stimulated by the LTAs. This does however not correspond with the *expert opinion* which assumes that good-housekeeping measures are fully stimulated by LTAs. About 50% of the firms respond that replacement investments are slightly stimulated by the LTAs. This result corresponds the opinion of the experts. The retrofit investments are, according to the expert opinions, largely stimulated by the LTAs. The firm response, depicted in Figure 2 shows however a contrasting picture. The retro-fit investments are, according to the firms, slightly to largely stimulated by the LTAs. The investments in CHP are according to 60% of the firms not promoted by the LTAs. The experts assume that the investments in CHP are slightly promoted by the LTAs. In section 2.3 this contrasting picture is discussed in more detail.

Figure 2: Survey response



3. In the third phase the expert opinions and the survey response are translated into weighting schemes in order to determine the actual effect of the LTAs in terms of saved energy.

The expert opinions and the survey response about the energy efficiency investment behaviour is translated into three different weighting schemes. Table 1 shows an average one (weighting scheme 1), a high variant one (weighting scheme 2) and a low variant one (weighting scheme 3).

Table 1: Weighting schemes

Degree of stimulation	Weighting 1	Weighting 2	Weighting 3
Not stimulated	0%	10%	0%
Stimulated to a slight extent	20%	30%	10%
Considerably stimulated	50%	60%	40%
Largely stimulated	80%	90%	70%
Fully stimulated	100%	100%	90%

Table 1 must be read as follows. In the case that investments in energy saving measures are for example ‘largely stimulated’, we assume that, according to the weighting scheme 1, 80% of the total saved energy is the actual effect of the agreement. If an investment is stimulated to a slight extent, only 20% of the saved energy is encouraged by the agreement, et cetera. The actual effect of all investments in energy saving measure is calculated in this way and aggregated on a sector level.

2.2 Results

We have applied the method presented in the previous section to the Dutch Long-Term Agreements (LTAs). LTAs were introduced as the main policy instrument for industrial energy conservation in the Netherlands in 1992. On average the LTAs aim at an energy efficiency improvement of 20% in the year 2000 compared with the level in 1989. Up till 1996 29 industrial LTAs on energy efficiency were concluded, covering a total energy consumption of 547 PJ a year. We have selected the following 5 industrial LTAs: margarine, fats & oils; paper & board industries; chemical industries; glass industries and the iron & steel industries. Table 2 shows the energy consumption of the five sectors as well as the total energy savings in the period 1989-1996 compared with a frozen-efficiency level in 1989.

Table 2: Energy consumption (1996) and total energy savings (1989-1996) on sector level

Sector	Energy Consumption (PJ) 1996	Total savings ¹ (PJ) 1989-1996
Chemical industries	318.0	46.0
Paper & Board	30.3	6.7
Glass	12.0	2.0
Iron & Steel	63.3	7.7
Margarine, Fats & Oils	8.3	1.4
Total	432.0	63.8

¹ Compared with a frozen efficiency level in 1989

The total saved energy (compared to a frozen-efficiency level) in the 5 evaluated industrial sectors amounted to 63.8 PJ in the period 1989-1996. The chemical industries are responsible for approximately 70% of the total energy consumption as well as the total energy savings.

The share of the 5 sectors in the energy consumption covered by all the industrial LTAs amounted to 79% in 1996.

1. First of all we have estimated the contribution of the five different energy investment categories to the total energy savings of 5 industrial sectors in the period 1989-1996. The aggregated results are presented in Table 3. The energy saving data per conservation category were derived from the annual LTA progress reports [Novem 1994a; Novem 1994b; Novem 1995a; Novem 1995b; Novem 1996b; Novem 1996c; Novem 1996d; Novem 1996a; Novem 1997d; Novem 1997a; Novem 1997b; Novem 1997c; VNP 1997].

Table 3: Estimated contribution of energy investment categories to total energy savings (1989-1996)

Conservation category	%	PJ
Good housekeeping	9%	5.8
Replacement investments	32%	20.3
Energy-saving investments (retrofit)	18%	11.2
CHP	22%	13.7
Other activities	20%	12.8
Total energy savings	100%	63.8

On average the investments in the replacement of existing equipment contribute the most to the overall energy savings. The conservation categories 'energy savings investments', 'CHP investments' and the category 'other activities' have approximately an equal share in the overall energy savings.

2. Next, we have assessed the energy-saving investments taken in the evaluated industrial sectors according to the procedure outlined in section 2.1. Table 4 shows the aggregated assessment results for the 5 evaluated sectors in case the expert opinion were used.

Table 4: Aggregated assessment results using *expert opinions*

Degree of stimulation	(PJ)	(%)
Not stimulated	12.8	20%
Stimulated to a slight extent	27.6	43%
Considerably stimulated	3.0	5%
Largely stimulated	14.7	23%
Fully stimulated	5.8	9%
Total energy savings	63.8	100%

These assessment results show that about 45% of the total energy savings are slightly stimulated, whereas about 30% of the energy savings are largely to fully stimulated by the LTA.

Table 5 shows the aggregated assessment results for the 5 evaluated sectors in case the survey response was used for assessment of the energy saving investments.

Table 5: Aggregated assessment results using *survey response*

Degree of stimulation	(PJ)	(%)
Not stimulated	27.3	43%
Stimulated to a slight extent	17.0	27%
Considerably stimulated	8.3	13%
Largely stimulated	8.4	13%
Fully stimulated	2.8	4%
Total energy savings	63.8	100%

These assessment results show that more than 40% of the total energy savings are not stimulated by the agreements. A minority of 17% of the energy savings are largely to fully stimulated.

3. We have applied the weighting schemes as outlined in section 2.1. Table 6 presents an overview of the energy savings promoted by the LTAs according to the three different weighting schemes in case the expert opinions were used.

Table 6: Energy savings (1989-1996) promoted by the 5 evaluated LTAs using *expert opinion*

Weighting scheme	Stimulated savings (PJ)	Stimulated savings (% of total savings)
Scheme 1	24.6	39%
Scheme 2	30.4	48%
Scheme 3	19.5	31%

According to Table 6 31-48% of the total energy savings can be attributed to the implementation of the LTAs, depending on the weighting scheme used. Using linear extrapolation of the results, we estimate the additional energy savings of all the 20 industrial LTAs that were contracted in the period 1989-1996 at 24-37 PJ.

Table 7 shows a less optimistic view on the amount of stimulated energy savings in case the survey response was used. According to Table 7 the percentage of energy savings promoted by the LTAs is about 21% to 36% depending on the weighting scheme used. Using linear extrapolation of the results, we estimate the additional energy savings of all the 20 industrial LTAs that were contracted in the period 1989-1996 at 16-28 PJ.

Table 7: Energy savings (1989-1996) promoted by the 5 evaluated LTAs using *survey response*

Weighting scheme	Stimulated savings (PJ)	Stimulated savings (% of total savings)
Scheme 1	17.0	27%
Scheme 2	23.0	36%
Scheme 3	13.4	21%

2.3 Discussion

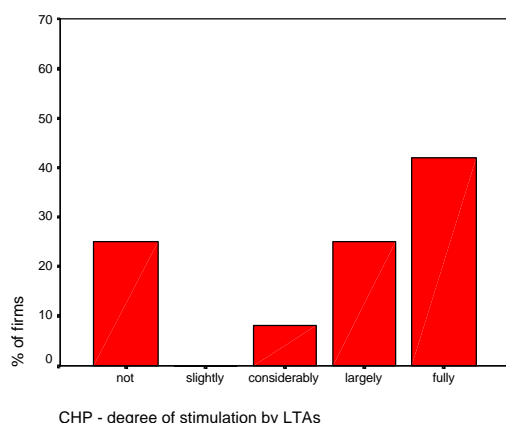
In this section we will discuss the assessment method and the results presented in the previous sections. The assessment method outlined in section 2.1 consists of 3 distinctive phases (classification of energy saving measures, assessment of investment categories and the translation into weighting schemes) which can all be subject of discussion.

The *classification of energy saving measures* in distinct investment categories can be a subjective process in itself. Moreover, due to a lack of detailed data and information in the monitoring reports, the purpose and thus the character of energy saving investments can remain unclear in some cases.

The use of expert opinions for the *assessment of energy saving measures* can be discussed as well. The expert opinions reflect their expectations about the firms' energy conservation behaviour. Hence, the expert opinion does not necessarily correspond to the actual investment behaviour of firms. Therefore, we have asked firms in survey to assess to what degree the LTAs have promoted the energy conservation investments. In section 2.1 we have compared the survey results with expert opinions. Large differences between the firms' own judgement and the expert opinion about the energy conservation behaviour of firms can be observed. This can either be due to a wrong interpretation of the survey questions or an overestimation of the expert opinions.

With the help of other survey data we were able to analyse the interpretation of the survey question regarding the stimulation of the CHP investments. The response to this particular survey question appeared to be much higher than the number of firms that actually had a CHP plant. This suggest a wrong interpretation of the survey question. In Figure 3 we have plotted the response on this particular question among the firms with a CHP plant. Figure 3 shows a completely different picture than the survey response in Figure 2.

Figure 3: Survey response among firms with a CHP plant



Among the firms with a CHP plant more than 65 % of the firms indicates that the CHP investments are largely to fully promoted by the LTAs. The survey response among the firms with a CHP plant is still in contrast with the expert opinion. The high response in the category ‘not’ stimulated can probably be explained by a large number of firms that invested in CHP installations before LTAs were concluded. When we apply these corrected survey response in the assessment procedure we estimate the percentage of stimulated energy savings to be 29-44%, which corresponds much better with the results presented in Table 6. Unfortunately the firms’ interpretation of the other survey questions could not be analysed. It is however expected that the other survey questions are less biased, since replacement investments, retrofit investments and good housekeeping measures are more common than the CHP investments.

The *translation of the expert opinions and the survey response into a weighting scheme* can also be a topic of discussion. The overall results can for a large part depend on the weighting scheme designed. Therefore, we have checked the sensitivity of the average weighting scheme by considering a low and a high variant. To our opinion the dispersion of the results, ranging from 31-48% is acceptable, although other uncertainties with respect to the assessment mentioned above must be taken into account.

The *outcome of the evaluation* largely depends on the assessment of the energy saving investments in the chemical industry, since this sector is responsible for more than 70% of the total energy savings in the evaluated sectors. In this respect it is regrettable that in this particular sector there are substantial discrepancies between the energy consumption data of LTA monitoring reports and national statistics. This means that the overall must be regarded as only preliminary. If the chemical industries are not taken into account in the evaluation, the effectiveness of the LTAs ranges from 41% to 59% (using expert opinion). Large differences in the effectiveness of the sectoral agreements can be observed.

2.4 Conclusion

In this chapter we have assessed the actual outcome of voluntary agreements in the Netherlands by investigating the additional investments made by industry. We have used expert opinions as well as the firms' own perception to judge to what extent these investments (and thus energy savings) were encouraged by the agreements. The estimations based on expert opinions indicate that **31-48%** of the total energy savings can be attributed to the implementation of the LTAs in the Netherlands. The assessment of the actual outcome based on the corrected survey response shows similar results (**29-44%**).

2.5 Further elaboration of the assessment method

As pointed out in the discussion section the classification of the energy saving measures in the several investments categories and the assessment to what degree the investments were promoted by the agreements influence for a large part the uncertainties in the results of this study. To improve the quality of the results we had the idea to increase the detail of investment categories and ask firms to assess to what degree the agreements have stimulated the investments in specific energy conservation measures.

This approach would however require also more detailed data on energy savings on lower technology levels. A quick scan among the Dutch sectoral LTA progress reports showed that only the annual progress reports of the glass manufacturing industry could provide sufficiently detailed energy saving data on disaggregated level.

In a small survey among 6 glass manufacturers in the Netherlands we have asked the firms to assess to what degree the agreements have encourage the investments in specific technical measures. The survey also aimed at uncovering the stimulating effect of other key elements in the LTA program. The response on the survey was however too low to draw any conclusions about the stimulating effects of the agreements.

3 Simulation of energy efficiency investment behaviour in the business-as-usual case

The second approach to assess the actual outcome of agreements compares the overall monitored energy efficiency improvement with the efficiency improvement in the business-as-usual (BaU) case. The BaU scenario reflects the energy efficiency improvement due to technological or operational changes that would have taken place anyway, also without the policy influence. The energy efficiency improvement in the BaU case is assessed by simulating the energy investment behaviour of industrial firms. Several models exist that describe the investment behaviour of firms regarding energy conservation measures. These models will be applied on a techno-economic database of energy efficiency improvement techniques to assess the energy efficiency improvement in the BaU case. Also in this chapter we will apply this approach to the Dutch LTAs. In the Netherlands, the LTAs are assumed to be the major policy instrument and the impact of other policy instrument and measures on energy efficiency improvement is thus negligible. Section 3.1 and 3.2 respectively deal with the presentation of the assessment method and the results of the assessment. Section 3.3 discusses the method and the results. Section 3.4 summarises the main conclusions.

3.1 Method

The behaviour of firms regarding the investments in energy savings measures depends for an important part on the pay-back period (PBP) of these investments. A simple PBP is calculated by dividing the total investments by the annual revenues. The PBP can be defined as follows:

$$PBP = \frac{\text{Total investments}}{\text{Net annual revenues}} = \frac{I}{SPEC - OM} \quad (1)$$

Where:

- I = investments costs (Dfl/yr)
- $SPEC$ = annual saved energy purchase costs (Dfl/yr)
- OM = annual operation and maintenance costs (Dfl/yr)

[Farla and Blok 1995] and [Beer et al. 1995] have developed an implementation model that describes the energy efficiency investment behaviour of firms. The model indicate the percentage of profitable investment with a certain maximum pay-back period (PBP) that are implemented in the BaU case. Table 8 and Table 9 show the implementation models by [Farla and Blok 1995] and [Beer et al. 1995] respectively. The models are different interpretations of basic survey data collected by [Gruber and Brand 1991] and [Koot et al. 1984]. The tables show the relation between cut-off pay-back periods and the adoption of energy conservation measures (in terms of technical potential). Table 8, for instance, indicates that 95% of the firms would adopt an energy efficiency technology with a PBP shorter than 1 year.

Table 8: Implementation model I

Pay-Back Period (year)	Adoption (%)
<1	95
<2	80
<3	55
<4	30
<5	10
>5	0

Source: [Farla and Blok 1995]

Table 9: Implementation model II

Pay-Back Period (year)	Adoption (%)
<2	100
<3	86
<4	56
<5	39
>5	15

Source: [Beer et al. 1995]

The implementation models can be applied on a techno-economic database of energy efficiency improvement techniques to assess the energy efficiency improvement in the BaU case.

3.2 Results

Next, we have applied the method presented in the previous section to the Dutch LTAs. In our study we have used the ICARUS³ technology database developed by [Beer et al. 1994]. ICARUS is a database containing information on the potential and details of costs of a large number of both demand-side and supply-side technologies for improving energy efficiency in all sectors of the Dutch economy. With the ICARUS database the industrial potential for energy conservation according to pay-back period (PBP) of investments can be calculated. In Figure 4 the cumulative energy efficiency improvement (CEEI) in the period 1990-2000 is plotted against the PBP.

The CEEI in Figure 4 reflects the aggregated value of the sectoral potentials for industrial energy efficiency improvement. The technical potential for energy conservation in all the industrial sectors is 28% of the projected frozen-efficiency primary energy demand in the year 2000⁴. The energy efficiency improvement achieved by CHP is included in these figures.

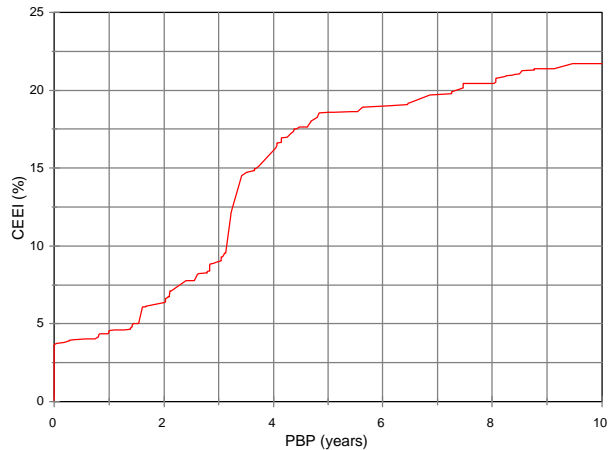
Next, we have applied the implementation model on the ICARUS database. We have multiplied the efficiency improvements of the investments with a specific PBP with the corresponding adoption percentages in Table 8 and Table 9. The outcome of these calculations corresponds to the energy efficiency improvement in the BaU case. The energy efficiency improvement in the BaU case in the period 1990-2000 is estimated at 9% using implementation model I and at 15% using model II, corresponding to an estimated annual average improvement of 1% and 1.6% respectively. These figures correspond very well with findings by [Grubb 1993]. According to [Grubb 1993] the average value for the energy

³ ICARUS is an acronym for 'Information system on Conservation and Application of Resources using a Sector approach'.

⁴ The European Renaissance scenario and a high energy price scenario were selected for the calculations. An average efficiency of power plants of 40% in the year 2000 was used.

efficiency improvement in the BaU case for all the regions in the world amounts to about 1.0%. However [Grubb 1993] mentions that in several studies more optimistic values of 1.5% are used as well.

Figure 4: Cumulative energy efficiency improvement (CEEI) in the industrial sector versus the pay-back period (PBP)



As stated in the introduction of this chapter we assume that the impact on energy efficiency of policies and measures other than LTAs is negligible in the Dutch case. The difference between the annual average monitored energy efficiency improvement and the annual average efficiency improvement in the BaU case can therefore be regarded as the actual outcome of the agreements. In 1996 the average energy efficiency improvement amounted to 12.5% compared with the level in 1989 [EZ 1997]. This corresponds to an annual average improvement of 1.9%. Consequently, the environmental effectiveness or in other words the agreements' contribution to the overall energy savings in the period 1989-1996 is estimated at 16%-47%, depending on the applied implementation model.

3.3 Discussion

In this section we would like to briefly discuss the method presented in this chapter. First of all, we would like to stress that this approach assumes that besides the agreements the impact of other policies and measure on energy conservation in the manufacturing industry is negligible. Besides the LTAs there is a programme to promote the introduction of new technologies in the industry. The short-term impact of this program is however expected to be low. No other important policy instruments aimed at industrial energy conservation have been implemented since the introduction of the agreements. In the Netherlands the LTAs (including a wide set of supporting measures to promote energy conservation) can therefore be considered as the main policy instrument for energy efficiency improvement in the manufacturing industry.

Secondly, we would like to point at the uncertainties with respect to the implementation models used in this study. It should be clear that there are several investment barriers other

than the profitability barrier that is modelled (e.g. lack of knowledge, lack of interest in energy efficiency investments). Here, we also want to point to the suggestion of [Korevaar 1997] and [Glasbergen et al. 1997] that exactly these barriers are attacked by the agreements. Therefor it is expected that the BaU energy efficiency improvement is overestimated and the environmental effectiveness of the agreements underestimated. Moreover, it can be argued whether an interpolated function representing the relation between the pay-back period and the adoption of technological potential energy conservation measures should be used in stead of the cut-off pay-back periods used in our implementation models.

Finally, it must be mentioned that there are also uncertainties in the technology database ICARUS. These uncertainties and their effects on the actual outcome of the agreements was however not be assessed within the scope of this study.

3.4 Conclusion

With this method we have been able to estimate the BaU energy efficiency improvement in the Netherlands. The environmental effectiveness of the Dutch agreements has been assessed by comparing to monitored efficiency improvement with the estimated BaU improvement. We estimate that about **16-47%** of the total energy savings can be attributed to the implementation of the LTAs in the Netherlands. As indicated in the discussion section the lower limit of 16% is considered as an underestimated value.

4 Monitoring of historical development of energy efficiency

The actual outcome of agreements can also be assessed by comparing the current energy efficiency improvements with the historical development of energy efficiency. In this approach, the historical development of the energy efficiency is considered as the BaU efficiency improvement. The historical development of energy efficiency can be determined on the basis of statistical energy consumption data and physical production of various products. As outlined in the introduction we have to face several methodological problems in this respect. The historical development is distorted by the influence of energy prices and other policy instruments aimed at energy efficiency improvement. Moreover structural changes in the economy can also have a significant effect on the energy efficiency. To tackle these problems we will use a decomposition analysis which disentangles the impact of changes in product mix, the penetration of CHP and process efficiency improvement on the overall energy efficiency improvement on sector level. In this case we consider the historical development of the *process efficiency* as a trend-scenario, since in the eighties CHP investments were mainly promoted by large subsidy schemes. Furthermore we assume that the effects of other policy instruments on energy efficiency improvement was negligible in the past. A comparison of the current energy efficiency improvement with the process efficiency improvement in the past should reveal the actual impact of the agreements.

In this chapter the paper and board industry will be used as an example to study the feasibility of this approach. The following section starts with describing a method to measure energy efficiency improvement in the paper and board industry. This section also explains the decomposition analysis very shortly. Section 4.2 deals with the origin of the data used in the analysis. Section 4.3 and 4.4 respectively presents the results and conclusions.

4.1 Method

This section describes a method to measure energy efficiency in the pulp and paper industry. Furthermore we will go into the decomposition analysis method very shortly.

Measuring energy efficiency

On the dis-aggregated level the energy efficiency improvement for one single product i can be measured by calculating the specific energy consumption (SEC), which is defined as:

$$SEC_i = \frac{E_i}{P_i} \quad (2)$$

where E_i is the energy consumption of the manufacturing process and P_i the physical production of commodity i . This indicator directly gives the state of the energy efficiency of the production process of commodity i . Often the final energy consumption is used as the numerator, since allocation of energy consumption of for instance CHP to different processes or products is difficult.

Usually more than one activity is performed at the (sub)sectoral level. The specific energy consumption can therefore not be used as an indicator. An aggregate *SEC* on sector level easily be calculated by dividing the total energy consumption on sector level (*SE*) by the total production (*SP*) in the sector:

$$SEC_{agg} = \frac{\Sigma E}{\Sigma P} \quad (3)$$

This aggregate *SEC* is however not a real energy efficiency indicator, since it does not take into account structural effects in the sector. Additional indicators, like the relative amount of pulp and waste paper in products, are required to compare the energy efficiency improvement in time among various countries.

For energy efficiency indicators at sector level the individual activities and processes have to be re-aggregated. To aggregate the products and activities in a sector we introduce a physical activity index:

$$PPI = \Sigma(P_x \times w_x) \quad (4)$$

where *PPI* is the physical production index, P_x the physical production of product x and w_x a weight factor of product x . [Farla et al. 1997] have chosen a reference *SEC* of pulping processes or paper products as a weight factor. The reference *SEC* must be considered as 'typical values for a modern plant'. Consequently, the *PPI* actually represents the 'expected' energy requirement at the given sector structure (product mix and different pulping processes).

In stead of the total production in the sector (*SP*), the *PPI* is used as the denominator in equation (3). This results in the following equation:

$$SEC_{agg} = \frac{\Sigma E}{PPI} \quad (5)$$

The aggregate *SEC* becomes a dimensionless energy efficiency indicator since the numerator and denominator are expressed in the same units. The aggregate *SEC* in this form serves as an index that indicates the relative development of energy efficiency in time. Preferably the net available energy is used as the numerator with the inclusion of CHP in the sector in which it is applied. In our study we have calculated the aggregate *SEC* on the basis of the primary demand for energy.

Decomposition analysis

The specific energy consumption in a sector is related to the product mix, the efficiency of the production process and the penetration of CHP in the sector. This relationship can be written as:

$$\Sigma SEC = \frac{PPI}{\Sigma P} \times \frac{\Sigma E_{nae}}{\Sigma E_{fin}} \times \frac{\Sigma E_{fin}}{PPI} \quad (6)$$

where PPI/SP is related to the sector structure and where SE_{nae}/SE_{fin} is an indicator for the CHP usage in the sector. Nae and fin respectively stand for ‘net available energy’ and ‘final energy consumption’⁵. SE_{fin}/PPI is an indicator for the efficiency of the manufacturing process. With an index decomposition approach as applied in [Farla et al. 1997] we will calculate the influence of changes in sector structure (STR), process efficiency (EFF) and the use of CHP (CHP) on the change in specific energy consumption in the paper and board sector in the Netherlands. For more detailed information on the applied method we would like to refer to [Farla et al. 1997].

4.2 Data used in the analysis⁶

The *energy consumption data* (net available energy and final energy consumption) were taken from [CBS Annual Publication]. The presentation and definition of energy consumption data by CBS changed in 1982 and 1993. Several adaptations were required to obtain a continuous data series, see [Farla and Blok forthcoming-b]. In the analysis we take into account eight different products in the paper and board: mechanical pulp, newsprint, printing paper, packaging paper, corrugated cardboard, other board, sanitary paper and the use of waste paper. The *production data* were taken from [CBS 1994; FAO 1996; VNP Annual]. For the derivation of the *weight factors* we would like to refer to [Farla and Blok forthcoming-b].

4.3 Results and discussion

Figure 5 shows the reduction of *SEC* in the Dutch paper and board industry in the period 1980-1996 (Efficiency total CBS). The total reduction in the *SEC* in the overall period amounts to 31%. The average annual *SEC* reduction in the period *before* the LTA amounts to 3.4%. The *SEC* reduction in the *period 1989-1996* is approximately 1.0%. These figures indicate a decelerated efficiency improvement since the introduction of the LTA. As a comparison we have also plotted the *SEC* reduction based on energy consumption data by the Netherlands’ Paper and Board Association in the same figure (Efficiency total VNP). The annual average *SEC* reduction in the *period 1989-1996* is much higher: 1.9%. The discrepancies can be best explained by differences in the sector coverage of the energy consumption.

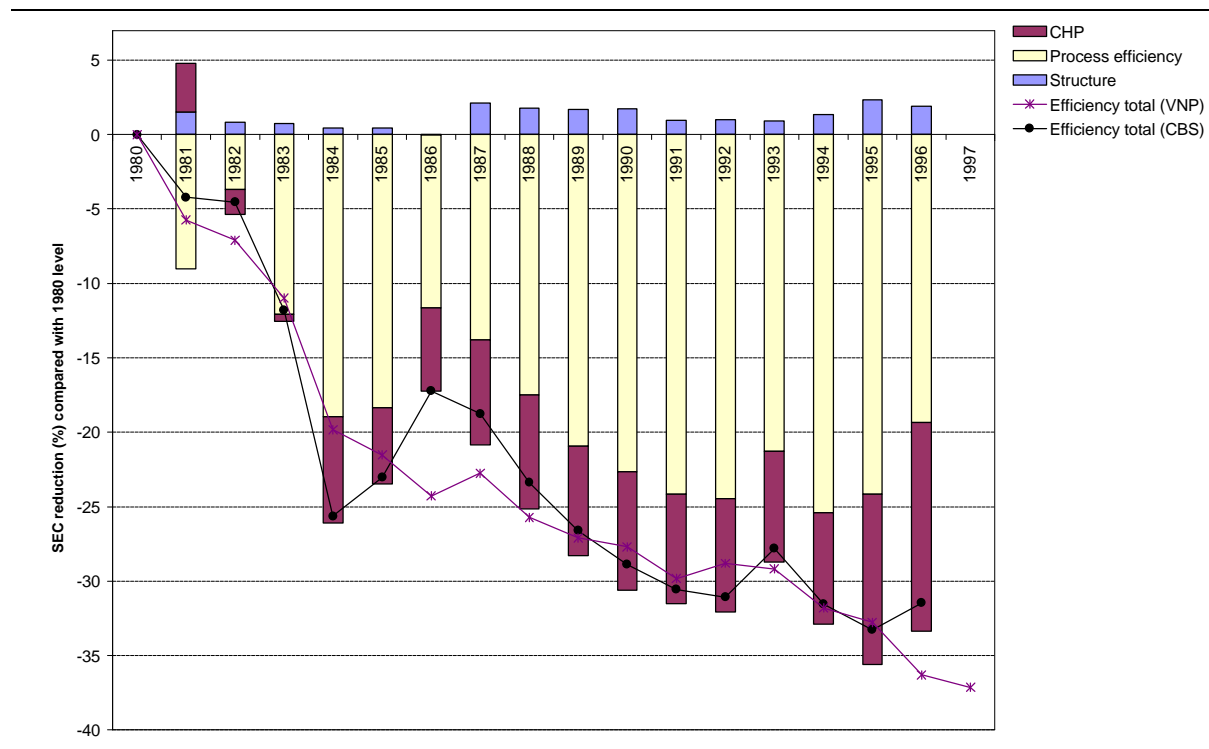
Figure 5 shows also the decomposition of the energy efficiency improvement in the Dutch paper and board industry in the period 1980-1996. The *SEC* reduced with more than 19% in the analysed period due to process efficiency improvements. The increased use of CHP resulted in a *SEC* reduction of 14%. Energy efficiency improvements due to the increased

⁵ For a definition of net available energy and final energy consumption we refer to section 5.3.2.

⁶ Data used in the analysis were kindly provided by J.C.M. Farla.

CHP capacity can be observed in mid eighties and nineties. The large efficiency improvements in the mid-eighties are however mainly due to the high energy price in that time, see Figure 6. The exact impact of the energy price on the *SEC* reduction could not unfortunately not be studied within the scope of this project⁷. Changes in the product mix had a relatively small impact (+2%) on the *SEC* in the Dutch paper and board sector.

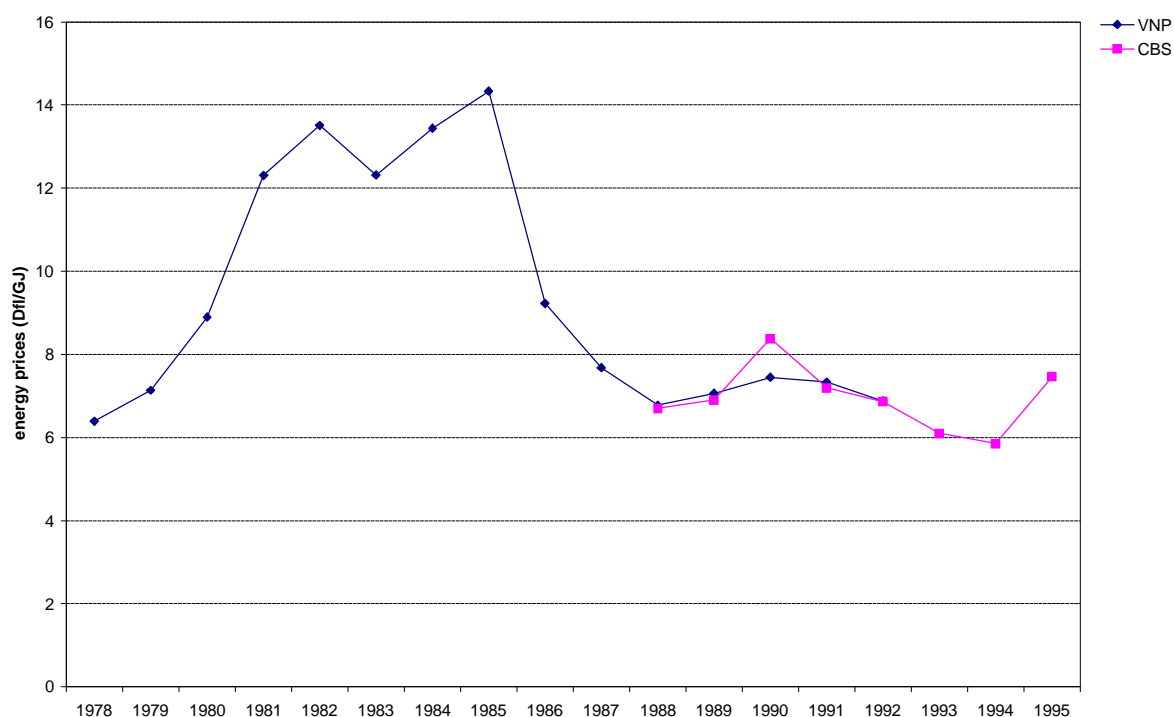
Figure 5: Decomposition of energy efficiency improvement in the Dutch paper and board industry



The decomposition of energy efficiency shows some unexpected results. First of all a negative influence of CHP on the energy efficiency can be observed in 1981. This is probably due to the changed definition and presentation of energy consumption in 1982 by the CBS. Secondly, Figure 5 shows an absolute decrease of process efficiency improvement in the period 1989-1996 and an absolute decrease of the overall efficiency improvement in 1996 compared with 1995. Both observations are in contrast with the LTA results published by [VNP Annual].

⁷ The obtained data series on energy prices were too short to lead to satisfying results.

Figure 6: Current energy prices (Dfl/GJ) in the Dutch paper and board industry *



* The figure shows two time series. The VNP series is based on energy consumption data and total energy cost derived from [VNP 1990; VNP 1993]. The CBS series is based on energy consumption data derived from [VNP 1990; VNP 1993] and energy costs derived from [CBS Annual Publication].

A comparison of the average efficiency improvement in the period 1989-1996 (1%) with the *process efficiency improvement* in the past (2.6%) should reveal the actual impact of the agreement. These figures also indicate a negative impact of the agreement.

4.4 Conclusion

On the basis of the results presented in the previous section we conclude that the historical development of the process efficiency is not a suitable BaU scenario, which can be used to assess the actual impact of the agreements. Moreover, we may conclude that the impact of energy prices and other energy conservation policies in the past are probably larger than expected. On the basis of the estimated actual impact of the agreements presented in the sections 2 and 3 and the large differences in CBS and VNP statistics we leave a negative impact of the agreements on energy efficiency improvement out of consideration.

To sum up, the decomposition analysis of the historical development of energy efficiency appears not to be a suitable method to isolate the impact of the agreements on energy efficiency improvement on sector level. In case the impact of energy prices is included in the decomposition analysis this opinion may be changed. The application of this approach on more aggregate levels may also lead to more satisfying results.

5 Comparative analysis of the environmental performance of agreements with paper and board industries

Within the VAIE-project voluntary agreements with pulp and board industries have been selected as a case study to compare the implementation and efficiency of the agreements among the 5 different countries participating in the project. The analysis of the environmental performance of the voluntary agreements can provide important quantitative support and evidence to the empirical results of these case studies. Therefore a benchmark study was carried out to compare the *energy efficiency improvement* in the paper and board industries in the various countries over time. We have also tried to evaluate the *effectiveness* of the agreements by assessing the actual change in energy efficiency investment behaviour in the paper and board industries. Due to a lack of detailed data a broader international comparison of the actual outcome of the agreements has however failed.

The outline of this chapter is as follows. Section 5.1 introduces the paper and board industry by describing the main manufacturing processes of pulp and paper. Section 5.2 outlines the important characteristics of the agreements concluded with the paper and board industry in the countries involved. Section 5.3 deals with the benchmarking of the energy efficiency improvement in the paper and board industry. Section 5.4 compiles the collected material for the international comparison of the actual outcome of agreements with paper and board manufacturers.

5.1 Manufacturing processes of pulp, paper and paper board

The pulp and paper industry (ISIC 2101 [UN 1990]/NACE 21.1 [Eurostat 1993]) is an important consumer of energy world-wide. Its share in the world wide industrial energy consumption is about 4% [WEC 1995]. Energy consumption for pulp and paper production is estimated at 5.7 EJ purchased energy in 1990 [WEC 1995]. An additional amount of 2.3 EJ non-conventional energy, i.e. from wood waste and pulping chemicals is used [Beer et al. 1998]. The most important energy-intensive processes in the paper production are wood pulping and paper making. The products of this industry are pulp, paper and paper board. The paper and board products can be distinguished in many different ways. The FAO distinguishes five different categories of paper products: 'newsprint', 'printing paper', 'packaging paper', 'sanitary paper' and 'other paper and board products'. This categorisation will be used in our study.

The fibre used to produce paper is supplied by two main sources; virgin fibre from wood and recovered fibre from manufacturing waste paper and discarded paper [Ruth 1998]. A small portion of fibre is derived from other sources, such as cotton fibre. Wood is prepared for pulping by slashing long wood into short wood, debarking and chipping. These steps only require a small amount of energy [WEC 1995]. Wood pulping can be done mechanically, chemically or in an intermediate form. In mechanical pulping the cellulose fibres in wood are most commonly separated by the grinding of wood. Mechanical pulping is a simple and cheap

process, but wood fibres are damaged to a large extent. The resulting lower fibre quality limits the use of mechanical pulping mainly to newsprint. In chemical pulping (also called the Kraft process) wood chips are cooked in an aqueous solution of chemicals. The chemical pulping process results in higher paper quality but with a lower yield. After pulping the material may be bleached [Phylipsen et al. 1998b].

If paper and board are not manufactured in an integrated pulp and paper plant, pulp is dried and transported to another production location [Farla et al. 1997]. In this case dried pulp is used as feedstock in the paper and board production. The production of paper from pulp involves a series of stages that begins with a stock that is prepared by mixing pulp and water (in case dried pulp is used). The stock is sprayed onto wire mesh to form sheets. Gravitation and suction remove a large part of the water. The sheet of pulp is further de-watered by pressure and heat [Ruth 1998]. Two thirds of the final energy needed to remove the water is used in the drying section of a paper machine to remove the final 1% of the water [Nilsson et al. 1995]. Different kind of coatings, depending on the use of the paper, can be put on the dried product. Finally the paper is cut and wound. Besides for pulping, electricity is mainly used to drive the paper machine and to drive the pumps for the transport of water [Farla et al. 1998].

5.2 Voluntary agreements with paper and board industry

This section outlines the characteristics of the voluntary agreements concluded with pulp and paper industry in the Netherlands, Germany, Denmark and Sweden. Attention is put on the target setting, coverage and the monitoring of energy efficiency improvement.

Germany

In the updated and extended 'Declaration by German Industry and Trade on Global Warming Prevention' [BDI 1996], the German Pulp and Paper Association declares that it will urge its member companies to reduce the specific CO₂ emissions of pulp and paper mills resulting from the use of fossil fuels and external electricity. The stated objective for the old Federal states is a reduction in the specific CO₂ emissions by 22% of the 1987 levels by the year 2005. This is expected to lower the specific energy input by 20%. Using the energy saving potentials in the new Federal States, the objective for all of Germany is to reduce the specific CO₂ emissions by 22% of the 1990 levels by the year 2005, corresponding to an average annual specific reduction of 1.6%. The use of non-fossil fuels is included in this target [RWI 1999c]. The measures required to accomplish this objective are expected to yield a decrease in the specific energy input by 20% over the same period [BDI 1996]. This corresponds to an annual reduction of the specific energy consumption of 1.5%.

The voluntary agreement in Germany covers pulp, paper and paperboard manufacturers, i.e. sector 21.1, according to Eurostat sector classification [Eurostat 1993]. The total paper production amounted to 15953 ktonnes in 1997 [FAO 1996]. In 1997 the total primary energy consumption, based on net available energy amounted to 217 PJ. The degree of coverage in

1996 in relation to production and energy consumption is between 85% and 93% respectively [RWI 1997a]. 105 companies have concluded an agreement [RWI 1997b].

The achievement of the objectives is measured on the basis of the average specific CO₂ emissions or on the basis of the average specific energy input in the sector [BDI 1996]. Both the indicators do not take into account the changes in product mix.

The Netherlands

In 1996 the Dutch Ministry of Economic Affairs, the Association of Provinces and the Paper and Board Association continued the voluntary agreement on energy efficiency improvement in the paper industry that was concluded in 1993. The old agreement aimed at 14% energy efficiency improvement in the period 1989-1995. In the continued agreement the Paper and Board Association aims at a reduction of the specific energy consumption of 20% in the year 2000 compared to 1989 [EZ 1996b]. This target, corresponding to an average annual decrease in the specific energy consumption of 2.0%, concerns the use of fossil fuels, heat and external electricity. The feedstock energy requirement and the consumption of renewable energy resources are not included in the target. Consequently the Dutch target is much more ambitious than the target in Germany.

In the Netherlands 28 companies (32 plants) have concluded a voluntary agreement [VNP 1998]. All the paper and paperboard manufacturers take part in the agreement [VNP 1998]. The total paper production amounted to 3159 ktonnes in 1997 [FAO 1996] requiring a total primary energy consumption, based on net available energy of 31.7 PJ [EZ 1998a].

The energy efficiency improvement is measured by the dimensionless energy-efficiency index (*EEI*). The *EEI* compares the actual energy consumption with a reference energy consumption. The frozen-efficiency energy consumption is used as a reference. In the reference year (1989) the *EEI* amounts 100. The *EEI* on firm level in year *j* can be described with the following formula:

$$EEI_j = 100 \times \frac{\text{Actual energy consumption}}{\text{Reference energy consumption}} = 100 \times \frac{E_j}{\sum_{i=1}^n P_{i,j} \times SEC_{i,1989}} \quad (7)$$

where E_j is the total primary energy consumption in the sector, $P_{i,j}$ the production volume of the individual manufactured products i and SEC_i the specific energy consumption of the individual process or product in the reference year (1989). The total energy consumption of a company is determined according to a black-box method. This means that the energy consumption includes only the use of energy carriers that cross the company border. CHP plants are considered to be inside the company. The *EEI* is calculated on an annual basis and does not depend on the introduction of new products or on the removal of products both on firm and branch level. The aggregation of the *EEIs* at firm level yields a *EEI* on sector level [EZ 1996b].

Denmark

The voluntary agreements in Denmark started on 1-1-1996 along with the new formulation of the Carbon (and Sulphur) Tax, which includes 3 categories of tax rates, the lowest for heavy industrial processes, followed light processes and heating, which is taxed with the highest rate. Tax rates were defined for companies with and without an agreement. Companies can enter an agreement to qualify for lower tax rates. Any eligible firm choosing to participate in this voluntary scheme must conduct an energy audit and energy plan and satisfy other energy management requirements, all which allows the firm to reduce carbon tax rates for heavy and light processes. Firms must implement all profitable investments described in the energy audit. The Danish Energy Agency (DEA) considers all investments with a pay-back-period of up to 4-6 years profitable [Togebly et al. 1998a; Togebly et al. 1998b]. Companies must deliver a yearly progress report of the agreement to the DEA.

In Denmark 6 companies in the pulp and paper sector have concluded an agreement, 3 in 1996 and 3 in 1997 [DEA 1998]. All the agreements cover a three year period. The total paper production amounted to 345 ktonnes in 1997 [FAO 1996] while the total primary energy consumption, based on final energy consumption, amounted to 4.6 PJ.

In contrast with the Dutch and German agreements no stated target with respect to specific CO₂ emission reductions or efficiency improvement has been formulated in the Danish agreement. However, the Ministry of Finance expects the CO₂-tax package to reduce CO₂ emissions from trade and industry by 4.6% of the total Danish CO₂ emissions in relation to the 1988 level by the year 2005 [Togebly et al. 1998a]. The reduction of the CO₂ emissions from trade and industry its self is expected to be reduced by 9-10%. Companies themselves have formulated individual targets for the specific energy consumption as part of their energy management systems. These targets are however not legally binding [AKF 1999].

To get an impression of the ambitiousness of the voluntary agreement scheme in Denmark, we have used the technology database by [Beer et al. 1994] to calculate the efficiency improvement in the Dutch pulp and paper industry in the case that all energy conservation investments with a maximum pay back period of 4-6 years are implemented. The total energy efficiency improvement in the period 1990-2000 is estimated at 17.5-20%, corresponding to an annual improvement of 1.9-2.2%. On the basis of these figures the Danish scheme seems to be rather ambitious.

Sweden

The Swedish EKO-Energi Program started in 1994, and os directed towards firms preparing for EMAS or ISO 14001 certification. A total of 30 companies (involving about 80 plants or sites) joined the program until it was closed to new participants in 1998. Firms are submitted to an independent energy audit and commit themselves to a series of individual standards regarding energy efficiency and management, which are not made public. The authorities provide the firms with advise and pay the cost of the energy audit. Moreover, firms are allowed to make use of a logo providing labelling advantages. The long-term target of the EKO-Energi program is to promote the goals of Agenda 21 at enterprise level, and to

contribute to the national goal of stabilizing CO₂ emissions by 2000 compared to the 1990 level [Kagstrom et al. 1999].

In Sweden two large pulp and paper manufacturers (StoraEnso and Södra) participate in the EKO-Energi program. The total number of firms in the pulp and paper industry is about 31 with several affiliated companies. The degree of coverage in terms of production or energy consumption is unknown. The total paper production in Sweden amounted to 9779 ktonnes in 1997 [FAO 1996]. In 1996 the total primary energy consumption amounted to about 226 PJ.

France

In France the program on voluntary agreements started in 1996. The scheme was designed in the framework of the Rio commitments set in 1990. The program aims at contributing to the overall climate policy objective to stabilise CO₂ emissions between 1990-2000 and also at limiting the competitive effects of carbon reduction policies in particular for energy intensive industries [Chidiak 1999b]. The program involves negotiated agreements at both branch and firm level. For so far 8 voluntary agreements have been concluded of which 6 industrial branches and firms. The type and level of target setting in the voluntary agreements differs widely among the branches and firms. The agreements can include specific CO₂ emission reduction targets, targets on reduction of specific energy consumption, as well as other environmental targets.

Neither an agreement has however been concluded with pulp and paper branch nor with an individual firm. The total paper production in France amounted to 8556 ktonnes in 1997 [FAO 1996]. In 1997 the total primary energy consumption, in the pulp, paper and board industry amounted to about 150 PJ.

5.3 Benchmarking energy efficiency in paper and board industry

A benchmark study was carried out to compare the development of energy efficiency improvement in paper and board industry among the various countries over time. The energy efficiency in the paper and board industry was studied with more or less standardised methodologies for the international comparison of energy efficiency improvement, see section 5.3.1. The data that were used in this study are described in section 5.3.2. Section 5.3.3 presents the results of the analysis, whereas section 5.3.4 discusses the results of the international comparison and vigorously addresses the quality and the comparability of the data used in the analysis. Section 5.3.5 summarises the conclusions of this benchmark study and presents some recommendations for further research on this topic.

5.3.1 Method

In section 4.1 we have presented the methodologies that can be used for the quantitative analysis of energy efficiency in the pulp and paper industry among countries. In this benchmark study we will compare energy efficiency among countries on the basis the aggregate specific energy consumption according to equations (3) and (5).

5.3.2 Data used in the analysis

The quantitative analysis of energy efficiency improvement requires large amounts of data. The Appendix contains an abstract of the data used in the analysis. This section describes the sources, modifications and corrections of the collected data used in the analysis. Moreover, the under- and overestimations of the energy consumption data due to these corrections and modifications will be assessed.

Energy consumption data

The energy consumption data for the German pulp and paper industry were derived from [VDP 1998]. The energy consumption data for the period 1992-1997 concern all federal states, whereas in the data before 1992 only the old federal states are represented. Therefore, the energy consumption data in 1990, the base year of the voluntary agreement, were derived from [RWI 1997a]⁸. The energy consumption data for 1991 were obtained by interpolating the 1990 and 1992 data.

For the Dutch pulp, paper and board industry three different time series for the energy consumption were obtained. Time series on the net available energy consumption as well as time series on the final energy consumption were derived from the industrial production statistics available in the National Energy Statistics [CBS Annual Publication]. The third time series were derived from the progress report of voluntary agreement on energy efficiency improvement in the Dutch pulp and paper industry [VNP 1998].

The energy consumption data for the Swedish pulp and paper manufacturing industry were derived from the national energy statistics [SCB Annual publication]. The French energy consumption data in pulp and paper manufacturing industry were derived from [SESSI Annual publication]. The Danish statistics [SD Annual publication] provide data on the energy consumption in the Danish pulp and paper manufacturing industry in the years 1990, 1993 and 1995-1997. The energy consumption data for 1991 and 1992 were also derived from [SD Annual publication]. The 1994 data were obtained by interpolating the data for 1993 and 1995.

Paper processing industry and printing & publishing sector

In some cases more aggregated energy consumption data were obtained. Consequently additional corrections were necessary. The Dutch energy consumption data include the energy consumption of the paper processing industry as well. Moreover, a new sector classification was adopted by the CBS in 1993. Consequently, the energy consumption data derived from the national surveys on industrial energy consumption since 1993 include the energy consumption of printing and publishing as well. Therefore the energy consumption data were corrected by subtracting the net available energy consumption for the printing and publishing sector and manufacturing of paper and board articles in the relevant years⁹.

⁸ In this respect it must be mentioned that the 1995 and 1996 data included in both sources, [RWI 1997a] and [VDP 1998] fully correspond to each other. Data in the other years could not be derived from [RWI 1997a].

⁹ Data derived from the industrial production statistics [CBS Annual Publication].

In the Swedish statistics the propane and steam consumption data the years 1990, 1991 and 1992 cover the paper and board processing industry in Sweden as well. No significant effects on the results are to be expected, since the energy consumption for the manufacturing of paper and board products is small compared to energy consumption for the manufacturing of pulp and paper. Moreover, the share of propane and heat in the total energy consumption is small as well (<3%) and the amount of used steam in the paper processing industries is expected to be limited.

The Danish figures for 1991 and 1992 also include the energy consumption in the paper and board processing industry. Although this is not expected to have significant effects on the Danish results, larger uncertainties of the research results must be taken into account.

Non-fossil fuel input

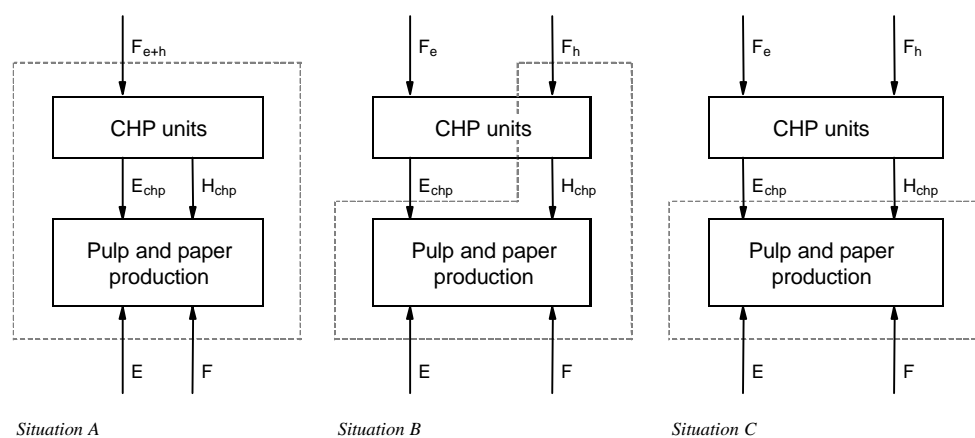
The German and Swedish statistics report data on the input of non-fossil fuels. The type of fuels reported in the energy statistics differ however among the two countries. The category 'other fuels' in the German statistics include lyse, bark, fibre waste, biogas and other waste. The category 'wood fuels and wood waste' in the Swedish statistics includes only the input of renewable energy in the production units and not the internal waste products [Helby 1999a]. Internal waste products are not reported in the Swedish statistics. The share of non-fossil fuels in the total energy consumption in Sweden and Germany amounts to about 16% and 11% respectively¹⁰. Since the input of wood fuels and wood waste is very high in Sweden, the research results in that country have to deal with larger uncertainties. The amount of renewable resources used in the Dutch, French and Danish pulp and paper manufacturing industry is unknown. The underestimation of the energy consumption in the Netherlands, due to a lack of data on the input of internal waste products, is however expected to be low since the amount of produced pulp is small compared with the total paper production.

Representation of CHP in energy data

In this study the demand for primary energy is preferably calculated on the basis of the net available energy, since we are also interested in the reduction of the specific energy consumption due to increased efficiency in energy conversion processes within the plant. The net available energy can be defined as the energy that actually becomes available to the user. However, many energy statistics include figures on the final energy consumption. The final energy can be defined as the amount of energy that is delivered to the industrial processes, after correction for conversions in the CHP plant [Phylipsen et al. 1998a]. The difference between the final energy consumption and the net available energy can be best explained in Figure 7. F_e and F_h are the fuel inputs for the production of electricity and heat in the CHP installation. E_{chp} and H_{chp} represent electricity and heat from the CHP installation delivered to the pulp and paper production. E is the electricity delivered from the electricity grid to the pulp and paper production site. F is the fuel directly delivered to the production site.

¹⁰ For the calculation of the renewable energy input in the Swedish pulp and paper manufacturing industry, we assumed an estimated moisture content of wood fuels and wood waste of 58% [Helby 1999a]. Furthermore we have assumed a density of 0.45 kg/dm³ and a heating value of 0.0182 TJ/tonne.

Figure 7: Representation of CHP in energy consumption data



Source: [Phylipsen et al. 1998b]

In situation A the fuel and electricity consumption is measured at the borders of the manufacturing plant including the CHP plant (net available energy). The production of electricity by in-plant conversion processes is not included in the electricity consumption. In situation C the CHP plant is considered to be outside the manufacturing plant. This is called the final energy consumption. The final energy consumption is the purchased energy by final energy users, corrected for conversions to other energy forms that take place with the final user of energy. In situation B the fuel consumption of the CHP plant is in one or the other way allocated partly to heat production and partly to electricity production. The part that is accounted to heat production is considered as final energy consumption of the manufacturing industry involved; the other part is considered to belong to the energy conversion sector [Phylipsen et al. 1998a]. Method B is applied by the IEA.

The representation of CHP in the energy consumption has to deal with another complication. The CHP representation in the energy statistics often depends on the *ownership* of the CHP plant and not on the *location* of the plant. In some countries, e.g. the Netherlands and Sweden part of the CHP-facilities are owned by the energy conversion sector or are joint-ventures. Consequently part of the CHP capacity in the pulp and paper industry can disappear from the statistics of the pulp and paper industry.

The CHP representation in the two time series obtained from the Dutch energy statistics corresponds to situation A (net available energy consumption) and C (final energy consumption) in Figure 7. Due to the sale of some CHP facilities and the installation of new CHP plants that are not included in statistics of the pulp and paper industry, additional corrections were necessary in the time series on net available energy since 1993.

According to [RWI 1998] the CHP in the German energy consumption data is represented as situation A in Figure 7. The imported heat in the pulp and paper industry is small; less than

3% of the total net available energy on a primary basis in 1996. About 72% of the pulp and paper companies in Germany produced heat and electricity in CHP installations [RWI 1997a]. In the Swedish statistics the CHP-facility is regarded as a separate plant, not belonging to the pulp and paper industry, but to the electric power industry [Helby 1999b]. The representation of CHP in energy statistics therefor corresponds to situation C in Figure 7. The representation of CHP in the Danish and French energy statistics is conform situation C in Figure 7 [SD Annual publication].

The conversion efficiency of electricity power plants can vary in time and among countries as well. The effect of different conversion efficiency rates in the analysed countries has deliberately not been taken into account in this study. The demand for primary energy in all countries was calculated by assuming a conversion efficiency for electricity power plants of 40%. The primary energy demand for heat is calculated at 110%. If heat is generated in a CHP, the primary energy demand is calculated at 60%.

Physical production data

The data on the physical production of wood pulp, other fibre pulp, paper and board products in the period 1989 to 1997 were derived from the FAO statistics. The production of wood pulp other than chemical and mechanical was calculated by subtracting mechanical and chemical production of wood pulp from the total wood pulp production. The production of other paper types was calculated by subtracting the production 'newsprint', 'printing', 'packaging' and 'sanitary' papers from the total paper and board production. The utilisation of recycled fibre in the paper and board industry was calculated by taking the wastepaper production, adding the waste paper import and subtracting the waste paper export. The data on the production, import and export of recovered paper for all the countries except for Germany were derived from [FAO 1996]. The German data on production, import and export of recovered paper for the period 1989-1997 were derived from [VDP 1997].

Weighting factors

The reference-*SECs* used in this study are listed in Table 10. These reference values should be considered as 'typical values for a modern plant'. The reference values were derived from [Farla et al. 1997] and concern the final energy consumption for each product or process.

5.3.3 Results

The five countries in this analysis together manufactured 15 Mtonnes of pulp and 36 Mtonnes of paper and board products in 1997. This corresponds to about 50% of the EU-15 pulp and paper production. Figure 8 and Figure 9 show the development of the pulp and paper(board) production in the 5 countries.

Table 10: Weighting factors for pulp processes and paper products

Process/Product	Fuel/heat (GJ/tonne)	Electricity (GJ _e /tonne)	Primary (GJ/tonne) ¹
Mechanical wood pulp	-2.1	5.3	8.5
Chemical wood pulp	10.0	2.5	15.0
Other wood pulp	-3.0	6.0	9.0
Other fibre pulp	-3.0	6.0	9.0
Recycled fibre input	0.4	1.4	3.2
Newsprint	2.5	1.4	5.3
Printing/writing paper	7.0	2.0	11.0
Sanitary paper	5.0	2.4	9.8
Packaging paper	5.0	1.5	8.0
Other paper	6.0	1.8	9.6

¹ Using a 40% electricity generation efficiency

Source: [Farla et al. 1997]

Sweden is by far the largest pulp producer with a total pulp production volume of more than 10 Mtonnes a year. France and Germany manufacture about 2 to 3 Mtonnes a year. Denmark and the Netherlands are the smaller producers of pulp. Denmark shows a doubling of the pulp production in 1992, which is in strong contrast with the decline of the production of pulp measured in turnover in the period 1990-1993.

Figure 8: Pulp production (Mtonne) in Germany, The Netherlands, Sweden, Denmark and France

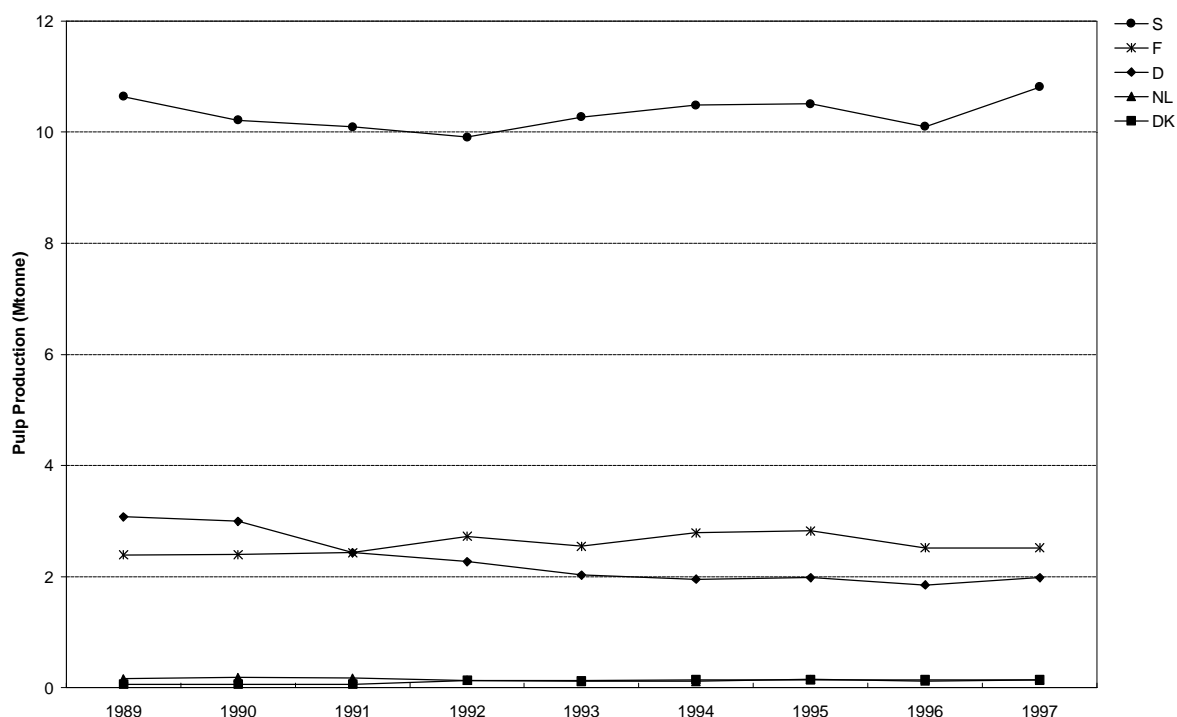
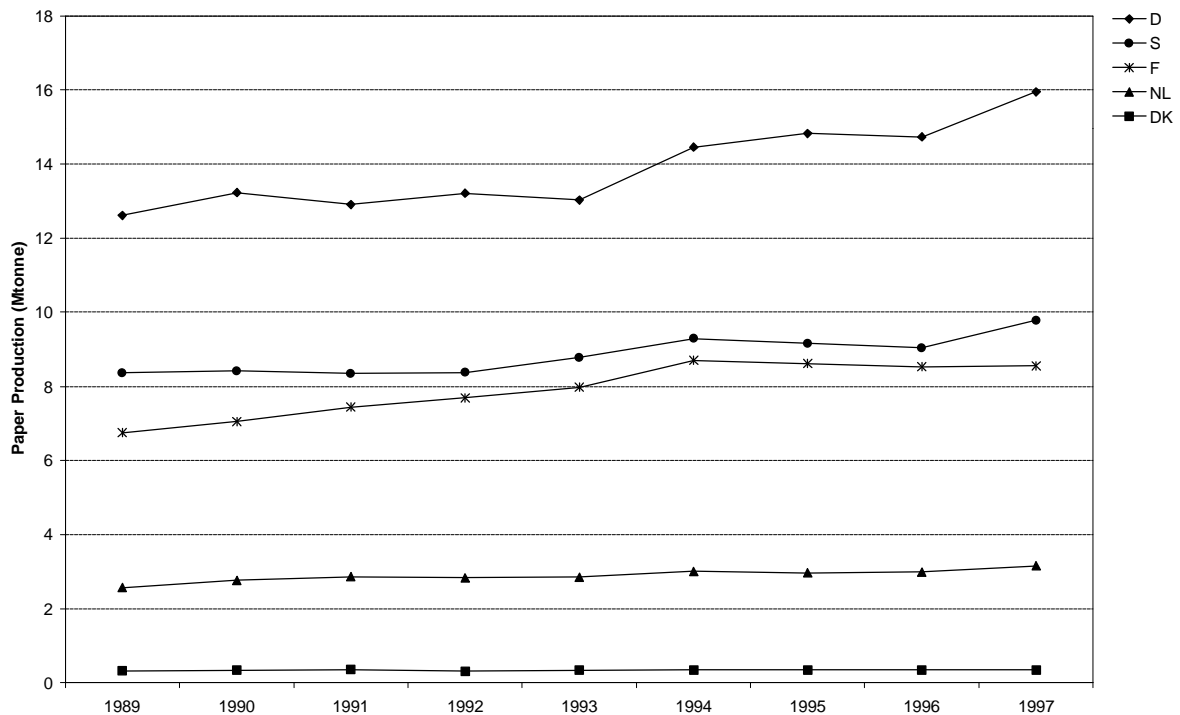


Figure 9: Paper and board production (Mtonne) in Germany, The Netherlands, Sweden, Denmark and France

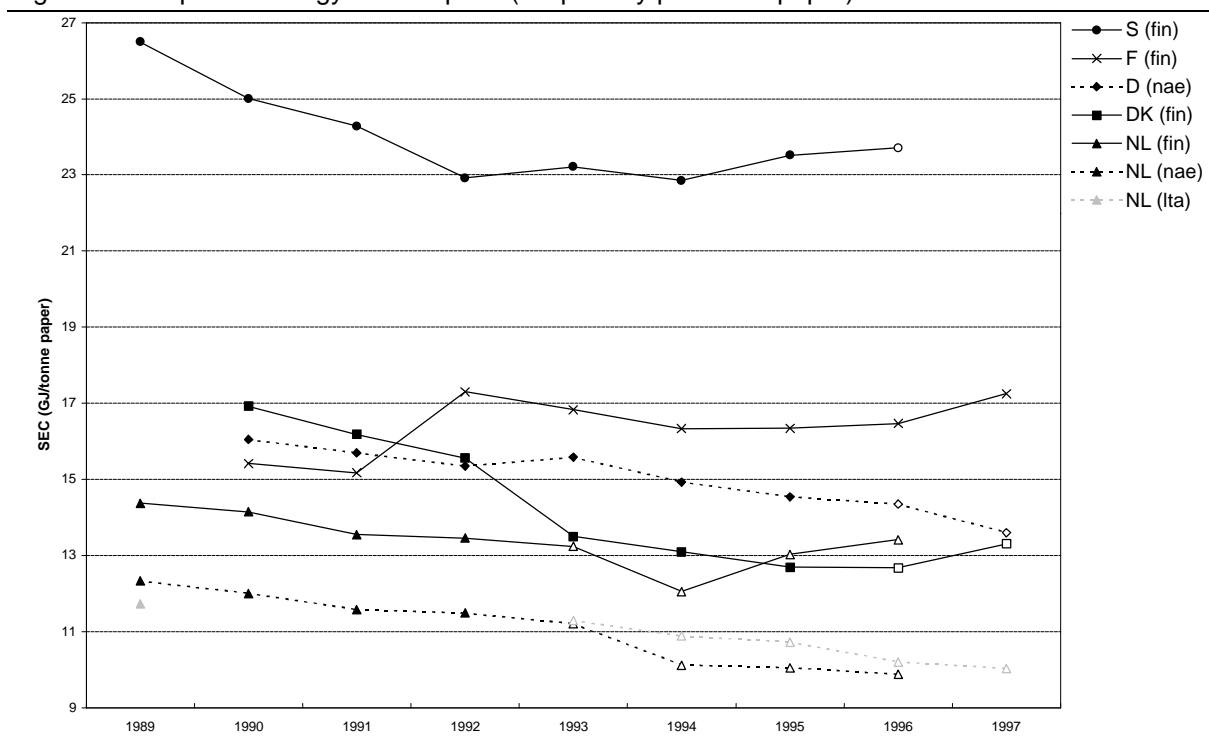


A comparison of the paper and board production in the 5 countries shows that Germany is the largest manufacturer, with a production volume of almost 16 Mtonnes in 1997. France and Sweden are medium-sized manufacturers with a production volume of about 8 to 10 Mtonnes a year. The Netherlands and Denmark are the smaller paper and board manufacturers. In all the 5 countries a clear increase of the paper production can be observed, in contrast with the stabilised production volume of pulp. This can probably be explained by the increased reuse of waste paper in the paper and board production. Figure 8 and Figure 9 also show that Sweden is a large exporter of pulp.

Next, we have analysed the energy efficiency in the pulp and paper industries with the efficiency indicators as proposed in section 2. Figure 10 shows the aggregate *SEC* in GJ per tonne paper produced in the five countries analysed, see equation (3). The open characters in the time series indicate the years in which voluntary agreements were in use.

The aggregate *SEC* in the Swedish pulp and paper industry is the highest in the five countries analysed. This is due to the different production structure which is characterised by a high pulp/paper ratio and differences in energy efficiency. The aggregate *SEC* is the lowest in the Netherlands and Denmark, which can be best explained by a relatively high input of recovered fibre. Moreover, the aggregate *SEC* can be underestimated since the input of non-fossil fuels is not included in the energy consumption.

Figure 10: Specific energy consumption (GJ primary per tonne paper)*



* 'nae' refers to net available energy consumption, 'fin' to final energy consumption and 'Ita' refers to the net available energy consumption according to the monitoring results.

Figure 10 also includes the time series on net available energy consumption in the Dutch pulp and paper industry. Since 1994 a small difference of about 7% between the net available energy according to national energy statistics [CBS Annual Publication] and the progress report of the voluntary agreement [VNP 1998] can be observed, which however can not be explained. The *SEC* in the German pulp and paper industry is underestimated compared with the French, Danish and Swedish figures, since the German figures concern the net available energy, whereas the other figures concern final energy consumption data. Assuming the same CHP capacity in the Netherlands and Germany the *SEC* in the German pulp and paper industry according to Figure 10 is underestimated with 15-25%. The large increase of aggregate *SEC* in 1992 in France can not be explained. The results as depicted in Figure 10 should be handled with care, since additional uncertainties with respect to the data must be taken into account (see the discussion part of this paper).

Table 11 shows the average annual change in aggregate *SEC* in the analysed countries. The table distinguishes the average annual change in aggregate *SEC* including and excluding the input of non-fossil fuels.

Table 11: Average annual change in aggregate primary SEC in the analysed periods (see Figure 10)

Time series (CHP representation)	Average annual change in aggregate SEC incl. non-fossil fuels	Average annual change in aggregate SEC excl. non-fossil fuels
Netherlands (A-CBS)		-3.1%
Netherlands (A-LTA)		-1.9%
Netherlands (C-CBS)		-1.0%
Germany (A)	-2.3%	-2.6%
France (C)		1.6%
Denmark (C)		-3.4%
Sweden (C)	-1.9%	-1.2%

On the basis of the Dutch results of the voluntary agreement [VNP 1998] we calculated a total reduction in the aggregate SEC, according to equation (3), of 14.5% in the period 1989-1997. The average annual reduction amounts to 1.9%. On the basis of the net available energy consumption data according to [CBS Annual Publication] a much larger annual reduction of 3.1% was calculated. As indicated before, the difference in the energy consumption according to both sources could not be explained. The annual change in the aggregate SEC, based on final energy consumption data, amounts to about -1.0%. A large difference between the annual average reduction in aggregate SEC of 1.9% and the EEI of 2.6% (see equation (7)) indicates structural changes in the pulp and paper sector in the Netherlands.

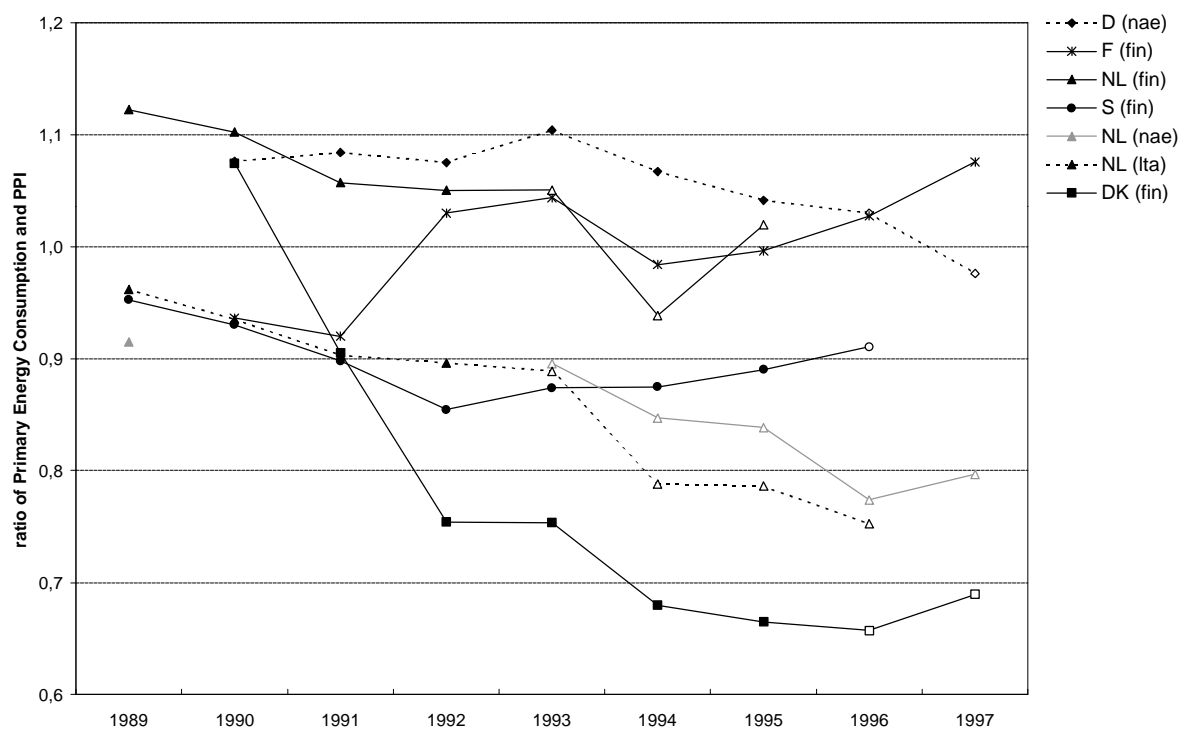
The German agreement aims at an average annual reduction of the aggregate SEC of 1.5%, including the input of non-fossil fuels, in the period 1990-2005. We calculated a total reduction in the aggregate SEC of 15% in the period 1990-1997, corresponding to an average annual reduction of 2.3%. On the basis of these figures it can be concluded that the agreement is well ahead on schedule; more than 75% of the target has already been reached. According to the official monitoring report by [RWI 1999a] the average annual reduction in the aggregate SEC, excluding the input of non-fossil fuels amounts to 3.0% over the period 1990-1997. The difference between the results of our own calculations and the official results can be fully explained by differences in data for production volume and different energy conversion efficiency factors.

In Denmark the total reduction in the aggregate SEC is the highest among the analysed countries. The annual average reduction in the aggregate SEC amounts to 3.4%. The average reduction of the aggregated SEC (excl. the input of non-fossil fuels) in the Swedish pulp and paper industry amounts to 1.2% a year. If the input of non-fossil fuels is taken into account the average reduction amounts to 1.9% a year. In contrast with the other countries an average increase in the aggregate SEC of 1.6% a year can be observed in France. This increase can unfortunately not be explained.

The figures on the average annual change in aggregate SEC must be handled with care, since these figures only depend on the data in the first and last year of the analysed period.

Figure 11 shows the ratio of the primary energy consumption and the *PPI*, see equation (5). This analysis of the energy efficiency takes into account the differences in the sector structure (product mix and different types of pulping) among the countries involved.

Figure 11: Ratio of the primary energy consumption and the *PPI*



According to this figure the Danish pulp and paper industry is the most efficient among the analysed countries. The decline in aggregate *SEC* in Denmark, can only be explained by a large energy efficiency improvements and a shift in the sector structure. Figure 11 shows that if sector structure is taken into account in the analysis, the Swedish pulp and paper industry ranks among the more efficient countries, whereas the Dutch and German appear to be less energy efficient than in the previous analysis. Again it must be mentioned that the German results are based on net available energy consumption data. The German results can be best compared with the Dutch figures.

5.3.4 Discussion

The discussion section will be devoted to the comparability of the data that we have used in our analysis as well as the possible errors in these data and other factors influencing the results of the international comparison that have not been taken into account in our study. Moreover, we will compare the outcome of our comparison with the results of other studies. Finally, we will discuss the verification of the official monitoring results with our own calculations.

Comparability of the data used in the analysis

The results of the energy efficiency analysis depend for an important part on the quality and the comparability of the energy consumption and the physical production data used in this study. In section 5.3.2 we have already discussed the under- and overestimation of the energy consumption data due to several corrections and modifications. Most of the collected data used in our study cover the sector of interest (21.1), see section 5.3.2. Data *interpolation* and the use of more *aggregate data* in some cases is not expected to have significant effects on the results. With respect to the *non-fossil fuel input* in the pulp and paper industry larger uncertainties exist. Here, we refer to the moisture content of wood fuels and wood waste in Sweden, and the differences in the fuels types included in the statistics and even the unknown amount of non-fossil fuels in the Netherlands, France and Denmark. The energy efficiency improvement by the *introduction of CHP* in the pulp and paper industry could not be analysed for all countries due to a lack of information and figures on the *allocation of conversion losses* in the energy consumption data.

Besides the uncertainties in the energy consumption data mentioned above, there are additional errors in the data as well as other factors that are not taken into account in the international comparison. The possible errors in the energy consumption data can be related to the *caloric value* of the energy consumption values¹¹. [Phylipsen et al. 1998b] gives an overview of other factors that must be taken into account when comparing energy efficiency improvement in the paper and pulp industry among different countries. In our study we did not take into account the effects of the *pulp drying for transport* and the *use of bleaching agents* on the international comparison. The pulp drying for transport can influence the total energy requirement in the pulp and paper industry. If pulping and paper making takes place at different sites pulp is dried before transporting it to the paper making site. If pulp is exported the question arises whether the energy efficiency of the exporting or of the importing country is involved. In our approach the energy consumption of pulp drying is included in the energy consumption of the pulp exporting country. Additional correction for the export of pulp did not appear to influence the results significantly. The use of bleaching agents can also influence the total energy requirement. Most bleaching agents are purchased. This means that the energy consumption for producing bleaching agents is not included. If ozone is used for bleaching, production occurs on-site and energy consumption is included. Using ozone can lead to an increase of the electricity demand of 5-10% [Nilsson et al. 1995]. Other factors that we did not take into account in the international comparison are differences in *climate* and the *differences in the grid efficiency* between the countries analysed. The effects of climate are expected to be low.

The physical production data were mainly derived from the FAO statistical database [FAO 1996]. Comparison with data derived from the Pulp and Paper International Fact and Price book [PPI 1997] and the national branch statistics learns that in some cases large differences

¹¹ The energy content of energy carriers is indicated by its caloric value. Either higher heating values (HHV) and lower heating values are used (LHV). HHV values measure the heat that is freed by the combustion of fuels in case the chemically formed water is condensed. LHV measure the heat of combusting in case the water formed remains gaseous [Phylipsen et al. 1998b] & [Jong 1998].

exist. For example in Germany, where the total physical production volume of paper in the base year of the agreement (1990) is much lower according to the PPI statistics than the FAO statistics¹². Consequently, the average annual change in aggregate *SEC* (incl. non-fossil fuels) in Germany calculated on the basis of the PPI data is much higher (2.8%) than in the previous analysis (2.3%). This shows that in some cases the uncertainties and differences in the physical production data can have significant effects on the results. The PPI statistics show different pulp production volumes in Denmark. In some cases differences of more than 100% can be observed. The Danish results should therefore be handled with care.

The reference values for the *SEC* used in our study were derived from [Farla et al. 1997]. As pointed out in [Farla et al. 1997] the derivation of the reference values is a complicated process due to difficulties regarding the matching of reference values with the production process and end products considered in the analysis. We have used the following alternative weighting scheme to test sensitivity of the analysis results.

Table 12: Alternative weighting factors for pulp processes and paper products

Process/Product	Fuel/heat (GJ/tonne)	Electricity (GJ _e /tonne)	Primary (GJ/tonne) ¹
Mechanical wood pulp	-3.5	5.3	9.8
Chemical wood pulp	7.8	2.3	13.6
Other wood pulp	-3.0	6.0	12.0
Other fibre pulp	-3.0	4.6	8.5
Recycled fibre input	1.0	1.1	3.8
Newsprint	2.3	1.5	6.1
Printing/writing paper	7.0	2.5	13.3
Sanitary paper	5.3	2.4	11.3
Packaging paper	6.0	1.8	10.5
Other paper	6.0	1.8	10.5

¹ Using a 40% electricity generation efficiency
Source: [Hekkert 1999]

Figure 12 shows ratio of the primary energy consumption and the PPI using the alternative weighting scheme. A comparison of Figure 11 and Figure 12 shows that the relative ranking of the countries does not change very much except for Sweden. Moreover it appears that the differences in ratio between the countries become smaller in case the alternative weighting is used.

Comparison with results of other studies

In this section we will compare the outcome of our analysis with the results of other studies. Several benchmark studies and studies aimed at the international comparison of energy efficiency in the pulp and paper industry have been carried out [Farla and Blok 1997; Jong 1998; Phylipsen et al. 1998a]. All these studies use, among others, energy consumption data

¹² This can probably be due to the reunification of Germany.

derived from the IES database by the Lawrence Berkeley National Laboratories. This IES database contains final energy consumption data which were also taken from the national energy statistics. We calculated the primary *SEC* in GJ per tonne paper on the basis of the IES data to verify our results.

Figure 12: Ratio of the primary energy consumption and the PPI using an alternative weighting scheme

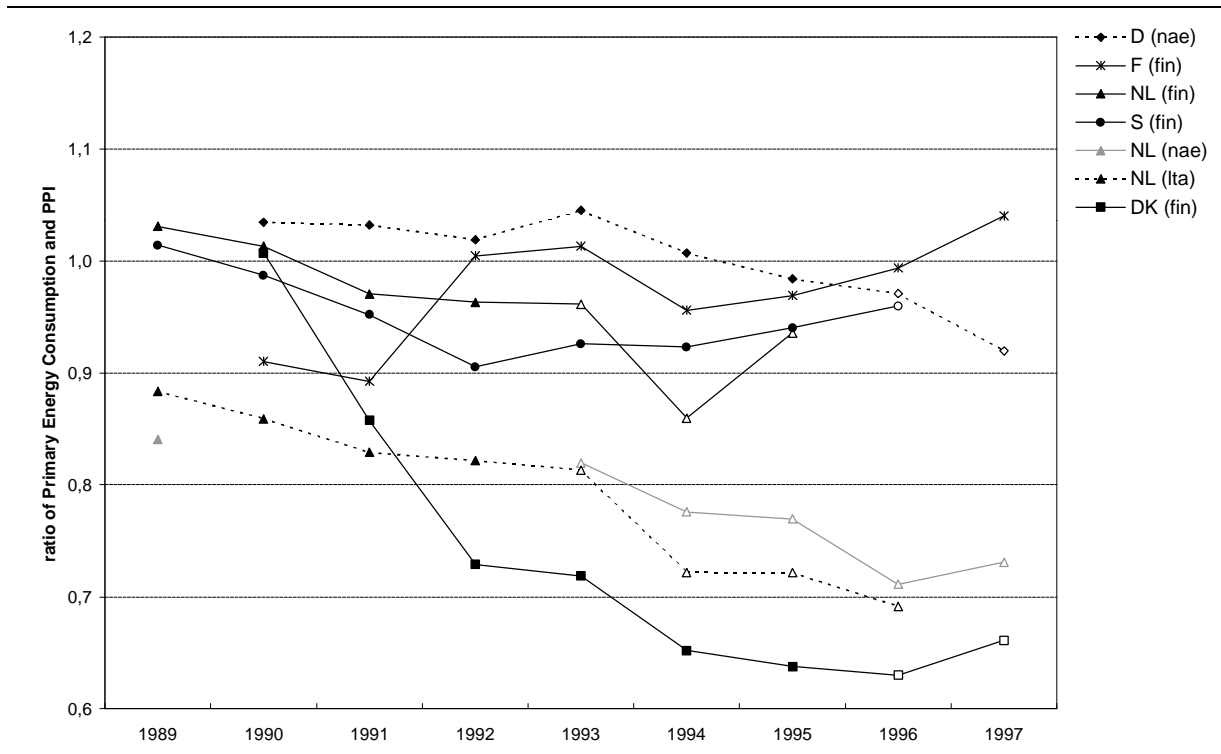
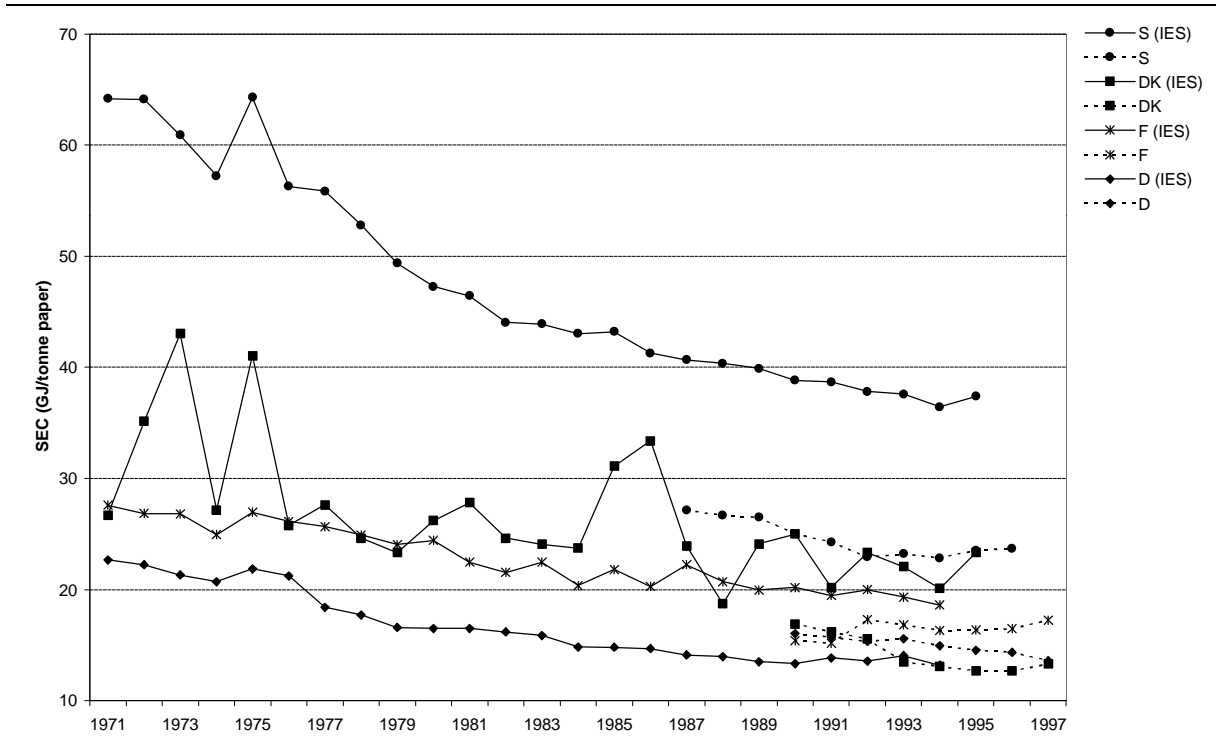


Figure 13 shows the results of these calculations for Germany, France, Sweden and Denmark. Differences in the national grid efficiency are not taken into account in these calculations. Figure 13 shows higher values for the aggregate *SEC* in the nineties for all the analysed countries compared with results depicted in Figure 10. Furthermore, the relative ranking of Denmark in this picture differs from the ranking in the previous analysis. Moreover, Figure 13 shows a more irregular development of the *SEC* in the Danish pulp and paper industry, compared with the development in other countries.

Analysis of the IES data learns that the French data cover also the paper and board processing industry, which fully explains the higher aggregate *SEC* in Figure 13. The higher *SEC* for Sweden in Figure 13 can be explained by the large input of internally produced waste products, which are not included in our data. Moreover, the SCB has in some publications wildly undercounted non-fossil fuels [Schipper 1999]. This results in a non-fossil fuel energy input which is ten times higher than in our calculations.

Figure 13: Specific energy consumption (GJ per tonne paper) calculated on the basis on IES data



The *SEC* in the German pulp and paper industry calculated on the basis of the IES data almost equals the *SEC* calculated with our own collected data. The energy consumption data in the IES database were provided by the Deutsches Institut für Wirtschaftsforschung (DIW). According to [DIW 1998] the data concern the final energy consumption. The CHP in those data is represented as situation B in Figure 7. To avoid double counting of energy resources for the internal production of electricity additional corrections were made in the DIW data. The large differences in the Danish energy consumption data are probably explained by the use of more aggregated figures in the IES database than in our own database.

The *SEC* in the Dutch pulp and paper industry according to the benchmark study by [Phylipsen et al. 1998a] shows higher values than our analysis. Analysis of the energy consumption data used by [Phylipsen et al. 1998a] showed that consumption figures for paper processing, printing and publishing industries were included.

Verification of the official monitoring results of the voluntary agreements

In section 5.3.3 we have verified the official German and Dutch monitoring results with our own calculations. As pointed out in section 5.3.3 the differences in the obtained results for Germany could be fully explained by differences in data for production volume and other energy conversion efficiency factors. The differences between the results of the voluntary agreement published by [VNP 1998] and our calculations are due to a discrepancy in the energy consumption figures in the base year of the agreement, which could not be explained unfortunately.

5.3.5 Conclusions and recommendations

In this section we have compared the energy efficiency of the pulp and paper industry in the five countries involved in the VAIE project. Moreover we have evaluated the results of the voluntary agreements on energy efficiency with the German and Dutch pulp and paper manufacturers. The Danish and Swedish agreements could not be evaluated due to the recent introduction of the agreement and the lack of data.

The agreement schemes in the five countries show large differences in the target-setting, coverage, monitoring and the duration of the agreement, which makes an international comparison of the policy outcome difficult (see section 5.2). The target of the Dutch agreement with pulp and paper manufacturers, aiming at an energy efficiency improvement of 20% in 11 years (excluding renewable energy resources), is much more ambitious than the German target aiming 20% energy efficiency improvement (including renewable energy resources) in 15 years. Also the Danish agreement, aiming at the implementation of all investments with a maximum pay back period of 4-6 years, seems to be more ambitious than the German agreement. The ambitiousness of the Swedish agreements could not be assessed due to the individual character of the agreements. The French pulp and paper industry has not concluded an agreement on energy efficiency or CO₂ emission reduction.

In section 5.1 we have seen that the differences in the energy use profile among countries are mainly determined by the kind of pulping process used, the level of substitution of wastepaper for wood pulp, product mix and the availability of an integrated paper mill. In section 4.1 we have presented two different indicators to study the energy efficiency in pulp and paper industry. One indicator compares the total energy consumption in pulp and paper industry with the total production volume of paper, whereas the other indicator also takes into account the differences in product mix and the pulping processes.

The results of our analysis show that the aggregate specific energy consumption (defined by ratio of energy consumption and the total paper production volume) in the Danish and Dutch pulp and paper industries is the lowest among the analysed countries. The specific energy consumption in the Swedish pulp and paper industry is the highest in the five countries analysed, due to the different production structure which is characterised by a high pulp/paper ratio. If sector structure (differences in product mix and different types of pulping) is taken into account in the analysis, the Swedish pulp and paper industry ranks among the more efficient countries, whereas the Dutch and German appear to be less energy efficient than in the previous analysis. Again, the Danish pulp and paper manufacturers appeared to be very efficient.

The results of our analysis must however be handled with care. The discussion (see section 5.3.4) shows that the comparability of the energy consumption data can be rather weak, due to different representations of CHP in the energy consumption data and uncertainties with respect to the input of renewable energy resources. Moreover, we did not take into account the differences in grid efficiency and effects of climate in our analysis. Furthermore, the energy

requirement for the drying of pulp for transport and use of bleaching agents can have significant effect on the total energy consumption in the sector. Both factors were not taken into account in our study.

The results of our study show large differences with the results of other studies. In general we have found much lower values for the specific energy consumption. Most of the lower values could however be explained by the use of less aggregated data in our study. The official monitoring results of the German agreement could be verified, within reasonable accuracy limits. According to our analysis the German agreement is well ahead on schedule; more than 75% of the target has already been reached. The observed difference between the official monitoring results in the Netherlands and our own calculations could not be explained. Both the evaluations indicate that the implementation of the Dutch agreement is on schedule.

As pointed out in the discussion section we have to deal with a large range of uncertainties and possible errors in the data. We therefore have to conclude that the results of this study have only a preliminary character. In this respect we recommend to further analyse the impact of CHP on the energy efficiency improvement in pulp and paper industry and moreover improve the quality and comparability of the data used in this study.

This study supports the conclusions by [Phylipsen et al. 1998a] that the data availability and related uncertainties can be a limiting factor for the actual benchmarking operation as proposed in the Netherlands.

5.4 International comparison of the actual outcome of agreements

Besides the evaluation of the *goal achievement* of the agreements with paper and board manufacturers and the comparison of the energy efficiency improvement, we have also tried to evaluate the *effectiveness* of the agreements in a broader international perspective. For this purpose we have tried to assess the actual change in energy efficiency investment behaviour in the paper and board industries in the various countries. However, due to a lack of detailed data a broader international comparison of the actual outcome of the agreements in other countries than the Netherlands has however failed. This chapter compiles however the collected material for the international comparison of the actual outcome of the agreements made with paper and board manufacturers.

5.4.1 Energy savings investments in paper and board industry

This section presents the investments made for energy saving purposes in the paper and board industry in the various countries involved in the VAIE project. If available additional information on the financial aspects, the amount of energy saved and the pay-back period is given.

Netherlands

Table 13 gives an overview of the total energy savings in the Dutch paper and board industry in the period 1989-1997 broken down into several conservation categories. The total energy savings in 1997 compared to a frozen efficiency situation in 1989 amounted to about 7.2 PJ. This corresponds to about 0.47 Mtons of avoided CO₂ emissions [VNP 1998].

Table 13: Breakdown of energy savings in Dutch paper and board industry (1989-1997)

Conservation category	Energy saving 1989-1997 (TJ) ¹		
	Increase	Decrease	Net
Good-housekeeping/energy management	+10	-140	-130
CHP/Energy conversion	+3	-3527	-3524
Energy saving investments	0	-417	-417
Strategic/replacement investments	+72	-2081	-2009
Product efficiency ²	+242	-1588	-1346
Not identified	+400	-220	+180
Total	+727	-7973	-7246

¹ Energy savings compared to a frozen efficiency level

² Projects in the category product efficiency are for example aimed at reducing waste, equipment failures, etc.

Source: [VNP 1998]

According to Table 13 most of the energy savings were achieved by the increased CHP capacity in the paper and board industry¹³. The share of the CHP in the total energy savings decreased in 1997 compared with the previous years. The energy efficiency in 1997 still improved due to the introduction of an energy management system and improvements of process efficiency [Delemarre and Scheurwater 1998]. Furthermore, strategic/replacement investments and product efficiency improvements have also contributed significantly to the overall energy savings. Further application of the method presented in section 2.1 shows that about 20-40% of the energy savings in the Dutch paper and board sector can be attributed to the agreement.

The interviews carried out in the framework of the sector case studies, see [Rietbergen et al. 1999], revealed a more qualitative judgement about the stimulating effect of the agreements. The firms indicate that all the energy saving investments in pulp and paper industry would have taken anyway on the basis of normal investment criteria. The firms agree however that there is indeed a stimulating effect of the agreement in the sense that the agreements have enhanced the firms' technical knowledge and possibilities to apply for subsidy schemes or tax reduction. Also in the other sector case study (glass manufacturers) no direct impact of the agreement on the energy saving investments can be observed. The interviewees agree that the agreement has structured and strengthened the firms' approach to energy conservation [Rietbergen et al. 1999].

¹³ CHP has for an important part been stimulated by agreements between the Dutch government and the energy distribution companies and special subsidies directed towards the promotion of CHP investments.

Denmark

As part of the case study on the implementation and efficiency of the Danish agreements, interviews with two paper and board manufacturers were carried out. The firms' estimated share in the total energy consumption of the sector amounts to 40%. The interviews have revealed a large number of detailed data on energy investment projects carried out in both the firms. Table 15 shows the energy investment projects explicitly mentioned in the individual agreement. Other projects may be identified and implemented during the energy audit or due to energy management [Johannsen et al. 1999]. The table includes the investments as well as the estimated effects on yearly energy savings and CO₂ emission reduction of the conservation projects. The total primary energy savings in both firms are at least estimated at 117 TJ a year. The total energy conservation potential of the measures listed in Table 15 is estimated at 6-7%, assuming a constant production volume. A sound evaluation of the actual outcome can not be made, due to the preliminary character of these data and the large uncertainties in the overall energy savings.

The interviews carried out in the framework of the Danish sector case studies show that the energy conservation projects no. 1 and 2 would have been carried out anyway, but sooner than without the agreement. Energy conservation projects no. 3 would have been carried out anyway and at the same time. The firm in question was not aware of the possibilities to implement energy conservation project no. 6. The project was carried out immediately after the energy audit. Project no. 7 would not necessarily have been carried out if it had not been part of the agreement. Since the PBP of energy conservation project no. 5 is longer than 6 years the firm was not automatically obliged to realise the project. The firm suggested this project however as a substitute for another less promising project. The company's assessment about the other projects is lacking.

Germany

The annual monitoring reports on the progress of the CO₂ emission reductions in the German pulp and paper industry [RWI 1997a; RWI 1999a] contain detailed CO₂ emission and energy consumption data. The following table lists a number of important energy conservation measures and other causes affecting the energy efficiency in the German pulp and paper industry in the period 1990-1997:

Table 14: Energy saving measures and other causes affecting energy efficiency

1	New co-generation facilities and more efficient energy conversion
2	Installation of 'shoe press' to mechanically de-water the web
3	Installation of frequency sensitive controllers for pumps and machinery with variable output
4	Installation of additional heat exchangers and improvement of existing heat recovery systems
5	Modification of refiner pulp mills
6	Substitution of waste paper for fresh vegetable fibre
7	Restructuring of the East German paper industry
8	Increased production volume

Source: [RWI 1997a; RWI 1999a; RWI 1999b]

The energy saving investments 3, 4 and 5 may be considered typically as retrofit measures that - at the present level of energy prices - will not be quickly taken up autonomously. Unfortunately the monitoring reports do not include quantitative data on the amount of saved energy per project or measure. A quantitative evaluation of the effectiveness of the German agreement by assessing the actual change in energy investment behaviour is therefore also in this case not possible.

In the framework of the German country study the implementation and efficiency of the agreements with three sectors (paper and board, cement and glass) has been studied. According to the respondents the investment measures taken on firm level could not explicitly be attributed to the branch commitment, but in some cases there were indications that investments were on the edge and the agreement gave the decisive last push. Furthermore all respondents agreed that the agreement created an additional momentum for energy efficiency (and GHG abatement), and thus, contributed to an already ongoing action. The main messages from the interviewees regarding the stimulation effect of the agreements are the following. First of all energy has always been a topic of high priority due to the high share of energy costs. Therefore, firms intend to do everything possible to save energy. Secondly, due to mature core processes there aren't many investment opportunities left, and if so, they are linked to general investment cycles and huge capital requirements. The scope for acceleration is therefore limited. Thirdly, the investment planning depends largely on strategic market prospects, i.e. capacity and productivity concerns. The direct influence of energy policy on this issue is therefore considered to be limited. Good housekeeping measures offers significant potential for energy efficiency improvement, which is used or neglected according to the quality of the general management. The agreement does not seem to change the principle attitude.

Table 15: Energy saving investments and estimated effects in two Danish paper manufacturers

No. ¹	Measure ²	Investment ² 1000 DKR ⁶	Estimated energy saving			Estimated CO ₂ reduction ² Tons/year	PBP ² Years
			Electricity ² Mwh/year	Heat ² Mwh/year	Total Primary ^{3,4,5} GJ/year		
1	Replacement of pump	102	51	0	462	54	6.1
2	Insulation of process pipes	78	0	300	648	407	0.8
3	Optimization of PM1	12500	516	13334	33445	5320	5.1
4	Further optimization of PM1	12000	3481	12287	57869	8457	
5	Optimization of PM3	6362	441	5793	16480	2526	7.5
6	On/Off drive of compressor ⁷	0	59		531	47	0.0
7	Sectioning of compressed air system	56	34		306	27	5.0
8	Closing down rectifier		250		2250		
9	Improved transportation and packaging procedures		597		5373	218	3.1
Total		19098	5429	31714	117364	12267	

¹ Measure 1-5: Firm 1; Measure 6-9: Firm 2. These measures are explicitly mentioned in the agreement. Energy savings due to energy management activities and other projects are not included.

² Source: [Johannsen et al. 1999].

³ The electricity grid efficiency is estimated at 40%.

⁴ Steam for Firm 1 is supplied by a local CHP. Heat is therefor calculated at 60%.

⁵ Firm 2 generates heat in steam turbine. Conversion efficiency is estimated at 40%.

⁶ 100 DKK ≈ 13.33 .

⁷ Although this project was carried before the agreement was signed, the project was identified in the energy audit.

Table 16: Energy saving potential of projected energy conservation investments in the French pulp and paper industry

No	Technology	Process	Rate of adoption	Rate of adoption	Energy consum-	Saving potential	PBP
			(%) 1990	(%) est. 2005	ption (1990) in ktep ¹	Initial in ktep ¹	Years
1	Impulse drying	Paper drying	0	10	1220	585.0	4.1
2	Pulp production by 'bivis' technology	Drive	5	40	260	66.3	1.8
3	Shoe press	Paper and board drying	9	40	1760	138.5	2.3
4	M.V.R. to concentrate black liquor	Concentration	45	45	24	23.6	4.9
5	Drying hoods	Paper and board drying	77	83	1220	178.3	3.2
Total					4484	992	

¹ 1 ktep ≈ 0.042 PJ.

Source: [Chidiak 1999a].

Sweden

The case study on the implementation of the EKO-energy program in the Swedish paper and board industry has not revealed a lot of significant quantitative energy saving data of conservation projects in the paper and board sector. The following table lists a number (the list is not complete) of implemented energy saving measures in a large Swedish multinational (with several firms) under the EKO-energy program.

Table 17: Energy saving measures in a large Swedish multinational under the EKO-energy program

Energy saving measure	Investments	PBP (years)	Savings
Peak control equipment			
Heating system	0.6-0.7 M	5	±30%
Speed control on motors and pumps			
Changed air blow system			±94%
More efficient motors			
Steering of heating equipment	11,500-23,000		
Energy efficient lighting			
Load-measuring and frequency controlled fans in air pumps			±40%

Source: [Kagstrom 1998]

[Kagstrom et al. 1999] remark that no methodology for making a distinction between results coming from the EKO-Energy program and results that would come anyway is available. The ISO 14001 and EMAS standards, being part of the program, do require the companies to monitor their progress concerning energy conservation, but not necessarily at the level of individual conservation projects. Moreover monitoring results are only for internal use in case of ISO 14001. Thus, also in the Swedish case a thorough quantitative assessment of the actual outcome of the agreement can not be made. Moreover, the value of an assessment based on the results of the only two companies in the pulp and paper sector that have joined the EKO-energy program must be doubted.

France

In France *no agreement* has been made with pulp and paper manufacturers. Although an inventory of implemented energy conservation projects in the sector is lacking, we have obtained a list of process specific energy saving options for the French pulp and paper industry, see Table 16. The table includes the energy consumption in 1990, the estimated energy efficiency improvement potential and the pay-back period of the specific technologies. On the basis of these data we calculate an energy conservation potential of 18.5% in 1990 on the core processes. This means that in case of a constant production volume 35 PJ can be saved in the future by implementing those measures.

The sector case studies (packaging glass and aluminium), carried out in the framework of the French country study suggest that the agreements indeed create an incentive for industry to push efforts to meet the commitments. The two agreements studied in the French country

study explicitly indicate that objectives are set at BaU levels [Chidiak 1999b]. According to [Chidiak 1999b] many assumptions of the BaU scenario were not confirmed and further efforts by industry were required in order to meet the specific emissions reduction objectives.

5.4.2 Concluding remarks

The previous section has shown that a broader evaluation of the effectiveness of the agreements on the basis of the actual change in energy investment behaviour is nearly impossible. This is due to the enormous lack of energy saving data of investments or measures in other countries than the Netherlands. In some countries the estimated effects of energy savings measures are known. However, due to the preliminary character and incompleteness of these figures these data are of limited value for an assessment of the actual outcome of the agreement. There are however indications that the agreements do have some stimulating effect but the magnitude is highly uncertain. An adequate monitoring of energy consumption and energy saving is certainly required to isolate the impact of the agreements from other effects.

6 Conclusions and recommendations

In this study we have tried to evaluate the environmental performance of agreements on energy efficiency improvement. The main focus was on the assessment of the actual outcome of the agreements. We have shown that several methodological problems complicate this kind of assessment. This chapter summarises the main conclusions of our research. We also give recommendations for further research on this topic as well as policy recommendations to improve (comparative) analysis of the environmental performance of agreements.

6.1 Conclusions

The main conclusion of this research is that, although an accurate assessment of the actual outcome is still lacking, a stimulating impact of the agreements on energy efficiency in the Netherlands can be observed. We have made different estimates of the actual outcome of the Long-Term Agreements in the Netherlands. The two estimates which are based on the actual change of energy investment behaviour indicate that respectively 31-48% and 29-44% of the total energy savings can be attributed to the LTAs in the Netherlands. The simulation of energy investment behaviour shows that about 16-47% of the total energy savings was promoted by the LTAs. As indicated in section 3.3 the lower limit of 16% is considered as a highly underestimated value. So, we conclude that on average about **one third to half** of the energy savings in the Dutch Manufacturing industry can be attributed to the Long-Term agreements, including the supporting measures like subsidy schemes and financial incentives. In other words the rate of energy efficiency improvement has increased with 40-100%. A large range of uncertainties must however be taken into account in this respect. Further research on the energy investment behaviour of firms is therefore required.

The quantitative assessment of the environmental performance of agreements with paper and board industries in other countries appeared to be very difficult. A sound comparison of the goal achievement was not possible due to the large differences in the main characteristics of the agreements. The individual evaluations show the targets of the Dutch and German agreements are likely to be reached. The goal achievement of the Danish and Swedish agreements could not be evaluated with the employed method because the goals of the agreements are set at company level. We have vigorously addresses the quality and the comparability of the data used in the benchmark analysis. Due to the weak comparability of the energy consumption data and the large differences with the results of other studies we must conclude that the results of this benchmark study have only a preliminary character. The data availability and related uncertainties can be a limiting factor for the actual benchmarking operation. The quantitative assessment of the actual outcome of agreements with paper and board industries in other countries was not possible due to a lack of detailed data. The interviews carried out in the framework of the country case studies however reveal traces of stimulating impact of the agreement on energy efficiency improvement.

6.2 Recommendations

This study has shown that the assessment of actual outcome of agreements is difficult from a methodological point of view. To improve the (comparative) analysis of the actual outcome of the agreements we recommend:

1. *Further analysis of the actual change in energy efficiency investment behaviour.* Further analysis of the actual change in energy efficiency investment behaviour (see chapter 2) is to our opinion the most promising route for further research. As pointed out in chapter 2 the classification of the energy saving measures in the several investments categories and the assessment to what degree the agreements have promoted the investments determine for a large part the uncertainties in the results. First of all, we recommend to *increase the detail of investment categories* used to distinguish and assess energy saving measures on the sector level. Secondly, we recommend to conduct *more systematic surveys* among firms. Although we have to deal with problems like the stated behaviour of firms, we propose to ask firms to assess to what degree the agreements have promoted the investments in the specific energy conservation measures. We suggest to take into account the impact of specific policy measures that support agreements as well as other incentives and barriers for further energy efficiency improvement in the survey. Furthermore, we suggest to do an ‘on line’ evaluation of the energy conservation projects: an annually returning survey could improve the quality of the assessment and could also better take into account the dynamic effects of the agreements. The number of data required for this analysis is rather large. More detailed data must be included in the existing database and new data must also be collected.

2. *Further decomposition of the historical development of energy efficiency.* An alternative route for further analysis of the actual outcome is the further decomposition of the historical development of energy efficiency into more different long term trends. In chapter 4 we have concluded that the impact of energy prices and other energy conservation policies are probably large. Decomposition of the historical development of energy efficiency into more different long term trends, like de-materialisation and price impacts, could create a better picture of the actual outcome of the agreements which are primarily aimed at increasing energy efficiency by improving process efficiency and energy conversion. Further elaboration of this approach is only promising if the energy efficiency improvement is sufficiently large; hence the approach is only applicable for a long term analysis. The number of data required for this kind of analysis is also large, but can often be easily derived from the statistics.

3. *Micro panel data analysis.* A promising alternative route, not taken into account in this study could be a micro-panel data analysis. [Bjørner and Togeby 1999] have for example analysed the effects of CO₂ taxation and agreements on energy saving on the basis of econometric panel data. Preliminary results from such type of analysis gives hope for improved evaluations of the actual outcome of various policy instruments, like voluntary agreements. Also in this case large amounts of data (on micro level) are necessary.

We would like to conclude with the following remark. The quantitative assessment of the environmental performance is always crucial when evaluating environmental policy instruments. The availability of (detailed) data and an adequate monitoring system to measure and collect these data is essential in this respect. Since this lacking in most of the countries we therefor recommend to design and implement a *transparent and more detailed monitoring procedures* to improve the possibilities for further (comparative) analysis of the agreements' environmental performance. A methodology for making a distinction between results coming from the agreements and results that would come anyway should therefor be the ultimate goal in this respect.

References

- AKF (1999). Personal communication with K.S. Johanssen. Copenhagen, Denmark, AKF (Institute of Local Government Studies).
- BDI (1996). Erklärung der deutschen Zellstoff- un Papierindustrie zur Reduzierung des spezifischen Kohlendioxidausstoßes aus fossilen Energieträgern. Köln, Bundesverband der Deutschen Industrie & Verband Deutscher Papierfabrieken.
- Beer, J. d., M. T. v. Wees, E. Worrell and K. Blok (1994). ICARUS 3; The Potentials of Energy Efficiency Improvement in the Netherlands from 1990 to 2000 and 2015. Utrecht, The Netherlands, Department of Science, Technology and Society, Utrecht University.
- Beer, J. d., E. Worrell and K. Blok (1995). Sectoral Potentials for Energy Efficiency Improvements in the Netherlands. Utrecht, The Netherlands, Department of Science, Technology and Society, Utrecht University: 31.
- Beer, J. d., E. Worrell and K. Blok (1998). "Long-term energy-efficiency improvements in the paper and board industry." *Energy* 23(1): 21-42.
- Bjørner, T. B. and M. Togeby (1999). Industrial Companies' Demand for Energy Based on a Micro Panel Data-base - Effects of CO₂ Taxation and Agreements on Energy Savings. ACEEE Industry & Innovation in the 21st Century.
- CBS (1994). Vijfennegentig Jaren Statistiek in Tijdreeksen, 1899-1994. Voorburg/Heerlen, The Netherlands, CBS (Netherlands Central Bureau of Statistics).
- CBS (Annual Publication). De Nederlandse Energiehuishouding; Jaarcijfers. Voorburg, The Netherlands, CBS (Netherlands Central Bureau of Statistics).
- Chidiak, M. (1999a). Personal communication with Mrs. M. Chidiak on the energy conservation potential of projected energy conservation investments in the french pulp and paper industry. Paris, France, Cerna.
- Chidiak, M. (1999b). Voluntary Agreements - Implementation and Efficiency French Country Study. Paris, France, Cerna.
- DEA (1998). Personal communication with Mrs. P. Svenstrup and Mrs. K. Thingvad about the Danish agreement with pulp and paper industry. Copenhagen, Denmark, DEA (Danish Energy Agency).
- Delemarre, V. and I. Scheurwater (1998). Doel voor 2000 al bijna bereikt. *Energie- en Milieuspectrum*. 6: 20-21.
- DIW (1998). Written communication from mrs. B. Praetorius. Berlin, Germany, DIW (Deutsches Institut für Wirtschaftsforschung).
- EEA (1997). Environmental Agreements, Environmental Effectiveness. Copenhagen, Denmark, EEA (European Environmental Agency).
- Eurostat (1993). NACE Rev. 1, Eurostat B6 Classifications.
- EZ (1996a). Long Term Agreements on Energy Efficiency, Progress in 1995. The Hague, The Netherlands, Ministry of Economic Affairs.
- EZ (1996b). Meerjarenspraak van de Minister van Economische Zaken, het Interprovinciaal Overleg, en de Vereniging van Nederlandse Papier- en Kartonfabrieken (VNP) over Verbetering van de Energie-Efficiency bij de Papierindustrie (Long-Term Agreement on Energy Efficiency between the Ministry of Economic Affairs, the Association of Provinces

- and the Netherlands' Paper and Board Association. Zeist, The Netherlands, Ministerie van Economische Zaken (Ministry of Economic Affairs).
- EZ (1997). Long Term Agreements on Energy Efficiency, Progress in 1996. The Hague, The Netherlands, Ministry of Economic Affairs.
- EZ (1998a). Long Term Agreements on Energy Efficiency, Progress in 1997. The Hague, The Netherlands, Ministry of Economic Affairs.
- EZ (1998b). Meerjarenaafspraken, over energie efficiency, resultaten 1997. Den Haag, Ministerie van Economische Zaken.
- FAO (1996). FAOSTAT; pulp, paper and paperboard, http://apps.fao.org/lim500/agri_db.pl. Rome, Italy, FAO.
- Farla, J. C. M. and K. Blok (1995). Energy Conservation Investment Behaviour of Firms: Analysis of Investments in Energy Efficiency in the Netherlands in the 1980's. ACEEE Summer Study, Grand Island, NY, USA.
- Farla, J. C. M. and K. Blok (1997). Monitoring of Sectoral Energy Efficiency Improvements in the Netherlands, 1980-1994. Utrecht, The Netherlands, Department of Science, Technology and Society, Utrecht University & National Institute for Public Health and Environmental Protection: 86.
- Farla, J. C. M. and K. Blok (forthcoming-a). "Energy Efficiency and Structural Change. The Impacts on Energy Consumption in the Netherlands between 1989 and 1995." .
- Farla, J. C. M. and K. Blok (forthcoming-b). "The Use of Physical Indicators for the Monitoring of Energy Efficiency Development in the Netherlands, 1980-1995." .
- Farla, J. C. M., K. Blok and L. Schipper (1997). "Energy Efficiency Developments in the Pulp and Paper Industry, A Cross-country Comparison using Physical Production Data." *Energy Policy* 25(7-9): 745-758.
- Farla, J. C. M., E. Worrel, L. Hein and K. Blok (1998). Actual Implementation of Energy Conservation Measures in the Manufacturing Industry, 1980-1994. Utrecht, Department of Science, Technology and Society, Utrecht University.
- Glasbergen, P., M. C. Das, P. P. J. Driessen, N. Habermehl, W. J. V. Vermeulen, K. Blok, J. C. M. Farla and E. M. Korevaar (1997). Evaluatie Meerjarenaafspraken Over Energie-Efficiency (Evaluation of Long-Term Agreements on Energy Efficiency). Utrecht, The Netherlands, Utrecht University, Department of Science, Technology and Society & Department of Environmental Science.
- Groot, H. L. F. d., E.T. Verhoef & P. Nijkamp (1999). Energy Savings by Firms: Decision-making, Barriers and Policies. Amsterdam, The Netherlands, Department of Spatial Economics, Vrije Universiteit van Amsterdam.
- Grubb, M., J. Edmonds, P. ten Brink, M. Morrison (1993). "The Costs Of Limiting Fossil-Fuel CO₂ Emissions: A Survey and Analysis." *Annual Review Energy Environment* 18: 397-478.
- Gruber, E. and M. Brand (1991). "Promoting Energy Conservation in Small and Medium-sized Companies." *Energy Policy* 19(3): 279-287.
- Hekkert, M. (1999). Written communication about weighting factors for pulp and paper products. Utrecht, The Netherlands, Department of Science, Technology and Society, Utrecht University.

- Helby, P. (1999a). Written communication from Mr. P. Helby about the renewable energy input in Swedish pulp and paper industry. Lund, Sweden, Department of Environmental and Energy System Studies, Lund University.
- Helby, P. (1999b). Written communication from Mr. P. helby about the Swedish energy statistics. Lund, Sweden, Department of Environmental and Energy System Studies, Lund University.
- IEA (1997). Voluntary Actions for Energy-Related CO₂ Abatement. Paris, France, IEA/OECD.
- Johannsen, K., A. Larsen and K. Hansen (1999). Energy Efficiency Through Agreements. Copenhagen, Denmark, AKF (Institute of Local Government Studies).
- Johannsen, K. and M. Togeby (1998). Evaluations of the Danish Agreement Scheme. World-Wide Use of Voluntary Approaches: State of the Art and National Patterns. CAVA seminar, Gent, Belgium.
- Jong, I. d. (1998). International comparisons of energy efficiency, based on an analysis of the Canadian pulp and paper industry. Utrecht, The Netherlands, Department of Science, Technology and Society, Utrecht University.
- Kagstrom, J. (1998). The Stora Case. Lund, Sweden, Department of Environmental and Energy System Studies, Lund University.
- Kagstrom, J., K. Åstrand and P. Helby (1999). Voluntary Agreements - Implementation and Efficiency The Swedish Country Report. Lund, Sweden, Environmental and energy Systems, Lund University.
- Koot, L. W., M. H. Brascamp, G. Gerritse, G. J. A. M. Meijer, A. G. Melman and H. J. Hunter (1984). Evaluatie van de werking en effectiviteit van de energietoelage op de WIR-Basispremie en de Regeling geldelijke steun beperking energieverbruik in de non-profit sector. Den Haag, The Netherlands, TNO Netherlands Organisation of Applied Scientific Research.
- Korevaar, E., J. Farla, K. Blok, & K. Schulte Fishedick (1997). A Preliminary Analysis of the Dutch Voluntary Agreements on Energy Efficiency Improvement. ECEEE, Spindleruv Mlyn, Czech Republic.
- Nilsson, L. J., E. D. Larson, K. R. Gilbreath and A. Gupta (1995). Energy Efficiency and the Pulp and Paper Industry. Berkeley, CA, USA, American Council for an Energy-Efficient Economy.
- Novem (1994a). Ontwikkeling Energy-Efficiency Nederlandse Glasproducenten 1989-1992. Utrecht, The Netherlands, Nederlandse Onderneming voor Energie en Milieu (Netherlands Agency for Energy and the Environment).
- Novem (1994b). Ontwikkeling Energy-Efficiency Nederlandse Glasproducenten 1993. Utrecht, The Netherlands, Nederlandse Onderneming voor Energie en Milieu (Netherlands Agency for Energy and the Environment).
- Novem (1995a). Ontwikkeling Energy-Efficiency Nederlandse Glasproducenten 1994. Utrecht, Nederlandse Onderneming voor Energie en Milieu (Netherlands Agency for Energy and the Environment).
- Novem (1995b). Voortgangsrapportage Energie-Efficiency in de Nederlandse Chemische Industrie (VNCI), 1989-1994. Utrecht, The Netherlands, Nederlandse Onderneming voor Energie en Milieu (Netherlands Agency for Energy and the Environment).

- Novem (1996a). Monitoring Rapportage Energie-Efficiency Nederlandse Margarine Vetten en Oliënindustrie: 1989-1995. Utrecht, The Netherlands, Nederlandse Onderneming voor Energie en Milieu (Netherlands Agency for Energy and the Environment).
- Novem (1996b). Ontwikkeling Energy-Efficiency Nederlandse Glasproducenten 1995. Utrecht, The Netherlands, Nederlandse Onderneming voor Energie en Milieu (Netherlands Agency for Energy and the Environment).
- Novem (1996c). Voortgangsrapportage Energie-Efficiency in de Nederlandse Chemische Industrie (VNCI), 1995. Utrecht, The Netherlands, Nederlandse Onderneming voor Energie en Milieu (Netherlands Agency for Energy and the Environment).
- Novem (1996d). Voortgangsrapportage Ontwikkeling Energie-Efficiency Nederlandse IJzeren Staalproducerende Industrie (NIJSI), 1989-1995. Utrecht, The Netherlands, Nederlandse Onderneming voor Energie en Milieu (Netherlands Agency for Energy and the Environment).
- Novem (1997a). Monitoring Rapportage Energie-Efficiency Nederlandse Margarine Vetten en Oliënindustrie: 1989-1996. Utrecht, The Netherlands, Nederlandse Onderneming voor Energie en Milieu (Netherlands Agency for Energy and the Environment).
- Novem (1997b). Ontwikkeling Energy-Efficiency Nederlandse Glasproducenten 1996. Utrecht, The Netherlands, Nederlandse Onderneming voor Energie en Milieu (Netherlands Agency for Energy and the Environment).
- Novem (1997c). Voortgangsrapportage Energie-Efficiency in de Nederlandse Chemische Industrie (VNCI), 1996. Utrecht, The Netherlands, Nederlandse Onderneming voor Energie en Milieu (Netherlands Agency for Energy and the Environment).
- Novem (1997d). Voortgangsrapportage Ontwikkeling Energie-Efficiency Nederlandse IJzeren Staalproducerende Industrie (NIJSI), 1989-1996. Utrecht, The Netherlands, Nederlandse Onderneming voor Energie en Milieu (Netherlands Agency for Energy and the Environment).
- Phylipsen, G. J. M., K. Blok and E. Worrell (1998a). Benchmarking the Energy Efficiency of the Dutch Energy-intensive Industry. A Preliminary Assessment of the Effect on Energy Consumption and CO₂ Emissions. Utrecht, The Netherlands, Department of Science, Technology and Society, Utrecht University.
- Phylipsen, G. J. M., K. Blok and E. Worrell (1998b). Handbook On International Comparisons of Energy Efficiency in the Manufacturing Industry. Utrecht, The Netherlands, Department of Science, Technology and Society, Utrecht University.
- PPI (1997). Pulp & Paper International, International Fact and Price Book.
- Rietbergen, M. G., M. Breukels and K. Blok (1999). Voluntary Agreements - Implementation and Efficiency. The Dutch country report. Utrecht, The Netherlands, Utrecht University, Department of Science Technology and Society.
- Ruth, M. (1998). "Dynamics of Material and Energy Use in the U.S. Pulp and Paper Manufacturing." *Journal of Industrial Ecology* 1(3): 147-168.
- RWI (1997a). Band 2: Fortschrittsberichte der Verbaende, Verband Deutscher Papierfabrieken. CO₂-Monitoring der deutschen Industrie - ökologische und ökonomische Verifikation. Essen, Germany, Rheinisch-Westfälischen Institut für Wirtschaftsforschung: 134-150.

- RWI (1997b). First Monitoring Report CO₂-emissions in German Industry 1995-1996. Essen, Germany, Rheinisch-Westfälischen Institut für Wirtschaftsforschung.
- RWI (1998). Personal communication with Mr. B. Hillebrand about the CHP representation in the energy consumption data. Essen, Germany, Rheinisch-Westfälischen Institut für Wirtschaftsforschung.
- RWI (1999a). 2. Monitoring-Bericht der deutschen Zellstoff- und Papierindustrie zur Reduzierung des spezifischen CO₂-Ausstosses aus fossilen Energieträgern. Essen, Rheinisch-Westfälischen Institut für Wirtschaftsforschung.
- RWI (1999b). Second Monitoring Report CO₂-emissions in German Industry 1996-1997. Essen, Germany, Rheinisch-Westfälischen Institut für Wirtschaftsforschung.
- RWI (1999c). Written communication from Mr. H.G. Buttermann about the definition of German target in the voluntary agreement with pulp and paper industry. Essen, Germany, Rheinisch-Westfälischen Institut für Wirtschaftsforschung.
- SCB (Annual publication). Swedish industrial statistics, Swedish Statistical Office.
- Schipper (1999). Written communication from Mr. L. Schipper about the Swedish energy statistics. Berkeley, USA, Lawrence Berkeley National Laboratories.
- SD (Annual publication). Energy Statistics Denmark, Statistics Denmark.
- SESSI (Annual publication). Les consommations d'énergie dans l'industrie, Service des Statistiques Industrielle, France.
- Togebly, M., T. B. Bjorner and K. Johannsen (1998a). Evaluation of the Danish CO₂ Taxes and Agreements. Industrial Energy Efficiency Policies: Understanding Success and Failure, Utrecht, The Netherlands.
- Togebly, M., K. Hansen, A. Larsen, R. Ezban and P. Svenstrup (1998b). Agreements as a Policy Instrument towards Industrial Energy Use - a Presentation of Danish Experience and a Comparison with the Dutch Agreements. IAEE Conference, Quebec, Canada.
- UN (1990). International Standard Classification of All Economic Activities. New York, USA, United Nations.
- VDP (1997). Papier '97 Ein Leistungsbericht. Bonn, Germany, Verband Deutscher Papierfabrikanten.
- VDP (1998). Papier '98 Ein Leistungsbericht. Bonn, Germany, Verband Deutscher Papierfabrikanten.
- VNP (1990). VNP jaaroverzicht 1990. Haarlem, The Netherlands, Vereniging van Nederlandse Papier- en Kartonfabrieken (Netherlands' Paper and Board Association).
- VNP (1993). VNP jaaroverzicht 1992/1993. Haarlem, The Netherlands, Vereniging van Nederlandse Papier- en Kartonfabrieken (Netherlands' Paper and Board Association).
- VNP (1997). Voortgangsrapportage Ontwikkeling Energie-Efficiency Papier- en Kartonindustrie (VNP) 1989-1996 (LTA progress report). Haarlem, The Netherlands, Vereniging van Nederlandse Papier- en Kartonfabrieken (Netherlands' Paper and Board Association).
- VNP (1998). Voortgangsrapportage Ontwikkeling Energie-Efficiency Papier- en Kartonindustrie (VNP) 1989-1997 (LTA progress report). Hoofddorp, The Netherlands, Vereniging van Nederlandse Papier- en Kartonfabrieken (Netherlands' Paper and Board Association).

- VNP (Annual). VNP jaarverslag (Annual Report). Hoofddorp, The Netherlands, Vereniging van Nederlandse Papier- en Kartonfabrieken (Netherlands' Paper and Board Association).
- WEC (1995). Energy Efficiency Policies. London, UK, World Energy Council.

Appendix I

Source	DENMARK	unit	1989	1990	1991	1992	1993	1994	1995	1996	1997
FAO	Total Wood Pulp	kton	68	68	68	133	130	146	146	146	146
FAO	Mechanical wood pulp	kton	0	0	0	68	67	75	75	75	75
FAO	Chemical wood pulp	kton	0	0	0	0	0	0	0	0	0
CALC	Other wood pulp	kton	68	68	68	65	63	71	71	71	71
FAO	Other fibre pulp	kton	68	34	34	34	34	34	34	34	34
CALC	Recycled fibre input	kton	259	179	399	369	238	329	317	317	317
FAO	Total Paper and Board	kton	326	335	356	317	339	345	345	345	345
FAO	Newsprint	kton	0	0	0	0	0	0	0	0	0
FAO	Printing/writing paper	kton	130	124	132	117	93	93	93	93	93
FAO	Sanitary paper	kton	18	16	17	0	0	0	0	0	0
FAO	Packaging paper	kton	136	195	207	200	246	252	252	252	252
CALC	Other paper	kton	42	0	0	0	0	0	0	0	0
Physical Production Index											
CALC	PPI fuel basis		1628	1689	1898	1527	1544	1570	1565	1565	1565
CALC	PPI electricity basis		1762	1441	1786	2005	1825	2052	2036	2036	2036
CALC	PPI primary basis		6031	5292	6362	6538	6106	6699	6654	6654	6654
Recovered Paper											
FAO	Production	kton	349	313	425	466	466	466	466	466	466
FAO	Import	kton	49	29	57	93	30	171	118	118	118
FAO	Export	kton	139	164	83	190	258	308	267	267	267
CALC	Recycled fibre input	kton	259	179	399	369	238	329	317	317	317
CALC	Pulp/paper ratio		21	20	19	42	38	42	42	42	42
Energy Consumption, final fossil											
CALC	fuel	PJ		3,7	3,8	2,9	2,9	2,9	2,7	2,7	2,8
CALC	electricity	PJ		0,8	0,8	0,8	0,7	0,7	0,7	0,7	0,7
CALC	primary ^{a,b}	PJ		5,7	5,8	4,9	4,6	4,5	4,4	4,4	4,6
Ratio Energy Consumption and PPI											
CALC	final fossil			1,07	0,91	0,75	0,75	0,67	0,66	0,66	0,69
Specific Energy Consumption											
CALC	final fossil	GJ/ton		16,9	16,2	15,6	13,5	13,1	12,7	12,7	13,3
Energy balance final											
DS	Coal	TJ	1600	1907	1541	796	435	60	3	0	
DS	Fuel	TJ	884	866	850	70	43	16	167	17	
DS	Gas	TJ	1260	986	480	1032	1321	1591	1350	1557	
DS	Electricity	TJ	777	800	824	653	662	660	659	699	
DS	Heat	TJ	-15	0	0	950	965	963	1095	1153	
CALC	Total	TJ	4505	4560	3694	3502	3427	3289	3275	3426	

Remarks

sector 34.110

Interpolated

^aconversion efficiency 40%

^bheat calculated at 110%

FAO = Food and Agriculture Organisation

CALC = Calculated

SD = Statistics Denmark

Source	FRANCE	unit	1989	1990	1991	1992	1993	1994	1995	1996	1997
FAO	Total Wood Pulp	kton	2390	2399	2434	2728	2543	2791	2822	2519	2519
FAO	Mechanical wood pulp	kton	662	667	810	922	823	886	934	757	757
FAO	Chemical wood pulp	kton	1607	1611	1501	1686	1603	1782	1774	1658	1658
CALC	Other wood pulp	kton	121	121	123	120	117	123	114	104	104
FAO	Other fibre pulp	kton	23	23	23	23	0,5	1	1	1	2
CALC	Recycled fibre input	kton	3090	2511	3368	3416	3410	4634	4092	4038	4105
FAO	Total Paper and Board	kton	6754	7049	7442	7691	7975	8701	8619	8531	8556
FAO	Newsprint	kton	379	422	509	670	802	844	890	783	783
FAO	Printing/writing paper	kton	2537	2773	2827	2948	2936	3268	3096	3141	3141
FAO	Sanitary paper	kton	320	321	365	381	396	478	489	508	508
FAO	Packaging paper	kton	3118	3131	3356	3342	3477	3838	3767	3817	3842
CALC	Other paper	kton	400	402	385	350	364	273	377	282	282
Physical Production Index											
CALC	PPI fuel basis		53780	55420	56195	58887	59419	65645	64509	63552	63701
CALC	PPI electricity basis		24486	24270	26606	28133	27664	31496	30745	29271	29409
CALC	PPI primary basis		114995	116095	122711	129220	128580	144384	141371	136729	137223
Recovered Paper											
FAO	Production	kton	2883	2255	3007	3007	2829	4075	3700	3700	3857
FAO	Import	kton	718	775	963	996	1005	1228	1178	1083	998
FAO	Export	kton	511	519	601	587	424	669	786	745	749,6
CALC	Recycled fibre input	kton	3090	2511	3368	3416	3410	4634	4092	4038	4105
CALC	Pulp/paper ratio		35	34	33	35	32	32	33	30	29
Energy Consumption fossil											
CALC	fuel ^a	PJ		52,0	53,1	56,8	55,8	56,7	56,9	61,6	62,8
	electricity ^b	PJ		56,7	59,7	76,3	78,4	85,4	83,9	78,8	84,8
CALC	primary	PJ		108,7	112,9	133,1	134,2	142,1	140,8	140,5	147,6
Ratio Energy Consumption and PPI											
CALC	fossil total			0,94	0,92	1,03	1,04	0,98	1,00	1,03	1,08
Specific Energy Consumption											
CALC	fossil total	GJ/ton		15,4	15,2	17,3	16,8	16,3	16,3	16,5	17,3
Energy Balance final											
SESSI	Coal, coke	PJ		8,0	7,7	7,7	7,8	7,9	7,5	8,0	8,1
SESSI	Petroleum products	PJ		15,2	15,7	15,5	12,6	12,4	10,7	10,5	10,2
SESSI	Gas	PJ		26,4	27,5	31,1	33,7	34,3	36,6	40,8	42,8
SESSI	Electricity ^b	PJ		56,7	59,7	76,3	78,4	85,4	83,9	78,8	84,8
SESSI	Steam	PJ		2,1	2,1	2,2	1,5	1,9	1,9	2,1	1,6
CALC	Total ^b	PJ		108,5	112,7	132,8	134,1	141,9	140,6	140,3	147,5

Remarks^aheat calculated at 110%^bon primary basis

FAO = Food and Agriculture Organisation

CALC = Calculated

SESSI = Service des Statistiques Industrielle

Source	GERMANY	unit	1989	1990	1991	1992	1993	1994	1995	1996	1997
FAO	Total Wood Pulp	kton	3078	2999	2431	2275	2032	1957	1984	1852	1983
FAO	Mechanical wood pulp	kton	1696	1648	1531	1461	1331	1236	1266	1133	1220
FAO	Chemical wood pulp	kton	987	994	829	720	682	698	684	683	738
CALC	Other wood pulp	kton	395	357	71	94	19	23	34	36	0
FAO	Other fibre pulp	kton	45	45	45	45	45	0	0	0	0
CALC	Recycled fibre input	kton	5947	6189	6421	6744	6995	8161	8599	8888	9458
FAO	Total Paper and Board	kton	12610	13224	12904	13214	13034	14457	14827	14733	15953
FAO	Newsprint	kton	1117	1244	1229	1222	1302	1499	1726	1572	1618
FAO	Printing/writing paper	kton	4774	4982	5114	5173	4928	5865	5872	5553	6390
FAO	Sanitary paper	kton	766	829	889	879	847	864	877	886	890
FAO	Packaging paper	kton	4070	4250	4685	5019	5024	5275	5348	5694	5953
CALC	Other paper	kton	1883	1919	987	921	933	954	1004	1028	1102
Physical Production Index											
CALC	PPI fuel basis		79056	82642	79958	80695	79335	88801	90087	89767	98203
CALC	PPI electricity basis		44867	45820	42759	43172	41863	45391	46757	46196	49647
CALC	PPI primary basis		191224	197193	186854	188624	183993	202279	206979	205257	222319
Recovered Paper											
VDP	Production	kton	6511	6803	7500	7917	8564	9690	10670	10912	11279
VDP	Import	kton	729	784	743	712	555	719	1141	934	918
VDP	Export	kton	1293	1398	1822	1885	2124	2248	3212	2958	2739
CALC	Recycled fibre input	kton	5947	6189	6421	6744	6995	8161	8599	8888	9458
CALC	Pulp/paper ratio		24	23	19	17	16	14	13	13	12
Energy Consumption, nae fossil fuels, excl. heat											
CALC	fuel	PJ	102	122	117	119	117	124	122	117	116
VDP/RWI	electricity	PJ	22	28	27	27	26	27	28	28	30
CALC	primary ^a	PJ	158	192	184	185	182	192	192	186	192
Energy Consumption, nae total											
CALC	fuel	PJ	119	143	136	136	138	148	145	142	141
VDP/RWI	electricity	PJ	22	28	27	27	26	27	28	28	30
CALC	primary ^a	PJ	175	212	203	203	203	216	216	211	217
Ratio Energy Consumption and PPI											
CALC	nae fossil fuels, excl. heat			0,97	0,98	0,98	0,99	0,95	0,93	0,91	0,86
CALC	nae total			1,08	1,08	1,08	1,10	1,07	1,04	1,03	0,98
Specific Energy Consumption											
CALC	nae fossil fuels, excl. heat	GJ/ton		14,5	14,3	14,0	14,0	13,3	13,0	12,6	12,0
CALC	nae total	GJ/ton		16,0	15,7	15,3	15,6	14,9	14,5	14,3	13,6
Energy balance nae											
VDP	Coal	PJ	27,5	44,4	40,1	37,8	33,6	33,8	35,0	31,0	29,3
VDP	Fuel oil	PJ	27,3	26,7	24,9	24,4	20,0	18,6	16,8	15,8	13,1
VDP	Gas	PJ	47,7	51,1	52,4	56,3	63,6	71,2	69,8	69,9	73,8
VDP	Other ^b	PJ	16,3	20,5	18,6	17,6	21,1	24,2	23,4	25,1	25,2
VDP	Electricity	PJ	22,4	27,8	26,6	26,7	26,0	27,2	28,2	27,8	30,2
CALC	Total	PJ	141,0	170,5	162,7	162,8	164,2	175,0	173,2	169,7	171,6

Remarks

West-Germany only

FAQ

RWI

Interpolated

^aconversion efficiency 40%^bother fuels include heat, lyse, bark, fibre waste, biogas and other waste

FAO = Food and Agriculture Organisation

CALC = Calculated

VDP = Verein Deutscher Papierfabriken

RWI = Rheisch-Westfaelisches Institute fuer Wirtschaftsforschung

Source	THE NETHERLANDS	unit	1989	1990	1991	1992	1993	1994	1995	1996	1997
FAO	Total Wood Pulp	kton	164	190	175	135	119	119	148	125	138
FAO	Mechanical wood pulp	kton	164	190	175	135	119	119	148	125	138
FAO	Chemical wood pulp	kton	0	0	0	0	0	0	0	0	0
CALC	Other wood pulp	kton	0	0	0	0	0	0	0	0	0
FAO	Other fibre pulp	kton	3	3	3	3	3	3	3	3	3
CALC	Recycled fibre input	kton	1690	1786	1901	2013	1963	2182	2119	2434	2105
FAO	Total Paper and Board	kton	2572	2770	2862	2835	2855	3011	2967	2987	3159
FAO	Newsprint	kton	280	300	309	306	326	311	361	338	373
FAO	Printing/writing paper	kton	737	819	834	797	775	902	818	840	878
FAO	Sanitary paper	kton	169	167	174	171	166	167	161	159	169
FAO	Packaging paper	kton	1386	1484	1545	1561	1588	1631	1627	1650	1673
CALC	Other paper	kton	0	0	0	0	0	0	0	0	66
	Physical Production Index										
CALC	PPI fuel basis		13956	15044	15589	15517	15536	16695	16096	16472	17228
CALC	PPI electricity basis		7603	8210	8443	8327	8183	8790	8737	9098	9009
CALC	PPI primary basis		32964	35570	36696	36333	35994	38671	37940	39218	39751
	Recovered Paper										
FAO	Production	kton	1490	1567	1746	1746	2040	2202	2306	2306	1977
FAO	Import	kton	788	857	1047	1252	935	1079	1434	1245	1245
FAO	Export	kton	588	637	892	985	1012	1099	1621	1117	1117
CALC	Recycled fibre input	kton	1690	1786	1901	2013	1963	2182	2119	2434	2105
CALC	Pulp/paper ratio		6	7	6	5	4	4	5	4	4
	Energy Consumption, nae fossil										
CALC	fuel ^a	PJ	24,9	26,1	26,2	25,7	26,5	25,6	30,6	34,2	
CALC	electricity	PJ	2,7	2,9	2,8	2,8	2,2	2,0	-0,3	-1,9	
CALC	primary ^b	PJ	31,7	33,3	33,2	32,6	32,0	30,5	29,9	29,5	
	Energy Consumption, nae total										
CALC	fuel ^a	PJ	24,9	26,1	26,1	25,7	26,5	25,6	30,6	34,2	
CALC	electricity	PJ	2,7	2,9	2,8	2,8	2,2	2,0	-0,3	-1,9	
CALC	primary ^b	PJ	31,7	33,3	33,1	32,6	32,0	30,5	29,8	29,5	
	Ratio Energy Consumption and PPI										
CALC	nae fossil fuels		0,96	0,94	0,90	0,90	0,89	0,79	0,79	0,75	
CALC	nae total		0,96	0,94	0,90	0,90	0,89	0,79	0,79	0,75	
	Specific Energy Consumption										
CALC	nae fossil fuels	GJ/ton	12,3	12,0	11,6	11,5	11,2	10,1	10,1	9,9	
CALC	nae total	GJ/ton	12,3	12,0	11,6	11,5	11,2	10,1	10,1	9,9	
	Energy balance nae										
CBS	Oil	PJ	0,1	0,1	0,1	0,1	0,2	0,2	0,1	0,1	
CBS	Gas	PJ	24,5	25,6	25,7	25,3	26,3	25,3	30,8	34,4	
CBS	Coal & Coke	PJ	0,1	0,1	0,1	0,1	0,0	0,0	0,0	0,0	
CBS	Biomass	PJ	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	
CBS	Heat	PJ	0,3	0,4	0,4	0,3	0,0	0,2	-0,5	-0,5	
CBS	Electricity	PJ	2,7	2,9	2,8	2,8	2,2	2,0	-0,3	-1,9	
CBS	Other	PJ	-0,1	-0,1	-0,1	-0,1	-0,1	-0,1	-0,1	-0,1	
CALC	Total	PJ	27,7	29,1	29,1	28,6	28,7	27,6	30,1	32,1	

Remarks^aheat calculated at 60%^bconversion efficiency 40%

FAO = Food and Agriculture Organisation

CALC = Calculated

CBS = Centraal Bureau voor Statistiek

Source	THE NETHERLANDS	unit	1989	1990	1991	1992	1993	1994	1995	1996	1997
FAO	Total Wood Pulp	kton	164	190	175	135	119	119	148	125	138
FAO	Mechanical wood pulp	kton	164	190	175	135	119	119	148	125	138
FAO	Chemical wood pulp	kton	0	0	0	0	0	0	0	0	0
CALC	Other wood pulp	kton	0	0	0	0	0	0	0	0	0
FAO	Other fibre pulp	kton	3	3	3	3	3	3	3	3	3
CALC	Recycled fibre input	kton	1690	1786	1901	2013	1963	2182	2119	2434	2105
FAO	Total Paper and Board	kton	2572	2770	2862	2835	2855	3011	2967	2987	3159
FAO	Newsprint	kton	280	300	309	306	326	311	361	338	373
FAO	Printing/writing paper	kton	737	819	834	797	775	902	818	840	878
FAO	Sanitary paper	kton	169	167	174	171	166	167	161	159	169
FAO	Packaging paper	kton	1386	1484	1545	1561	1588	1631	1627	1650	1673
CALC	Other paper	kton	0	0	0	0	0	0	0	0	66
	Physical Production Index										
CALC	PPI fuel basis		13956	15044	15589	15517	15536	16695	16096	16472	17228
CALC	PPI electricity basis		7603	8210	8443	8327	8183	8790	8737	9098	9009
CALC	PPI primary basis		32964	35570	36696	36333	35994	38671	37940	39218	39751
	Recovered Paper										
FAO	Production	kton	1490	1567	1746	1746	2040	2202	2306	2306	1977
FAO	Import	kton	788	857	1047	1252	935	1079	1434	1245	1245
FAO	Export	kton	588	637	892	985	1012	1099	1621	1117	1117
CALC	Recycled fibre input	kton	1690	1786	1901	2013	1963	2182	2119	2434	2105
CALC	Pulp/paper ratio		6	7	6	5	4	4	5	4	4
	Energy Consumption, final fossil fuels										
CALC	fuel ^a	PJ	19,2	20,5	20,7	20,1	20,1	18,1	20,3	22,4	
CALC	electricity	PJ	7,1	7,5	7,3	7,2	7,1	7,3	7,3	7,1	
CALC	primary ^b	PJ	37,0	39,2	38,8	38,2	37,8	36,3	38,7	40,0	
	Energy Consumption, final total										
CALC	fuel ^a	PJ	19,2	20,5	20,6	20,1	20,0	18,1	20,3	22,4	
CALC	electricity	PJ	7,1	7,5	7,3	7,2	7,1	7,3	7,3	7,1	
CALC	primary ^b	PJ	37,0	39,2	38,8	38,2	37,8	36,3	38,6	40,1	
	Ratio Energy Consumption and PPI										
CALC	final fossil fuels		1,12	1,10	1,06	1,05	1,05	0,94	1,02	1,02	
CALC	final total		1,12	1,10	1,06	1,05	1,05	0,94	1,02	1,02	
	Specific Energy Consumption										
CALC	final fossil fuels	GJ/ton	14,4	14,2	13,6	13,5	13,2	12,1	13,0	13,4	
CALC	final total	GJ/ton	14,4	14,1	13,5	13,5	13,2	12,1	13,0	13,4	
	Energy balance final										
CBS	Oil	PJ	0,1	0,1	0,1	0,1	0,2	0,2	0,1	0,1	
CBS	Gas	PJ	5,3	5,7	6,1	5,0	4,4	1,7	3,3	4,0	
CBS	Coal & Coke	PJ	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	
CBS	Biomass	PJ	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	
CBS	Heat	PJ	12,5	13,3	13,1	13,6	14,1	14,7	15,4	16,6	
CBS	Electricity	PJ	7,1	7,5	7,3	7,2	7,1	7,3	7,3	7,1	
CBS	Other	PJ	-0,1	-0,1	-0,1	-0,1	-0,1	-0,1	-0,1	-0,1	
CALC	Total	PJ	25,0	26,6	26,6	25,9	25,7	23,9	26,1	27,8	

Remarks^aheat calculated at 110%^bconversion efficiency 40%

FAO = Food and Agriculture Organisation

CALC = Calculated

CBS = Centraal Bureau voor Statistiek

Source	SWEDEN	unit	1989	1990	1991	1992	1993	1994	1995	1996	1997
											56122
FAO	Total wood pulp	kton	10638	10215	10088	9909	10272	10487	10506	10097	10813
FAO	Mechanical wood pulp	kton	3000	2953	2709	2525	2722	2858	2861	2753	2959
FAO	Chemical wood pulp	kton	7053	6677	6768	6789	6967	7060	7075	6783	7269
CALC	Other wood pulp	kton	585	585	611	595	583	569	570	561	585
FAO	Other fibre pulp	kton									
CALC	Recycled fibre input	kton	961	1044	1041	1233	1319	1825	1859	1847	2019
FAO	Total paper and board	kton	8363	8419	8349	8378	8781	9284	9159	9038	9779
FAO	Newsprint	kton	2165	2273	2063	2124	2325	2415	2346	2283	2411
FAO	Printing/writing paper	kton	1690	1655	1793	1805	1884	2061	2047	2170	2459
FAO	Sanitary paper	kton	285	283	291	296	298	295	293	282	292
FAO	Packaging paper	kton	3981	3974	3986	3949	4067	4495	4456	4287	4581
CALC	Other paper	kton	242	234	216	204	207	18	17	16	36
	Physical Production Index										
CALC	PPI fuel basis		102884	99188	100964	101690	104800	108144	107817	104943	113350
CALC	PPI electricity basis		51890	50869	49942	49235	51400	53752	53670	52173	56122
CALC	PPI primary basis		232609	226360	225818	224778	233301	242524	241991	235374	253656
	Recovered Paper										
FAO	Production	kton	890	909	877	900	920	1408	1428	1502	1652
FAO	Import	kton	218	275	308	472	542	583	614	523	553
FAO	Export	kton	147	140	144	139	142	166	183	178	186
CALC	Recycled fibre input	kton	961	1044	1041	1233	1319	1825	1859	1847	2019
	Pulp/paper ratio		127	121	121	118	117	113	115	112	111
	Energy Consumption, final fossil fuels										
CALC	fuel ^a	PJ	25	21	20	19	24	31	35	38	
CALC	electricity	PJ	72	69	67	64	67	68	68	66	
CALC	primary ^b	PJ	205	194	188	180	191	200	205	203	
	Energy Consumption, final total										
CALC	fuel ^a	PJ	41	37	35	31	37	43	46	49	
CALC	electricity	PJ	72	69	67	64	67	68	68	66	
CALC	primary ^b	PJ	222	211	203	192	204	212	215	214	
	Ratio Energy Consumption and PPI										
CALC	final fossil fuels		0,88	0,86	0,83	0,80	0,82	0,82	0,85	0,86	
CALC	final total		0,95	0,93	0,90	0,85	0,87	0,87	0,89	0,91	
	Specific Energy Consumption										
CALC	final fossil fuels	GJ/ton	24,5	23,1	22,5	21,5	21,8	21,5	22,3	22,5	
CALC	final total	GJ/ton	26,5	25,0	24,3	22,9	23,2	22,9	23,5	23,7	
	Energy balance final										
SCB	Oil	PJ	20,8	18,3	15,3	15,2	20,7	27,1	28,0	32,0	
SCB	Coal & coke	PJ	3,0	0,0	0,0	0,0	0,0	0,0	1,2	1,3	
SCB	Gas	PJ	0,7	1,0	0,9	0,9	0,7	0,8	2,3	2,3	
SCB	Electricity	PJ	72,1	69,4	67,2	64,3	66,8	67,7	67,7	66,3	
SCB	Biomass	PJ	16,8	16,4	15,0	12,2	12,8	12,2	10,9	10,8	
SCB	Heat	PJ	0,0	1,2	3,2	2,7	2,3	2,5	3,4	1,9	
CALC	Total	PJ	113,5	106,3	101,6	95,3	103,4	110,4	113,6	114,7	
	Remarks										
	^a heat calculated at 110%										
	^b conversion efficiency 40%										
	FAO = Food and Agriculture Organisation										
	CALC = Calculated										
	SCB = Statistics Sweden										

Contents of the VAIE Project

The VAIE project has been organised in different tasks, which followed quite different approaches to the analysis of voluntary agreements, *ref.:* the web-site of the project: www.akf.dk/vaie.

- Task A: Theoretic model and meta-analysis followed an approach from economics and here three theoretic models on voluntary agreements are presented. The models are confronted with a meta-analysis based on existing investigations of agreements. The goal is to point to central actors in the policy-making and implementation processes, and to discuss ways of distributing knowledge and information among the actors. Given the simplifying assumptions, the analysis derives the welfare implications of agreements.

Ref.: Chidiak, M., M. Glachant, and L.G. Hansen (1999): VAIE Project Task A Final Report. Theoretical Perspectives on the Efficiency of Voluntary Approaches to Promote Energy Efficiency, Cerna, Paris.

- Task B: Framework for country studies describes the methodological framework for the country studies undertaken.

Ref.: Kræmer, T.P. & K. Hansen (1999): Task B Framework for the Country Studies. AKF Forlaget, Copenhagen.

- Task C: Country case studies . The five country studies in Denmark, France, Germany, the Netherlands, and Sweden are based on case studies of agreement schemes and voluntary agreements. The objective primarily is to identify impact mechanisms at firm level in relation to the implementation process of agreement schemes respectively the voluntary agreement.

Ref.: Chidiak, M. (1999): Voluntary Agreements Implementation and Efficiency. The French Country Study. Case studies in the sectors of packaging glass and aluminium. Cerna, Paris.

Ref.: Johannsen, K.S. and A. Larsen (2000): Voluntary Agreements Implementation and Efficiency. The Danish Country Study. Case studies in the sectors of paper and milk condensing. AKF Forlaget, Copenhagen.

Ref.: Kågström, J., P. Helby and K. Åstrand (1999): Voluntary Agreements Implementation and Efficiency. The Swedish Country Study. Case study in the sector of paper and pulp. Lunds University, Lund.

Ref.: Ramesohl, S. & K. Kristof (1999): Voluntary Agreements Implementation and Efficiency. The German Country Study. Case studies in the sectors of cement and glass. Wuppertal.

Ref.: Rietbergen, M.G., M. Breukels & K. Blok (1999): Voluntary Agreements Implementation and Efficiency. The Netherlands Country Study. Case studies in the sectors of paper and glass manufacturing. Utrecht University, Utrecht.

- Task D: Actual outcome - the nonintervention case . Three methods: monitoring of the historical development, the actual change in energy-efficiency investment behaviour and simulation of energy-efficiency investment behaviour are described. The methods are used on data mainly from the Netherlands and the actual outcome of voluntary agreements is assessed.

Ref.: Rietbergen, M.G. & K. Blok (1999): The Environmental performance of Voluntary Agreements on Industrial Energy Efficiency Improvement. The Task D report from the VAIE project. Utrecht University, Utrecht.

- Task E: Voluntary Agreements in an EU-perspective The other tasks in the project, especially the country studies and task A, are discussed in task E from an EU perspective, focussing on the question of implementing agreement schemes at the EU level.

Ref.: Helby, P. (1999): Voluntary Agreements Implementation and Efficiency. Task E. Transferability of case study lessons to voluntary agreement schemes at the European level. Task E report from the VAIE project. Lunds University, Lund.

- Task F & G: Conclusions and policy recommendation summarizes the findings in the project and gives policy recommendation concerning voluntary agreements.

Ref.: Krarup, S. and S. Ramesohl (2000): Voluntary agreements - Hot air or a key to higher efficiency? AKF Forlaget, Copenhagen.