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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION
COMMON FUND FOR COMMODITIES

PRODUCT AND MARKET DEVELOPMENT FOR SISAL AND HENEQUEN

MARKET STUDY AND TRIALS
SISAL PULP FOR PAPERMAKING

phase one

THE OUTLOOK FOR SISAL IN PAPER MANUFACTURE

sisal pulp market study

1980 TO 2010

WORLD AND REGIONAL PAPER PRODUCTION
FIBER FURNISH IN PAPER MANUFACTURE
FIBER BALANCE

SISAL CELLULOSE AS REINFORCEMENT PULP
SISAL IN SPECIALTY PAPER MANUFACTURE

editors
Punya B Chaudhuri, Erik J van den Ent and Mich R Lauer
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market study and trials : sisal pulp for papermaking

the outlook for sisal in paper manufacture

sisal pulp market study
phase one

1980 to 2010
world and regional paper production
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the role of reinforcing pulps in world paper furnishes

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sisal cellulose in specialty paper manufacture

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annex reports [i] to [vi]
(annex one)
based on the work of gill clarke and richard cockram
(annex two)
based on the work of richard cockram, mich r lauer and erik j van den ent
(annex three)
based on the work of mich e lauer
(annex four)
based on the work of richard cockram
(annex five)
based on the work of punya b chaudhuri, richard cockram, mich e lauer and erik j van den ent
(annex six) confidential & restricted
based on the work of erik j van den ent and mich e lauer

united nations industrial development organisation & common fund for commodities
product and market development for sisal and henequen

the outlook for sisal in paper manufacture : 1980 to 2010
sisal pulp market study

executive summary

Paper is made with various long and short fiber pulps. We are interested to identify the present and future volumes of reinforcement pulp in paper and review the potential of sisal cellulose for papermaking.
Reinforcement pulp is long fiber pulp, made from softwood, but not the entire volume of long fiber pulp is reinforcement pulp. Reinforcement pulp is bleached or semibleached long fiber cellulose, used in the manufacture of printing grade papers and tissue, which are made from short fiber pulps with weak bonding properties. Reinforcement pulp is manufactured in paper mills (integrated pulp) or purchased on the market.

There have been two objectives in the market study. The major objective has been to identify the potential use of sisal cellulose for reinforcement, in order to complement or even replace conventional softwood reinforcement cellulose. Sisal cellulose has superior sheet properties, in comparison to softwood reinforcing pulp.

Reinforcement is widely practised in printing paper manufacture, a large scale business. The market study has followed three approaches :

[i] Statistics on paper production for 1980 to 2000 were collected and stored in an electronic database. The fiber furnishes of paper were analysed and their fiber profiles likewise stored. Database figures for paper represent 94 pct of the world total. The reinforcement and all other pulp volumes were identified in five year intervals, and equally stored. Projections on paper and pulp for the 2000 to 2010 decade were prepared, using the database *plus* information on economic growth, change in society, the progress in papermaking technology, changing furnish profiles in paper and price trends. The projections were stored electronically.

[2] Queries and interviews with paper producers around the world were held concerning production practices on reinforcement and producer attitudes to change. The results have been evaluated by statistical means, and were stored electronically as above.
An assessment on sisal pulp for reinforcement was made, using scenarios from the database, and alternative scenarios were also reviewed. The conclusions represent our best judgment on the reinforcement situation in the decade 2000 to 2010.

[3] The present and future capacities of reinforcement and other long fiber pulps have been identified and analysed in relation to wood and forest reserves, the future availability of pulp wood, demand for pulp and production economics. The difference between present and future capacity in pulp reflects the increase in demand for pulp, caused by the growth in paper, forecast for the decade 2000 to 2010. The increase in reinforcement pulp volume is inferior to the expansion of paper, as technology continues to change.

The secondary objective was to explore other uses for sisal pulp, in niche and specialty paper applications.

For both objectives, paper producers were identified who have expressed interest in sisal pulp and who might wish to evaluate it and follow through with further development.

conclusions

The three streams of information [i] [ii] [iii] have been cross referenced. Database paper will grow by one third in the 2000 to 2010 decade, from 301 million tons presently to 416 million tons in ten years (for comparison : world paper figures are 321 and 437 million tons).

Market reinforcement pulp will increase from 18 million tons to 24 million tons. The additional volume is 5.6 million tons. The difference will be met by improved efficiency in existing mills *plus* greenfield capacity. Accessible wood reserves exist for both categories. A world-wide shortage in reinforcement pulp is not foreseen for the decade, and unlikely thereafter.

Therefore, sisal pulp will have to meet supply and price conditions *in competition with* long fiber market cellulose, as a contender for reinforcement. The industry is hesitant to switch to unfamiliar pulp. For sisal pulp to be considered, it would have to offer additional benefit in cost or convenience.

Experimental proof that sisal cellulose is a suitable replacement for softwood reinforcement pulp is impossible to deliver. Although papermaking properties of sisal are superior to those of softwood pulp, this is insufficient to convince paper mill operators or investors. The objections from paper makers are price and supply of sisal pulp, not properties.

The conclusion is that sisal cellulose, despite superior papermaking properties, is not a suitable raw material for paper on a large scale. The logistics of sisal on a large scale do not concur : they are unfavorable, compared to softwood pulp mills.
A large scale wood pulp operation enjoys scale economies, not available in a sisal scheme. The unit manufacturing cost of sisal pulp is twice the price of softwood pulp. Papermakers will not consider sisal because the cost of using it is out of range and the supply of pulp not assured.

The overriding conclusion is that sisal pulp is unsuitable as a substitute for softwood reinforcement pulp.

However, the logistics of growing and producing sisal pulp suggest that smaller schemes are feasible, if versatile pulp qualities can be produced. Dedicated production methods hold the promise of a valuable and versatile cellulose, obtainable from sisal, at much lower cost than presently. In a dedicated scheme, sisal should be grown at lowest cost and processed into fiber and pulp by new processing methods, enhancing the price-to-quality relationship in fiber and pulp. This is a departure from conventional decortication and routine pulping process.

In fiber separation and pulp making, new process technology offers the prospect of much larger use of sisal cellulose in specialty papermaking. The research on process conditions should be supported by further market research, enlisting the help of selected paper producers, who have expressed interested in the potential of sisal during the current market study.

recommendations

From the queries and interviews, about one hundred paper mills have indicated some interest in sisal pulp. It is suggested that Unido and the project form and monitor a cooperative group of five to fifteen mills, to initiate and support further research on pulping, process design, cost feasibility and niche paper applications, within the limits congruent with the logistics of sisal.

epilogue

Elaborate conclusions and recommendations are found in *paragraphs 12.1 - 12.2* in *chap 12.*

product and market development for sisal and henequen
the outlook for sisal in paper manufacture
sisal pulp market study

contents

chapter 1 introduction & nature of this report

overview	this market study reviews the prospects of sisal pulp in two feasible applications [i] as a reinforcement pulp in 'common' paper manufacture [ii] for specialty paper

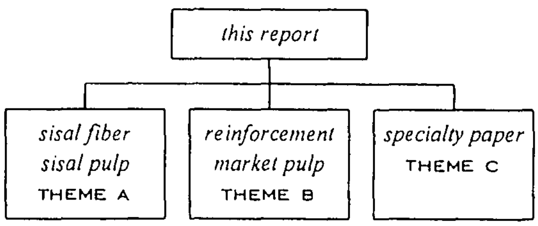
1.1 introduction

Paper is made, using a variety of papermaking pulps. Most paper is made from wood pulp. Recycled paper is made from paper waste. The properties and cost economics of these fiber resources are well known throughout the industry. Paper mills are skilful in selecting various fiber furnishes from the viewpoint of papermaking properties and cost economies.

Nonwood fiber plant species play a role in papermaking in certain countries, and, of course, in certain specialty paper. Otherwise, paper mills are much less familiar with nonwood pulp. Sisal is one of the few long fiber nonwood resources, from which specialty paper is produced. Sisal pulp has superior papermaking properties, compared to the best softwood cellulose, from temperate coniferous forests. Nevertheless, sisal pulp is used only to a limited extent : it is not widely available and the cost is excessive.

This study explores whether sisal can be used more widely in paper manufacture. The simple question is : *where* can *sisal pulp be used to advantage*. To find the answers, the present study has followed three lines of analysis, which are discussed in three themes :

[i] the properties of sisal fiber and sisal pulp
[ii] the market position of reinforcement pulp
[iii] applications of sisal pulp in specialty paper



THEME A

Sisal pulp (from *Agave species*) has outstanding papermaking properties. The fiber and pulp properties of sisal are reviewed in *chapter 2*. Although highly regarded for certain specialty paper applications, where it is used regularly, the annual consumption of sisal pulp is very limited, having descended to only 14,000 tons in recent years.

Sisal pulp is commonly manufactured by the soda process and bleached with chlorine and hypochlorite. Even such conventional pulp has properties superior in tear resistance, porosity and wet fiber bonding. The reactivity of fresh fiber to maceration suggests that papermaking properties can easily be improved even further. The potential significance of sisal is far greater than present use suggests. But where is sisal used to best advantage ?

THEME B

Reinforcement is widely practiced in the manufacture of printing paper. This practice has been the primary target of the market study. The discussion and findings on reinforcement are presented in *chapters 3* to *10*. The possible substitution of reinforcement wood pulp by sisal pulp is analysed.

THEME C

The present practices concerning sisal pulp in specialty paper manufacture have been queried and are summarised in *chapter 11*. User attitudes were also recorded. The expressions of interest and willingness to cooperate in testing (*market study phase two*) are reported, and the quantities of fiber and pulp determined.

In summary : three factors *seemingly limit* the use of sisal in paper : price, the availability of fiber, and pulp properties (*chapter 12*). Even in higher value specialty papers, sisal is used sparingly. The constant drive to substitute expensive nonwood long fiber pulps is a further threat. A fresh approach to sisal processing, with ensuing improvements in price and pulp properties -as discussed in THEME A - may open the prospect of wider use of sisal in paper.

1.2 reinforcement pulp

Reinforcement is the practice of adding a long fiber component to the furnish of printing papers, as the paper is made.
Printing papers are made from short fiber furnishes. These impart many of the desirable properties to printing paper (notably smoothness and opacity), but have poor fiber bonding. Mineral fillers, used for the same purpose, have no bonding potential at all. The long fiber component assures that web integrity is maintained in the wire and press sections and coating stations of high speed paper machines. Without a reinforcing network from long fibers, the wet sheet would disintegrate in the wet phases of papermaking.

Reinforcement pulp is manufactured from softwood species. Softwood (conifer) species are the raw material source for long fiber pulp. Only bleached and semibleached softwood pulps are reinforcement pulps. Unbleached softwood pulp, or bleached long fiber pulp if used for packaging paper, is not considered reinforcement pulp.

The most common reinforcement pulp is northern bleached softwood kraft (NBSK). This is bleached long fiber sulphate cellulose from northern softwood species (Canada, Scandinavia). It has superior fiber bonding, tear and wet tensile properties. Semibleached long fiber cellulose is also used for reinforcement.
The premium grade is produced from slow growing softwood in the temperate forests of Canada and Scandinavia. This is mature wood, having *balanced* fiber properties, due to the prevailing climate, and produces a superior reinforcement grade pulp. Other grades of bleached softwood pulp are less suitable, but softwood radiata pulp is increasingly accepted for reinforcement. The papermaking properties of sisal pulp suggest that it is a suitable alternative to long fiber wood pulp.

The reinforcement practice is significant because half of the world's volume of long fiber pulp is used for reinforcing printing paper. The extent of reinforcement is readily recognised by reviewing the fiber furnish and paper production data (from *chapter 6*), summarised below.

The *total worldwide* production of paper is 321 million tons in the year 2000, and will reach 435 million tons in 2010. Total pulp requirements are 175 and 212 million tons respectively. This excludes recycled paper, which is expanding rapidly, from 114 to 179 million tons.
In the pulp segment, the long fiber pulp requirements expand modestly, from 75 million tons presently to 87 million tons in 2010.

million tons	*2000*	*2010*
bleached, integrated & market	38	44
unbleached, id	36	43
integrated, bleached & unbleached	53	57
market pulp, id	21	29

table 1.1 long fiber pulp volumes

The volumes of integrated and market pulp and those of bleached and unbleached pulp are summarised in *table 1.1*. Most bleached long fiber pulp is reinforcement pulp. It comprises integrated and market pulp.

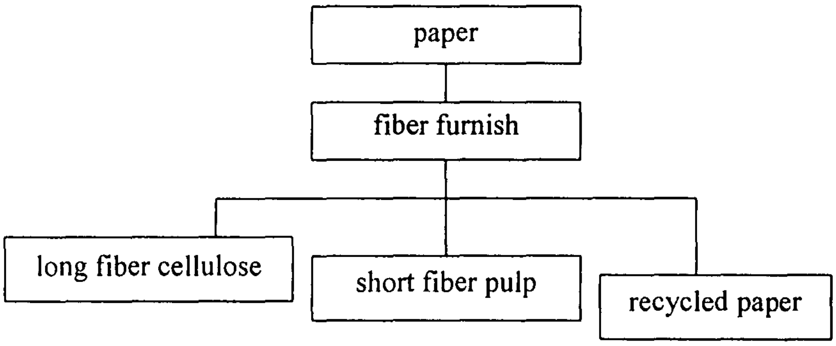
Integrated pulp is manufactured at the site of the paper mill where it is consumed. Evidently, it has a much lower price. For *our purpose*, we are interested in bleached long fiber *market cellulose* : the volumes are 19 million tons in 2000 and 24 million tons in 2010 (*table 6.7*). Within these target volumes, sisal reinforcement pulp would have to compete with the world market commodity NBSK.

As mentioned above, most reinforcement pulp is manufactured from nordic softwood species (*chapter 8*). There is speculation that softwood pulpwood may be in short supply in the future. If this happens, it reflects on the competitive position of sisal pulp vis-a-vis softwood pulp. Incidentally, this implies that we need to review the competitive prospects of other softwood resources and the plans for new softwood pulp capacities.

Paper producers around the world have been questioned concerning their use of long fiber and reinforcement pulp. The evaluation of their answers is presented in *chapter 9*.
The results reflect the outlook on reinforcement and the possible role of sisal pulp. In addition, mills were tallied on their willingness to cooperate on laboratory testing of fiber and pulp.

1.3 fibers for papermaking

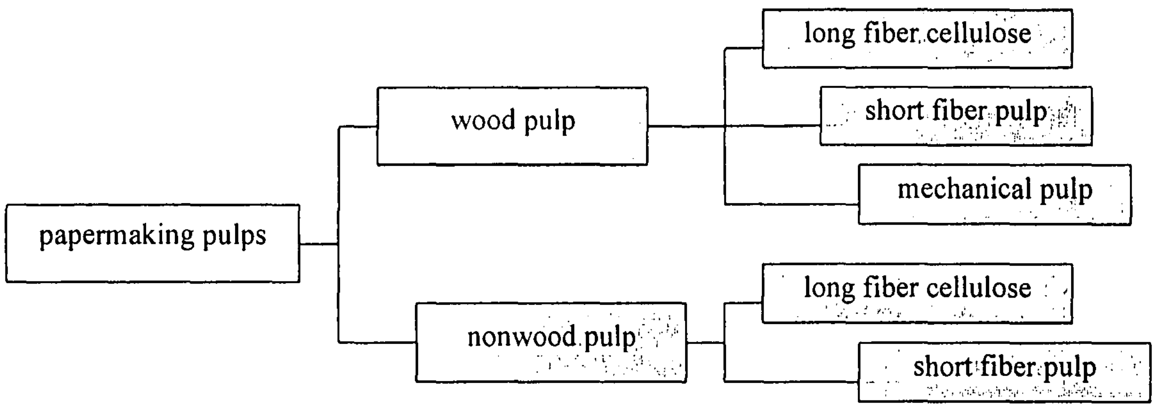
Paper is a complicated product, not the uniform material that it seems to be. It is, of course, made from one or various fiber types (*pulps*), but also contains papermaking and conditioning substances. Fibers and additives together determine the performance of paper. At the same time, performance and price are intimately associated. In practice, the properties (performance) and price (manufacturing cost) are always balanced. Cost is of major concern. In other words, the papermaker seeks to produce paper conform the required properties (market) at the least possible cost.



Fiber types (*pulps*) differ in fiber properties. Pulps for printing and packaging papers have contrary sheet properties. Printing paper requires opacity, a function associated with mechanical pulps and short fiber cellulose. The packaging functions are related to fiber length, intrinsic fiber strength and fiber bonding.

Only to a certain extent are pulps interchangeable. Nevertheless, fiber furnish variations may occur in seemingly the same product. Variations are legitimate in certain papers for reasons of cost, machine configuration, market and available raw material. As we shall see later, this is true throughout the industry, from the regional level down to individual mills. We will, for instance, find significant differences in paper composition between mills in North America and continental Europe.

Pulps can be distinguished in several ways : by fiber length, plant species (wood or nonwood plants), pulp process (mechanical pulp or chemical cellulose), virgin pulp or recycled (secondary) fiber. A major functional distinction is between short fiber and long fiber pulps.



Most pulp is manufactured from wood (*hardwood* or *softwood* species). Short fiber pulps are made from hardwood species. Softwood is used to produce long fiber cellulose (pulp). Cellulose is chemical pulp, either long- or short fibered. Mechanical pulp is made from softwood, but is considered a short fiber pulp. Nonwood pulp is usually chemical cellulose, made from annual plant species

About nine pct of worldwide pulp is made from short fiber *nonwood* species, for example straw. The specialty long fiber nonwood pulps (celluloses) are made from cotton, flax, hemp, abaca and sisal.

As mentioned, reinforcement pulp is *bleached softwood cellulose*, and used in the manufacture of printing paper. Packaging paper is made from long fiber pulp, not considered reinforcement pulp. Most long fiber pulp for packaging is unbleached kraft (some is bleached, although not reinforcement grade). It is usually made from other softwood species, not those that are most suitable for reinforcement grade pulp. Typically, premium reinforcement pulp is traded at premium price. Most pulp for packaging is integrated pulp. Of course, packaging paper is also made from recycled waste.

Paper waste (*secondary fiber*) has become an important source of fiber for papermaking, first of all in packaging but increasingly for printing paper also. Recycled paper will soon account for half the fiber balance in world paper.
The fiber properties in recycled paper tend to deteriorate, as re-use increases. The addition of a long fiber furnish improves the properties of recycled paper and can extend recycling. This application is another suggested use for sisal reinforcement pulp.

1.4 pulp and paper scenarios

A balanced fiber supply is essential for world paper production. Therefore, one of the early tasks in the market study has been to establish the fiber balances of worldwide paper for the time interval between 1980 and 2010. A shortfall in reinforcing pulp might provide a market opportunity for sisal.
Present and future fiber balances have been prepared from data, collected during the market study and assembled in an electronic database.
The database has been used to prepare basic (*most likely*) scenarios concerning future demand and supply of paper. Alternative scenarios are generated by feeding alternative assumptions (economic growth, technological change) into the model.

The paper statistics and fiber furnish profiles have been correlated for all the major paper grades. The resulting data show the pulp volumes in five year horizons between 1980 and 2010. The volumes are fully differentiated by fiber type, countries and regions. By this procedure, the present and future *required volumes* of reinforcement pulp are found.

The volumes of reinforcement pulp for the 2000 to 2010 period are taken and compared with the present and future *long fiber pulp capacities* throughout the world. Mill expansions and greenfield projects are assessed for their investment status, project progress, raw material availability and wood volume. The supply and demand situations of reinforcement pulp are obtained and shortfalls noted. Refer to *chapter 8.*

1.5 long fiber pulp supply and substitution of reinforcement pulp

From time to time, concern emerges that softwood resources may become scarce in the future. There are seemingly plausible arguments. Environment regulations are getting stricter and restrictions on forest exploitation are becoming more commonplace. Surely, the nordic coniferous forest reserves are finite, whereas the consumption of paper continues to expand. There may not be enough land reserve for radiata pine plantations. Or, is the *substitution* of softwood pulpwood by a nonwood long fiber source timely ?

Public opinion is supportive of forest conservation, certainly in some regions in North America but also in Europe. Substitution can sustain the forest conservation effort. Even if the required volumes of softwood reinforcement pulp seem to be assured well into the future, the question arises whether *some amounts* of softwood cellulose can be *substituted* by sisal pulp. The market study has reviewed the expertise opinion from paper producers concerning substitution in *chapter 9* and presents the conclusions concerning sisal in *chapter 10.*

1.6 replacing softwood reinforcement pulp

We will see that sisal cellulose has sheet properties that are superior to those in softwood pulp (*chapter 2*). For instance, sisal paper has better tearing resistance and wet web strength. In laboratory handsheets for instance, sisal cellulose can replace softwood cellulose in ratios 7 to 10 (*chapter 2*) for the same paper strength. Superficially, this suggests that sisal pulp is a suitable reinforcement pulp. It has been proposed that sisal cellulose can replace softwood reinforcement pulp in commercial papermaking in the same ratio.

However, some questions remain unanswered. There is a large body of experience about the reinforcement wood pulp in short fiber furnishes, on high speed paper machines. With sisal pulp, unfortunately, this information does not exist. The laboratory data are not suitable to predict the dynamic properties of sisal pulp in production practice. A commercial scale pilot run, to produce paper using sisal pulp for reinforcement, is an impossible undertaking. Therefore, whereas -in theory- sisal cellulose has excellent reinforcement properties, the substitution effect cannot be established with certainty, unless production runs are possible. Presently, the market study relies on expertise assessment, querying paper producers about their attitude on reinforcement, the limits of substitution. It analyses their responses (*chapter 9*), in order to draw conclusions on the possible role of sisal pulp as a reinforcement substitute (*chapter 10*). Prior to the queries and interviews, we have established the world and regional volumes of long fiber cellulose that are used as reinforcing pulp (*chapters 6* and *7*). A detailed database was established on paper and fiber furnishes throughout the world (*chapter 3* and *4*), which enabled us to obtain best possible estimates of the reinforcement pulp volumes in the future.

1.7 sisal pulp for specialty paper

Sisal pulp is too expensive for common paper applications. Besides, it is in limited supply. Specialty paper mills use sisal cellulose in some furnishes of some of their paper grades, but they do so to a limited extent. Sisal pulp is eminently suitable for porous, lightweight, wet strength, pliable, abrasive and bulk papers and tissue.

In the last decades, the worldwide use of sisal pulp for paper has continued to decrease. In the last several years, consumption has been stable around 14,000 to 16,000 tons. Sisal pulp is used by paper mills in Europe, North America and Japan, as a constituent in some specialty papers.

During the market study, specialty papermakers have been interviewed on their use of sisal and other nonwood pulps (*chapter 11* and *annex report six*).
Their reflections have been based on their perceptions about sisal pulp, meaning *conventional* sisal pulp (*chapter 2* and *11*). Very few operators have recognised the considerable potential of sisal cellulose by resorting to new technologies (*chapter 2*).

1.8 objective of the market study

The market study has focussed on applications of sisal cellulose in two areas of papermaking :

[i] reinforcement practice
[ii] specialty paper manufacture.

The *primary objective* of the market study is :

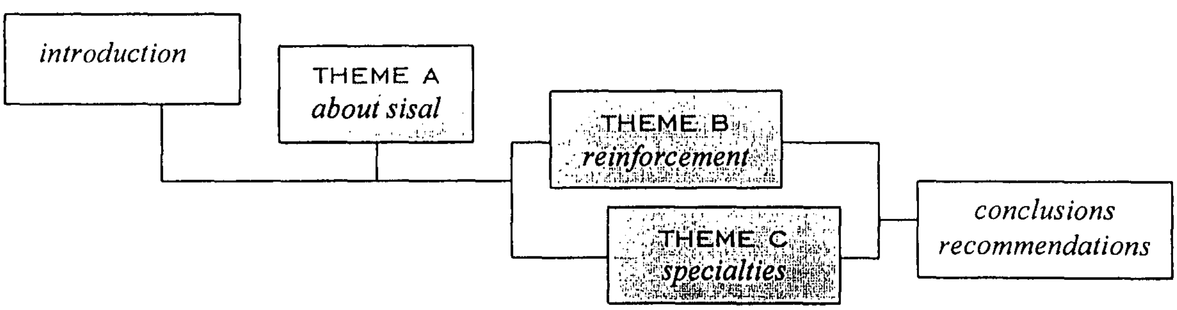
[iii] estimate the quantities of reinforcement pulp, used throughout the world
[iv] check production routines related to reinforcement practice
[v] verify acceptable cost for a reinforcement pulp substitute
[vi] analyse the possibilities to introduce sisal pulp for reinforcement in commodity paper mills in the affluent world

The *second objective* is to review the use of sisal cellulose in the specialty paper industry :

[vii] check the use of sisal pulp in specialty paper mills
[viii] review opinions on pulp cost
[ix] identify interest in sisal pulp
[x] tally mills that wish to cooperate in sisal research

1.9 set up of this report

The report is organised in three themes. The common underlying question in all three is : where, in the manufacture of paper, will sisal cellulose be employed to best advantage ? The themes are summarised in the paragraph that follows.



1.10 route planner through the report

THEME A	in chapter 2

A synopsis of published data on sisal pulp properties is presented. Some of the cost-related factors of fiber growing, fiber processing and pulp manufacture are analysed. The prices of fiber and sisal pulp are reviewed.
Process routes are indicated that may improve price and pulp specifications simultaneously. Some confirmative laboratory research is required, before the *second phase* of the market study can be implemented successfully. Half of the interviewed specialty papermakers are interested in testing fiber and pulp samples.

The analysis and conclusions on sisal fiber and -pulp are presented in *chapter 2.*

THEME B	*reinforcement*	*in chapters 3 to 10*

The *primary objective* of the market study is to establish the reinforcement pulp volumes in world paper and review the potential of sisal pulp to replace softwood reinforcement pulp in large scale paper manufacture. The reference standard in reinforcement pulp is northern bleached softwood kraft : bleached long fiber cellulose from temperate softwood species.

The reinforcement pulp volumes have been established by an elaborate procedure, interpreting paper statistics and fiber furnish profiles, using a software program. The outcome is the volume of reinforcement pulp for the years 1980 to 2010, corresponding to paper production in the same period.
The comparison with present and projected new capacities in long fiber pulp will reveal whether reinforcement pulp will be in short supply in the future.

The next question is whether sisal pulp can replace or complement the commonly used softwood reinforcement pulp, even if future supplies are assured. This issue has been analysed by queries and interviews with paper producers and by expertise assessment.

The study has followed three approaches [i][ii][iii] :
[i]
The volumes of softwood reinforcement pulp *in the past* were determined from paper statistics and fiber furnish information. The *projections* for 2000/2010 were determined in the same way, using best available forecast estimates for the national economies.
The expansions in pulp capacity are shared between existing mill expansions and greenfield mills. They are compared to the incremental volume of reinforcement pulp demand.

sub [i] The approach to statistics is explained in *chapter 3*. The method of forecasting is revealed in *chapter 4*. Results from forecasting for the North American region are presented as an illustration of the procedure.

The statistics on paper (*chapter 5*) are dissected to determine their fiber furnish profiles and pulp volumes (*chapter 6*) in detail. The pulp profiles are analysed by grade (*chapter 6*) and geography (*chapter 7*). Paper in Africa and in developing countries is considered separately (*par 7.9 to 7.13 ; par 9.10*).

Reinforcement pulp is analysed by status and market share, present and future, in *chapter 6.* Integrated and market pulp are treated separately. The requirements for reinforcement market pulp have been analysed in detail for each of the major paper grades.

A discussion on fibrous raw material resources for reinforcement and on the pulp itself follows in *chapter 8*. Reinforcement pulp and the fibrous raw materials are discussed from the viewpoints of availability and cost. Price series of softwood market pulp for the period *1970 to 1999* are reproduced.
The *production cost structure* of softwood reinforcement pulp is illustrated by the individual profiles for all the market pulp mills worldwide (*graph 8.3*). It illustrates the position of mills and producer regions and will help to consider sisal pulp in the proper perspective.

The present and future pulp demand and -supply situations of reinforcement pulp are presented. The additional volumes of pulp for the 2000 to 2010 period are determined. The incremental pulp volume is compared to the capacity increases for the same period.

[ii]
Paper mills have been queried on reinforcement practice. Their habits and attitudes have been charted (*chapter 9*), and the responses have been statistically evaluated. Questions on reinforcement pulp and the possibilities to replace it with sisal pulp have been highlighted. Interviews were held with key respondents to clarify unanswered viewpoints.

sub [ii] The questioning procedure among paper mills is explained in *chapter 9*, where the results from queries are also discussed and a statistical evaluation is presented.

[iii]
Expertise assessment has been solicited from consultants in North America and Europe concerning reinforcement practice, involving fast running paper machines and large capacities. In these situations, reinforcement is most exacting. A comparison of practices between the regions is presented, and the outlook discussed.

sub [iii] The expertise assessment on reinforcement is presented in *chapter 10*. The possible role of sisal reinforcement pulp is discussed. The procedures and results have been presented in detail in *annex reports two* and *four*, issued separately.

THEME C	*specialty paper*	*in chapter 11*

The *second objective* in the market study is to analyse present and future user' attitude among specialty paper makers concerning sisal pulp. The queries and interviews were conducted in Europe, North America and Japan. It was evident from the onset that the response from specialty mill respondents would be highly specific and restrained.
There were many surprisingly frank and positive responses from the paper mills. Mills were also asked to express their interest in follow-up evaluations. The responses have been recorded in the present report. The response tallies are in *annex report five* and *six*, issued separately.

The discussion and results are represented in *chapter 11*.

1.11 conclusions and recommendations

The market study was originally conceived to be carried out in three phases. Phase one is the survey on *present and possible use* of sisal pulp in paper mills. This report reports on *phase one* of the market study.
Phase two is about experimental evaluations of sisal fiber and -pulp, carried out by cooperating paper mills.
Phase three concerns pilot production of fiber and pulp. It proposes to check the commercial applicability of sisal pulp for paper manufacture.

A pre-feasibility analysis on sisal pulp manufacture is part of the sisal project. The information, collected during the market study, will help to establish the terms of reference.
The *phase one* market study has been carried out ahead of the laboratory research on fiber extraction and pulping (completed in late *1999* in *Wageningen, Netherlands*). It is unfortunate that the results from *Wageningen* were not available during the *phase one* market survey. According to the project outline, *phase two* of the market study encompasses laboratory testing of sisal fiber and pulp. Paper mills will be selected from among a group of mills that have expressed such interest during *phase one*. The current market study has identified paper mills for the *phase two* research (*annex report six*). Unido will coordinate the testing and monitor the results. The amounts of fiber and pulp (*the samples*), needed for this task, have been identified.

The results, summary and recommendations of the *phase one market* study are presented in *chapter 12*.

1.12 final report and annex reports

1.12.1 draft market report

The draft market report (*ver 3.1*) was discussed with associates in the first half of 1999. Draft *version 3.2* was issued to Unido in july 1999, to solicit comments and observations from project participants.

A complex study such as the present analysis was expected to arouse manifold and controversy reactions from a good many experts in the field of agriculture, fiber production, processing, and papermaking. Following the issue of the draft reports, their comments and observations were evaluated and used in the revision of *ver 3.3 of* the report.

An ongoing activity among associates is the analysis of market related information in the areas of specialty pulp and paper. Other continuing activities are related to research on fiber extraction techniques, new process technology, generation of energy from waste and the energy balances in fiber processing. This research supports the quest for identifying cost effective applications of sisal pulp in specialty paper manufacture.

The previous comments from project participants suggested that a more readable account of the survey would be helpful in focussing the understanding of sisal industry experts on the complex situation concerning sisal and paper. A re-issued report would also include additional information, generated since mid 1999.
In the last quarter of 2000, it was decided to update and re-issue the market report. The re-issued market report *ver 4.2* was sent to contributing associates for comments in march 2001.

1.12.2 re-issued market report and annex reports

The present market report *version 4.4* was distributed among associates in may 2001 and was ready to be submitted to Unido in june 2001.
The *annex reports one to five*, submitted in 1999, include the results and discussions on various aspects of the market survey and were not re-issued.
The *annex report six*, originally issued among associates as *versions 1.1* to *1.4*, was re-issued as *ver 2.2* (restricted), discussed internally and scheduled to be transferred to Unido in june 2001.

1.12.4 acknowledgements

The editors take this opportunity to express their gratitude for the many expressions of interest from many knowledgeable experts in the industry. Their frank observations have been instrumental in helping to shape the present report and chart the outlook for future research on the use of sisal for paper.

THEME A

chapter 2 sisal pulp production factors, a synopsis

overview	Synopsis of published data on sisal pulp properties. Assessment of cost-related factors for growing sisal, for fiber processing and for pulp manufacture. Improved process technology brings better pulp properties and optimises the production cost of fiber and pulp at the same time.

2.1 introduction

A meaningful analysis of the potential of sisal for paper should begin by overviewing the paper scene. The world production figures provide a suitable starting point : *table 2.1.*

The *total* world production of paper (*all countries*) was 321 million tons in the last year. And 308 million tons of fiber (pulp *plus* recycled paper) are required to produce the paper.
The problem with such information is that it is insufficient for our purpose of identifying where sisal pulp can be used to best advantage. When one descends into more detail, the game stops.

We have, therefore, chosen a universe of papermaking countries (*the database*), representing the affluent world, about which detailed information on paper can be collected (*chapter 4*). The universe consists of the 30 most important papermaking countries in the world. These produce 94 pct of world paper volume. Therefore, *our world volume* of paper is 301 million tons (*chapter 5* presents detailed figures), and the fiber balance is 289 million tons.

table 2.1 paper and pulp statistics

year 2000	*million tons*	
paper production	321	*entire world*
fiber balance	308	
paper production	301	*database 30 countries*
fiber furnish	289	
total pulp	175	
recycled paper	114	
included in total pulp		
long fiber cellulose	75	*database*
-unbleached pulp	36	
-bleached cellulose	39	
included in bleached cellulose		
integrated pulp	20	*database*
market pulp	19	
sisal pulp	0.014	

The fiber balance includes 175 million tons of pulp and 114 million tons of recycled paper. The pulp volume includes 75 million tons of long fiber pulp, of which 39 million tons is bleached pulp. Unbleached pulp is 36 million tons. Integrated and market pulp hold equal shares in the volume of bleached pulp, respectively 20 and 19 million tons.

Almost all bleached long fiber pulp is reinforcement pulp, 38 million. Reinforcement pulp is *bleached long fiber cellulose*, produced from softwood species, preferably those of the northern temperate zone. It is an essential fiber furnish component in most printing papers, especially coated papers or papers containing mechanical pulp and mineral filler. The reinforcing fiber component assures runnability on fast, modern paper machines.

table 2.2 statistics on sisal fiber production

sisal and henequen		**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
	world production	***379,215***	***398,743***	***379,622***	***427,470***	***389,840***	***314,102***	***326,253***	***318,836***	***297,686***	***339,150***	***293,033***	***379,970***	***368,706***
Africa	Angola	1,000	1,000	1,000	1,000	500	500	500	500	550	600	650	500	500
	C Afr Republic	260	270	275	280	285	290	300	300	300	300	300	320	325
	Ethiopia	830	840	840	800	800	800	800	800	800	800	800	800	700
	Guinea	120	120	120	120	120	130	130	130	130	130	130	130	130
	Kenya	36,900	37,319	39,617	38,800	34,100	35,100	33,900	27,810	28,100	28,188	27,000	26,000	25,000
	Madagascar	19,500	19,955	20,000	15,000	10,000	18,000	17,200	16,300	17,000	18,000	18,000	17,000	15,000
	Malawi	100	100	100	100	70	100	70	80	100	90	100	100	90
	Morocco	1,600	1,700	1,800	1,900	2,000	2,100	2,200	2,200	2,200	2,200	2,200	2,200	2,200
	Mozambique	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
	South Africa	7,500	5,164	4,264	4,084	3,010	2,666	2,889	2,672	2,700	2,700	2,600	2,500	2,600
	Tanzania	33,268	32,265	33,743	35,662	24,309	30,500	25,500	32,000	23,000	25,000	15,000	24,000	22,000
Asia	China	16,510	20,411	30,030	28,482	29,010	38,868	40,855	43,442	27,882	38,363	36,952	38,000	34,000
	Indonesia	450	480	506	546	527	300	450	450	450	450	450	450	450
	Thailand	65	65	65	65	50	50	40	40	35	35	35	35	38
Latin America	Brazil	189,654	221,231	185,083	233,721	204,227	126,076	131,421	118,066	129,247	137,887	115,882	194,157	195,313
	Cuba	6,629	6,731	6,700	6,700	6,700	6,700	6,700	6,000	6,000	6,000	6,000	6,000	6,000
	Dominican Rep	198	208	210	225	235	235	226	206	436	397	400	256	260
	Haiti	10,000	10,000	10,000	10,000	9,000	8,500	8,000	7,000	5,660	5,700	5,660	5,700	5,700
	Jamaica	300	300	300	300	300	300	300	300	300	300	300	300	300
	Mexico	45,805	31,248	35,156	35,650	48,712	35,387	35,969	43,100	37,000	57,010	45,870	46,000	46,000
	Venezuela	7,526	8,336	8,813	13,035	14,885	6,500	17,803	16,440	14,796	14,000	13,704	14,519	11,500

other hard fibers		**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
	world production	***58,253***	***65,407***	***63,791***	***77,998***	***59,804***	***65,864***	***67,230***	***59,679***	***64,047***	***67,100***	***54,955***	***54,218***	***56,718***
Asia	Philippines	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,800	4,000	4,000	4,000	4,000	4,000
Latin America	Colombia	23,900	23,980	21,610	35,080	21,678	23,054	21,353	29,149	33,416	35,570	23,125	22,268	22,268
	Cuba	11,900	12,000	12,000	11,500	11,500	11,500	11,500	11,500	11,500	11,500	11,500	11,500	11,500
	Ecuador	3,448	3,571	2,141	3,173	2,426	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200
	El Salvador	7,511	8,556	9,140	9,145	9,900	9,800	9,057	1,000	891	980	980	1,000	2,500
	Guatemala	294	100	100	100	100	110	120	130	140	150	150	150	150
	Mexico	4,600	10,500	12,000	12,100	7,200	12,000	15,700	8,000	8,000	8,700	9,000	9,000	10,000
	Nicaragua	3,100	3,200	3,300	3,400	3,500	3,700	3,800	3,900	3,900	4,000	4,000	4,100	4,100

annual production figures in thousand air dry metric tons - faostat 2001, officially published statistics
group one : sisal and henequen
group two : fibers from botanically related and from comparable species : aloe, cabuya, caroa, doum, letona, maguey ; fique, phormium, other

Softwood reinforcement pulp and sisal pulp have many similar properties, such as fiber length, aspect ratio, interfiber bonding ability, wet sheet strength and so on.
This returns us to the subject of sisal pulp. The primary objective of the market study is to examine whether some of the reinforcement pulp volume can or should be replaced by sisal pulp, or whether some of the incremental volume should be so supplied.

Just by the simple comparison of the world volume of reinforcement pulp and sisal fiber production (*table 2.2*) or sisal fiber prices (*table 2.3*), it is obvious that the two (sisal and reinforcement practice) are ill-matched companions. The present use of sisal pulp for specialty paper manufacture offers a limited prospect as well.

A different perspective, however, is conceivable if the production factors of fiber and pulp are drastically changed (*paragraph 2.7 and chapter 12*). The technical and research approaches are understood well enough (*ibidem*) and process routes exist, but need to be explored. In all cases, the central question remains the same : to identify and evaluate the value added applications of sisal pulp in paper manufacture.

2.2 sisal pulp : present use

The amount of sisal pulp, consumed in the manufacture of paper worldwide, is very limited. The annual fiber volume is just 29,000 tons, equivalent to 16,000 tons of sisal pulp. This amount of pulp is insignificant, compared to the 308 million tons in the fiber balance, required to produce the 321 million tons of paper of the year 2000 (*table 2.1*). In contrast, the significance of sisal for specialty paper manufacture is far greater (*paragraph 2.3*).

In the affluent world, sisal is not used at all in the production of mass commodity paper grades. Nevertheless, it has been proposed as a reinforcing (*long fiber*) component in such paper (*this project, this survey*).

2.2.1 sisal fiber use for common and semi-specialty paper

Sisal is used so little because it is too expensive for most paper. Besides, it is in limited supply. Sisal prices in the last several years have been between 1,400 and 2,800 dollars per ton. This compares with softwood NBSK in its price range of 480 to 680 dollars for the same period (refer to *chapter 8*).

On the other hand, sisal pulp is a useful component in common paper manufacture in some developing countries. If mills use sisal, there are exceptional circumstances.

There are, for instance, countries where coniferous cellulose is unavailable or simply too expensive. Where sisal is grown and processed locally and sisal waste is available, the use of it (be it waste or lower grades) for pulping can be cost effective. Certain mills in India, China and Brasil appreciate sisal pulp as a reinforcing papermaking component. A case in point is the manufacture of printing paper from straw pulp.

A few examples may illustrate the extent to which sisal is presently used in developing countries for papermaking : as a component in common paper grades, replacing softwood pulp.

In Brasil (in Pernambuco, where sisal is grown), there is a paper mill where sisal fiber is processed into pulp and used as a furnish for multiwall (cement) grade paper. Some other paper mills, also in Brasil, use sisal pulp (purchased) for higher value added semi-spec papers.
In China, sisal is reported to be elaborated and used in four integrated common paper mills ; formerly there were many more where sisal or comparable nonwood species were used. Effluent regulations have forced the closure of many of these. A handful of mills in China

remain, which produce paper from sisal pulp, although these concern semi-spec papers.
In India, some paper mills produce sisal pulp for fine and specialty but also common grades.

2.2.2 *sisal fiber production statistics*

Sisal fiber production statistics are shown in *table 2.2.* The worldwide production of sisal (including comparable hard fibers) was 434,000 metric tons in 1999. Representative fiber price data are shown in *table 2.3.*
A comparison of sisal fiber prices with softwood pulpwood prices will be made in *chapter 8.*

table 2.3 sisal fiber prices

annual average		*1980*	*1981*	*1982*	*1983*	*1984*	*1985*	*1986*	*1987*	*1988*	*1989*
east african	3L	787	687	623	638	651	619	613	612	643	710
east african	UG	765	644	593	571	583	525	513	512	540	651
brasilian	nr 3	657	628	566	484	486	442	442	437	490	511

annual average		*1990*	*1991*	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*
east african	3L	735	667	509	668	772	776	976	925	965	871
east african	UG	705	639	479	616	654	721	870	781	823	688
brasilian	nr 3	531	400	370	451	542	582	660	647	578	528

monthly average		*2000*	*jan-jun*	*jul-dec*	*2001*	*jan-jun*
east african	3L		773	800		*n.a.*
east african	UG		619	650		*n.a.*
brasilian	nr 3		436	450		*n.a.*

us dollars per air dry metric ton cif european ports

2.3 *sisal pulp and other specialty nonwood pulp producers*

2.3.1 *specialty cellulose*

Nonwood long fiber specialty pulps are made from cotton, cotton linter, hemp, flax, kenaf, sunn hemp, jute, abaca and sisal fibers. The pulps are not just 'pulp' ; they are chemical celluloses with exact specifications, high quality and price.
Most demand for specialty pulps comes from paper mills in North America, Japan and Europe. Although some pulp is produced by integrated mills, most is market pulp, manufactured in dedicated pulp mills and sold to specialty papermakers.

2.3.2 *specialty pulp mills : size of operations*

Cotton linters pulp mills in North America and Europe are large scale operations, producing a single market commodity : cotton linters cellulose. Elsewhere, in developing countries, even cotton linters pulp mills are small in size.
In contrast, other nonwood pulp operations are invariably of small size. Their size testifies to the incidence and pulp volumes which paper mills require. Nonwood specialty pulps -except cotton linters- are produced in dedicated pulp mills. These are of small size, integrated or not with paper mills.

2.3.3 *specialty paper mills*

Many specialty paper mills nowadays consume only chemical wood pulps. Other paper mills, however, remain where specialty nonwood long fiber pulps are used. Such pulp is made from long fiber plant species, for example abaca, sisal, hemp, flax or other species.

There is a characteristic differentiation in the nature of specialty paper mills. They elaborate *either* cotton content papers, *or* they use other specialty pulps. Paper mills where cotton based pulp is consumed do not use other nonwood pulp. Paper mills, which use nonwood cellulose, use either cotton or other nonwood pulp. Another characteristic : paper mills that use specialty pulp are specific in their choice. They will not substitute pulp from other fibers (*chapter 11*).

Formerly, specialty paper mills would elaborate their own specialty pulp. Nowadays, few integrated specialty paper mills remain. Most integrated specialty pulp capacity has disappeared. Specialty paper mills in Europe and North America purchase their nonwood long fiber pulp needs. More than 70 pct of the nonwood long fiber pulp volume is market pulp.

Japanese specialty paper mills -they are quite a few in number- were the first to switch to purchasing their long fiber specialty pulp needs : *abaca* and *sisal* pulps. Mills in North America and Europe have followed.
Even so, certain paper mills continue to produce their specialty pulp requirements *in house*. The annual production in the remaining integrated specialty paper mills, which produce sisal pulp, is less than 6,000 tons.
They produce highly specialised grades of paper. They purchase raw fiber and process it to exacting standards. These mills are highly specialised, producing filter, tea bag, sausage casing or cigarette, condenser, tissue or light weight printing specialty grades. A treatise on specialty pulp and specialty paper is outside the scope of this report.

2.3.4 nonwood long fiber specialty pulp manufacture

Nonwood specialty pulp mills are capable of processing various nonwood fiber plant species, even if they are customarily confined to one species. Some market pulp mills, for instance, where abaca is processed, will elaborate sisal fiber in occasional quantities. Other specialty pulp mills habitually produce pulp from various plant species to customer specifications.

Many specialty pulp mills were phased out in the last decades, when strict effluent controls became established. Small size integrated pulp operations in North America and Europe were especially affected. In the same time, there were developments in technology and market aspects, which affected demand for nonwood specialty pulp. There was a gradual decline in the demand for such cellulose, which ran in parallel with the closure of integrated pulp capacities.

It was realised that paper products were often *over-engineered* in properties ; hence *too expensive*. As the quality standard was brought closer to *'just acceptable'*, wood cellulose would often suffice to meet market requirements. Change in technology was helpful inn setting the trend towards using less expensive wood pulp. For common and specialty papers alike, the trend was to use more wood pulp and less specialty pulp. Presently, this trend continues, driven by the search for more cost effective fiber formulations. This observation is significant in assessing the potential of sisal pulp for the future ; refer to *paragraphs 2.7* and *2.8*.

While the changes took place and many small operations were phased out, certain dedicated specialty pulp mills have modernised their operations and became established producers of specialty market pulp. As will be suggested later, there is ample opportunity for additional improvements in the production and processing of sisal fiber and other specialty fibers.

2.3.5 specialty market pulp mills

At present, there are 22 specialty nonwood *market pulp mills* in operation throughout the world. By far, most capacity is in linters pulp. Half of the 22 mills, including all the large ones, are dedicated cotton or cotton linters pulp mills. A few mills are smaller size and produce cotton pulp from textile waste. The remaining nine or ten pulp mills are small size operations and produce nonwood long fiber pulps, other than from cotton.

There are four pulp mills in the world where sisal cellulose is produced for the market more or less regularly. Just two, in Tanzania and Brasil, are exclusive producers. Two sisal pulp mills in Kenya are idled.

There is one market pulp mill in Europe (in Spain) which produces long fiber nonwood pulp from different species regularly : flax, hemp, kenaf, abaca and sisal. One of the three abaca pulp mills (formerly five) in the Philippines manufactures occasional quantities of maguey pulp (maguey is a fiber plant species similar to sisal, ref *par 2.4*).

One dedicated pulp mill in Brasil produces sisal market pulp. The mill in Tanzania produces paperboard (from wood and waste) for the internal market, and sisal pulp for export. It was idled for some time but is again producing.

A *sisal market pulp mill* was in operation in Brasil for some time, 1981 to 1986. In 1970, a modern *large scale* sisal market pulp mill in Brasil was proposed. It was given prominence when the world energy crisis in 1974 affected the Brasilian economy rather badly. The idea was to produce long fiber pulp for export, but also to support the national paper industry, which relies heavily on domestic eucalypt (short fiber) pulp. The mill would produce long fiber *reinforcement* cellulose for both markets. The mill would be built in Bahia and supplied from sisal plantations in the interior. There were delays, due to financing difficulties, but the mill came into operation in 1981. In the five years that followed, the mill experienced various problems. One of the defaults was that the supply of raw fiber was not cost effective, nor assured. It ceased operation in 1986, and converted to wood pulp in 1987.

2.4 a future for sisal cellulose ?

Sisal fiber is obtained by decorticating. Decortication is the fiber extraction process, by which line fiber is produced. Sisal products are elaborated from conventional line fiber, *fiber strands*. Fiber strands are the composites of individual fibers. Fiber strands are 20 to 160 cm long. They are graded according to length and color. UG grade and combings, may be even shorter.

In contrast, the individual fibers in leaf tissue are 3.0 to 3.2 mm length on average, largely comparable to softwood fibers in temperate coniferous wood species. The fibers are bonded together, a.o. by intercellular pectin, and form the fiber strands.

Although an excellent raw material for paper (*paragraph 2.5*), we will see that sisal fiber is not cost competitive, compared to softwood (*chapter 10*).
The fiber content in softwood pulp costs 120 to 260 dollars (*graph 8.1*), against 600 to 1,040 dollars in sisal pulp. The scale dis-economies in pulping contribute further to the price gap between sisal and softwood pulp.
The result is that sisal *pulp* is four times more expensive than reinforcement wood pulp : 1,800 to 2,800 dollars per metric ton, compared to 600 dollars for wood pulp.

As a fibrous raw material for paper, line fiber is *over-engineered* in fiber properties from the papermakers' viewpoint.
For this and other reasons, specialty pulp and paper makers prefer to use the lower grades of fiber, and waste. However, availability is limited because the decorticating technique is focussed on producing higher priced grades. This sets a limit on the output of lower priced fiber. The lower grades of sisal fiber are the by-product of line fiber.
Besides, sisal waste and lower grades are used for a variety of products that compete with paper for any available raw fiber stock. There is no fundamental relationship between the prices of line and waste fiber. The price difference is arbitrary, determined by market

momentum. But even at 300 dollars for flume tow (the lowest waste grade), sisal is out of reach for ordinary paper.

Sisal waste is mechanically *and* chemically more disintegrated. This is due to the nature of the decorticating process. As a surprise consequence, waste is more suitable for pulp manufacture. On the other hand, waste -flume tow in particular- is subject to some over-deterioration as it is being recovered.

For cost and other reasons, most sisal specialty pulp is manufactured from lower grades of line fiber : for example UG, combings, or # 3. In other words : paper makers are familiar with a standard quality of sisal pulp, which is made from lower fiber grades (or from waste), and pulped and bleached by conventional processes, which further erode the native properties of sisal fiber. We will examine some possible approaches to production economy and process technology, to identify ways and means to improve the situation (*paragraphs 2.6-2.7-2.8*).

2.5 sisal fiber and pulp properties : review of published information

2.5.1 botany

In many fiber bearing *Monocotyledoneae* species, the leaves are oblong and contain elongate sclerenchyma cells (*fibers*), that envelop the conductive tissue and support the leaf structure. In contrast to the bast fibers of *Dicotyledoneae* species, the sclerenchyma fibers are more highly lignified. In the trade they are distinguished as *hard fibers*. The commercially important fibers are obtained from species in the *Agavaceae* and *Liliaceae* plant families. Agave species are native to Mexico and Central America.

The plant family Agavaceae includes 20 genera with 600 species. The commercially important fiber bearing species are Agave sisalana, A. amaniensis x angustifolia (*H 11648*), A. four-croyides (*henequen*), A. cantala (*maguey*), A. letonae ; Furcraea foetida (*mauritius hemp*), and F. macrophylla (*fique*). Hesperaloe funifera and H. nocturna are frost resistant species.

Another fiber bearing species, comparable to sisal in fiber properties but different botanically (hence an interesting species for fundamental research on pulping), is Phormium tenax (*new zealand flax*), belonging to the Liliaceae family, grown in Australia.

2.5.2 published information on sisal pulp [a]

References about sisal in the literature of the last forty years are scanty. A general search on *sisal* produces a number of references on agriculture, but none on paper. This subparagraph is limited to meaningful references on sisal in relation to pulp and paper.

The standard work on sisal by Lock (1962) is a useful introduction to sisal, although it is now dated. It provides a useful account of the situation in East Africa at the time. Unfortunately, the book has only one or two references about sisal for paper [1].

Thirty or forty years ago, research on nonwood fibrous raw materials for papermaking was en vogue in countries like India and the Philippines. In the pursuit of self-sufficiency, many government sponsored institutes would carry out programs on laboratory pulping and paper testing, probing all the various fiber species indigenous or compatible in the countries concerned. Numerous nonwood fiber plant species were analysed in view of their possible usefulness for papermaking. Their pulping characteristics would be investigated in minute detail ; their handsheet papermaking properties tested likewise. The investigation would follow the conventional approaches of soda, sulphate or sulphite cooking, semichemical and

[a] *references at the end of this chapter*

mechanical pulping. Scores of articles have been published, reporting the laboratory aspects of pulping and testing reported. Among these, reports on sisal and comparable fiber are also found. See for instance *ref* [2].

table 2.3 fiber dimensions and chemical analysis of sisal fiber

fiber properties	*unit*	*average*	*range*
fiber length	mm	3.21	1.9-5.4
fiber width	micron	19	

chemical analysis		*average*	*range*
solubles	cold water	2.7	
idem	benzene/alcohol	1.9	
ash		0.6	0.5-1.1
lignin		8	7.6-9.2
holocellulose		88	
a-cellulose		60	44-62
cb cellulose		72	65-73
pentosans		18	17-24

tappi standards
ref [2][3][4]

table 2.4 representative pulp cooking and bleaching data

item	*unit*	*cook 1*	*cook 2*	*cook 3*		*commercial production*	
				average	*range*	*average*	*range*
caustic soda	*pct*	15.5	15	13.5	12-16	14	13 - 15
anthraquinone	*pct*			0.1		0.1	
oxygen		yes					
liquor ratio				3		3	
temperature	*centigrade*		168	1687	168-173	173	168-173
time	*min*			140	120-160	120	120-180
pulp yield	*pct*	68	67	64	61-68		64 - 68
kappa	*ml*	19	12	12	10	10	
unbl. viscosity	*cp*		34				
bleaching	*tcf*						
brightness	*iso*		87				
bl. viscosity	*cp*		16				
a-cellulose	*pct*		95				
csf	*ml*			600		600	

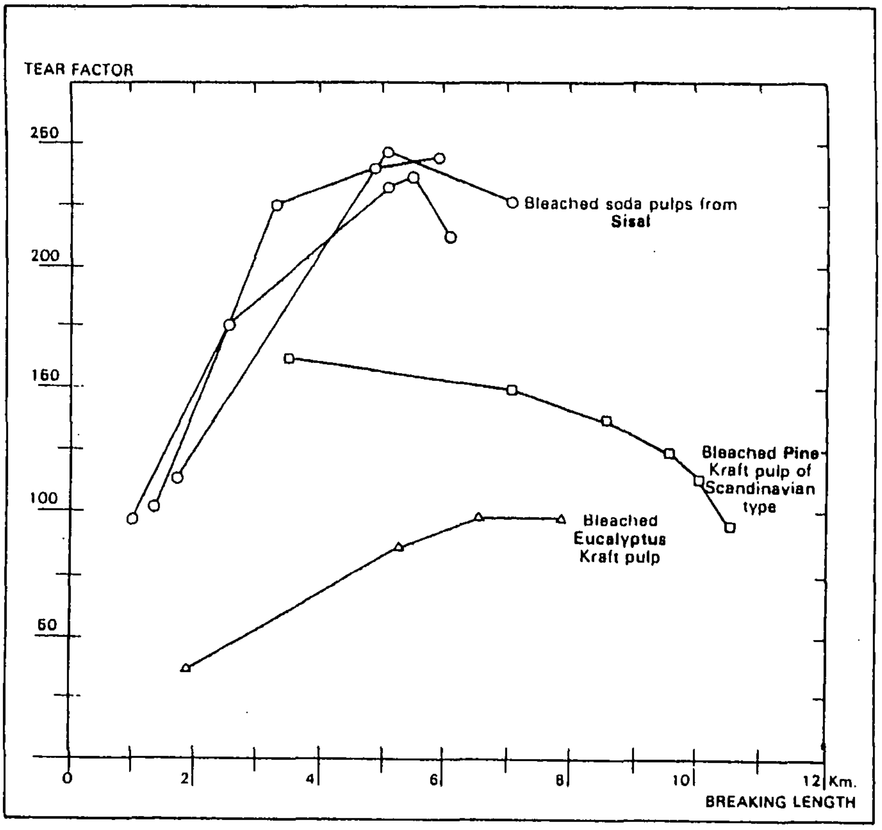
representative results from ref [2][3][4]

table 2.5 representative beater curves of sisal cellulose

measurements		*cook 2 experimental pulp*				*cook 2 experimental pulp*				*commercial pulp*	
ref table 2.4	*unit*	*never dried*				*dried once*				*dried*	
pfi rev	#	0	750	2,500	4,500	0	750	2,500	5,000	550	3,000
freeness		600	550	450	325	625	565	486	385		
burst	*gf.cm.m2/g*	27	42	60	76					52	80
tear	*100 gf.m2/g*	236	320	260	198	190	266	310	220	326	273
tensile	*km*	4	6	8	10	3.5	5.2	7.2	9	6.7	9.4
stretch	*pct*	2.6	4.1	5.2	6.4	2.3	3.4	4.7	5.9	4.1	4.7
mit fold	#									5.1	230
bulk	*cm3/g*	2	1.7	1.6	1.5	2.2	1.9	1.7	1.5	1.96	1.7

tappi methods

graph 2.1
tear tensile relationships



ref [4]

By hindsight, we are now able to recognise the limited usefulness of this research. Their results are largely unrelated to industrial practice or production economics. The emphasis has shifted from routine laboratory analysis to feasibility and cost effective production technique.

There are some conclusions that can be drawn even now. Those early investigations are of academic interest, although compatible with present thinking about sisal pulp. However, they hold no promise on the potential of sisal for paper (*paragraph 2.7*). Nothing remarkable is reported on process technology, nothing useful on sisal feasibility. No fundamental clues are given on the approaches to sisal pulping in the future.

Progress reports of the *Nonwood plant fibers committee* of the North American Tappi organisation is the annual series of conference papers in North America on nonwood pulp and paper aspects. The conferences, held annually, were initiated by Atchison. in 1970.
Since the inception of the *committee*, two publications on sisal, or containing some relevant information on sisal, were published in the *Progress reports* [3][4].

In the paper trade press, one article on sisal appeared in 1979 [5]. An early unpublished review is *ref* [6].

Not long ago (in 1997), the results of laboratory pulping were published by Hurter [7], following the completion of their feasibility study for the Tanzanian Sisal Authority in 1993, for which the research was commissioned. The articles include experimental results on chlorine free bleaching.
It is unfortunate that the pilot runs on sisal pulping, as reported, were just larger scale laboratory cooks, not the pilot size runs that are necessary for the process and engineering designs of a production pulp mill, in the uncharted territory of industrial sisal pulping.

A patent [8] on pulping and fiber use of a plant species, related to sisal, was issued in 1993 in

North America. It refers to tissue making and reinforcement with nonwood long fiber pulp ; *ref* [9][10] in that context. Another recent reference is [11].

The Bahia (*Brasil*) sisal pulp mill was originally proposed in 1970, implemented from 1975 onwards and on stream in 1981. The process and engineering designs for the mill were supported by considerable research effort, carried out between 1970 and 1978 (*unpublished*). Most of it was pulping and evaluation of sisal on the laboratory scale ; some were paper machine trials. Pulping was carried out in Brasil , Finland and Sweden. The paper reinforcement properties of sisal pulp were evaluated in Finland, without, however, considering cost implications. Review articles on the Bahia mill were published later [3][5].

The sisal pulp and paper mill in Jabotao (Recife, PE) was expanded and modernised in 1972-1974. Pulping research on sisal and mixed tropical hardwoods was carried out by brasilian and dutch consultants in 1973, to support the design and engineering for the expansion. The research results were not published [12]. The rebuilt mill went on stream in 1974.

On six occasions, feasibility and subject (pre-feasibility) studies on sisal pulp were prepared for entities in Tanzania and Kenya (1966 through 1993). None of these were published, but *ref* [13] mentions recent feasibility study for the Tanzanian Sisal Authority. As mentioned above, the research results for this feasibility study were published later [6] in two papers.

Other studies of a more occasional nature on sisal pulp and paper have not been referenced. Prefeasibility studies for Venezuela (1975) and the Dominican Republic (1989) were not followed through.

2.5.3 data on sisal pulping and pulp properties

Representative data on sisal fiber and sisal pulp properties have been collected and compiled in *tables 2.1-2.2-2.3-2.4-2.5* and in *graph 2.1*. The reader is reminded that these data refer to conventionally processed fiber and pulp, *not necessarily* to the potential of sisal pulp.

Even conventional soda pulps have papermaking properties, quite superior to those from reinforcement softwood pulps (*graph 2.1*). Despite the chemical degradation in pulping, sisal soda pulp retains considerable integrity. The tear/tensile curves ascend rapidly and descend slowly at the extreme end of the beater curves. For a broad treatise on fiber properties, beating and pulp evaluation (not confined to sisal), refer to Clark [14].

In view of promising alternative pulp process techniques (*paragraph 2.7*), the standard pulp properties which have been reproduced here (*tables and graph in this chapter*) are of limited value. With sisal fibers of a different age (whole plant harvesting), applying different pulp process routes (oxygen assisted pulping) and more focussed refining, the refined pulp properties are remarkably adaptable (*research work, not published*).

2.6 sisal pulp potential

Beginning in the sixties, synthetic substitutes have competed with sisal in traditional applications such as rope and twine. In a gradual way, sisal has declined and lost its prominent place as a world commodity. The production of sisal fiber has dwindled from around one million tons (in the early sixties) to less than half, in a greatly expanded world economy. At a time, sisal was the second most important fiber crop in the Americas, after cotton.

Although the sisal industry has maintained its position in recent years (*table 2.2*), it has been unable to regain its former position of prominence. Traditional uses (rope and twine) have fluctuated, and new applications have helped to create and sustain demand for raw fiber in a fiber geometry. *The fiber and pulp properties change and need to be verified.* This is a routine task, easily done from available plant material at any agriculture research station. It involves fiber measurements and basic chemical analyses plus some confirmatory (desktop) pulp cooks. Refer to *chapter 12.* The pulps can be sent elsewhere for testing.

The analysis of fiber geometry is an *indispensable part of the research task*, without which further market study is meaningless. Respondents to further market queries are unable to comment on fiber and pulp properties, unless these have been identified. The present market study, based on known properties and conventional pulping, has gone as far as possible in the circumstances. Additional market analysis requires the influx of fresh results.

[ii] *task two - pulp process routes*

The other, equally *indispensable* field of analytical research, is the exploration of viable process alternatives for pulping. This is best assigned to a dedicated research group (wood pulp research institutes are not necessarily the best place for this task).
The task is to identify the *viable* alternative process routes for pulping sisal. The soda process can easily be improved : selective pulp process routes and bleaching may have a better balance of paper-making properties and cost. Engineering criteria (as in *task three*) should guide the selection of pulping agents and process conditions for lowest possible pulp production cost.

A minor but significant part of the task is to probe the fine chemical structure of sisal fiber, the topo-chemistry and reactivity of constituents. It may be limited to an experimental review of the reactivity of selected pulping agents and -conditions, using fresh and dried sisal fiber. Many oxidative and redox maceration (*pulping*) steps are easily observed by microscopic analysis. The maceration routes, identified from such observations, are easily confirmed by benchtop pulping cooks.

The sclerenchyma fibers in sisal are sometimes said to resist maceration. The tissue is more lignified than bast fibers (*Dicotyledoneae species*), but less than softwood (*Gymnospermae species*). Some major features in the lignins are known to differ by *plant classes.* In *Monocotyledoneae* species, the polymer building blocks are fairly open, rather easily disintegrated in the fresh state. This is a helpful incidence in the design of novel pulp process routes for sisal.

Although this contradicts some published research, it is certain that the bleached pulp yield from fresh sisal fiber is higher (*66 to 73 pct*) than generally accepted. This implies that spent liquor from sisal pulping does not have the heat content, normally associated with chemical pulping, as in softwood cellulose. This changes the energy balance.

Compared to wood, sisal fiber contains more cellulose and a higher proportion of hemicelluloses and other carbohydrates. The data on *hemicelluloses* content are non-conclusive. From other research, it is implied that hemicellulose sheaths may attenuate the degradation of cellulose during pulping. It has been observed that the fine cellulose structure is largely preserved in the initial cooking phase (*unpublished information*).

[iii] *task three - process flow sheets*

Of course, research *task two* is inundated with innumerable variations. Few variables are realistic options on the production scale. The *third task*, therefore, is to limit the experimental work to technically *proficient processes*, which are cost effective at the same time.
The method is to draw up all possible process variations, but accept only the proficient ones. We want, for example, to restrict the extent of the chemical, energy, water and waste circuits. This imposes a restriction on the number of valid process variables.

For the few accepted process routes, summary process flow sheets are developed. The valid variables from the sheets are taken to *task two* to be analysed. The research results are returned to the process flow sheets. The flow sheets are used to monitor research progress and identify the *cost effective valid variables*. Simultaneously, the latter are used to determine the process data for the pre-feasibility study on sisal pulp, which the sisal project endeavors to carry out.

The aim of this procedure is to confine the experimental work to those *few elements* that represent valid process routes.

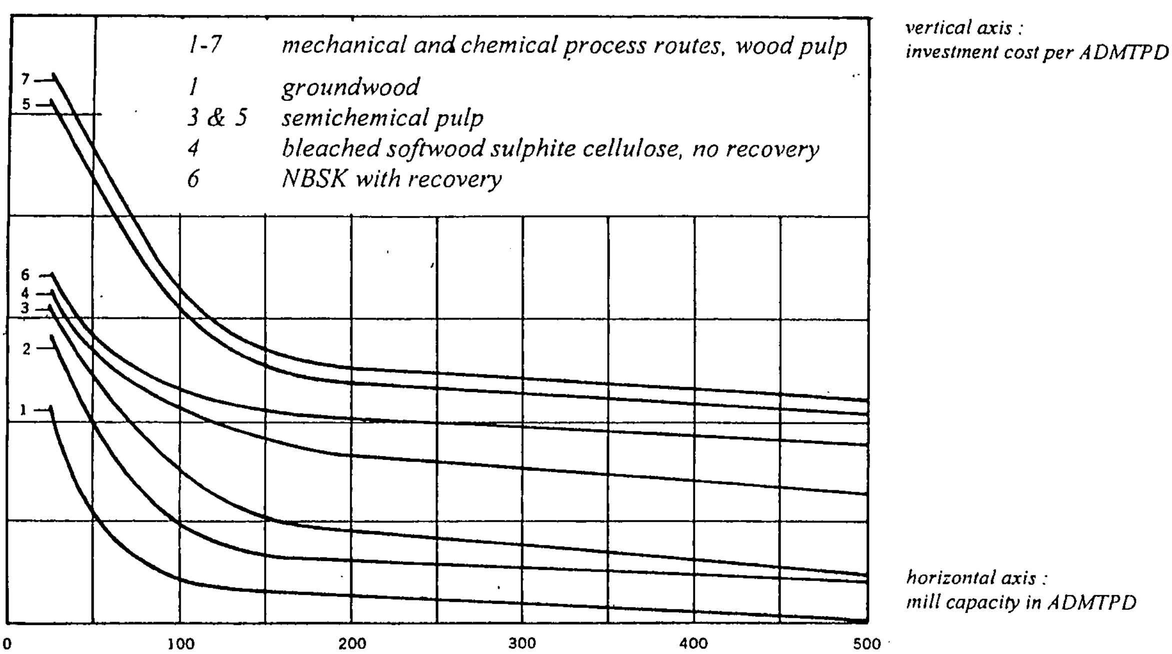
2.8 manufacturing cost

First of all, the three terms associated with 'cost', should be clearly outlined. The terms are defined as follows.

All the cost items, associated with raw materials, chemicals, energy, water, supplies are comprised in *direct unit cost of manufacture*. For simplicity, the semi-direct costs (labor, operating overhead, maintenance, site services) are included in the direct unit manufacturing cost. All the costs, associated with total investment (interest, depreciation) are allocated in the *indirect unit cost of manufacture*.
Both terms together comprise the *total unit cost of manufacture*. The term *unit cost* refers to cost items on a unit basis, in our case metric tons or OD metric tons for fiber, and AD metric tons for pulp.

Note that investment and investment cost are different things. The term 'investment' refers to money, *invested* in a manufacturing facility : money for 'dead plant' (site, buildings, roads, equipment, installations, engineering) plus 'live plant' (training, start up, initial operation). Total investment includes risk and loan capital.
The term 'investment cost' indicates the *cost* of all this money (capital) during the life cycle of the investment. It is usually expressed on annual or per ton basis. In the calculation of total unit manufacturing cost, the *indirect manufacturing cost items* are those that refer to depreciation and the cost of capital.

graph 2.2 scale economies in conventional pulping



mechanical and chemical wood pulp process routes. ref [15]

The term *scale economies* refers to economies that are obtainable by *larger scale operation.* They are expressed as the difference in total unit manufacturing cost between two capacities. The term *dis-economies* refers to the disadvantage of small size. See *graph 2.2.*

Let us return to the previous paragraph. The aim of *tasks two* and *three* is to reduce the unit manufacturing cost.
For small scale pulp capacities to be viable, flat curves (*scale economies*) are preferred, not the steeply ascending curves of wood pulping (*graph 2.2*). Although it was not mentioned in the previous paragraph, the quest for these is the core task in *target two* : a pulp process with cost curves as flat as possible.

It has been explained how to seize the opportunity which *fresh sisal fiber processing* affords. By selecting process conditions that are insensitive to scale, size becomes largely arbitrary. The remaining constraints are the logistics of raw fiber supply.
In present practice, the cost of sisal fiber is accidental to paper, and the availability of sisal fiber for pulp limited by the nature of the decorticating technique. If sisal is produced and processed in a dedicated pulp and paper scheme, cost and availability will change. Fiber properties also change.

Estimates, prepared for a dedicated sisal scheme in Tanzania, suggest that decorticated fresh fiber can be delivered for 120 to 160 dollars, OD basis, to an adjacent pulp mill of limited capacity. The year around delivery of 15,000 tons of fiber is reasonably assured with prevailing conditions of climate, soil and topography. The fiber volume corresponds to a field scheme of 1,000 tons of fresh leaf daily and 10,000 ADMT of pulp annually. Assuming fiber cost, new process technology and mill capacity as indicated, sisal pulp can be produced from *fresh fiber* in a dedicated pulp mill for 1,020 to 1,280 dollars per ADMT.
The indicated cost of sisal pulp is half the current price of sisal pulp. The added advantage is that pulp specifications are improved and pulp produced to buyer specifications at no additional cost. Both effects t*ogether* are bound to increase the interest and wider use of sisal.

Larger scale operations, using *fresh fiber*, are possible but require different harvesting and fiber delivery situations (climate, topography).
The other alternative to larger scale is using *dried fiber*. This bypasses the logistics of fresh fiber, but entails the drastic process conditions of conventional pulping. The auxiliary circuits cause most of the steep ascent of the investment cost curves in small mills. To have a reduced manufacturing cost *in that case* requires larger production size.
The cost of fresh sisal fiber compares favorably to the 170 to 260 dollars for the wood fiber content in softwood reinforcement pulp (*chapter 8* and *graph 8.1*). The advantage is lost by the *dis-economies* of small scale pulping.

In conclusion, the processing of fresh fiber presents a unique opportunity for small scale sisal and abaca pulp capacities. The processing of fresh fiber affords pulping conditions that are largely insensitive to scale. As indicated, the quest for these is the core task in *target two*. For the experimental *task two* to be realistic, it needs to be guided by viewpoints from *target three*.

Target three, it is recalled, defines the process conditions in accordance with cost engineering principles, wherein unit cost of manufacture is the guiding principle. It is imperative that the experimental research (*task two*) is guided by cost engineering viewpoints, identified in *target three*. The mere assigning of experimental research to a dedicated research institute, or incidental research by cooperating mills, is laudable but *insufficient* to reach the described aim.

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chapter 3 the approach to paper statistics and fiber balance

overview	The nature of pulp and paper statistics is explained. They show production, imports, exports and apparent consumption ; abbreviated P-I-E-AC. For *this* study, consumption data are not necessary. But we require *detailed* paper *production figures* to determine the present and future reinforcement pulp volumes. The first task, therefore, is to set up a suitable database on paper production and fiber furnishes. This has been done for five year intervals between 1980 and 1995. The next task was to elaborate estimates for 2000-2010. For the *projections estimates*, assumptions must be made about the economy in the future. The database includes the thirty largest paper producing countries. These countries together produced an estimated 301 million tons of paper last year (2000). This is 94 pct of world production.

3.1 production statistics

The conventional approach to paper statistics is to compile the necessary data (*production P* and *trade I-E*) from national sources. The *apparent paper consumption AC* is calculated from these inputs. This procedure is satisfactory for the macro-economic analysis of paper.

We are, however, only interested in *paper production* figures and their *pulp volumes*, although in far more detail than published. Therefore, we have collected the necessary data and developed a database, suitable for the market study (*chapter 4*).

From the production figures on paper and their fiber compositions, the fiber balance is established. A detailed fiber balance shows the pulp types and pulp volumes, required to produce the paper. The fiber compositions vary for each of the paper grades, they are a function of product specifications and production technology, and change over time.
The fiber balance includes reinforcement pulp. The market study is focussed on the *volumes* of *reinforcement pulp*.

The initial task, therefore, was to develop the detailed database on paper production and fiber furnishes, the information for which has been collected from the paper industry, machine manufacturers, consulting engineers and industry associations.

3.2 database

There is a difference between the 'true' total world production of paper and the 'database' world production (*table 3.1*). This understanding is essential to comprehend the discussion throughout this report.

The discussion refers to figures from the database. They represent 94 pct of true world volume. For our survey we require certain *detailed* information concerning production practices in paper and pulp, for instance fiber furnishes by individual paper grades. These can differ substantially between countries and regions. They are influenced by such diverse factors as forest reserves, *table 3.1 true world paper production, compared to production in the database*

million tons	*1995*	*2000*	*2005*	*2010*
world paper production (*faostat*)	280.3	-	-	-
total world paper (*database forecast*)	-	321.4	374.2	434.6
total paper, database (*94 pct*)	260.4	301.1	352.0	408.5
fiber balance in database	250.6	289.0	337.3	391.1

species in the forest, electric energy and market response. This information is not available from all countries to the same degree of reliability. It entails considerable work to collect reliable data, even from some of the countries, included in the database (*table 3.2*). We have ascertained that the database accounts for all significant production aspects (*cost profiles, market change, paper technology*) that influence fiber furnishes and change (*annex report one* and *two*).

table 3.2 countries in the electronic database

Europe	**North America**	**Latin America**	**Asia**	**other Asia**	**Pacific**
Austria	Canada	Argentina	China	India	Australia
Belgium	United States	Brasil	Japan	Indonesia	New Zealand
Britain		Chile		Malaysia	
Finland		Mexico		Philippines	
France				South Korea	
Germany				Taiwan	
Italy				Thailand	
Netherlands					
Norway					
Portugal					
Sweden					
Spain					
Switzerland					

3.3 projections on paper production

Paper is a mature sector and paper use expands rather slowly, averaging between 1 and 3 pct annually, growing irregularly at times, but rarely faster than 5 pct. The consumption of paper broadly reflects the course of the economy.

As a rule, paper capacity lags behind consumption. Capacity adjustments follow the demand by leaps and bounds, influenced by momentary perceptions about the market outlook. In other words, although the productive capacities increase in synchrony with the economic activity on the long term, their dynamics are affected by considerations on inmediate prospects. The long term aspects of investing in capacity are difficult to reconcile with the short term dynamics of the market. At times, this can result in abrupt change. This has been increasingly the case in recent years.

Assumptions are required to estimate future paper production. Assumptions reflect how the economy is perceived to develop, and how changes in society and technology affect paper use. Projections far into the future have speculative character.
For the intermediate term outlook, the consensus is that a ten year forecast can be made within

acceptable limits of error. The time horizon for a sizeable investment, such as for pulp or paper, is three to five years and the period for project amortisation is 18 to 22 years.

The projections about paper production in the database have been determined by using basic assumptions on the growth of the economy. The procedure is explained in *annex report one*. The assumptions are differentiated for countries, time intervals, and paper grades.

3.4 types of pulp

An overview of the different types of pulp is presented in *table 3.3*. The main differences are the source of fibrous raw material (*species*), fiber length, pulp process and pulp yield. The properties of the fibrous raw material determine, *together with* the effects from the maceration (pulping) process, the paper-making properties of pulp.

These, the papermaking properties, depend on the opposite characteristics of *fiber strength* and *fiber bonding*. Fiber *strength* refers to a single fiber, and *bonding* to the fiber network.
Their balance determines the choice among pulps in any papermaking furnish. Besides, the choice of pulps is largely influenced by cost. In practice, the fiber furnish of any paper reflects the balance of pulp properties and cost.

Chemical cellulose has the best interfiber bonding ability. Long fiber and short fiber may have equal fiber bonding potential, but differ in sheet properties that depend on fiber length, as in tear resistance. Mechanical pulp exhibits weaker sheet properties, because fiber integrity and fiber bonding are less perfect. Mechanical pulp is used for reason of cost, but also for opacity ('shine through') for which is it well suited.

Not only pulp, but also paper waste is used for papermaking. Waste has 'averaged' fiber properties. These suffer as a result of repeated recycling. The fibers are weakened in strength, length and bonding ability. Waste, of course, is used for cost reasons.

table 3.3 overview of pulp types

process	*fiber type*	*brightness*	*process*	*available*
chemical cellulose	long fiber	unbleached	kraft	integrated, (market)
		semi-bleached	sulphate, (sulphite)	integrated
		bleached	sulphate	market, integrated
		bleached	sulphite	(integrated)
chemical cellulose	short fiber	(unbleached)	soda	integrated
		semi-bleached	sulphate, soda	integrated
		bleached	sulphate, soda	market, integrated
semichemical pulp	long fiber	unbleached	high yield kraft	integrated
		unbleached	NSSC	integrated
mechanical	long fiber	crude	groundwood, TMP	integrated
	long fiber	brightened	TMP	integrated, (market)
	short fiber	crude	TMP	integrated
	short fiber	brightened	TMP	integrated

major types of pulps are shown ; brackets indicate minor share

Although insignificant in Europe, nonwood pulps play a role -sometimes significant- in some developing countries. Nonwood fiber species, used in common paper grades, include straw and reeds (*short fibers*), bagasse (*containing some long fiber, but mostly short fibered*) and bamboo (*containing long and short fibers*).

Fiber length and -strength largely determine the mechanical strength of packaging paper, provided that fiber bonding is assured. Therefore, long fiber cellulose is the preferred pulp for packaging paper.
Corrugated cases are made from liner and medium. The properties of the corrugating medium (*fluting*) depend on sheet stiffness, not fiber strength. The best pulp for this purpose is neutral sulphite semichemical pulp, made from hardwoods (short fiber species). Much of it is made with waste, for reason of cost.
Although a packaging product also, solid packaging board relies much less on fiber length. It may contain mechanical pulp, even low grade waste, and still maintains sheet resilience, simply by a higher basis weight. For this grade, cost is the overriding argument.

Printing paper is preferably made from short fiber pulps. These provide the required printing opacity ('shine through'). Depending on the price and durability, short fiber cellulose *or* mechanical pulp is used to produce printing paper. A reinforcing (*long fiber*) pulp is added to the furnish of printing paper, to assure paper machine runnability.

3.5 fiber furnish

Fiber furnish information has been collected from various sources : paper mills, equipment manufacturers and consulting organisations. The questionnaires and interviews have been complemented by available information (*chapter 9*).

Fiber profiles have been established in detail. Paper compositions have been dissected, grade by grade and country by country. Their fiber furnish profiles were identified down to the level of individual grades, for all paper types and for individual countries (*annex report one*). The profiles were used to determine the present and future pulp volumes for paper, and the volumes have been checked against published statistics.
The ensuing data universe contains differentiated figures on paper and pulp volumes, in the time series between 1980 and 2010.

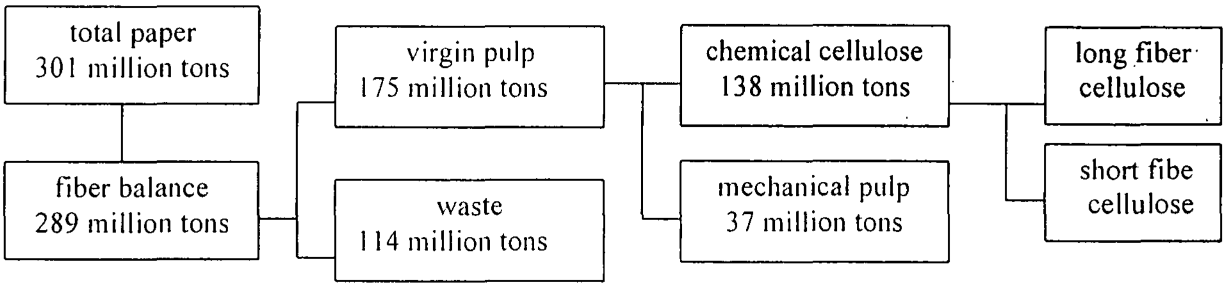
Changes in the society and economic activity influence the demand for paper as it is consumed and produced. Such change does not alter the fiber furnish, although it affects total pulp volume. Change in papermaking technology, however, influences the fiber furnish profiles. Pressure from the market has a similar effect. The assessment of such change has been carefully embedded in the projected fiber furnishes.

Newsprint is a good example to illustrate such change. In two decades, newsprint technology has developed beyond recognition. The change in fiber profiles testifies to this dramatic change.
First, there were the groundwood/long fiber furnishes of former days. Then, TMP came, a new technique in fiber separation with revolutionary fiber properties. Presently, the recycle technology of newspaper waste has taken center stage. The newest of technologies, state-of-art, feature all waste recycling.

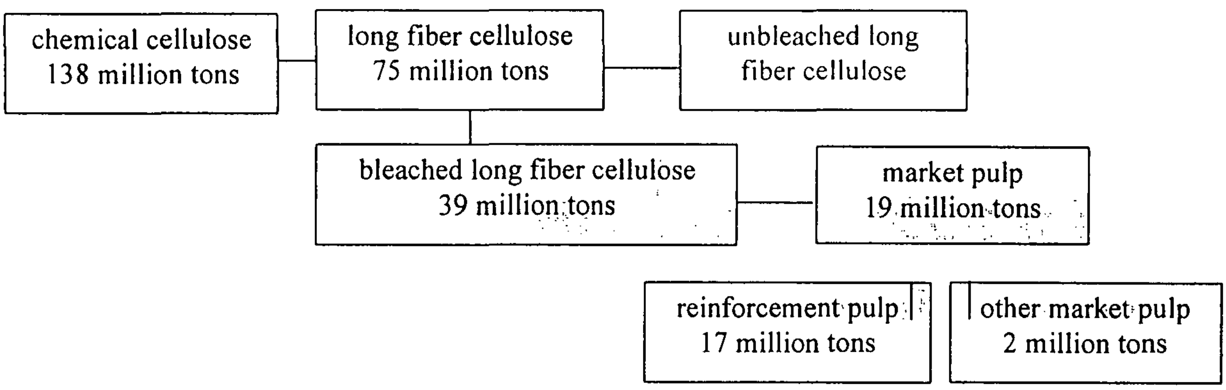
3.6 fiber balance and long fiber pulp

The fiber furnish data (in the database) are differentiated by pulp grades, fiber length, pulp yield and bleach status. Although the chemical pulps (*sulphate, sulphite, soda*) were differentiated in detail, this information has not been used for the reinforcement analysis, because this is not relevant for the reinforcement analysis. It will have a role in phase two of the market study.

The fiber and pulp volumes for 2000 are shown in the first diagram, to illustrate their respective positions in world paper. The figures are taken from the database, the reader is referred to *chapter 6*, where a detailed discussion of the fiber balance is presented.



Half of the volume of chemical cellulose is long fiber cellulose. Half of the long fiber cellulose volume is true reinforcement pulp (*'reinforcing printing paper as it is manufactured'*). Less than half of the world's reinforcement pulp is traded on the world market : 17 million tons, the target of this study.



It might be possible to introduce sisal pulp as reinforcement pulp to paper mills that purchase long fiber pulp for that purpose. Sisal might *replace* or *complement* the presently used NBSK market pulp. The other half of reinforcement pulp -22 million tons- is integrated pulp and therefore not substitutable. The market volume of reinforcement pulp is considerable.

The reinforcement segment has been the principal target of our queries to paper mill operators. They were questioned on reinforcement practice and attitude. The response analysis is presented in *chapter 9*. Other information on reinforcement is scattered throughout the report.

table 3.4 paper production and long fiber furnish (database)

million tons [1]	*1995*	*2000*	*2005*	*2010*
paper production	260.39	301.08	352.00	408.49
fiber balance	250.63	288.95	337.26	391.08
long fiber pulp > all pulp	67.79	74.53	81.44	87.14
long fiber pulp > market	18.57	21.48	25.36	29.42

[1] *reference years in the database 1980 to 1995 (statistics) and 2000 to 2010 (projections), five year intervals*

3.7 *the database universe*

As the statistical work was in progress, the information became increasingly complex. The result was a rapidly expanding structure, as *table 3.5* illustrates. It became necessary to shift through the information, and retain only what was significant for our purpose.

Annual or biennial records are sensitive to incidental change. Five year terms attenuate the sharp and incidental swings. A test run on sample data largely confirmed this observation. Another argument is that five year intervals are more congruent with the planning and implementation cycle of large projects such as greenfield pulp mills and mill expansions. Therefore, five year intervals are used throughout the database of this report.

table 3.5 statistical information : how data cells multiply

paper production	*item*	*variables*	*cells*	*cumulative*
9 groups	historic series	*4 time intervals 1980 to 1995*	*36*	*36*
idem	projections	*3 time intervals 2000-2005-2010*	*27*	*63*
idem	by fiber balance	*5 variables*	*45*	*315*
idem	by furnishes	*22 cases*	*198*	*1,386*
idem	individual countries		*270*	*41,580*
idem	fiber furnishes	*8 pulp grades*	*72*	*332,640*
idem	technological change		*27*	*997,920*

The database contains all the necessary statistics on paper production and fiber furnish, to determine the pulp volumes for the reference years *1980-1985-1990-1995,* and their companion estimates for *2000-2005-2010.* The data are stored separately for paper grades, for each of the 30 paper producing countries. Fiber furnish information is also stored in detail.

The pulp volumes for 1980/1995 have been checked with published statistics, and their estimates were compared with the projections, made by other market investigators. From the comparisons, we are satisfied that the underlying database information is the best available and is suitable for the purpose of this study.

We have used the basic (*most likely*) scenarios to determine the reinforcement pulp volumes for the 2000 to 2010 period (*chapter 6* and *7*, *annex report two*).
By entering his own assumptions, reflecting alternative growth scenarios for 2000 to 2010, the reader can easily determine the pulp volumes that correspond to his particular views on how the future will unfold and, if desired, adjust his estimates.

Although the data are available on the country level, they are more significant for the regional and world horizons. The thirty year time span provides considerable insight in the changing furnishes of paper.

Summarising, we have four different main groups of data (*table 3.6)*, for every country in the universe, for the regions and for the world.

table 3.6 four main groups of data

statistics on paper production 1980 to 1995	projections on paper production 2000 to 2010
fiber balance 1980 to 1995	fiber balance estimates 2000 to 2010

THEME B

chapter 4 *forecasting*

overview	There are many forecasting methods available to predict the growth of pulp and paper. Most have insufficient focus and are therefore unsuitable for the purpose of this analysis. The NLK *forecast model* has been found satisfactory. It has been adapted for our purpose. The model uses electronic worksheets that accommodate accurate information on fiber furnish profiles in paper. It allows to input various alternative scenarios, in order to assess the sensitivity of pulp demand to various assumptions on the economy, on production factors and technological change. *Base scenarios* and *alternative assumptions* on growth in demand for paper have been prepared. Their impact on fiber demand is discussed. The electronic database works with detailed *country worksheets*. These contain all necessary information on fiber profiles and -volumes. Regional and world worksheets are produced from the country sheets. A sample sheet on North America illustrates the method. The regional and world sheets provide significant conclusions on future pulp volumes. These are then used to answer questions on reinforcement pulp, that are significant for our present purpose.

4.1 introduction

Forecasting methods are used to predict the volumes of paper and pulp in future years. They are useful for various purposes, from macro-economic analysis to mill planning.
To produce reliable estimates, rather complicated procedures are necessary. Their reliability is crucial in view of the very considerable investment, necessary to build pulp capacities and the lead time to get a new facility into operation.

The widely used methods of forecasting (*paragraph 4.3*) are not satisfactory *for our purpose*, because they show insufficient detail and cannot be manipulated. We require details on fiber furnishes and individual pulp volumes, over time intervals of ten to thirty years. We have adopted the NLK forecasting model (*paragraph 4.4*) as the starting point and elaborated the necessary details for the target of this study. The target : identify *if* and *where* the necessary reinforcement pulp volumes for paper will be forthcoming.

The general procedure has been as follows. The initial step is to establish the present and future volumes of paper production. Then, the paper grades are identified in which reinforcement is commonly practised. Following this, their fiber furnish profiles are identified. The profiles reflect market and technological changes. From the forecast values, the future volumes of reinforcement pulp are established.

4.2 growth in paper production

As a mature commodity, modest growth rates are typical for paper, the long term average being 1 to 3 pct annually. Notwithstanding, considerable short term fluctuations in output may occur. Although output *follows* market demand, it is also driven by anticipation of future growth.

The short and long term driving forces are not easily reconciled. The short term outlook largely determines momentary production, because paper is not an inventory product. The longer term prospect must underlie the expansion of capacity, because the lead time is long.

Pulp output follows the short term swings in paper production, typically delayed in phase. This can result in sharp reversals in pulp output and price. Just as in paper, pulp producers try to anticipate future demand by expanding productive capacity, equally phase-delayed.
The result is that pulp capacities and -output are out of balance from time to time. Such imbalance is reflected in the short term price cycles of paper and pulp (*figure 8.2* and *8.3*). Imbalance in pulp is quite pronounced at times of over-supply. This was the case when the market study was carried out, during 1998 through 1999.

National and regional economies develop in unequal ways. Even for individual paper types, demand growth is uneven. The whimsicalities of the market and technical change both play a role. Individual assumptions are necessary to elaborate the estimates on future paper production and identify future pulp volumes.
Whereas annual variations in production are incidental, market shift and change in technology are systematic. The latter have a decisive influence on the growth rate of paper. They are of a more fundamental character and imply changes in fiber use.

A common principle is that production graduates to the least expensive raw material, consistent with the requirements of paper buyers. More expensive pulp is replaced by less expensive pulp as demand and technology unroll. As a consequence, differences between Europe and North America are significant (*chapter 7*). This includes reinforcement practices.

⌘ *Two examples*. Compare the reinforcement practices in newsprint, wood content printing paper or tissue and examine the fibrous raw material base on both sides of the Atlantic (*chapter 5* and *chapter 7*). Even when the technologies converge, furnish profiles continue to have their particularities.

Another example: compare corrugated cases. Long fiber use for corrugating case materials in North America remains closely linked to the American forest base. The emphasis in Europe is on waste re-use (*ibidem*). Even though recycling is spreading widely in the United States, the fiber balance for case materials remains forest based. Interestingly, North American case materials constitute a sizeable portion of the recycled fiber base in continental Europe.

To complicate things further, manufacturing practices change over time (*best seen in the data sheets*), reflecting the influences from the market, fiber availability, allowable cost and change in manufacturing practice. The scenarios of pulp use are changing, and recycled fiber is finding ever more use.
Even among paper mills within one region, in northern and continental Europe for instance, remarkable differences in papermaking practice continue to exist (*chapter 5 and chapter 7*), although these are changing. Historically, the Scandinavian countries produce paper from wood (their forest base). In continental Europe, on the other hand, paper recycling is a practice that was already firmly established decades ago. Presently, mills in Scandinavia are increasingly orienting themselves to waste use.
Throughout the world, waste paper is now considered a valuable fibrous raw material, even for white papers. Whether this has implications for reinforcement pulp use has been the subject of queries, as in *chapter 9*.

4.3 forecasting methods

Two or three decades ago, just the trends in population and GDP per capita were considered ample basis for the forecasting of future paper demand. The approach is straightforward : the apparent consumption (*AC*) is calculated from the production, import and export data ;

the *P-I-E-AC* model referred to in the previous chapter. The estimates of future consumption of paper are extrapolated from past and present statistics, and related to population numbers and GDP. Between the fifties and the eighties, this approach was considered largely sufficient for the planning of new mills in many countries of the world.

Over time, the econometric model has become increasingly complex. The cyclical nature of the economy has been recognised ; the impact from industrialisation, alphabetisation, social cost and disposable income given a proper place. Substitutions, consumer acceptance, productivity have found a place in the model. Import substitution, cost comparisons, social cost, investment and manufacturing cost profiles are now commonly employed variables in some of the analyses.

The presently most complete *macro-economic* approach is the one which was pioneered by FAO and adopted by the UN/European Timber Committee, the expert group on forest products of United Nations in Geneva. In three decades, significant refinements were contributed by paper producer organisations in European countries, North America and Japan.
The method is the preferred approach for overviewing broad scenarios on pulp and paper. It delivers informational help on the national level, useful for dissecting developments in printing and packaging in society and for sectorial planning.

Organisations such as the OECD, FAO and the UN/European Timber Committee, and the European Union regularly publish reports, using the described methods.
Annual surveys are published by industry producer organisations such as CEPI and AFPA. Other national agencies also issue annual reviews and statistics on paper and pulp. Commercial market analyses, that employ refined methods of forecasting, are available as well.

However, these commonly used statistics on paper and long fiber pulp do not represent the reinforcement situation adequately. For our purpose, *specific estimates* on reinforcement pulp are required. The assessment of reinforcement scenarios requires considerably more detail than is available from above sources. For our purpose, a more specific database was necessary.

⌘ *A note of caution* in concluding this paragraph : it is essential to understand the nature of the specific forecasting method, used in this survey. It describes events on the meso-economic level. It provides useful information on pulp use *between* the regional (macro-economic) and project (micro-economic) levels. It establishes the outlook for sisal pulp generally. It indicates where it can be employed to advantage. The survey results do not have the feasibility character of bankable documents. For a specific sisal project, the market prospect must be re-studied by using specific information on product specifications, production price and process and investment outlines, as in any feasibility study.

4.4 the forecasting model in this analysis

The market study was initiated by reviewing forecasting methods. The NLK forecast model was identified as appropriate for our purpose. Its database incorporates the various input data, from which detailed estimates on pulp volumes (relating to present and future paper volumes) can be prepared. The model has been adapted for this study and is described below.

The model, a software program, accommodates different scenarios in order to assess the sensitivity of pulp demand to the various forecast assumptions, required to drive the model. The model 'builds' the regional and world pictures on paper and pulp volumes, using country data sheets. The regional and world paper and pulp overviews are discussed in this report (*chapter 6 and chapter 7*) ; regional data sheets are reproduced in *annex report two.*
The regional sheets are produced from country worksheets, developed for each of the 30 countries in the database (*table 3.1*). The country sheets contain the necessary forecast elements for the economic outlook and associated paper use, fiber profiles and so on.

The country profiles are defined down to individual paper grades (*table 4.2*). Besides, the model accommodates effects from technological change, such as machine manufacturers and the industry foresee. We have made liberal use of information from these and other consulting engineering sources.

The database has been confined to the thirty most significant paper producing countries in the world. These include the developed world and the relevant developing countries.
Together, these account for 94 pct of paper production worldwide. The 30 countries have been grouped into seven regions. The countries and regions were previously presented in *table 3.1*.

The software consists of 30 country workbooks, each with several spreadsheets. They contain forecasting parameters, paper statistics (1980 to 1995), forecasts on paper production (2000 to 2010), capacity information (1995-2000), the fiber furnish profiles, mill production and operating ratios, furnish change and pulp volumes. In addition, the spreadsheets include economic and demographic data. The spreadsheets on printing paper have splits for the subgrades woodfree/ uncoated/coated and for wood content/uncoated/coated.
The fiber furnish spreadsheets contain detailed data on paper composition by grade and subgrade. The pulp volume sheets show the furnish matrices and pulp volumes by grade, for each of the paper grades in the model.

The database holds the statistics of past production for 1980 to 1995. They have been taken as reference, to which the assumptions for 2000-2010 are linked. Assumptions are required to estimate the production volumes of the future. They are linked to the growth of paper production. The inputs for demand and production, domestic deliveries and exports are based on our assessment of demand and capacity. Other assumptions than the basic ones can be entered into the spreadsheets, to analyse their effect.

The NLK worldwide capacity database 1980-2000 has been used as reference for all capacity figures. Capacity changes for 2000-2005-2010 are superimposed onto the reference.
The capacity additions are found by adding firm and confirmed new capacities plus half of speculative ('announced') capacities (50 pct ratio). It is possible to analyse other ratios.

The existing and projected paper capacities (related to the 'most likely' growth of paper) *plus* the change in fiber furnishes establish the volumes of pulp, corresponding to the projected paper volume in the 2000 to 2010 period. The model does this for all the individual paper grades and countries.

The model allows to input alternative assumptions on growth rate, capacity, fiber composition. The worksheets on printing paper are linked within the printing paper group. The other grades (packaging, tissue) are not linked, except for their respective series of historical statistics. This approach ensures that bleached pulps (including reinforcement pulp) are linked, whereas unbleached pulps remain independent from bleached pulp.

The regional worksheets are obtained by combining all the country spreadsheets within one region. They can be manipulated in the same way. The links within the printing papers group remain active as before. The regional spreadsheets provide significant insight in the fiber furnish situations of individual paper grades. They also show the outcome of technological change.

The world worksheets are obtained by combining all the regional data sheets into one set of spreadsheets. They can be given alternative inputs, just as the country and regional sheets. Their significance is in predicting the world total and differentiated pulp volumes for future paper consumption.

For a full understanding of the approach, the reader should work with all the data sheets in the electronic database, and preferably go through these with his own assumptions.

⌘ The database was developed in microsoft excel (ver 5.0) with ms windows for workgroups 3.11 and runs successfully under windows 95/98. The full data files require 22 MB hard disk capacity.

The complete user guide (*the manual*) is presented in *annex report one*, together with all the printed regional spreadsheets that represent the *basic scenarios* for the pulp and paper volumes, presently and future. The manual is designed to be used 'hands-on', while the electronic system is being manipulated.

4.5 forecasting assumptions and basic scenarios

Reasoned assumptions have been made about the 'most likely' future demand for paper. The assumptions are derived from past performance, economic outlook, prospects of growth and other parameters of change.

Basic scenarios represent our assessment of the 'most likely' development in the regions. The data in this report reflect these *basic scenarios*. As previously explained, the scenarios can be manipulated by using alternative input assumptions.

⌘ *For example* : someone has a different opinion on the use of waste paper, or about the reinforcement fiber content in recycled paper. Just by entering other input data, worksheets are generated that reflect the changes. The result is that other worksheets are displayed, that have other assumptions (*alternative scenarios*).

The model is designed to work with commodity paper grades and their fiber furnishes. For this study, the database was focussed on the primary target, *reinforcement*. Of course, reinforcement pulp is only part of the total volume of long fiber pulp. When the software was ready, we have made numerous checks with various input assumptions. The results have been compared with information, obtained from the reinforcement questionnaires (*chapter 9*). We are satisfied that the model gives meaningful forecast profiles on commodity paper grades.

The model is not suitable to study the intricate differences at play in specialty paper. The model is insensitive to small segment pulp grades such as *specialty pulps*, because these require assumptions of a different nature. Therefore, specialty paper has been analysed separately (*chapter 11*).

The basic scenarios ('from reasoned assumptions') have been established, using paper profile data for the 1980 to 1995 time interval, *plus* change factors from technology and market .
The profiles were obtained from production practices in representative mills around the world. Note that fiber furnish formulas are not identical throughout the world. They have their own peculiarities, deviate by regions and change over time.

The basic scenarios are fully explained in *annex report two*. It was impractical to reproduce all the basic scenario country worksheets. They comprise approximately 600 pages, and are available in electronic format.
However, the regional and world data sheets, as far as these are related to fiber furnishes, have been reproduced in *annex report two*, to which the reader is referred.

4.6 alternative scenarios

As explained, the model accepts alternative scenarios for paper and fiber furnishes. By elaborating these, it can assess the sensitivity of pulp demand to the many assumptions that drive the model.
A hands-on description of is found in *annex report one*. The reader is advised to familiarise himself by manipulating the regional or world sheets with his own assumptions.

4.7 underlying data

The statistics on paper production have been collected from national accounts in the thirty most prominent paper producing countries (*table 3.1*). The period between 1980 and 2010 has been charted for 1980-1985-1990-1995 intervals. The data for 2000-2005-2010 are projections.

table 4.1 comparison of forecast and true paper production figures

million tons	1995	1996	1997	1998	1999	2000	2010
paper, worldwide production	280.3 [1]	282.1 [1]	289.3 [1]	293.6 [1]	296.8 [1]	321.4 [2]	434.6 [2]
paper, database production [2]	260.4					301.1	408.5
database fiber furnish [2]	250.6					289.0	391.1

1 *faostat*
2 *estimates using the database*

Furnish change is only noticeable and significant over time, it is not easily recognised in annual data. For that reason, five year intervals are preferable.

⌘ *Notes* : 1995 is the last year with actual production figures. Figures for the years 2000-2005-2010 are estimates. Actual figures for 2000 will be introduced when available, however this requires the update of the model's database, foreseen for 2002.

Note that the world total of paper production differs from the database 'world total', as the latter accounts for 94 pct of world production ; similarly for pulp. Figures for paper and pulp do not add up, the differences being in additives and filler content, fiber loss in process and moisture content.

As previously mentioned, all the major paper grades of common papermaking and their fiber components are included in the electronic data sheets. There is a list of paper grades in *table 4.2* for ease of reference. The printing grade info is elaborated in greater detail, because these grades often contain reinforcement pulp.

table 4.2 paper grades, featured in the worksheets

printing & writing papers : grade splits, fiber composition

newsprint worldwide production, statistics and projections, forecast assumptions, fiber balance

printing and writing papers
worldwide production, statistics and projections, forecast assumptions, fiber balance

uncoated wood content printing
worldwide production, statistics and projections, forecast assumptions, fiber balance

coated wood content printing
worldwide production, statistics and projections, forecast assumptions, fiber balance

uncoated woodfree printing & writing
worldwide production, statistics and projections, forecast assumptions, fiber balance

coated woodfree printing
worldwide production, statistics and projections, forecast assumptions, fiber balance

other paper	worldwide production, statistics and projections, forecast assumptions, fiber balance
paperboard	worldwide production, statistics and projections, forecast assumptions, fiber balance
tissue	worldwide production, statistics and projections, forecast assumptions, fiber balance

complete regional and world spreadsheets on fiber furnish are presented in annex report two

4.8 example of fiber furnish worksheets and pulp data sheets

North America represents an easy-to-understand situation, with its considerable forest base and well developed pulp and paper industry. One of the American data sheets is reproduced in *table 4.4* and summarises the fiber furnish volumes in paper for the year 2000. These data are just the summaries of other worksheets. Their hierarchy is shown in *table 4.3*. The data sheets for other regions work in the same way. It is recommended that the reader goes through the electronic worksheets to get familiarised with the method of forecasting. A convenient starting point are the regional sheets. More detailed information is found in *annex reports one* and *two*.

table 4.3 hierarchy of the worksheets on North America and North American countries

		fiber balance	*paper production*	*paper projections*	*fiber furnish*
block one	**North America**	1995 2000 2005 2010	1980 1985 1990 1995	2000 2005 2010	1995 2000 2005 2010
block two	**United States**	1995 2000 2005 2010	1980 1985 1990 1995	2000 2005 2010	1995 2000 2005 2010
block three	**Canada**	1995 2000 2005 2010	1980 1985 1990 1995	2000 2005 2010	1995 2000 2005 2010

notes
[i] all blocks are differentiated for : total paper, total printing paper, tissue, board, other paper
[ii] grade splits for : newsprint, uncoated wood content, coated wood content, uncoated woodfree and coated woodfree
[iii] the same categories were included in the white paper sections of the questionnaires on reinforcement (chapter 9)

The abbreviations and explanations for *table 4.4* are as follows :

horizontal fields

paper grades	as in table 4.2
T	total pulp
M	market pulp
I	integrated pulp

vertical fields

-BKS	bleached kraft long fiber sulphate
-N	nordic long fiber sulphate
-R	sulphate from radiate pine
-USA	USA sulphate
-OT	other long fiber sulphate
total	*group total*
-BKH	bleached hardwood sulphate
-B	birch
-E	eucalypt
-EU	other short fiber sulphate from EU
-NA	idem, north american origin
-OT	idem, other origins
total	*group total*
tot K	*total bleached sulphate*
-UKP	total unbleached long fiber kraft
-BS	total bleached sulphite
-SW	sulphite from softwood
-HW	sulphite from hardwood
total	*group total*
US	unbleached sulphite
SC	semichemical pulp
MECH	total mechanical pulp
OWP	other wood pulp
NWP	nonwood pulp
SF	secondary fiber
-DIP	deinked fiber
-OSF	other waste fiber
total	*group total*
-MIN	minerals content
Total	*grand total*
LF	long fiber
SF	short fiber

table 4.4 *North America : fiber furnish volumes by paper grades for the year 2000*

North America : fibrous furnish volumes by paper grades

	coated woodfree			uncoated woodfree			coated mech.			uncoated mech.			tissue			board			newsprint			other			arithmetic total			actual total		
	T	M	I	T	M	I	T	M	I	T	M	I	T	M	I	T	M	I	T	M	I	T	M	I	T	M	I	T	M	I
BKS																														
N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
USA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
total	1123	723	400	3898	798	3100	1576	876	700	525	200	325	1466	636	830	4584	734	3850	1445	100	1345	890	-	890	15506	4066	11440	15506	4066	11440
BKH																														
B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
EU	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
total	1076	126	950	4476	326	4150	-	-	-	-	-	-	1759	799	960	5025	475	4550	-	-	-	3116	192	2924	15452	1918	13534	15452	1918	13534
tot K	2200	850	1350	8374	1124	7250	1576	876	700	525	200	325	3225	1435	1790	9609	1209	8400	1445	100	1345	4006	192	3814	30959	5985	24974	30959	5985	24974
UKP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	655	-	655	-	-	-	24482	0	24482	25136	0	25136	25136	0	25136
BS																														
SW	-	-	-	262	13	249	-	-	-	-	-	-	350	-	350	-	-	-	-	-	-	-	-	-	612	13	599	612	13	599
HW	-	-	-	316	15	301	-	-	-	-	-	-	16	-	16	-	-	-	-	-	-	-	-	-	332	15	317	332	15	317
total	-	-	-	578	28	550	-	-	-	-	-	-	366	-	366	-	-	-	-	-	-	-	-	-	944	28	916	944	28	916
US	-	-	-	-	-	-	-	-	-	315	-	315	-	-	-	-	-	-	161	0	161	-	-	-	476	0	476	476	0	476
SC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3561	-	3561	3561	-	3561	3561	-	3561
MECH	140	100	40	433	233	200	1418	0	1418	3045	-	3045	586	526	60	50	-	50	10433	0	10433	-	-	-	16105	860	15245	16105	860	15245
OWP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NWP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SF																														
DIP	468	268	200	1444	644	800	158	58	100	263	63	200	3152	352	2800	200	65	135	3763	-	3763	200	100	100	9646	1548	8098	9646	1548	8098
OSF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5039	-	5039	250	-	250	12263	-	12263	17552	-	17552	17552	-	17552
total	468	268	200	1444	644	800	158	58	100	263	63	200	3152	352	2800	5239	65	5174	4013	-	4013	12463	100	12363	27198	1548	25650	27198	1548	25650
MIN	1872	1872	-	3609	3609	-	2101	2101	-	1103	1103	-	-	-	-	818	818	-	-	-	-	-	-	-	9503	9503	-	9503	9503	-
TOTAL	4680	3090	1590	14438	5638	8800	5252	3034	2218	5250	1365	3885	7330	2313	5016	16371	2093	14279	16050	100	15951	44512	292	44220	113882	17923	95959	113882	17923	95959

year 2000

figures in
1,000 ADMTPY

ref :
electronic database,
annex report one,
annex report two

THEME B

chapter 5 fiber profiles in paper

overview	The properties of paper depend on the fiber profiles from which it is made, but they also depend on the available pulp, or the fibrous raw materials for pulp. Comparable paper grades can have significant differences in fiber compositions. In this chapter, the fiber profiles in the most common mass paper grades are discussed and reviewed as to *where* and *to which extent* long fiber pulps are commonly used.

5.1 statistics on paper

Paper is used for two or three major purposes : industrial use (*packaging, protection and transportation*), as a social and cultural commodity (*printing, communications, knowhow*) and for convenience (*tissues*). By gross approximation, unbleached (*brown*) papers are for industrial use. In contrast, *white* papers serve cultural purposes.

Paper use is fairly equally divided between white and brown paper grades. Their fiber profiles depend on paper specifications and how the paper is made and used.

Worldwide production of paper, presently 321 million tons, will reach 435 million tons in ten years' time to 2010, and the fiber balance (presently 308 million tons) will be 416 million tons. These figures, extrapolated from the database (*chapter 4*), are in general agreement with published projections (*table 5.1*).

⌘ The differences in paper and pulp volumes account for moisture content, chemicals and fillers. Note that *total world production* and the *world database production* are not the same.

However, general figures such as these are not helpful for our task : explore the reinforcement situation. Our analysis should provide data on *the volumes of reinforcement pulp* and it should explore the possibilities to use sisal pulp for the same purpose. This should help us to estimate the potential of sisal pulp for reinforcement use.

Unfortunately, information concerning reinforcement is not readily available from published statistics. For a proper assessment of reinforcement practices, detailed information is necessary - for instance on production practice, machine size and machine speed, fiber furnish profiles and the change in these, market trends and so on.
The task is complicated because the information must be differentiated for the individual paper grades which will be considered, for regional differences and so on. An additional complication

table 5.1 paper production and fiber balance (from table 4.1)

paper, million tons	*source*	*1995*	*1998*	*2000*	*2010*
total worldwide production	*faostat*	280.3	293.6	321.4	434.6
worldwide fiber balance [1]	*sasa*	269.8		308.5	416.1
database production [2]	*NLK*	260.4		301.1	408.5
database fiber furnish		250.6		289.0	391.1

[1] *our estimates*
[2] *figures from the database are not compatible with published sources elsewhere as their reporting bases differ*

is that technological change causes change in the production routines over time. Considerations such as these and many others have been studied and incorporated into the database (the database is explained in the *annex two report*).

Of course, it is impossible to collect such detailed information from all the countries in the world. Therefore, the figures on *total world production* have been substituted by those from the database. For an explanation, refer to *chapter 4*. The database figures are 93 to 94 pct of total world production figures (*table 5.1*). We have ascertained that the relevant changes, affecting fiber use over time intervals, have their proper place in the database. Throughout this report, we use the database figures and not the worldwide figures.

This chapter discusses the fiber compositions of common paper grades, reviews the changes in fiber profiles over time, and explores alternative fiber furnishes and regional differences. In addition, it explores the changes from price pressure, market shift and technological shift, all the factors at play in the paper landscape over the 1980 to 2010 period.

5.2 paper grades

5.2.1 differences in demand develop over time

Between the years 2000 and 2010, world production of paper will increase by one third (*36 pct,* refer to *table 5.1*). This might suggest that the demand for pulp expands in the same way and to the same extent. This is not necessarily so. Although paper and pulp volumes seem to be expanding evenly (*table 5.2*), notable differences between grades will emerge, appearing gradually but steadily.

The changes are many. First, there is the shift in the volumes of white and brown paper types over time (*table 5.3*). In the second place, a significant change is observed in the present and

table 5.2 paper production

paper, million tons	*source*	*1995*	*2000*	*2005*	*2010*
worldwide production	*faostat, PPI*	280.3	321.4	375.1	434.6
database production	*NLK*	260.39	301.08	352.00	408.49
by paper types	*NLK*				
newsprint		32.75	35.74	36.87	39.05
other printing paper, total		74.24	89.43	106.25	122.59
- wood content printings, total		22.50	25.62	28.57	33.46
- woodfree printings, total		51.74	63.80	77.68	89.12
tissue		15.05	18.03	21.60	25.65
other paper and paperboard [1]		97.22	111.60	133.77	158.30
miscellaneous, not otherwise specified		41.13	46.28	53.51	62.90
selected paper grades	*NLK*				
- coated wood content printings		11.87	13.94	15.96	19.12
- wood content, not coated printings		10.63	11.69	12.61	14.34
- coated woodfree printings		15.56	20.62	26.15	31.62
- uncoated woodfree		36.18	43.18	51.53	57.51

[1] *most is packaging paper*

future fiber balances. The latter reflects not only the shifting emphasis between cultural (*white*) and industrial (*brown*) paper grades, but also technological change. For the present study, we are concerned not only how differences develop over time, but also why changes in fiber balance take place. Some reasons may reveal clues on the possible use of sisal pulp as reinforcement pulp.

table 5.3 percent shares in paper production

paper, million tons	*1995*	*2000*	*2005*	*2010*
database production	260.4	301.1	352.0	408.5
percent share in database production	100	100	100	100
newsprint	12.6	11.9	10.5	9.6
wood content printing	10.1	10.2	9.8	9.7
woodfree printing	20.4	21.1	21.5	21.3
packaging	51.1	50.8	52.1	53.1
tissue	5.8	6.0	6.1	6.3

5.2.2 the expansion of paper

From *table 5.3*, it is evident that, although all paper types share in the projected expansion, they do so at different rates.

Newsprint is in decline, but wood content printings will remain fairly even. The volume of woodfree printing paper is expected to increase rather considerably. Also, more packaging paper will be made and consumed, even though the expansion of virgin pulp for packaging will be less than proportional. An impressive increase is forecast for tissue paper. By coincidence, newsprint and tissue are the areas where new papermaking technology has advanced markedly, an advance which has greatly affected the prospect for reinforcement pulp.

In any case, the shift among paper grades influences the relative positions of pulp types in the fiber balance of the future. The volumes of long fiber pulp will definitely grow, but less than proportional to paper, and the relative positions of integrated and market pulp will change.

The interesting questions are : where will the additional volumes of long fiber pulp be manufactured, which raw materials will be available, in which order of priority will the new greenfield pulp capacities find their place on the market, and will they be on time ?
Before we address these questions (in *chapter 8*), we will review the major paper grades and their fiber profiles.

5.2.3 change in pulp process technology

During the past four or five decades considerable developments in pulp have taken place. Driven by new process technologies, cost considerations and scale economies, certain sectors in pulp manufacture have developed dramatically. The effect is visible in paper products with much improved qualities and lower cost. On the other hand, the mature state of the industry is perhaps best illustrated by the long term downward price trend of -by example- softwood reinforcing pulp (cf *graph 8.2*).

In half a century, process changes in cooking and bleaching have advanced the sulphate process into a foremost position. Reinforcement cellulose, for instance, is made by the alkaline sulphate process and enhanced by sophisticated cooking and bleaching sequences. Concerning other pulps, the new mechanical processes occupy a prominent place. Recycle technology has made paper waste a major alternative source of papermaking fibers, the third area of change.

Thermomechanical (TMP) pulps have all but replaced groundwood, providing much wider scope for wood content papers. The momentum in mechanical pulp was entirely cost driven. Once the technology was properly established, the new mechanical pulps were appreciated for their superior printing and sheet formation properties. Thermomechanical pulps have reduced - and at the same time sharpened- the need for reinforcement in many printing papers.

The expansion in recycled paper has been just as revolutionary. The recycle technology was driven by economies as well as public perception. Technological advances in chemistry and process technology have made paper waste accessible for higher value added recycled paper. Paper waste has traditionally been confined to packaging, but has now found a place in higher value added paper types, such as printings and tissue. The new process technologies (deinking) and machine designs have given paper waste a prominent place in the white paper sector. Although driven by cost and environmental concern, waste fiber has found a cost effective role in the high-volume white paper grades sector, where it continues to expand.

The forecast model (*chapter 4*) accommodates changes such as those from technology that have been mentioned. It can emphasise or attenuate the effects from technological change. We have gone through various alternative scenarios, before settling on the most likely ones that underlie the present study.

5.2.4 short fiber pulp

Although short fiber pulp was not a new grade, short fiber applications have expanded considerably in the last decades. Besides thermomechanical pulp and waste, eucalypt cellulose is a prominent example. The expansion of short fiber pulps seems to suggest that reinforcing pulps have also gained in prominence. This view, supported by people in many quarters, suggests that non-conventional long fiber pulps, such as sisal, might be used for reinforcement. In *chapters 6* and *8*, we will review the extent and future of conventional long fiber pulps.

Change in technology will continue to exert their influence on fiber use in the future, shifting the volumes *and* the balance between individual pulp types. The ways in which papermakers respond will influence the fiber compositions, hence the need for reinforcing pulp.

5.2.5 chemical pulp in general

We need to discuss some aspects of chemical pulps, before proceeding to the analysis of the major paper grades, beginning in the next paragraph. Short comments follow on long fiber cellulose and the 'new' short fiber pulps from eucalypts and acacias.

In chemical pulping, scale economies -and improved cooking and bleaching procedures- have placed sulphate cellulose firmly at the top in long and short fiber pulps alike.
In three decades, the production of long fiber bleached sulphate cellulose has multiplied, with mills in the traditional coniferous forest areas of the nordic temperate zones, as well as in southeast USA, but also in certain subtropical zones where radiate pine plantations have been established on a large scale. For the present analysis, it is significant that major land spaces can still be found throughout the subtropical zones, where radiata pine can be grown for pulp. Besides, forest reserves in Canada and Siberia exist, so far inaccessible. Mobilisation of untapped resources is a question of investment feasiblity, not whether the wood exists at all.

Pulp mills have grown in size. For long fiber bleached sulphate market cellulose, the average mill size has grown from 85,000 tons in around 1960 to about 400,000 tons presently.

Greenfield capacities of 400,000 to 500,000 tons are now common for softwood cellulose (*chapter 8*).

Presently, there are 85 market pulp mills in the world where long fiber sulphate cellulose is produced and sold to the world market. The cost profiles of these mills are shown in order of increased unit manufacturing cost in *figure 8.5*. Together, these mills can produce 24 million tons annually of long fiber cellulose. Three quarters of the volume is reinforcement pulp.

Sulphite pulps are a valuable constituent in certain papers, but are no longer a major market commodity, even though some market mills still produce and sell it and several integrated mills like to use it. Sulphite long fiber pulp has almost become a specialty pulp. The major obstacle to maintaining its position has been the effluent associated with the process. The process is difficult to reconcile with the new emission regulations.

Eucalypt species are short fiber hardwood species. Originating from Australia, eucalypt species have been widely planted throughout the subtropical and the warm temperate zones of Latin America, Europe, Africa and Asia. Being exotic species, some eucalypts have very high growth rates. Brasil was one of the first countries where extensive plantations were established, from the 1930's onwards, initially for fuelwood for the railways. In those early years, eucalypt wood was considered unsuitable for paper.
Eucalypt pulping was pioneered in Brasil, beginning in the fifties. The first euca pulps were used as filler pulp. Later, it was discovered that euca pulp has remarkable printing properties, although it is inferior in fiber bonding.
The appreciation for euca cellulose grew as the pulp became a commodity on the world market, first from Brasil, then from Spain, Portugal, Chile. Paper mills found that the printing properties of euca pulp are comparable, even superior to pulp from northern hardwoods, developed two decades earlier in the US.
At a later stage, it was realised that euca pulps from Brasil, Chile, Spain and Portugal have their own specific user profiles, due to the wood species and growth conditions.

Reinforcement is practiced in mills that use these pulps on high speed paper machines. Wet web fiber bonding in euca pulp is insufficient under such conditions. Certain of the printing papers require liberal amounts of reinforcing pulp. The need for reinforcement furnish is much less on slower speed machines. The reinforcing component provides production economies. Reinforcement is practiced for cost economy.

5.3 differences in manufacturing practice between Europe and North America

For a worldwide commodity such as paper, one expects to see similarities in technology rather than differences. This is true, but only in a superficial sense. There are numerous differences in operating practice among paper mills, often related to the fibrous raw material base, but also to specific market considerations.

Differences in manufacturing practice, for instance, are manifest between Europe and North America. Even within regions, differences are obvious : between Scandinavia and continental Europe, for example, and between USA and Canada.
There are rather fundamental differences that are related to the choice of raw materials ; for instance, whether paper mills use only long fiber pulp, or short fiber pulp, or paper waste. Differences such as these are at play, for instance, in newsprint, woodfree printing and copy paper, stationary and tissue ; they are also important in packaging grades, especially case making materials.

The *similarities* in production practice are just as much worth noting. Similarities in fiber formulas and operations exist above all in the wood content paper grades, wood content and woodfree coated papers. Each grade will be looked at in the paragraphs that follow.

5.4 newsprint

5.4.1 newsprint and reinforcement

Newsprint is one of the paper commodities where -it is thought- nonwood reinforcement pulp would be a useful component. Newsprint is made from short fiber furnishes, and often loaded, i.e. mineral pigment added. The short fiber component in newsprint is weak in fiber bonding. A reinforcing network assures web integrity at the machine speeds usually practiced. The long fiber pulp, added to the newspaper furnish, forms the reinforcing network as the sheet is cast. Normally, softwood cellulose is used for the purpose.

⌘ Even so, newsprint is increasingly made without any additional long fiber furnish ; see *par 5.4.4.*

It has been suggested that sisal cellulose forms a more effective network than softwood pulp : the suggestion is to substitute the softwood pulp component by nonwood long fiber cellulose. Less sisal pulp would be required to replace softwood cellulose for the same reinforcing effect. In addition, there are those who believe that softwood pulp will be in short supply in the future, and long fiber nonwood pulps such as sisal will be needed some day anyhow. The situation is however far more complex.

5.4.2 North American newsprint

Canada is the lowest cost producer of newsprint, due to its forest reserves and inexpensive electric power. The country is the largest producer of newsprint, and the leading exporter in the world. Canada supplies most of the newsprint, consumed in the United States, and more than 30 pct of newsprint requirements in other countries.
Most Canadian newsprint is made from softwood TMP, with or without help from reinforcing pulp. Less than 50 pct of the fiber furnish in Canadian newsprint is recycled paper (ONP) ; most of this is first cycle, retaining a measure of fresh 'virgin like' properties. In any case, more than 50 pct of the fiber furnish in Canadian newsprint is virgin pulp. We will see the significance of this later on.

The United States is a marginal producer of newsprint, although it is the world's largest consumer. Most newsprint, produced in the US, is made from recycled news and usually fortified with reinforcement furnish. More and more states in the Union demand a minimum recycled fiber content in the newspapers in their state. This policy supports the US recycled newsprint mills (*interviews, chapter 9*).
The recycled content in the US fiber balance is low, just 50 pct, although rising ; much of the recycled ONP retains the fresh properties of virgin newsprint, because of the influx from Canada. Like in Canada, this means that half of the US fiber balance in newsprint is near-virgin pulp. Besides, US recycle mills are adding reinforcing pulp to the furnish. For such reasons, North American newsprint has more resilience and grip in comparison with European paper.

⌘ Newsprint recycling was pioneered in the United States as far back as the fifties. It was recognised that ONP is easily collected in the urban centers of North America, a too valuable source of fiber to be wasted. Pilot research in Syracuse showed that such waste can be reused by proper washing (*deinking*). At the time, any additional reinforcement component (NBSK from eastern Canada) would not need to exceed 10 pct, even though newsprint then was made from stone groundwood. Since then, TMP has replaced stone groundwood.

A pioneer project, producing recycled newsprint, was built in 1962, 'newsprint *without* a forest base'. It was set up in New Jersey, across from New York City, the world's largest newsprint consumer. The mill was quite successful, and other mills followed suit.

5.4.3 Canadian newsprint

Canada has held the position of lowest cost newsprint producer and leading exporter for a long time. Three companies in eastern Canada dominate the market. They have ready access to wood and hydroelectric energy. Mechanical pulp requires considerable electric energy for fiber separation.

⌘ Formerly, Canadian newsprint was made from a 80/20 furnish of stone groundwood and integrated sulphite pulp. Canadian mills were late in adopting the TMP process. TMP has better bonding ability and requires less reinforcement furnish. With TMP furnish, less reinforcing pulp was necessary even on faster paper machines. Indeed, some newsprint is made entirely from TMP. The TMP process came at a convenient moment, as sulphite pulping was became considered more and more objectionable. At that time, mills began to substitute sulphite pulp with purchased reinforcement pulp. They found that, with TMP in stead of groundwood, it was possible to use less reinforcing fiber. A helpful factor was that Canadian mills have machines of a certain age and speed, and require less reinforcement ; a distinct cost advantage. This is in sharp contrast with the new state-of-art newsprint mills elsewhere.

Recently, recycling is gaining share in Canada, especially in the eastern provinces. On balance, the recycled fiber content in Canadian newsprint remains inferior to what is practiced elsewhere. Indeed, Canadian mills have little reason to abandon its virgin fiber base. Domestic ONP is limited in volume ; and the urban centers of North America are far away.

5.4.4 newsprint in Europe

Continental Europe is the leading producer of recycled newsprint. It has become established practice to produce recycled newsprint from 100 pct waste. Little or no reinforcement pulp is used. As much waste as possible is used, without sacrifice in machine speed. The reasons for the situation, of course, are the elevated cost of wood and energy. Contrary to popular opinion, Scandinavia is *not* a prominent producer of newsprint - for the same reasons.

The recycled newsprint industry is dominated by the new deinking technologies. Although invented in North America, it has seen considerable development in Europe in recent years. Deinking has been developed into a highly sophisticated process, to the point where it is now manageable to produce recycled news from 100 pct waste furnish, on suitably configured, fast and wide machines (*1400 to 1800 m/min*). The new state-of-art newsprint machines in Europe are capable of producing standard 45 gsm news from waste without adding reinforcing pulp. The hypothesis is that recycled waste contains long fiber fractions which assure wet web cohesion as the paper is made.

The likely explanation is as follows. Virgin newsprint incorporates a fair amount of long fiber, originating from the TMP from which virgin newsprint is manufactured and from any reinforcement cellulose, added when the paper was made. Canadian newsprint contains fair amounts of the one or the other, perhaps both. Even today, east Canadian newsprint on average is made from 70 pct virgin fiber. This implies that most of the 30 pct recycled fiber balance in Canadian newsprint is first cycle fiber.
Canada has suitable and accessible softwood forests, cost effective pulpwood and low cost energy. In the fiber balance of recycled newsprint in Europe, virgin newsprint from Canada figures prominently.
Therefore, the long fiber content from virgin newsprint, when recycled, is believed to assume the reinforcing role in European recycled newsprint mills. Our analysis of North American

newsprint furnishes, compared to those in recycled ONP in Europe, supports this point of view (refer to the *database* in *annex two report*). Virgin imported newsprint is continuously added to the ONP circuit, and 'diluted' ONP is bled off to lower grades of recycled paper. The long fiber component is replenished by the reinforcement content in virgin newsprint. This feature is characteristic of the European and US situations alike.

The conclusion is that the influx of virgin newsprint -for the time being- is sufficient to allow newsprint mills elsewhere to develop all-waste newsprint even further. This applies particularly to Europe, where the need for reinforcement is most pronounced. There is no direct prospect that the situation will change, because the Canadian mills are low cost producers and retain unrivalled access to wood and energy. This situation is expected to continue for the foreseeable future. Canadian producers will continue to use a fair share of wood, as the waste alternative is relatively unattractive. This scenario remains in force as long as the long term price trend of newsprint is stable, a condition equally important to the Canadian as to the European producers and newspaper publishers.

⌘ The practice of newsprint manufacture in Sweden is somewhat behind, but catching up. Recycled waste constitutes only 65 pct of fiber furnish in Swedish newsprint, although this is now rising under the influence of energy cost, wood cost and recycle economies. The reader is reminded that Scandinavia is not an important producer of newsprint.

5.4.6 deinking

After recycled newsprint was launched in North America, most of further research occurred in Europe, influenced by environmental concern. The research was better focussed, benefiting from the fact that it was undertaken at a later stage.
The developments in process (*deinking*) and equipment were entirely cost driven. Of course, waste is a more cost effective fibrous raw material than TMP, for which wood and electric energy are needed. Wood and energy have always been expensive cost elements in Europe.

The technology of deinking has progressed to the point where all waste recycled newsprint is feasible on high-speed state-of-art machines and at competitive cost. Whether this system requires the inflow of more reinforcing pulp remains a matter of dispute.

5.4.7 reinforcement scenarios in Europe

We have found that, in the short term scenarios, sufficient reinforcement fiber enters the ONP circuit so that continental European mills are safe in pursuing all-waste newsprint. This concurs with widely held viewpoints among newsprint producers in Europe (*interviews, chapter 9*). The discussion is undecided whether even more recycling is sustainable without using additional reinforcement pulp. In our findings, this is indeed the case.

In the long term view, machine manufacturers and newsprint producers expect that further development in deinking and stock preparation technology will allow full recycling to continue to expand. We agree with this viewpoint.

However, proof is elusive. To provide experimental proof, one has to have a unified, closed system of waste recovery (ONP), multiple but comparable paper machines, producing recycled newsprint to exact operating standards, and manipulating the reinforcement content until proof is reached. Such a system would have to be in stable operation for a certain time. It has been suggested that the newsprint-and-paper system in Germany might represent a suitable approximation for such experimental setup. However, it is obvious that the experimental conditions cannot be met : it involves too much risk on the part of the producers.

In practice therefore, the nearest approach to evidence on reinforcement is to identify the changes in furnish and reinforcement practice in newsprint over time. The database offers a suitable opportunity for such analysis.

5.4.7 sisal pulp for newsprint reinforcement

We have seen that newsprint contains *some* reinforcing fiber content and that the new recycle mills can produce it without adding fresh reinforcement pulp. In any case, paper makers try to reduce the addition of reinforcement pulp to a minimum, consistent with production economics and runnability. Machine and process technologies have helped in both aspects. The conclusion is that newsprint manufacture requires less reinforcement pulp than twenty years ago. This trend is expected to continue.

If sisal pulp could be proven to have the wet runnability, which laboratory handsheets suggest, it would be a desirable reinforcement medium for newsprint. This presupposes that sisal pulp will also meet the other conditions of newsprint manufacture, including cost economies. The comparison of NBSK prices and sisal pulp price estimates (*chapters 8* and *10*) confirms that sisal pulp as a reinforcement component in newsprint will not meet the cost criterion.

5.5 printing paper in general

Printing paper without coating is a traditional product, produced from bleached cellulose ('woodfree') or from mechanical pulp ('wood content'). Coated paper uses the same fiber components and is subdivided in the same types.

Printing paper is produced from short fiber and long fiber pulp in a wide range of basis weights and qualities. The fiber profiles depend on paper use and price, and sizing, coating and finishing also influence the choice.

Printing papers are woodfree (*made with chemical p*ulp) or wood content (*containing mechanical pulp*). The major differences are durability and price.
Woodfree printing paper is manufactured from short fiber cellulose from birch, poplar, maple or mixed hardwoods, acacia or eucalypt wood species. Straw pulp is only used in developing countries. Wood content paper, as already mentioned, contains mechanical pulp.
Reinforcing pulp is added to assure wet sheet cohesion in the formation and consolidation phases of papermaking. It improves runnability on high speed printing presses as well. The long fiber component improves characteristics like sheet resilience, fold, wear and durability. And it ameliorates the handling properties of higher quality papers like book, map, document.
The reinforcing component is softwood cellulose, integrated or market. Printing paper grades (in the database, *chapter 4*) have a long fiber pulp content between 20 and 50 pct on average.

5.6 coated paper

5.6.1 overview

Coated papers are mass commodity grades for magazines and books, where image reproduction is essential. Coated papers are classified as wood content or woodfree grades. They are made from short fiber furnishes ; some are made with mineral fillers. The furnish is weak in fiber bonding. Coated paper mills use reinforcement pulp for cost economies. Together, they consume most of the reinforcement market pulp.

Production practices in North America and Europe are similar, and although the reinforcement content varies (*table 5.4*), it is substantial in all cases. The similarity is in the reinforcement *table 5.4 reinforcement content in printing paper : regional differences*

percent	*examples*	*Europe*	*North America*
directory and catalogue	*groundwood content, MC, SC*	15	11
coated wood content	*magazine, MC*	29	32
woodfree	*general printing*	28	30
coated woodfree	*magazine, glossy, art*	25	24

pulp they use. The differences are in their short fiber furnishes and furnish ratios. The leading American mills are semi-integrated, and elaborate wood from surrounding forests ; northern hardwood species, which have excellent printing properties as pulp. And, whereas European wood content mills are also semi-integrated, the woodfree mills more often purchase all their pulp needs on the market. The latter are limited to the short fiber pulps, which the market provides. North American LWC *magazine* paper (woodfree as wood content) has a peculiar handle and compactness, which European paper does not have. The effect is contributed to the fiber characteristics of northern hardwood species which American mills use. Precisely these minute differences illustrate the competitive status of coated magazine grades.

5.6.2 wood content coated and uncoated paper

In contrast to newsprint, the United States is the leading producer of *coated wood content magazine* paper. Europe trails in second position. All the wood content coated paper mills are semi-integrated. They purchase the missing reinforcement grade. The same applies to uncoated wood content paper.

Wood content magazine is paper, used for mass circulation magazines such as Time or Newsweek ; for advertising, catalogue and for a host of other mass publications. Wood content magazine exists in coated and uncoated grades. For both types, reinforcement cellulose is used, for the coated grades to considerable extent. See, for instance, the worksheet in *table 4.4.*

The reinforcement content varies between 20 and 50 pct of the fiber furnish. Because the world volume of wood content coated paper is so large, the amount of reinforcement pulp is very substantial.

5.6.3 woodfree coated

The production of woodfree coated is more equally divided between America and Europe. Most paper mills purchase both fiber components : hardwood cellulose and long fiber pulp. Only some mills in Europe are semi-integrated. The leading producers are in Europe.

Semi-integrated mills produce their own hardwood pulp and purchase the reinforcing component. It was previously observed, that northern hardwood species (found in eastern US) are particularly suitable for coated paper. The American mills are integrated and have the advantage of ample access to these species.

The hardwood species, used for printing papers, are birch, poplar and eucalypt (in Europe) ; and mixed northern or eastern hardwoods, maple, poplar, oak (in North America). Among market pulps, birch and poplar are available but euca pulp is by far the leading market pulp in the short fiber segment. Acacia pulp from Indonesia (a notch weaker in bonding) has recently appeared on the market.
Europe is the largest user of eucalypt pulp. Brasil is the foremost producer and exporter,

followed by Portugal, Spain and Chile. Birch cellulose is a market pulp from Scandinavia, and birch and poplar cellulose are also used by integrated mills in Sweden and Finland. Surprisingly, Sweden is an important importer of eucalypt pulp. A considerable volume of euca cellulose, of course, is used in the integrated white paper mills in Portugal, Spain, Brasil and Australia. Brasilian mills have assumed prominence as paper exporters. For production economies, these purchase and import reinforcement pulp.

5.6.3 market pulps

The major bleached short fiber chemical market pulps are euca, acacia, birch and poplar. The chemical pulps from eucalypt and acacia, birch and poplar, and the North American hardwoods, have different paper properties. Mechanical pulps are traded in low volumes.
The largest volumes in market pulp are eucalypt pulp ; even here, properties depend on the species and age from which the pulp is made. Brasilian and Chilean or Portuguese eucalypt pulps differ in bonding ability, opacity and bulk. Their need for reinforcement is not the same. Besides, the properties between Scandinavian birch or eucalypt pulp, and pulp from northern or eastern hardwoods (in the United States) differ in printing behavior.

5.6.4 recycling

Recycling is not yet widely practised in coated paper, but is expected to become established in the decade. This may have consequences for the positions of mills in both continents.

5.6.5 reinforcement

The *volumes* of reinforcement cellulose are very substantial. The consequences for market reinforcement pulp will be discussed in *chapter 6.*
By first appearance, sisal cellulose is an interesting alternative in coated papers. However, the hurdles are substantial. We will analyse the prospect in *chapter 10.*

5.7 copy paper

5.7.1 standard grade

Standard copy paper is a homogeneous grade, much the same throughout North America and Europe, manufactured from short fiber chemical cellulose and reinforced with softwood pulp.

Emerging from the standard grade (now a commodity) are the various higher value qualities of color copy, laser and jet paper that have come on the market in recent years. These papers differ in sizing and short fiber structure, and some are coated. They have enhanced dimensional stability and surface smoothness, valuable especially for fine and color reproductions. Eucalypt pulp and cellulose from birch, maple or northern hardwoods are equally used.

At the onset, copy paper was an occasional product on middle size machines, alternating with other printing grades. As demand grew, specialisation and scale economies became important factors. The producers of leading brands now manufacture copy paper on dedicated machines of large size, adapted for short fiber furnish. The production conditions on both sides of the Atlantic are comparable.

There is no specific reason why sisal cellulose should be a preferred furnish component in copy paper. The use of reinforcement pulp in copy grade is price oriented.

5.7.2 history

Nevertheless, the history of copy paper sheds some interesting light on the use of papermaking pulps.

Photocopying was developed in North America from the 1950's onwards. The first copy paper was stiff, white, woodfree, made from softwood cellulose, as was usual in those days for printing paper. There were simple criteria for caliper, dimensional stability, stiffness, opacity. The fiber recipes evolved slowly. Initially, copy grade was made from long fiber cellulose. The furnish developed into a blend of long and short fiber cellulose, to predominantly short fiber chemical cellulose as nowadays.
In the sixties, mixed hardwood pulping came of age in North America. Bleached NSSC pulp from eastern temperate hardwoods was introduced (Hammermill bond), soon followed by bleached sulphate pulp from similar hardwood sources. Both were suitable for copy paper. As the process was very polluting, bleached NSSC pulp is no longer made.
Another revolutionary development occurred when, twenty years later, eucalypt pulp emerged as a market commodity. Mechanical pulp was tried but rejected, since it lacks the necessary dimensional stability and permanence.
As the fiber compositions changed, different reinforcing strategies were followed. Initially, southern BKS was selected (it has stiff fibers), but later on, NBSK was preferred. The flexible, slender, long fibers from fir and spruce would form the matrix for embedding the short fibers (opacity) from hardwood cellulose, just as in printing paper. The change occurred when the opacity and surface smoothness of pulps from northern hardwoods and Brasilian eucalypt were better understood. The new short fiber pulps were useful for opacity and image reproduction, but they required a different approach to reinforcement.

5.8 stationary

There is no doubt that the Unites States produce the finest office ('*bond*') papers in the world, a role which Britain fulfilled before. American stationary possesses a distinct 'handling', which the market rewards ; the result of furnish formulas together with a long standing tradition in papermaking. The long fiber component, between 30 and 100 percent of furnish, is BKS or, nowadays less often, NBSK. Some is cotton content bond paper, also a commonplace paper in the American business scene.

There was an important momentary change in North America when, in the fifties, mixed northern hardwood pulps were introduced as a furnish for office paper ; Hammermill bond. Such pulp has distinct sheet properties, compact yet with high opacity, and superior fiber and surface bonding. For reinforcement, softwood sulphite or sulphate was used, alternating with with cotton pulp.

Such exceptional paper is less in use in Europe. With few exceptions, European stationary has a common look, although equally produced from modern hardwood pulps such as birch, poplar and, indeed, eucalypt. Similar to North America, the long fiber component is NBSK or BKS, varying between 40 and 80 percent. Cotton pulp is hardly ever used.

There are no urgent reasons to replace the BKS and NBSK in stationary paper. The use of sisal pulp might be considered when more people begin to see that sisal pulp has distinct characteristics, suitable for paper grades such as letter head. The properties at play are fiber stiffness, sheet handle, fiber bonding, tear, fold, density to bulk ratio.

5.9 tissue

Tissues are an important and fast growing paper segment almost every where. The trend in tissue manufacture is towards using waste, conditioned by better deinking techniques.

Among the different types of tissue, three important grades will be discussed in this paragraph. The other tissues have specialty character (*chapter 11*). The grades to be reviewed are hygienic tissue, toweling and diaper tissue.

5.9.1 hygienic tissue

Sanitary tissues differ in fiber composition and in the way they are manufactured. Most tissue in Europe is made from selected waste. More American tissue is made from virgin long fiber cellulose. Short fiber pulps, such as mechanical pulp and hardwood cellulose, are used for bulk and absorbency.

The fast American tissue machines, which dominate the market, are run with extreme efficiency and they are characterised by low production cost. The long fiber content in their furnishes is necessary for wet reinforcement at the machine speeds at which the paper is made. Such reinforcing pulps are invariably purchased. The premium grades for virgin tissue are pulps from Canadian Picea mariana and P. glauca, seconded by those from certain west coast species.

In contrast, most tissue in Europe is made from waste. Their tissue machines operate at slower speed and cheaper furnishes are chosen. The better qualities are made from deinked and bleached waste. Virgin grades are on the market, although their volume is limited. Most virgin fiber tissue in Europe is manufactured in Scandinavia, and recycled tissue is made in the continental European countries.

Most hygienic tissue in Europe, therefore, is manufactured from selected waste, and rarely reinforced with long fiber pulp. It is a sales argument in Europe that toilet tissue is made from recycled paper. Because machines have slower speeds and the selected waste contains long fiber, the addition of reinforcement pulp is considered unnecessary.

5.9.2 tissue production

The production of tissue requires paper machines with specific configurations, designed for low basis weight at highest possible speed. Fiber bonding in the wet phase is a critical variable, and several wire, press and dryer designs are available that assure the integrity of the wet web. The choice among designs depends on the fiber furnish that will be used. In this respect, the production practices in North America and Europe differ substantially. Market differences are reflected in the furnish and in price. Whether the furnish includes mechanical pulp or paper waste, depends on the market segment but also on the mill's raw material base. As before, we find that American producers use long fiber cellulose more readily.

Most tissue in Europe is produced from waste, and little or no long fiber virgin pulp is used. See also *chapter 9*. Of course, the waste grades are *selected waste*.

Waste tends to slow down machine speed, because the stock has slower drainage and the wet sheet is prone to rupture. On the other hand, waste provides a cost advantage, which helps to explain why tissue machines in Europe are profitable, even when allowed to run slower.

5.9.3 diaper tissue

Diaper tissue is an American invention, owing much to the American pursuit of convenience ; something quite unthinkable from the old days of European tradition. The diaper market has grown phenomenally in the last two decades. Diaper stock is a nonwovens fledgling come of age and contains a surplus of absorbent *fluff pulp*, nowadays specially prepared TMP. A super absorbent polymer is added to the fluff layer. This fiber mass is embedded in a matrix from virgin long fiber cellulose. The preferred grade is BKS, although other grades are used incidentally. There is scope for sisal pulp, but only if it is priced competitively with softwood cellulose. In our findings, producers will not consider sisal pulp for diaper products.

5.9.4 toweling
Industrial toweling (garages, laboratories, enterprises) is a high class tissue sheet from the best virgin long fiber pulp, preferentially BKS or radiata BK. Short fiber cellulose is added for absorbency. Household toweling is a cheaper grade, made from selected waste, virgin long fiber pulp and mechanical pulp.

5.9.5 reinforcing component in tissue
Sisal might be a suitable reinforcement fiber on high speed American machines in the first place. Much of American tissue still contains liberal amounts of long fiber cellulose, even as recycled content is increasing. Any alternative long fiber component would be compared with presently used softwood cellulose, in performance and in price.

5.10 wrapping paper

Wrapping paper exists in a wild variety of qualities. The best grades are made from virgin kraft, in integrated mills in North America and Europe. Lesser qualities are made from mixed kraft waste. The lowest grade is schrenz, from low grade waste. Schrenz is still used in some European countries, and is of course a regular means of wrapping in many developing countries, a notch above old newspapers.
Wrapping paper is used in the retail trade and in industry. The market is relatively small, in comparison with paper from mixed virgin/waste, the most common variety in Europe.

5.10.1 multiwall sack grade
There are many specific wrapping grades, and one is multiwall sack paper. In multiwall sack grade, the manufacturing practices do not differ greatly. The strict code of properties and well established markets concur to have made this the most uniform grade in the industrial world. All but marginal amounts are produced in integrated operations, from kraft, on fast machines. All furnish is from long fiber pulp.
A fair amount of multiwall waste is now recycled, as a co-furnish in virgin kraft, without much affecting paper performance ; the bags are collected at point of use and sent for reuse.

The few exceptions to the quality of multiwall grade are found in developing countries, where the paper is usually made from furnishes that may include short fiber pulp or bagasse.

5.10.2 retail sack
For retail sack paper, on the other hand, the fiber formulas vary. The North American grade is the best quality ; it is seconded by Scandinavian wrap. Most operations are integrated. In both instances, paper is preferentially made from high yield chemical kraft, although recycled kraft is gaining momentum.
In the retail market in North America paper sacks are normally used, where in Europe most merchandise is handed over in plastic 'carry' bags. Where paper remains in use in continental Europe, a lower quality wrapping paper (retail sacks included) replaces the higher quality variety, for reason of cost. Quite a few wrapping paper mills, often smaller size, continue to operate, producing lower grade and fancy wrappings from recycled kraft or comparable waste.

The market attitude influences the possible use of sisal pulp for packaging. The questionnaires (*chapter 9*) have analysed the response of paper mills in this respect.

5.11 *corrugated case making materials*

5.11.1 overview

Corrugated case making materials are the largest single grade in packaging. Such cases are made from liner and corrugating medium. The inner and out liners differ in fiber composition, according to their function.

In virgin paper mills, liner and medium are produced by paper mills from high yield kraft and semichemical pulp. Virgin mills may use some waste ; the proportion of waste, indeed, is gradually rising. The leading producers, whether in North America or in Europe, are fully integrated. They have control over their raw material (wood and waste), they produce the paper in dedicated mills and have a substantial share (typically 50 pct) in box converting. The boxes are made in converting plants near the consumers. This typifies the situation in virgin case making mills. They produce the higher quality boxes which the market demands ; the sector represents 20 to 30 pct of the worldwide market volume in corrugated boxes.

The balance in the worldwide volume of corrugated boxes is made from waste. Paper mills in continental Europe have the largest share in this sector, seconded by US mills. The driving force behind the market divide is cost, i.e. the ratio of cost versus performance. The difference between North America and Europe is in the performance of boxes which the industry requires. European users emphasise lowest cost for product protection in storage and transportation.

The differences in paper use between America and Europe are illustrated by their fiber profiles (*table 5.5*). They characterise the difference in emphasis on both sides of the Atlantic.

table 5.5 fiber balance in paperboard (solid board and corrugated board) [1]

million tons	*production*	*fiber balance*			
	total board	*long fiber* [2]	*short fiber* [3]	*nonwood* [4]	*waste*
North America	15.00	5.24	5.03	-	5.24
Europe	7.81	2.99	1.64	-	3.34
world database	41.52	10.21	10.18	2.74	19.20

[1] *total paperboard for the year 2000 ; includes solid board and corrugated boards*
[2] *long fiber pulp from wood, bleached and unbleached*
[3] *short fiber pulp from wood*
[4] *developing countries in the database*

Corrugated cases are a traditional product for transportation and storage, a mature product with a long history. Corrugated packaging came of age in Europe a long time ago, where it has held and maintained its function of utmost economy. In contrast, it proliferated in America, where '*everything is packed in corrugated boxes*' (*quote* from interviews, *chapter 9*).
The furnish overview shows better than anything else the liberal attitude to packaging (*over-quality*) in America, and, in contrast, the cost conscious approach (*lowest acceptable quality*) which dominates in continental Europe.

5.11.2 North America

Traditionally, conditions of storage, transport and trade have been different in North America. The American railroads have placed priority on packaging ; witness the *box certificates* which every American box carried obligatorily until recently. American boxes seem to have been made for eternity.

⌘ The famous neutral sulphite semichemical (NSSC) process, invented in Madison in 1924, has helped to establish the rigorous and obligatory railroad packaging code. NS semichemical pulp, produced from chestnut (a hardwood tree species) has extremely high stiffness. At the time, the chestnut blight, a fungus infection, affected entire chestnut forests in the southeastern Appalachians.
In the decades that followed, the railway box code remained strictly enforced. The certification obligation was finally abolished some years ago, but the American love for *over-packaging* still lingers.

The best evidence of overkill is the piles of boxes, every night in the streets of urban America. Not content with a modest price-to-life-cycle ratio, corrugated boxes are made to the highest standards for the lowest echelons of products. So it is that corrugated board is made with fibrous raw materials that would have found higher value added applications elsewhere.

5.11.3 fiber formulas in North America

The fibrous raw materials in containerboard are hardwood, for the medium, and softwood (pine) for the liner. Increasingly, box waste is recycled. North American OCC (*old corrugated cases*) contributes cost economies without sacrifice in quality. This waste is a valuable fibrous raw material ; indeed, certain mills use it to produce bleached pulp. American OCC is also a valuable export product to overseas countries. So much of it is produced in the US from virgin fiber that it easily upgrades the waste systems elsewhere in the world. Only half of post consumer containerboard in the US is recycled domestically. Besides, the recycle rates in containerboard in North America are only half of those in Europe.

North American mills are lowest cost producers, enjoying a strong market position domestically and abroad. The United States are also the leading exporter of case making materials. The export volume -to Europe, Latin America, Japan, Asia- is very substantial. Banana and fruit boxes almost anywhere are made with North American liner.

American mills enjoy very considerable production economies. The industry maintains assured access to its fibrous raw material base. Their operations are fully integrated and they have no need for outside sourced long fiber pulp (*quoted from* interviews with boxmakers (*chapter 9*).

Therefore, any alternative pulp (as from sisal) is not in question. Virgin kraft liner (the paper) has always traded below the market price of UBK (pulp). The sisal pulp price estimates are twice as high. The most illustrative argument came from one of the interviewed mill operators : 'allow us to supply twice your needs for half the price'.

5.11.4 Europe

The corrugated box trade in Europe operates on altogether different principles. Most corrugated board is manufactured from recycled waste. Only 20 pct of the manufactured volume is virgin fiber based. Sweden produces most of the virgin case making materials in Europe. Whereas the Swedish mills have a forest base, comparable to their American counterparts, their wood cost is twice as high.

⌘ As a consequence, the virgin fiber corrugated case industry in Europe is smaller, compared to North America. Stand alone semichemical mills, producing medium, have all but disappeared. Due to price pressure, virgin mills have turned increasingly to OCC as a co-furnish and found that modest amounts are compatible with maintaining the quality of the board.

Recycled corrugated boxes are the mainstay of the board mills in continental Europe. Their logistics and operating economies have come the longest possible way. The leading corrugating mills operate on the verge of the technically possible.

A characteristic feature of packaging in Europe is the fierce competition from solid board. Solid board is the lowest cost packaging material. This fact typifies the situation : the price of recycled corrugated boxes is just 10 pct higher. The recycled mills maintain cost economies by an ingenious system of waste use and other means, lower basis weight for example.

5.11.5 box makers in Europe
Approximately half of the volume of virgin corrugated boxes in Europe is produced by box makers, associated with paper mills. All but a few of these belong to companies in Scandinavia. The box converters consume case making materials from company sources. Waste based liner and corrugating mills own and operate box plants in the same fashion.
Independent box makers produce the balance. They are at liberty to purchase board anywhere, for example from North America. They may also purchase paper from waste mills in Europe.

The fully integrated mills in Scandinavia are close to their wood source and consume their own paper to produce the boxes. They also sell paper. Although the leading nordic producers are world size, they are handicapped by the cost of wood and energy. They have turned to using OCC together with virgin pulp, for economies. As in North America, they sell to box makers close to the industrial consumers, or they operate their own converting mills.
The recycled producers have set up their own waste collecting centers everywhere in Europe. They do not purchase exterior reinforcing pulp, except on very rare occasions. The virgin board producers in northern Europe are fully integrated and have no need for outside sourced long fiber pulp.
Therefore, reinforcement pulp is not an issue. Mills have no reasons to consider alternative long fiber sources, such as sisal. They see even less reason to consider sisal pulp of twice the price (*quotes* from interviews, *chapter 9*).

5.11.6 differentiated use
The retail trade is typically focussed on minimising cost. Therefore, it resorts to lowest quality corrugated cases *one way short time*. This is compatible with their logistics of short term storage and rapid door-to-door transportation. At their points of delivery, the boxes return to waste. Virgin fiber is not affordable (*interviews with logistics managers*).

In principle, two types of boxes are required for industrial packaging. The retail (display) boxes have face features, such as white, coated, even printed outer liner. These are made from intermediate or higher value fiber, virgin or recycled or both. The inner layers are from similar or lower quality fiber. The retail boxes are assembled in outer boxes, which protect the product during storage and transport. Outer boxes vary in the quality of their liners and medium. The outer liner is more impact resistant. It may carry a product identification imprint. The inner liner and medium plies are commonly made from intermediate qualities, depending on the purchaser. Most of the inner and medium board is recycled or selected waste. Mixed virgin/ waste board is used for more expensive ends.
A peculiar circumstance is that certain consumers prefer solid board over corrugated board, especially in Europe ; far less so in North America. The reasons : cost economy and order size.

Cold storage poses specific demands on corrugated boxes. Corrugated board from virgin fiber resists moisture somewhat better, but the effect is short lived and, according to users, does not justify the higher price. The problem is that air moisture affects (weakens) the stacking ability of boxes. This is not compensated by using virgin fiber furnish but needs moisture proofing. Chemical additives are effective. This procedure costs less than improving the fiber furnish.

Recycled board mills (for corrugated boxes) are found in the populated centers of Europe, where the collection of waste is well organised. The leading recycled operators are extremely

cost conscious. Their mills produce liner and medium on dedicated state-of-art machines, and operate exclusively on waste. Their daily concern is to allocate waste for the various board qualities as best as they can. They use virgin pulp on very rare occasions.
Yet, mills say that repeated recycling weakens the fibers and that they are interested in compensating this effect. Some mills are more specific : they say that after eight or so cycles, fiber resilience is lost (*interviews, chapter 9*). Their belief is that resilience is restored by the influx of fresh, quasi virgin waste from overseas sources. The use of purchased virgin pulp is no solace, because the cost is prohibitive.
Some operators will consider reinforcement pulp, but only if discounted. The conclusion is that there is no opportunity for sisal pulp in corrugated boxes.

5.12 solid board

5.12.1 overview

Solid board forms a heterogeneous family of grades with little common ground. It comprises a wide range of qualities, from exclusive grades to common and inexpensive coarse board. Accordingly, it is made from virgin pulps or waste. It is convenient to classify board by the fibers from which it is made. The higher value boards are made with chemical cellulose and mechanical pulp. Coarse board is made from the lowest waste grades. Solid board exists in duplex, triplex and multiplex varieties ; some is produced on fourdrinier or multiwire machines.

Solid board is used for packaging a bewildering array of products, ranging from delicate articles (toiletries, drugs, luxuries, software, photo film, retail products, food, liquid packaging) to fast food corners. The common grades are waste based and are appreciated for transportation and storage : for food, fish, fresh vegetables and other supermarket goods.

(The solid board group also includes specialty grades, for diversified uses such as filtration, transformer, electric, luggage, car interiors, advertising, ticket, book cover, leather, imitation and other specific applications).

Virgin pulp is widely used for pricey applications. For example : luxury goods, prestige articles, expensive retail products ; 'image' products such as photo film, software, cosmetics, medicines, health products, toothpaste, and many more. Virgin pulp is also used where food and board are in direct contact, especially in liquid packaging like pasteurised milk.
The fine qualities of board are manufactured from virgin pulp, groundwood in the inner layers and a resilient top layer from chemical long fiber pulp, as in folding boxboard. The 'face' ply of cilinder board is virgin cellulose, whenever prestige or recognition are desired qualities.

5.12.2 multiply board

Cilinder board is multilayered board, with the inner plies made from mechanical pulp or waste. Especially in Europe, coarse solid board competes with low cost corrugated board. Coarse board is the largest single grade by volume, made from waste throughout (*paragraph 5.12.3*). This grade is much appreciated by supermarket chains, but also by industrial and agro users for the price *versus* performance which is offers.

Fine quality board has two or three plies (duplex, resp. triplex), and coarse board has four or more (up to nine or ten) layers. The out and inner plies differ in fiber composition : the outer plies are often made from cellulose and the inner plies from mechanical pulp or waste.

Higher value multiply boards are used for retail packaging of dry food products and a great variety of retail products. The photo film boxes are ubiquitous examples. Duplex and triplex are

widely used for food and retail products packaging. These are examples where fold and print presentation are decisive elements. Sharp folds are essential, and the long fiber content on the outside face assures these.
The plies in duplex and triplex grades have different fiber compositions and the outer and inner faces also are different. Duplex and triplex are also used for office products.

⌘ Liquid board, used for milk, juice packaging, is an altogether different product, made from fourdrinier plies and virgin high yield softwood cellulose.

5.12.3 long fiber content

For the outer plies, softwood pulp is used ; 10 to 30 pct is usual. For coarse board, depending on the quality, virgin softwood pulp or long fiber waste is used. The long fiber component assures smooth operation in the converting plant.
In none of the multiply grades, true reinforcement is necessary. The plies themselves, even from waste, have sufficient cohesion in the wet state. The cohesion *between* the layers is critical, but this is a matter of stock preparation, not a function of the long fiber content itself.

Several queries were exchanged with producers of cilinder board (*chapter 9*). The replies indicate that the long fiber cellulose furnish for multiply board should have cohesive ability *vis-a-vis* the other plies with heterogeneous profiles (z-bonding). They also indicated that, although *some* long fiber component is desirable, mills are unwilling to consider any price premium over BKS, which they preferentially use.

5.12.4 solid board from waste

Coarse board has a well established place in packaging. It offers reliable performance at low price. It is the largest grade by volume. It is entirely made from low grade waste. No virgin long fiber is used. In the manufacturing process, mills select the waste according to the plies for which it will be used. The outer plies contain long fiber waste. Not a true reinforcement function, the face ply assures proper folding in converting the board into boxes.

Europe is the world leader in solid board. Solid board is the preferred commodity for lowest cost containerboard. Contrary to corrugated cases, solid board boxes can be made in small volumes with little cost disadvantage. The scale of processing, customised properties, ease of handling and superior protection have given solid board a solid reputation. It is a tough and resilient product with versatile applications, excellent for transport protection and storage. It can easily be made moisture resistant, or given moisture barrier or moisture proof properties. It is used for packaging applications as diversified as flowers, fruit, fish, shoes, clothes, metal wares, spare parts, furniture ; air cargo, cold storage and many others.

⌘ Five decades ago, *straw board* was a major packaging grade. It has remarkable stiffness and resistance to wear and impact. Solid board was used for boxes, even replacing corrugated cases. Indeed, straw *semichemical* pulp was used for corrugating medium.
The straw board was produced from straw, by a cheap semimechanical process, in integrated mills. Straw board mills were found everywhere in the wheat and rye growing areas of Europe. The board was widely used throughout Europe.
Thirty years ago, most straw mills in Europe had switched to waste, as the pollution from straw pulping was no longer acceptable. The conversion has made the board industry into a thriving sector in packaging. Solid board has sound economies : it uses low priced fiber, the lowest possible waste grade in its final life cycle (*paragraph 5.1*). At this point, paper recycling stops : solid board is the last useful product at the end of paper recycles.

THFME B

chapter 6 fiber furnishes and pulp volumes

overview	the fiber furnishes in major paper grades are discussed and their pulp volumes determined

So far, we have found this information on paper and fibers :

Paper production will increase by more than 100 million tons in the decade from 2000 to 2010. The fiber balance grows accordingly. However, the expansion of long fiber cellulose is modest. Short fiber pulps and waste grow more aggressively.

million tons		2000	2010
world paper production	*annual production in FMT*	301	408
fiber balance	*ADMTPY*	290	393
fiber furnish components	*ADMT*		
long fiber cellulose		75	87
short fiber pulp, all types		100	125
paper waste		114	179

We have also seen that paper grades have individually differentiated fiber furnishes.

We will now see that individual furnish profiles change over time. The driving forces behind this change are technology and cost of manufacture.

6.1 pulp classification

6.1.1 fiber length

Paper is made from long and short fiber pulps. Fiber length is a pulp property that is related to the fiber length in the fibrous raw material ('native fiber properties'). A side effect from pulping is that it reduces the fiber length, for instance by rupture (as in mechanical pulping).

Wood is the common source of fibrous raw material for pulp and paper. Forests and wood plantations are the sources of pulpwood. Softwood (*coniferous*) species are long fiber species. Hardwood (leaf bearing) species have short fibers.
Fibers in softwood have a *weight average* fiber length between 2.2 and 3.8 mm, with most fibers in the 2.8 to 4.2 mm numerical range. Fibers in hardwood species are 0.6 to 1.8 mm long, but most are between 0.9 and 1.6 mm. Although certain hardwood species have fibers 1.6 to 2.0 mm long, they are still considered short fiber species.

Representative fiber length distribution curves of wood and nonwood species are compared in *figure 6.1*. The wood curve is typical for temperate coniferous species, whereas the nonwood curve represents straw pulp.

The fiber length distribution curves of wood fibers are steep and narrowly confined. On the other hand, those of nonwood plant fiber species are broad and flat, with the extreme fiber fractions extending far out on either side. Straw for instance has an average fiber length of 0.9 to 1.1 mm, definitely a short fibered material, but contains fiber fractions 2.4 mm and longer.

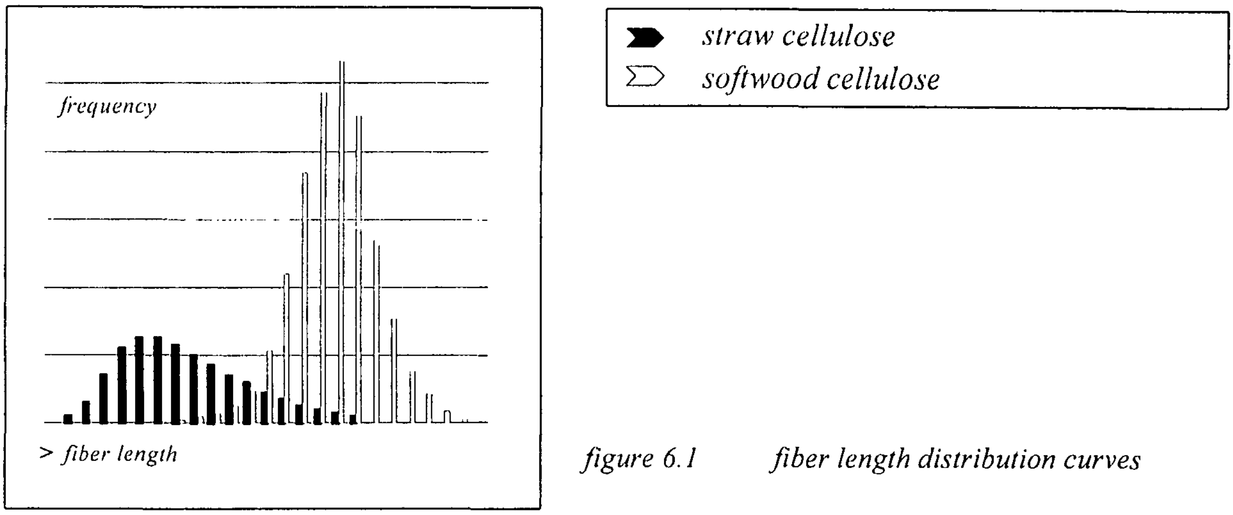


figure 6.1 *fiber length distribution curves*

Such broad fiber length configurations are characteristic of nonwood fiber plant species in general. They are most easily observed in juvenile fibrous tissue in annual plants, but the same pattern is found in mature (perennial) nonwood species. As plant tissue matures, the curves ascend and descend more, but they retain their broad base.
Long fiber nonwood plant species have comparable shallow spreads (unlike coniferous wood). Of course, their average fiber length is much longer : just a shift in the apogee of the curves.

Bamboo species have similar shallow curves. Their fiber length spread is considerable : 0.8 to 4.8 mm. Bamboo pulp is a desirable furnish for paper, because of their long fiber fractions. Yet, it is not a long fibered species. Rather, the bamboo's are considered intermediate between short and long fiber nonwood plant species. In this respect, somewhat comparable is bagasse.

The technology of papermaking -through time- has evolved in close dependence on the pulps that were available. Seen from this angle, fiber length is also a fundamental property in making paper. In the long range perspective of the industrial revolution (1800 onwards), short fiber pulps are a relatively recent discovery. The broad specter of fiber length in pulps is in *table 6.1*.

6.1.2 pulping process

Pulps are not only classified by fiber length but also by process. The major difference is between chemical and mechanical pulps. The properties of pulp depend not only on the 'native fiber properties' of the fibrous raw material, but also on the method of fiber separation. Mechanical pulping especially reduces the average fiber length in the resulting pulp. Chemical degradation (during chemical pulping) has a similar, if less drastic effect.

Pulps are characterised by pulp yield (*table 6.1*). The broad differences are between the *methods of fiber separation* (maceration) : the chemical processes or mechanical fiber separation. Semichemical pulp is in between.

Most cellulose is made from wood. The most important routes for chemical cellulose are the sulphate and sulphite processes. The chemical processes dissolve the bonding substance between fibers (as in wood) by cooking with chemicals. Hence, this method requires the application of heat. It results in lower pulp yields (42 to 52 pct) as part of the raw material is dissolved. In mechanical pulping, the bonds in the fibrous raw material are ruptured by mechanical or thermomechanical means (whereby heat and electric energy are applied).

The major *market pulps* are kraft (unbleached softwood sulphate cellulose) ; bleached long fiber sulphate cellulose (from softwood) ; and bleached short fiber sulphate pulp (for example *table 6.1* *pulps for papermaking*

species	*frm* [1]	*fiber length*	*which pulps ?*	*pulp yield*	*process*
long fiber					
conifer	*lf*	2.4 – 4.4 mm	*chemical cellulose*	44 - 52	
	lf		*high yield kraft*	54 - 58	
	lf		*mechanical pulp*	90 - 96	
short fiber					
hardwood	*sf*	0.9 – 1.8 mm	*chemical cellulose*	46 - 52	sulphate
	sf		*semichemical cellulose*	58 - 74	NSSC, SC sulphate
	sf		*mechanical pulp*	88 - 96	RMP, TMP
nonwood					
bamboo	*if*	1.0 – 3.8 mm	*chemical cellulose*	42 - 46	soda
bagasse	*if*	1.2 – 3.4 mm	*chemical cellulose*	40 - 44	soda
straw	*sf*	0.6 – 1.6 mm	*chemical cellulose*	34 - 38	soda

[1] *lf = long fiber pulp, sf = short fiber pulp, if = intermediate*

eucalypt pulp). The sulphite pulps (bleached and unbleached, from softwood or hardwood species) are disappearing as market pulps.

In this discussion, we are not greatly concerned with the fine differences between the cellulose process types, sulphate or sulphite. Whereas the pulps have different papermaking properties, these are due to process, but not fiber length.

When the sulphate process was invented (1871,1884), the word ‘kraft’ was used for unbleached coniferous sulphate pulp from pine wood (long fibered wood species). Kraft is the German word for strength. Nowadays, the term kraft is used widely to denote long fiber or short fiber sulphate pulp, even if bleached (‘bleached kraft’).

Sulphite pulping was discovered in 1867 and sulphite pulp was the major cellulose type during a century, a major market commodity as well. It has retained a place in certain printing and specialty papers. Sulphite market pulps have become almost a semi-specialty commodity.

Semichemical pulps are short fiber pulps by nature, as they are made from hardwood species. High yield kraft is a near-chemical softwood kraft pulp for linerboard, fiberised mechanically after ‘high yield’ cooking.

The mechanical fiber separation process cuts through the fiber bundles and shortens the fibers. Besides, the process does not reduce the lignin content in fibers. The presence of lignin affects fiber bonding unfavorably.
Mechanical pulps are considered short fiber pulp, although they are produced from softwood. Seen in a more functional way : mechanical pulps are short fiber pulps *because* they have weak sheet properties. This is most evident in groundwood.

The modern, well elaborated thermomechanical pulps, are somewhat different. Despite their mechanical nature (shown by fiber rupture), they contain long fiber fractions with considerable bonding ability, by itself superior to short fiber cellulose.
For this reason, thermomechanical pulps *can* contribute *certain* reinforcement qualities, although always less than long fiber cellulose. In any case, TM pulp are *not* considered reinforcement material.

table 6.2 *pulp volumes in worldwide paper production*

		1995			2000			2005			2010		
		production	market	integrated	production	market	integrated	production	market	integrated	production	market	integrated
total paper production		260.39			301.08			352.00			408.49		
virgin pulp													
	LF all	67.79	18.57	49.22	74.53	21.48	53.05	81.44	25.36	56.09	87.14	29.42	57.72
	SF all	58.21	14.18	44.02	63.20	17.27	45.93	70.05	19.88	50.16	76.54	23.13	53.41
	mech all	32.95	2.13	30.82	36.93	4.65	32.28	41.66	7.88	33.78	48.59	12.47	36.11
	virgin total	*158.94*	*34.88*	*124.06*	*174.66*	*43.40*	*131.26*	*193.15*	*53.12*	*140.03*	*212.27*	*65.02*	*147.24*
fiber balance													
	long fiber bleached	35.67	16.76	18.91	38.51	18.56	19.95	41.28	20.99	20.30	44.27	24.11	20.16
	long fiber unbleached	32.12	1.81	30.31	36.02	2.92	33.10	40.16	4.37	35.79	42.87	5.31	37.56
	short fiber	58.21	14.18	31.32	63.20	17.27	45.93	70.05	19.88	50.16	76.54	23.13	53.41
	mechanical	32.95	2.13	30.82	36.93	4.65	32.28	41.66	7.88	33.78	48.59	12.47	36.11
	waste	91.69	1.01	90.68	114.29	2.53	111.76	144.11	4.75	139.36	178.81	6.67	172.14
furnish balance													
long fiber	bleached sulfate	31.74	15.57	16.17	35.10	17.75	17.35	38.48	20.31	18.17	41.97	23.52	18.45
	northern	*12.83*	*7.65*	*5.19*									
	radiata	*1.09*	*1.02*	*0.07*									
	southern us	*12.38*	*3.29*	*9.10*									
	other	*2.77*	*1.42*	*1.35*									
	bleached sulfite	2.81	1.08	1.74	2.39	0.70	1.68	1.86	0.55	1.32	1.30	0.44	0.86
	unbleached sulfite	0.91	0.11	0.80	0.73	0.12	0.62	0.54	0.13	0.41	0.51	0.15	0.36
	unbleached sulfate	32.12	1.81	30.31	36.02	2.92	33.10	40.16	4.37	35.79	42.87	5.31	37.56
short fiber	bleached sulfate	38.00	13.26	24.75	42.51	16.17	26.34	46.79	18.66	28.13	51.16	21.76	29.40
	birch	*3.21*	*0.99*	*2.23*									
	eucalypt	*5.84*	*4.12*	*1.72*									
	european	*1.05*	*0.72*	*0.34*									
	american	*16.30*	*3.35*	*12.95*									
	other	*6.50*	*0.55*	*5.95*									
	bleached sulfite	1.00	0.25	0.75	0.83	0.18	0.65	0.61	0.15	0.46	0.42	0.13	0.29
	nonwood	12.70		12.70	13.78		13.78	17.24		17.24	20.17		20.17
	other wood pulp	0.17	0.16	0.01	0.25	0.24	0.01	0.34	0.33	0.01	0.44	0.43	0.01
	semichemical	6.34	0.52	5.81	5.83	0.68	5.15	5.07	0.75	4.32	4.35	0.81	3.57
mechanical		32.95	2.13	30.82	36.93	4.65	32.28	41.66	7.88	33.78	48.59	12.47	36.11
waste		91.69	1.01	90.68	114.29	2.53	111.76	144.11	4.75	139.36	178.81	6.67	172.14
long fiber	nonwood specialties (n.i.)	0.79	0.68	0.11	1.12	0.80	0.32	1.34	0.90	0.42	1.47		

figures in million ADMTPY - data from report annex two

Most papermakers consider paper waste a short fiber raw material. Fibers become shorter and weaker as the waste is recycled repeatedly. Theoretically, this calls for reinforcement.
In practice, the degradation by re-using waste is offset by the constant influx of virgin fiber into the waste system. Besides, waste is generally used in paper where it has a price effect.

The waste system contains fiber fractions with considerable resilience. The 'over-quality' which some of the waste possesses maintains the resilience of the system. The addition of first cycle waste and the bleeding off 'dead' fiber occur in a continuous fashion. The true problem in the recycling and reinforcement questions is governed by the *dynamic character of the waste system*. The net result is that more waste can be recycled and less reinforcement is required than theoretically expected.

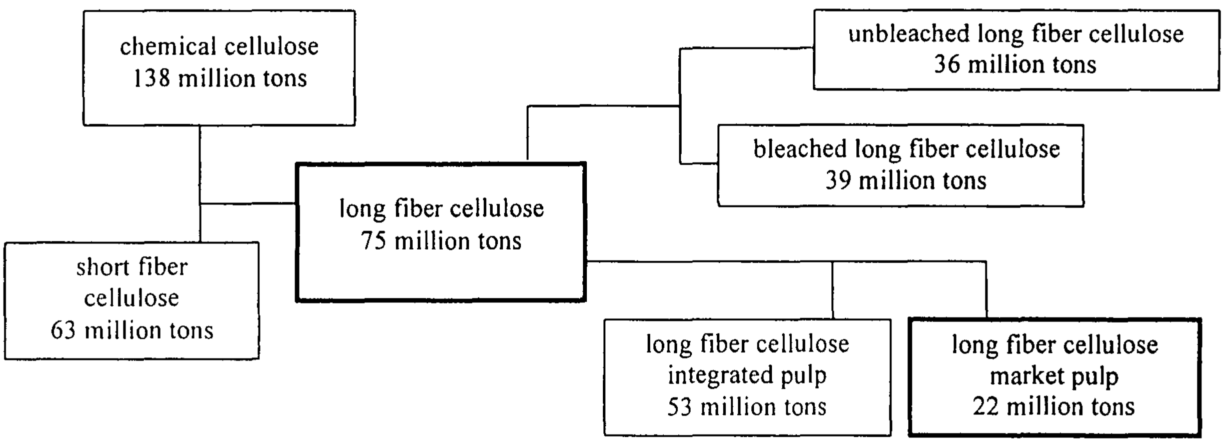
6.2 fiber balance and reinforcement pulp

Our target is to establish the volumes of reinforcement pulp in the future and at present.
To achieve this, we need to elaborate the differentiated fiber balances of all the paper grades, down to where variations still occur : the regional production levels.
The representative information has been compiled in *annex report two* from the complete data, assembled in the electronic database.

The database fiber balances for 1995-2000-2005-2010 have been reproduced here with the details which we need for our discussion (*table 6.2*). And, for ease of reference, the pulp volumes (those in the database) have been summarised in *table 6.3* on the next page.

The first diagram (*below*) illustrates the pulp volumes for the year 2000. The second diagram (*bottom*) illustrates the reinforcement pulp positions (the data are from *table 6.2*).

The world volume of long fiber cellulose is 75 million tons. For *our purpose*, we are interested in the volume of reinforcement market pulp. By its nature (*chapter 5*), most of reinforcement pulp is bleached cellulose. We have now found that two thirds of reinforcement pulp is *integrated cellulose*, and only one third or 17 million tons is market cellulose.



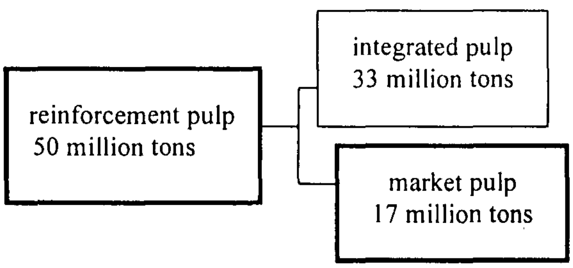


table 6.3   fiber balance (pulp volumes) in the paper database

million tons	*1995*	*2000*	*2005*	*2010*
total paper	260.39	301.08	352.00	408.49
fiber balance	250.63	288.95	337.26	391.08
fiber types				
virgin pulp	158.94	174.66	193.15	212.27
long fiber cellulose	67.79	74.53	81.44	87.14
short fiber cellulose	58.21	63.20	70.05	76.54
mechanical pulp	32.95	36.93	41.66	48.59
waste	91.69	114.29	144.11	178.81

6.3 future needs for pulp

Paper production will grow from 301 million to 408 million tons in the decade (*table 6.4*). This is a 36 pct augmentation.

In contrast, the consumption of long fiber cellulose will increase by just 12.6 million tons in ten years, a modest augmentation of 17 pct. The ratios between long and short fiber cellulose are fairly equal and will remain so. The long fiber volume remains the largest one.

Short fiber cellulose is set to grow faster, by 21 pct or 13.3 million tons. On the world scale, these are modest expansions. As we will see later, the wood raw material base for both exists.

Cost competitive pulps will expand faster. Mechanical pulp will expand by 32 pct.

Waste paper use will expand by 56 pct on a worldwide basis, a *considerable expansion.* The driving reason for the interest in waste is environmental concern and legislation. Convenient for paper producers is that waste fiber has a much lower price. And the public image is helpful.

table 6.4   comparison of paper and pulp expansions between the years 2000 and 2010

all paper grades	*production volume*		*production increase*	
	million tons		*million tons*	*percent*
	2000	*2010*	*by 2010*	
total paper	301.08	408.49	107.4	36
fiber balance	288.95	391.08	102.1	35
fiber types				
virgin pulp	174.66	212.27	37.6	22
long fiber pulp	74.53	87.14	12.6	17
short fiber pulp	63.20	76.54	13.3	21
mechanical pulp	36.93	48.59	11.7	32
waste	114.29	178.81	64.5	56

6.4 integrated versus market pulp

Let us discuss the various pulp positions in the present and future fiber balance and review their volumes.
For the year 2000, the virgin fiber needs were 175 million tons. This includes all types of pulp (the remainder is waste). This volume of virgin pulp was produced by the integrated *plus* the market pulp mills. Virgin fiber will increase to 212 million tons in the year 2010.

Integrated mills produce a substantial part of the pulp and cellulose volumes : 74 pct of the world fiber balance. The balance is market pulp.

We have seen that the share of long fiber pulp in the virgin fiber balance is rather modest : 74 million tons in 2000, and 87 million tons in the year 2010. The growth rate is only 17 pct (*table 6.4*).

Long fiber cellulose, at least on the world level, is divided fairly equally between bleached and unbleached grades. However, the reasons for using long fiber pulps are not the same, in white or brown papers.

In packaging grades, long fiber pulp is used for sheet strength (*dry reinforcement*). Most unbleached long fiber pulp ('kraft') is integrated : only 10 pct is market pulp.
The world production of unbleached long fiber pulp in 2000 was 33 million tons ; and only 2.9 million tons was market pulp. The figures for 2010 are 38 million tons for total pulp and 5.3 million tons for market pulp. Note that the demand for unbleached market cellulose will increase by 2.4 million tons.

Most unbleached long fiber pulp is kraft (unbleached long fiber sulphate cellulose from softwood). Sulphite pulps historically have had a substantial share in long fiber pulp, but their market share is disappearing. Whereas long fiber kraft is 71 million tons presently, long fiber sulphite is only 3.1 million tons. In 2010, kraft pulp will be 85 million tons and long fiber sulphite only 1.8 million tons, and market sulphite pulp only 0.6 million tons.

table 6.5 long fiber pulp

million tons	*1995*	*2000*	*2005*	*2010*
total long fiber pulp	67.79	74.53	81.44	87.14
bleached, total	35.67	38.51	41.28	44.27
unbleached, total	32.12	36.02	40.16	42.87
integrated pulp				
bleached	18.91	19.95	20.30	20.16
kraft	30.31	33.10	35.79	37.56
market pulp				
bleached	16.76	18.56	20.99	24.11
kraft	1.81	2.92	4.37	5.31

Now consider printing papers and bleached long fiber pulp. Here, the integrated and market shares of bleached long fiber cellulose are evenly divided. The dominant grade is bleached softwood sulphate. As previously, bleached sulphite pulp has a modest share, which it will not maintain. Sulphite will assume a marginal role except in certain integrated mills.

We have seen that reinforcement is practised in printing paper manufacture, where short fiber furnishes are used, which often need *wet reinforcement* as the paper is made.

For this study, we are interested in the future market share of reinforcement pulp especially in *those paper grades*, where the differences in *reinforcement practice* in papermaking are consequential. This is the case in many printing papers.

6.5 market pulp

A more extensive overview of market pulp volumes and their shares is presented in *table 6.6*. Full details are available in the electronic database, from which *annex report two* has been excerpted.

table 6.6 market pulp shares and pulp volumes

million tons	*1995*	*2000*	*2005*	*2010*
fiber balance	250.63	288.95	337.26	391.08
in which :				
long fiber cellulose	67.59	74.23	81.04	86.64
short fiber cellulose	39.00	43.34	47.40	51.58
mechanical pulp	32.95	36.93	41.66	48.59
waste	91.69	114.29	144.11	178.81
bleached long fiber cellulose				
integrated	18.71	19.65	19.90	19.66
market	16.76	18.56	20.98	24.01
percent market share	47.3	48.6	51.3	55.0
unbleached long fiber cellulose				
integrated	30.31	33.10	35.79	37.56
market	1.81	2.92	4.37	5.41
percent market share	5.6	8.1	10.9	12.6
short fiber cellulose				
total pulp volume	39.0	43.3	47.4	51.6
market	13.5	16.4	18.8	21.9
percent market share	34.6	37.8	39.7	42.4
mechanical pulp				
total pulp volume	33.0	36.9	41.7	48.6
market	2.1	4.7	7.9	12.4
percent market share	6.5	12.6	18.9	25.7

6.5.1. Virgin pulp use will rise from 175 million tons presently to 212 million tons in ten years' time. Integrated paper mills produce all or substantial amounts of their internal needs for pulp. Of course, many of the integrated mills are regular buyers of pulp. Not all mills produce all their internal pulp needs. It is quite common for wood content paper mills to produce thermomechanical pulp and purchase reinforcement pulp.

Last year, in 2000, the integrated mills produced 118.6 million tons of pulp (all grades), representing a 74 pct share of worldwide virgin pulp. The balance is market pulp.

The *market volume* of virgin pulp was 41.9 million tons last year. All three categories of pulps are traded on a global scale, although mechanical pulp to a lesser extent. Most of the trade is in bleached sulphate cellulose, where the threshold for non-integrated mills is substantial.

Although a larger share of 63.7 million tons for market pulp is projected in 2010, cost effective pulps will account for most of the increase. Cost effective pulp and fibers are mechanical pulp and paper waste.

We have already seen that long fiber cellulose will grow by only 17 pct. Nevertheless, the demand for long fiber market pulp remains substantial : presently 21.5 million tons, expanding to 29.4 million tons in 2010.

6.5.2 There are important differences in pulp use between printing and packaging papers. The packaging paper sector is largely integrated and self-reliant. Integrated pulp provides 90 pct of virgin fiber needs. This is a decisive factor in their cost economy.

All the leading non-integrated packaging paper mills in Europe control the collection and selection of waste. Containerboard mills in urban areas in Europe, for instance, consume only waste and purchase no virgin pulp. Even forest based integrated mills in Europe are now pioneering the use of waste as a co-furnish.
The industry in North America lags behind as it recycles to a much lesser extent. The American containerboard market is far more demanding. North American urban mills (those where recycling is practiced) have much better waste.

The major paper and board producers everywhere use waste *or* they have integrated pulp. They are the dedicated producers of containerboard, multiwall sack, wrapping and retail sack grades. Only in exceptional circumstances will they purchase kraft to support routine operations.
The 10 pct market pulp share is scattered over so many diversified users, that it was impossible to chart their characteristics. Some mills nevertheless are significant.
For the better quality folding boxboard and multiply printing board grades, bleached kraft is used, invariably purchased, often the best quality. Some of the more esoteric applications also require bleached kraft. All these purchased pulps are packaging grades, not reinforcement pulp.

6.5.3 White paper is the second largest volume segment in world paper, after packaging. The white paper sector includes printing paper and tissue. Whereas tissue occupies a modest place with 18 million tons presently, it has the highest growth rate, 42 pct, reaching 26 million tons in just ten years to 2010.

Tissue mills have a diversified fiber base. A large volume is produced from waste and short fiber pulp (mechanical pulp included), but long fiber pulp is also used (3.6 million tons presently), especially in North American mills. American mills operate the fastest tissue machines in the world. The long fiber pulp is used for reinforcement and to support tissue properties at the same time. Whether such pulp is used in a specific mill depends on tissue grade and machine configuration. Most of long fiber pulp in world tissue is consumed in American mills, which purchase it in direct competition with printing paper mills.

6.5.4 The printing paper industry is the most important and the largest buyer of reinforcement pulp. Refer to the paragraph that follows.

6.5.5 The major paper mills in developing countries are regular buyers of long fiber market pulp. They also buy long fiber waste, which they use to replace some long fiber pulp. In recent years, 20 pct of the world volume of long fiber market pulp has gone to Asia.

Elsewhere in this report, we have noticed that developing countries have few long fiber forest resources, or none at all. This applies to virtually all the tropical countries in Asia, Africa and Latin America. The populated countries have paper mills that traditionally produce for the domestic market and use locally procured fibrous raw materials, usually short fibered. Illustrative examples are India, Thailand, Java, the Philippines, but also Brasil. Other long fiber raw materials, such as from annual plants, are usually in short supply or difficult to procure. If reinforcement pulp would be available, their efficiency could be much better. Sisal is one of the few suitable fibrous raw materials in many such circumstances.

6.6 *fiber furnish in printing paper*

Printing paper mills produced an estimated 130 million tons of paper in 2000, for which 109 million tons of pulp is required. Their production will increase to 166 million tons in 2010.

The pulp volumes for the production of printing papers are summarised in *table 6.7.* More

table 6.7 *pulp volumes and market shares for printing paper*

million tons		1995	2000	2005	2010
fiber balance		250.63	288.95	337.26	391.08
long fiber pulp, total volume		67.79	74.53	81.44	87.14
	for white paper use	35.47	38.21	40.88	43.77
	for brown paper use	32.32	36.32	40.56	43.37
integrated long fiber cellulose		49.02	52.75	55.69	57.22
	for white paper use	18.71	19.65	19.90	19.66
	for packaging	30.31	33.10	35.79	37.56
other captive long fiber pulp [1]		0.20	0.30	0.39	0.50
long fiber market cellulose		18.57	21.48	25.36	29.42
	for white paper use	16.76	18.56	20.98	24.01
	for packaging	1.81	2.92	4.37	5.41
short fiber bleached hardwood cellulose		39.00	43.34	47.40	51.58
	integrated	25.49	26.99	28.59	29.69
	market	13.50	16.35	18.81	21.89
nonwood cellulose		13.69	14.90	18.98	22.14
semichemical pulp		6.34	5.83	4.35	5.07
	market	0.52	0.68	0.81	0.75
mechanical pulp		32.95	36.93	41.66	48.59
	integrated	30.82	32.28	33.78	36.11
	market	2.13	4.65	7.88	12.47
waste, total volume		91.69	114.29	144.11	178.81

[1] *includes softwood semichemical pulp*

detailed furnish compositions are shown in *table 6.8*. The reader who desires to study some particular aspects of reinforcement, regional differences for example, is referred to the data sheets in *annex report two* that provide useful information. On the level of countries and regions, the electronic database (*annex report one*) is indispensable.

Printing paper mills require reinforcement pulp for operational economies. Reinforcement is a matter, greatly influenced by the individual character of the paper machine (*chapter 7*). To which extent reinforcement is practiced, depends largely on machine configuration, stock

table 6.8 *fiber furnishes in printing paper*

million tons	*1995*	*2000*	*2005*	*2010*	*production increase 2000 > 2010*	
paper type					*volume*	*pct*
coated grades	29.88	37.04	44.79	53.82	16.78	*45.3*
uncoated grades	49.40	57.15	65.39	72.81	15.66	*27.4*
newsprint	32.75	35.74	36.87	39.05	3.31	*9.3*

paper type	*pulp volume – year 2000*			*pulp volume – year 2010*		
	long fiber	short fiber	mechanical	long fiber	short fiber	mechanical
coated printing						
total pulp requirement	8.03	6.92	6.80	9.39	8.72	10.99
integrated	3.52	3.70	-	3.46	4.23	-
market	4.96	3.22	-	5.93	3.99	-
uncoated printing						
total pulp requirement	11.13	14.34	14.18	6.65	15.69	19.57
integrated	6.01	10.18	-	6.13	10.78	-
market	5.12	4.17	-	0.52	4.91	-
newsprint						
total pulp requirement	3.10	none	19.71	3.76	0.13	18.37
integrated	2.07		-	1.98	-	-
market	1.03		-	1.79	-	-

notes
-1- *mechanical pulp includes nonwood pulp*
-2- *coated printing includes wood content and woodfree grades*
-3- *uncoated printing includes wood content and woodfree printing grades*

preparation, the fiber base and the grades that are produced. Different paper grades have distinct reinforcement needs. The state-of-art machines and those which have been adapted to high volume production are configured for pre-defined production conditions (including choice of pulps), configured in a way, which leaves no room for alternatives.

Printing paper mills are the largest buyers of reinforcement pulp. Where reinforcement is practiced, the volumes of pulp are substantial : 20 to 50 pct of the fiber furnish. There are significant differences in reinforcement practice between the world's regions (*chapter 7*).

Worldwide on average, the printing paper mills produce 74 pct of their entire fiber needs in-house. The extent of integration depends on the grades produced. Mills, which manufacture wood content paper, usually produce all their mechanical pulp themselves, and purchase all or most of the long fiber cellulose, which they need. Mills, producing woodfree printing paper, *either* produce their pulp or some of it *or* they purchase all their short fiber cellulose and long fiber cellulose needs. Other mills, especially in the wood content sector, produce short fiber pulp themselves and buy the remainder. It is not unusual even for fully integrated mills to purchase cellulose types from time to time, as the need arises (*chapter 9*). Cost economy and the market position of their particular paper grades determine the fiber scenario that mills will follow.

Printing paper mills produce paper of low basis weight (at least compared to board), they use short fiber pulps to improve printing properties, and they have high speed paper machines. The reinforcing component in the fiber furnish is required to stabilise the wet paper web, something which a short fiber furnish under dynamic conditions cannot accomplish.

6.7 regional differences

In considering the world fiber balance, regional differences are overlooked. There are many causes for inequality in pulps. The wood resources may be different, electric energy and other production factors vary, scale economies and market structure may not be the same.
As a result, furnish mixes can vary considerably around the world. For that reason we have analysed each region separately in the following *chapter 7*. This provides a more realistic outlook about the world role of long fiber pulps in general and sisal pulp in particular.

THEME B

chapter 7 *regional analysis*

overview	The fiber composition of paper is not the same around the world. Furnish mixes can vary considerably by region. We need to analyse each region separately (*this chapter*) before conclusions can be drawn about the role of long fiber pulps in general and sisal pulp in particular. The situation in the database regions is discussed in *paragraphs 7.1 to 7.8.* Following these, the situation in Africa is reviewed in *paragraphs 7.9-7.12.* A brief note on other developing countries (*par 7.13*) concludes this chapter.

7.1 *introduction*

The same paper is not made from the same fibers in all corners of the world. On the contrary : some fiber furnishes differ considerably in seemingly the same papers, or in papers for the same purpose.

There are all sorts of reasons for this. It may be that the national markets demand specific qualities or prices. Or good reasons are found in the raw material basis of certain regions and countries. The temperate coniferous forests in Scandinavia and North America are good examples that contrast with 'urban fiber resources' in continental Europe.

Other valid reasons are the cost of energy, effluent regulations, fiber substitutions, and competitive technology. Scale economies are a decisive factor in the availability of pulp. Witness the recent surge in pulp capacities and wood plantations in Indonesia. Or, recall the origins of eucalypt pulping in Brasil.

In any case, the analysis of regional situations promises to get us closer to the questions on fiber use in papermaking. We will review the fiber balances in the database regions (*table 3.2*) and match these to the production practices in paper manufacture. Just as before, the statistics from the electronic database have been perused in preparing the regional fiber balances.

⌘ The reader is reminded that paper is made from different fibers, and that long fiber cellulose has two major functions : the obvious one for paper strength (related to packaging), and the more intricate function for reinforcement (related to printing papers and tissue).

Remember that *white paper grades* have low basis weight, are made from short fiber furnishes on fast machines, and therefore need reinforcement. The reinforcement function is a technical necessity, but it is in principle a critical cost variable

The regional analyses of paper and pulps are in *paragraphs 7.2 to 7.8*, and the world analysis is summarised in par *7.9*. These should give some clues on the market position of long fiber wood pulps, and, perhaps, a glimpse about substitution by other long wood pulps (think sisal, of course). All figures throughout this chapter are in million tons per year as ADMTPY or FMTPY, as applicable.

An entirely different topic is paper in Africa (*paragraphs 7.10 and 7.11*). The important sisal growing countries in Africa are in East Africa. Most other paper producing countries in the continent are on East African shipping lines. The question arises whether East African sisal might be a valuable raw material for some of the paper mills in the countries along the transportation axes.

The foremost task of the market study was to establish the potential of sisal for reinforcement in the major papermaking markets of the world. The conclusions from the regional analysis give a sharp picture of the position of long fiber cellulose. As we shall see later, the outlook for sisal from this perspective is not assured.

7.2 *Europe*

7.2.1 fiber furnishes

Bleached softwood sulphate pulp (BSK) is in great demand in Europe, where it is used widely for reinforcement in the manufacture of certain printing papers.

The first *table 7.1* summarises the role of long fiber market pulps in the furnishes of the main grades of bleached paper and board.
Over 7 million tons of market bleached kraft softwood (BKS) is used in Europe. This figure includes 4.5 million tons of NBSK. In addition, 3.3 million tons of integrated long fiber pulp are generated annually, mainly in the Nordic countries.

table 7.1 furnishes in Europe for 13 countries, million tons

	printing papers		*newsprint*	*tissue*	*board*	*other*	*total*
	woodfree	*mechanical*					
BKS market	2.4	1.9	-	0.4	1.1	1.4	7.2
BKS integrated	0.7	1.1	-	-	1.1	0.4	3.3
BKH	5.2	-	-	0.9	1.3	1.1	8.5
bleach sulphite	1.6	-	-	0.6	-	0.1	2.3
mechanical	0.3	5.1	5.7	0.2	0.6	0.1	12.0
other wood pulp	-	-	-	-	-	6.2	6.2
nonwood pulp	0.1	-	0.1	-	-	-	0.2
recovered paper	0.6	1.0	4.6	1.8	2.4	17.0	27.4
minerals	5.0	4.2	-	-	0.3	-	9.5
total	*15.9*	*13.3*	*10.4*	*3.9*	*6.8*	*26.3*	*76.6*

Sisal pulp seems to suggest itself as a reasonable alternative choice for softwood reinforcement cellulose, especially in Europe, where so much pulp is market-purchased.

7.2.2 woodfree paper

The largest end use is woodfree papers, in which reinforcing pulps account for less than 30 % of the fiber furnish (excluding minerals) while bleached kraft hardwood (BKH) pulps, such as birch, eucalyptus and mixed hardwoods, account for nearly 50 pct.

NBSK in woodfrees is gradually being replaced by cellulose from cheaper softwoods such as US southern pine and Chilean radiata pine, since strength is not normally a critical factor for woodfrees, especially in the middle to higher weight ranges. The shift in attitude can be seen when the fiber profiles over ten year intervals are compared. Price is more crucial than quality for these grades, because the mass printing papers market is fiercely competitive.

Any use of sisal pulp is likely to be limited to the lighter weight grades such as business or bible papers, which are specialty grades.

7.2.3 *wood content paper*

In wood content (mechanical) papers, long fiber pulps account for 33 pct of the fiber furnish, whereas integrated mechanical pulps account for 56 pct and recovered paper for 11 pct, both of which are rising.

Most of the market long fiber pulp in mechanical papers (1.9 million tons) is NBSK and is used in France, Germany, Italy and the UK. Up to half of this is supplied by parent company pulp mills in the Nordic region, e.g. Stora Enso, UPM Kymmene, Metsä-Botnia, SCA, Norske Skog, as a matter of company policy. These volumes will be hard to replace with sisal pulp.

7.2.4 *tissue*

In principle, tissue is made from a short fiber furnish (such as hardwood cellulose or waste) which provides absorbency, embedded in a matrix of long fiber pulp (virgin cellulose or selected waste).
Common tissue paper in Europe is made from recovered paper, to which long fiber pulp may be added. Virgin tissue is manufactured in Scandinavia. Tissue in Germany, Britain, France, Italy and Spain is made from waste.

Sheet cohesion is particularly important in tissue, because it has low basis weight. Sisal pulp possesses wet sheet strength properties, not available in other cellulose except abaca. The absorbency as well as strength characteristics make it suitable for applications in the tissue sector. Price would be critical though, since BKS is the standard reinforcing pulp, sold at a discount to NBSK ; and most tissue is made entirely from waste. The preferred short fiber component in virgin tissue is euca cellulose, normally selling at a $50 discount to NBSK.

7.2.5 *white board*

In board, 2.5 million tons of market BKS is used. This amount of pulp goes into board grades : bleached or white-top linerboard, wallpaper base and specialty boards.
A more specific analysis of these grades is not currently possible, though it is safe to state that sisal would be assessed on its price, not on any strength advantage.

7.2.6 *growth forecast*

The table that follows shows the growth forecasts for the main paper and board grades for the 2000 to 2010 decade.

table 7.2 growth in paper demand in Europe, annual pct

time interval 1985 to 2010	*85-90*	*90-95*	*95-00*	*00-05*	*05-10*
woodfree papers	6	3.5	2.5	3	2
mechanical papers	0.5	0.5	1	- 0.5	-1.0
tissue	4	3.5	3	2.5	1.5
paperboard	4	3	2.5	1.5	1
newsprint	6.5	2	2	-2	-2
other	8	1	3	2.5	2
total	*5.5*	*2*	*2.5*	*1.5*	*1*

7.2.7 *demand change*

The European paper industry is maturing. The lower grades of printing papers (office papers, directories, catalogues, newsprint) are expected to lose market share to electronic communications via the internet and intranets. Magazine stock, representing higher grades, continue to gain in volume ; so do paperboard and miscellaneous grades.

In *table 7.3* we show how we expect demand for the various grades of pulp to change by 2010. This assumes that hardwood pulp will continue to replace softwoods in woodfree papers and that recycling rates will steadily increase.

In this scenario, the increased use of recovered paper and the emphasis on mechanical (high yield) pulps reduce the need for hardwood chemical pulps, but increase the requirement for reinforcing pulp by over one million tons p.a. by 2010. By itself, this might arouse the interest of papermakers for alternative reinforcement pulps such as sisal cellulose.

We will comment on the supply implications of this in *chapter* 8, and find that market pulp is a truly international commodity. As we will see in *chapter 10*, this places severe restrictions on the idea of replacing reinforcing wood pulp with sisal pulp.

table 7.3 demand for raw materials in Europe, million tons

	1995	*2010*	*change*
BKS	10.5	11.8	+1.3
BKH	8.5	7.1	-1.4
bl sulphite	2.3	1.2	-1.1
mechanical	12.0	16.0	+4.0
other woodpulp	6.2	6.0	-0.2
non-wood pulps	0.2	0.2	-
recovered paper	27.4	44.9	+17.5
mechanical	9.5	13.9	+4.4
total	*76.6*	*101.1*	*+24.5*

7.3 North America

7.3.1 fiber furnishes

North America is the largest consumer of long fiber pulp in the world. The North American consumption of BSK is 15 million tons, but market volume is only 4 million tons. This might still be of interest in the quest for large volume applications of sisal pulp.

The structure of the industry is different from Europe. The industry is integrated to a far greater degree. For instance, just for newsprint 1.5 million tons of BKS is used, and virtually all of this is integrated. A second example : the industry uses more virgin fiber pulps and far less waste. Historically, paper use seems to be surrounded by a more lenient yet quite demanding market attitude (price), supported by cost economies and plentiful wood reserves.

The fiber furnish volumes in North America are shown in *table 7.4*. We conclude that even more long fiber pulp is used in North America than in Europe. The volume of market pulp, in contrast, is only half in that comparison.

7.3.2 softwood cellulose and reinforcement pulp

Most of the integrated long fiber pulp is based on southern pine, where softwood forest reserves still are plentiful and the major markets easily accessible. A considerable part of this is unbleached kraft, for packaging.

table 7.4 furnishes in North America, million tons

	printing papers		newsprint	tissue	board	other	total
	woodfree	mechanical					
BKS, integrated	3.3	1.0	1.4	0.8	3.7	0.9	11.1
BKS, market	1.5	1.0	0.1	0.6	0.7	-	3.9
BKH	5.8	-	-	1.7	4.9	2.6	15.0
bl sulphite	0.7	-	-	0.4	-	-	1.1
mechanical	0.2	4.1	11.1	0.4	-	-	15.8
other woodpulp	-	0.3	0.4	-	0.6	25.7	27.0
nonwood pulps	-	-	-	-	-	-	-
recovered paper	1.3	0.2	3.7	2.7	4.9	10.5	23.3
minerals	5.1	2.9	-	-	0.8	-	8.8
total	*17.9*	*9.5*	*16.7*	*6.6*	*15.6*	*39.7*	*106.0*

BKS from southern pines is increasingly used in *certain* printing papers where the reinforcement function is secondary to the cost of pulp. The reinforcing properties of BKS from southern pines is inferior to NBSK from Canada and Scandinavia.

In North America, BKS accounts for nearly 40 pct of the fiber furnish in woodfree papers, compared with less than 30 pct in Europe. This reflects the relatively low strength of both the long and short fiber components of the woodfree papers produced in integrated mills.

Nearly half of the market BKS is from southern pines, often shipped from parent company mills in the US. The remainder of the market volume is NBSK from Canada, shipped to the US mainly by independent market pulp suppliers. NBSK from Canadian is comparable, often even superior, to Scandinavian NBSK.

7.3.3 tissue

Facial tissue is made from virgin fiber short *plus* long fiber cellulose. The short fiber component is chemical pulp from southern mixed hardwoods or eucalypt. The low strength of these requires that a reinforcing component is added, especially at the high machine speeds in most mills.
The reinforcing component is BKS or NBSK. Canadian cellulose from spruce is the preferred choice, but interior BC (Canada) pulp is also suitable. These pulps provide the wet tensile strength which lightweight tissue grades require. Increasingly, BKS from southern pines is used as an alternative.
In hygienic tissue, deinked waste now constitutes half of the overall furnish. Many mills add a liberal amount of virgin reinforcing pulp (BKS).

7.3.4 recycled paper

The US and Canada have abundant wood resources, but are now following Europe's steps in recycling and using recovered paper. North American waste has superior quality, undoubtedly due to the industry's extensive wood base.
Recycling rates have some way to go in North America before they reach European levels, particularly in the mechanical papers and newsprint sectors. The trend of using more waste will reduce the quantities of BKS required, and put more emphasis on wet sheet strength.

7.3.5 nonwood pulp

The scenarios assume that non-wood pulp will not be used in the future. The American paper industry is entirely wood based, and is expected to remain so in the decade ahead. There is some concern about the industry 'depleting forest resources'. A few companies and public institutions have shown interest in nonwood fibrous raw material for paper. Some research is being carried out on straw and kenaf. Much of this is driven by public concern about forest reserves and the environment. The short term prospects for the logistics of straw for paper are not encouraging. A curious phenomena is the research effort which has been extended on kenaf for newsprint for some decades. The short fiber content in kenaf, to be sure, will require a substantial development in papermaking technology, if kenaf will come through. Similar reasoning applies to straw paper.

7.3.6 sisal pulp

Imported sisal cellulose would have to confront Canadian NBSK and compete with the best grades of NBSK, on the levels of performance *and* price. Refer to *chapter 10* where the situation is assessed. As part of the market study, paper mills have been questioned on the subject of reinforcement, see *chapter 9.*

7.3.7 forecast for paper

Growth forecasts for the main grades of paper into the year 2010 are summarised in *table 7.5.* Impact from electronic communications is presently spreading from the US to Europe. It has been a real feature in North America for some years, affecting newsprint and business forms in particular. Compare the growth rates in this sector, which are all declining. This offers little scope for introducing new pulps, sisal for example.

table 7.5 demand growth in North America, pct per annum

	85-90	*90-95*	*95-00*	*00-05*	*05-10*
woodfree papers	4	1.5	3	2	1
mechanical papers	7	3	1.5	-	-1
tissue	3.5	1.5	2	1.5	1
paperboard	2.5	4	2	1.5	1
newsprint	1	-0.5	-1.5	-2	-2.5
other	2	4	3	2	1
total	*2.5*	*2.5*	*2*	*1.5*	*0.5*

7.3.8 forecast for pulp

The US has by far the highest per capita consumption of paper in the world and, consequently, future growth prospects are extremely limited. Nonetheless, even small growth rates generate substantial shifts in demand for raw materials, as *table 7.6* shows. The demand for BSK is in slight decline. The additional volume in BKH is easily met by US capacity adjustments and imports from Brasil.

7.3.9 paper waste

The use of recovered paper is expected to increase dramatically. Waste is easily collected in the urban centers of the United States. It can be channeled to existing paper mills and processed without undue effort. Production economies are considerable. Comparable economies are available to mills in nearby Canada, using US urban waste.

Recovered paper is the lowest cost fibrous raw material. North American waste is of superior quality, because a large proportion is from virgin origin. The quality of waste deteriorates with *table 7.6 demand for raw materials in North America, million tons*

	1995	*2010*	*change*
BKS	15.0	14.6	-0.4
BKH	15.0	16.2	+1.2
bl sulphite	1.1	0.3	-0.8
mechanical	15.8	16.8	+1.0
other woodpulp	27.0	30.9	+3.9
nonwood pulps	-	-	-
recovered paper	23.3	34.7	+11.4
minerals	8.8	11.1	+2.3
total	*106.0*	*124.6*	*+18.6*

the re-cycles through which it has gone. The waste volume in North America is so large that there is a flourishing export trade with Europe and Southeast Asia.

The waste situation in North America offers little prospect for sisal cellulose as reinforcement pulp. The long fiber content in waste has reinforcement properties at much lower cost than virgin BKS, even discounting the fact that it is less effective than virgin pulp.

7.4 South America

7.4.1 paper industry

South America has a considerable papermaking industry, especially in the large and populated countries. The domestic forest reserves, mixed hardwoods, are not particularly appropriate for pulp manufacture and are not exploited for that purpose. Some countries have paper mills, operating on bagasse or bamboo.

Brasil and Chile have extensive forest plantations, and the potential for more. Brasil is the world leader in bleached eucalypt cellulose, a commodity that has established itself as the choice raw material for printing papers. It has 3.6 million tons of pulp capacity, and building more. Chile is the leading exporter of radiata cellulose, most in bleached form (the best return on investment). Radiata market cellulose has been accepted as a realistic alternative, the second choice for reinforcement pulp, after NBSK and well before BKS from southern pines.

Argentine, Brasil, Chile and Mexico have large and well established paper industries. Most of the large mills operate integrated pulp mills (from pulpwood plantations), and some produce export market pulp.

Chile is an important long fiber pulp producer. Trade with the east coast of South America is somewhat problematic, but transoceanic shipping is favorable. Chilean pulp is exported to Europe, Japan and the Far East.

Brasil is the world leader in eucalypt cellulose. The paper industry has grown to considerable size. It has the benefit from integrated pulp or it purchases domestic market pulp, it has scale economies and has enjoyed a prospering economy.
Unfortunately, the industry has insufficient long fiber wood resources. The climate is not conducive to plantations with exotic pine species, as in Chile. One leading paper enterprise produces long fiber cellulose from Araucaria plantations, the scope of which unfortunately is limited. Other mills are successful in producing pulp from bamboo. Some mills use bagasse to produce white and packaging paper. One mill produces sack paper with a mixed furnish :

bagasse, mixed hardwood and sisal. None of these long fiber pulps are available for purchase from domestic sources, all the capacity is integrated. Recycled paper has taken off and occupies an increasingly important space in Brasilian papermaking.

As a consequence, a peculiar characteristic is that wood content (mechanical pulp containing) printing paper, such as newsprint and magazine, has hardly come off the ground as yet. Although not impossible technically, young eucalypt wood is not quite so adaptable to mechanical pulp. Other, more suitable wood species for TMP are difficult to find. There has been insufficient incentive from the market to explore alternative opportunities for coated wood content grade.

In Argentina, the leading and important mills produce integrated pulp or they have captive pulp sources, or use waste. Poplar species in the Plata delta are exploited for mechanical pulp (newsprint, magazine, wood content grade). There is an important long fiber market pulp complex in operation northeast of Buenos Aires, not far from Uruguay. In Uruguay, the feasibility of a market pulp mill is being studied.
One or two bagasse pulp and paper mills play a significant role. Paper waste has become increasingly important. Most of the balance of long fiber cellulose comes from Chile, despite the shipping route. Trade liberalisation has eased pulp imports, which were formerly restricted. The nation's history and economy have thwarted the large scale development of wood plantations and domestic pulp production.

In Mexico, the paper industry has acquired mature status, greatly relying on domestic sources such as bagasse and hardwood, some softwood pulp capacity and, increasingly, waste paper. The balance of fiber needs is imported from North America, Chile, Brasil.
It is remarkable that the important exotic pine species, radiata pine, which have been planted throughout the world, have come from Mexico, yet these were not successful in Mexico itself.

7.4.2 long fiber pulp

Most of the domestic fiber resources in these countries are hardwood forests or plantations. Mechanical paper production has hardly started to develop yet.

table 7.7 furnishes in South America (four countries : Argentine, Brasil, Chile, Mexico)

	printing papers		*newsprint*	*tissue*	*board*	*other*	*total*
	woodfree	*mechanical*					
BKS, market	0.1	0.1	0.2	0.1	0.1	0.2	0.8
BKS, integrated	0.2	-	-	-	-	-	0.2
BKH	1.3	-	-	0.6	0.1	0.2	2.2
bl sulphite	-	-	-	-	-	-	-
mechanical	0.1	0.2	0.7	0.1	0.1	-	1.2
other woodpulp	-	-	-	-	0.2	1.5	1.7
nonwood pulps	0.1	-	-	-	-	0.2	0.3
recovered paper	0.1	-	0.1	0.4	0.5	3.0	4.1
minerals	0.6	0.1	-	-	0.1	-	0.8
total	*2.5*	*0.4*	*1.0*	*1.2*	*1.1*	*5.1*	*11.3*

Latin American countries, except Chile, are short in long fiber resources. One million tons annually of reinforcing fiber is used in South America. This includes 340,000 tons in Brazil, 300,000 tons in Mexico and 100,000 tons in Argentina. Most is imported from the nordic countries and from Chile. Only 200,000 tons of long fiber cellulose is integrated : in Chile. As these countries approach western living standards, demand for lightweight papers with good opacity will rise and reinforcing fibers will be required to assure runnability.

From the adjoining *tables 7.7-7.8-7.9*, the role of long fiber market pulps in Brazil, Chile, Argentine and Mexico can be seen. Our growth forecast for the main paper and board grades is given in *table 7.8*, whereas *table 7.9* shows how the use of raw materials is changing.

7.4.3 growth forecast

Growth rates in paper in South America will be considerably higher than in Europe or North America. Influenced by higher economic growth rates, the GNP per capita gap between developing and developed countries will be narrowed in the decade. The forecast indicates a considerable increase in demand for imported reinforcing fibers.

table 7.8 growth in paper demand in South American countries (database), pct per annum

	85-90	*90-95*	*95-00*	*00-05*	*05-10*
woodfree papers	-	7	6	6.5	6.5
mechanical papers	15	10	15	12	12
tissue	5	5.5	5	5	5
paperboard	-	7	7	7	7
newsprint	2	5.5	5	5	5
other	4.5	3	3.5	3.5	4
total	*3*	*5*	*5*	*5.5*	*6*

7.4.4 forest plantations

Chile and Argentina both have coniferous forest resources and pine plantations. The native coniferous forests have been exploited for timber, but are not significant for pulp. The plantations produce pulpwood, which is processed into kraft and BKS. Especially Chile is likely to expand its softwood plantations even further. Uruguay is actively exploring the feasibility of pine plantations and pulp manufacture on a world scale, 400,000 tons or more of long fiber cellulose. Argentine, a modest producer of coniferous cellulose, has the potential for expansion of its current modest capacity.

table 7.9 demand for raw materials in South America, million tons

	1995	*2010*	*change*
BKS	1.0	2.5	1.5
BKH	2.2	4.1	1.9
bl sulphite	-	-	-
mechanical	1.2	3.5	2.3
other woodpulp	1.7	2.6	0.9
non-wood pulps	0.3	0.6	0.3
recovered paper	4.1	8.1	4.0
minerals	0.8	2.3	1.5
total	*11.3*	*23.7*	*12.4*

7.4.5 sisal in Latin America

Sisal is or can be grown in most of the tropical countries of Latin America. Of course, Brasil is the leading producer and exporter of sisal fiber in the world (*table 2.2*). As a producer of hard fiber, Mexico -henequen- occupies the second place. Venezuela produces sisal on a modest scale. The production of sisal in Central America and Cuba has fluctuated with the ups and downs of the line fiber market, although growth conditions are suitable.

In Brasil, a prestigious, major sisal market pulp mill project was initiated in the seventies : the only dedicated sisal market pulp mill the world. After a few years, the project collapsed for financial reasons. Feasibility studies in Venezuela and Mexico were not followed through.

As a raw material for long fiber pulp, sisal has unequal chances in Latin America. In Uruguay and Argentine, for example, sisal would have to compete with exotic pine plantations, with more suitable growth conditions and better logistics as a raw material for pulp. In Brasil, Venezuela and Mexico the outlook for reinforcement pulp from sisal is much better, provided that cost effective logistics and process technology are identified.

In summary, the best prospects for sisal and pulp are found in tropical countries where the following conditions are met :

[i] soil and climate, suitable for sisal
[ii] the climate is unsuitable for exotic pine plantations
[iii] the domestic paper industry has dormant capacity that can be mobilised by having cost effective and domestically produced long fiber pulp

Item [iii] means that machine capacity is unlocked by increasing paper machine speed through the use of domestic long fiber pulp. The approach is to use reinforcement pulp that has the same cost structure as locally produced short fiber pulp.
The bottleneck in paper in developing countries is that paper machine output is often restricted by the available short fiber furnishes (rice straw, for instance), whereas imported pulp is difficult to procure. Although this is not true everywhere, examples are not hard to find : in *certain* mills in Brasil, for instance, these conditions are easily identified. The same can be said for mills in Mexico, Colombia and Venezuela.

7.5 Japan

7.5.1 fiber furnishes

Furnishes in Japan are shown in *table 7.10,* and *table 7.11* shows our paper and board demand growth forecasts to 2010. *Table 7.12* shows our forecasts of raw materials demand to 2010.

table 7.10 furnishes in Japan, million tons

	printing papers		*newsprint*	*tissue*	*board*	*other*	*total*
	woodfree	*mechanical*					
BKS, market	0.4	0.4	0.1	0.3	0.5	-	1.7
BKS, integrated	0.4	0.3	0.3	-	-	0.1	1.1
BKH	3.9	-	-	1.0	0.8	2.0	7.7
bl sulphite	-	-	-	-	-	-	-
mechanical	0.1	0.7	1.0	-	-	-	1.8
other woodpulp	-	0.1	0.3	-	0.2	1.4	2.0
non-wood pulps	-	-	-	-	-	-	-
recovered paper	0.2	1.0	1.7	0.3	1.7	8.6	13.5
minerals	2.4	1.0	-	-	0.2	-	3.6
total	*7.4*	*3.5*	*3.4*	*1.6*	*3.4*	*12.1*	*31.4*

7.6.2 prospect

With the expansion of domestic consumption, the demand for fibrous raw materials and pulp rises accordingly (*table 7.15*). The changes are considerable and demonstrate the inmediate problems which the industry faces. Although China's policy emphasises domestic production, imports of pulp and paper will rise dramatically.

table 7.15 demand for pulp in China, million tons

	1995	*2010*	*change*
BKS	0.9	5.1	+4.2
BKH	0.4	3.7	+3.3
bl sulphite	0.2	-	-0.2
mechanical	0.6	4.7	+4.1
other woodpulp	0.6	1.8	+1.2
nonwood pulps	12.1	19.4	+7.3
recovered paper	9.9	27.2	+17.3
minerals	1.0	4.6	+3.6
total	*25.7*	*66.5*	*+40.8*

The newly established pulp mills in Indonesia anticipate on China's demand, as far as short fiber cellulose is concerned. They will of course not alleviate the lack of long fiber resources.

7.6.3 wood resources

China lacks the necessary forest resources to match the growing demand for pulp. From other information (*not shown ; refer to annex report two*), it is evident that not all of the fibrous raw material (in the 2010 paper balance) will be found from domestic sources.
Forest plantations are being established in parts of China, which in time will alleviate the imbalance. They will not be able to satisfy the entire demand (*table 7.15*) of the next 10 years.

The situation affects two of the largest sectors : packaging paper and wood content printing paper. For the latter, the imbalance seem to indicate that more paper will be manufactured outside China and imported from countries like Indonesia.

7.6.4 imports

Imports of long fiber wood pulp are limited but the demand for these will also increase dramatically. The significance of long fiber pulps in the furnish of the main grades of paper is easily seen in the statistics.
Again, the inmediate problem is the lack of long fiber raw material resources (softwood forest reserves), which the country tries to remedy by establishing plantations.

7.6.5 nonwood pulp

Three quarters of the world's nonwood pulps are produced and consumed in China. These, along with 10 million tons of recovered paper and a minimum of conventional wood pulp make up the fiber balance (*table 7.14*). A distinction must be made between short fiber and long fiber nonwood pulping. The staple nonwood pulp is short fibered cellulose from straw, but China has many paper mills, where long fiber species such as bamboo, kenaf, crotalaria or sisal are used on a small but locally important scale.

Nonwood pulp mills have many advantages in countries like China, but also present certain problems. Their effluent problem is difficult to tackle, the available techniques are quite expensive and the average size of nonwood mills aggravates the situation. In the last ten years, more than 800 paper mills have been phased out for environmental reasons (pollution), among these many nonwood mills.

Given the expertise of the Chinese in utilising nonwood fibers, sisal pulp should be welcomed as an alternative reinforcing pulp to imported softwood pulps. China can benefit from the current sisal project, by reviewing fiber and pulp production techniques and examine the feasibility of domestic manufacture of sisal cellulose on a larger scale.

7.7 *Other Asia*

7.7.1 *fiber furnishes*

Virtually no BKS is produced in these countries. Most investment in paper machines is going into woodfree papers, tissues and board. The most important current end uses for reinforcing pulps in these countries are woodfree papers and paperboard.

In *table 7.16* the average furnishes of paper are shown for the seven other Asian countries (*table 3.2*). These countries are : India, Indonesia, Malaysia, Philippines, South Korea, Taiwan and Thailand.

table 7.16 furnishes in seven other Asian countries, millions tons

	printing papers		*newsprint*	*tissue*	*board*	*other*	*total*
	woodfree	*mechanical*					
BKS, market	0.5	0.1	0.2	0.1	0.3	0.1	1.3
BKS, integrated	-	-	-	0.1	-	-	0.1
BKH	2.4	-	-	0.3	1.0	0.3	4.0
bl sulphite	-	-	-	-	-	-	-
mechanical	0.1	0.1	0.2	0.1	-	0.1	0.6
other woodpulp	-	-	0.1	-	0.3	0.9	1.3
nonwood pulps	0.6	-	0.2	-	0.2	0.1	1.1
recovered paper	0.5	0.1	1.5	0.2	2.1	8.0	12.4
minerals	0.9	0.1	-	-	0.2	-	1.2
total	*5.0*	*0.4*	*2.2*	*0.8*	*4.1*	*9.5*	*22.0*

The forecast paper volumes are presented in *table 7.17*. These assume no significant local availability of long fiber pulps. Otherwise, demand for reinforcement pulp will surpass the volume foreseen.

table 7.17 growth in paper demand in seven other Asian countries, pct per annum

	85-90	*90-95*	*95-00*	*00-05*	*05-10*
woodfree papers	11	8.5	7.5	5	3.5
mechanical papers [1]	11	-	23	17	10
tissue	10	11.5	10	10	10
paperboard	9	5.5	8	8	8
newsprint	11.5	10	8.5	7	6
other	13.5	11	10	9	8
total	*11.5*	*9.5*	*9*	*8*	*7*

[1] *very small base figure in 1985*

The figures from *table 6.18* show the raw material volumes that are required to produce the paper by the year 2010. They represent an even faster growth in demand for raw materials inthis region than in China, reflecting the fact that many of the paper machines aimed at supplying demand in China will be built outside mainland China.

table 7.18 demand for raw materials in seven other Asian countries, millions tons

	1995	*2010*	*change*
BKS	1.4	4.5	+3.1
BKH	4.0	11.5	+7.5
bl sulphite	-	-	-
mechanical	0.6	3.6	+3.0
other woodpulp	1.3	4.2	+2.9
nonwood pulps	1.1	2.0	+0.9
recovered paper	12.4	46.6	+34.2
minerals	1.2	4.2	+3.0
total	*22.0*	*76.6*	*+54.6*

7.7.2 reinforcement pulp

Any local availability of reinforcing fibers will influence the investment policies of the leading and emerging paper producers in countries such as India, Pakistan, Thailand and Taiwan. In India and Pakistan, very little reinforcing fiber is currently used, but this will change as the industry modernises and faster paper machines are installed.

7.7.3 Indonesia

World scale woodfree paper machines have been installed in Indonesia in recent years. At present, they run on mixed tropical hardwood pulps. This requires substantial volumes of NBSK to ensure high runnability. The proportion of NBSK that is needed will be reduced as mixed tropical forests are replaced by eucalyptus and acacia plantations. On the other hand, paper volumes are growing rapidly. This would balance the reinforcement requirement on roughly the present basis.

Indonesia currently imports around 500,000 tons annually of long fiber pulps for reinforce-ment use. The volume can be reduced to 250,000 tons annually when the mills switch to integrated hardwood pulp from acacia or eucalyptus plantations, as intended. This will take place in 6 to 10 years, as plantation pulpwood becomes available. However, by the time this transformation has taken place, the volume of paper produced will have doubled.

7.7.3 prospect for paper

The population in the countries of this region is becoming increasingly literate and affluent. As a consequence, demand for paper in both sectors -printing and packaging- is rising fast. Most countries have an established paper industry, producing for the needs of their domestic markets. The industry tries to meet the expanding demand but is handicapped by the cost of investment for new capacity and the lack of fibrous raw material. The domestic availability of reinforcement pulp would help to increase machine speed (hence : capacity) without additional investment.

7.7.4 sisal

In all the countries of Southeast Asia (those in the database *plus* those in the Mekong Delta), suitable climatic zones for growing sisal exist. Sometimes, in certain locations, it is possible to find large tracts of land, for large scale sisal growing. In other instances, it is possible to grow sisal in small farms or cooperative schemes.
Whether the latter is indeed possible, depends importantly on social acceptance in the farming community. This is not invariably the case (especially not in Southeast Asia), but it can be boosted by considering sisal as a cash crop, for which it is eminently suitable.
Such schemes, which depend on community cooperation, are ideally suited for small or medium scale paper mills in the region of the community. A suitable small scale fiber extraction technology exists, which is not even disabled by scale dis-economies on the village level.

It is recommended to review this possibility for its financial and technical feasibility, choosing a suitable pilot location somewhere in South or Southeast Asia, in cooperation with a paper mill in the pilot area. A suitable companion is a straw pulp and paper mill with dormant machine capacity. Sisal is a logical crop in or near dry land (monsoon) rice growing areas, where straw is used for pulp and paper.

7.8 Australia and New Zealand

The production and fiber furnish data are presented in the market report annex two (the fiber *furnish report*) and are not shown here, because the domestic markets are relatively limited.

Australia has the potential for producing sisal cellulose on a world scale. It has previously looked at kenaf pulp, but the plans were subsequently abandoned.
The Australian paper industry lacks long fiber resources, but it has considerable short fiber potential from eucalypt forest reserves, already exploited. Besides, the new capacities in Indonesia are near by.

New Zealand, an important producer and exporter of softwood cellulose already, has considerable further potential as the leading regional producer of reinforcement pulp from softwood. The markets in Southeast Asia are nearby and attractive.

7.9 world summary

7.9.1 pulp forecast

In *table 7.19, we s*how how we expect demand for pulp to grow between 1995 and 2010, in the countries covered in the database.

We see that long fiber cellulose will increase from 36 million to 46 million tons, and total short fiber pulps from 85 million to 120 million tons. The shifts between these categories of fibers are of interest to our study. The ratios of long *versus* short fiber pulps, for instance, show that more short fiber cellulose will be used. Those of chemical *versus m*echanical pulps are shifting likewise, favoring mechanical pulp. The most dramatic shift is in the virgin fiber *versus* waste balance. Superficially, reinforcement pulp would increase at the same rate as the volumes of hardwood and mechanical pulps (and waste) rise. In practice, counteracting influences will attenuate the demand for reinforcement pulp.
Long fiber cellulose and reinforcement pulp will be used more effectively. So far, the assumption has been that the growing volumes of short fiber cellulose, mechanical pulp and waste require that more reinforcement pulp is used in the future.

table 7.19   change in the major types of pulps, 1995 to 2010

	1995	*2010*	*change*
long fiber cellulose	31.8	44.2	+12.4
short fiber cellulose	38.2	54.2	+16.0
bl sulfite	4.2	1.9	-2.3
mechanical	32.7	45.6	+12.9
other woodpulp	39.5	49.2	+9.7
nonwood pulps	13.8	22.0	+8.2
virgin fibers, total	160.2	217.1	+56.9
recovered paper	91.6	181.9	+90.3
fibers, total	251.8	399.0	+147.2
minerals	25.0	42.0	+17.0
materials balance, total	*276.8*	*441.0*	*+164.2*

The reverse is true, as we found previously (*chapter 6*). New papermaking technology accommodates the use of ever increasing quantities of short fiber pulps. The driving force is cost economy. The other driving force is the resilience of waste, the 'reserve quality' of the long fiber content in recycled paper, as yet not exhausted. This implies that less reinforcement pulp is needed than the figures would suggest.

7.9.2   long fiber cellulose : the impact from change

It now remains to be seen *where* the changes in fiber compositions have their greatest impact. We have focussed this discussion on long fiber cellulose, being the segment where sisal cellulose is a possible substitute.

In the world perspective, long fiber pulp will go from presently 36 million to 46 million tons. Short fiber pulps (including mechanical and nonwood pulps) will increase from 85 million to 120 million tons. The ratios change from 0.43 to 0.38. This seems not a dramatic shift, until we see that the shift in long fiber pulp represents 3.7 million tons. Without the shift, long fiber demand would be 16 million tons.

The shift is dramatic, when we also take paper waste into account. The ratios change from 0.20 to 0.15. As mentioned, this reflects the viewpoint that all paper waste is short fibered in nature, which overstates the situation. A future ratio of 0.14 adequately reflects the dormant 'over-quality' in waste fiber. This means that long fiber pulp capacity would need to grow by even less than 12.4 million tons -by 3.9 million tons less-, and yet provide sufficient control over reinforcement.

The prudent approach, which we have adopted for this market study, foresees a demand increase of 12.4 million tons of long fiber cellulose which is believed to be sufficient for the industry's long fiber *plus* reinforcement needs to 2010. The chapter that follows will review the plans for capacity expansions throughout the world.

7.9.3   regional differences

The remaining question is about regional differences. We will focus on long fiber pulp needs for the major grades, and review the findings from the previous paragraphs.

The major markets for long fiber cellulose are United States, Europe and Japan. We will summarise the long fiber pulp positions, with a view to any possible replacement by sisal pulp.

Europe uses 12 million tons of long fiber cellulose of which 7.2 million tons is market pulp, and 4.5 million tons of this is NBSK. NBKS in woodfree paper is gradually being replaced by BKS from southern pines and radiata, since price is a more critical factor than strength. This places sisal pulp in a disadvantageous position. Sisal pulp might, however, be considered for lightweight specialty printings such as bible or business papers.
In wood content paper, the pulp volume is 1.9 million tons, and most is NBSK, used for reinforcement. About half of this is supplied by nordic companies to dependent mills in Europe, and therefore hard to replace by sisal pulp.
Most tissue in Europe is made from waste, but some tissue from virgin fiber contains long fiber cellulose. Sisal pulp is eminently suitable for tissue, but price is the critical factor.
For paperboard, there are no obvious benefits to replace BSK. Sisal cellulose would be assessed on price.

The growing share of waste and emphasis on mechanical pulps in Europe increases the need for reinforcement pulp by more than one million tons annually. Sisal cellulose is a suitable reinforcement medium, but so far unproven in cost efficiency.

North America consumes 15 million tons of BKS, the largest consumer of long fiber pulp in the world. Market volume, in contrast, is only 4 million tons. The industry is entirely wood based, and far more integrated than in Europe. The increase in softwood cellulose capacity, foreseen for 2010, seems to be assured.
Cost economies from integrated operations are widely available, because wood is plentiful.
The reinforcing long fiber content in North American newsprint (1.5 million tons) is integrated pulp. Printing paper mills, especially woodfrees, improve their cost performance by using BKS from southern pines, a less expensive grade compared to NBSK. The wood content mills are the major buyers of market reinforcement pulp, divided between NBSK and southern BKS. The tissue mills have replaced most NBSK by BKS, because of price. The major kraft paper mills (in the packaging sector) are integrated. The superior quality of recycled waste offers cost economies at little expense in quality.
The market volume of 4 million tons might still be of interest to a sisal pulp producer. The obstacles are considerable. The foremost one is competitive price.

South America presents a different scenario. The tropical countries in particular, Brasil and Mexico included, lack the wood resources to produce reinforcement pulp. If the new technologies in fiber extraction and pulping are cost effective, Brasil and Mexico might become sisal pulp producers of domestic significance. This could notably reinforce the competitive position of Brasil in printing paper.
The specialty paper sector in Latin America is not large, but significant in Brasil, Argentine and Mexico. As Brasil shows, the prospect for sisal is favorable in this sector, even if limited.
There are no reasons to import sisal pulp, but domestic production is a promising prospect.

Japan uses approximately 3 million tons of BKS, of which 1.7 million tons is market pulp. It produces BKS from imported chips, but this pulp is too expensive. The reinforcement use of sisal pulp, a potential competitor, would need to orient itself on the cost of using imported BKS. In practice, this means that sisal pulp cannot be sold without a discount to wood pulp. For sisal pulp as an imported commodity, the most promising applications are in the specialty paper sector, which is a large activity in Japan.
China lacks the softwood resources, which it requires for the expansion of the paper industry. This is a formidable handicap in improving the output and efficiency of some of its mills.

Despite considerable effort in plantations, this situation will continue for the foreseeable future. In specific cases, alternative long fiber pulp can contribute to improving paper output : by fewer breaks for example, lower basis weight, better paper quality and similar measures. Increasing the speed of a paper machine unlocks the dormant capacity of the production line at minimal investment. Long fiber pulp is very effective in mills, which are limited to short fiber resources. Sisal is a convenient crop in many of these situations, especially since it can be processed even on a small scale or village level, and implemented in a far shorter time.
New processing technologies for sisal offer a suitable and fast approach to better production efficiency in some of the smaller paper mills. It is not suggested to replace the forestation programs, which should be developed as much as possible. Merely, the suggestion is made that paper mills on a more modest scale can benefit enormously from agro schemes to grow and process sisal in the surroundings of suitable mills, and where soil and climate allow to do so. This is a worthwile pursuit for a project, aiming to support developing nations in their social and industrial endeavours.

The same reasoning is valid for countries like India, Thailand, Indonesia (Java, where most paper mills are found) and the Philippines. With the exception of Sumatra, these countries lack softwood forest reserves that are suitable for pulp. It is difficult or impossible to establish pine plantations. Yet, these countries have large populations and well established paper industries. Usually, the mills are restricted in output because their fiber furnishes limit the machine speeds. A recommendable alternative to investing in more machine capacity is to produce long fiber raw material. Sisal is a suitable species for such purpose.

Australia has the potential to produce sisal cellulose on a world scale. It is suitably located near Southeast Asia where considerable paper expansions have taken place in recent years. The performance of short fiber furnishes, for instance in Indonesia but also in Australia itself, can be greatly enhanced by reinforcement pulp such as sisal. In the Australian case, the feasibility of a sisal pulp scheme would have to be checked against world market conditions. New technologies in growing, processing and pulping of sisal are imperative for such project to be successful.

7.10 paper in Africa

Paper in Africa is a separate subject. Published statistics for eastern Africa are reproduced in *table 7.20*. The data include the production, trade and consumption figures in Kenya and Tanzania, plus the east African countries with regular trade with these. The reliability of some of these data is not assured.

A nutshell view of Africa (*table 7.21*) shows paper production data in the paper producing countries.
Most countries in Africa produce and consume very little paper. Even including South Africa, the production of pulp and paper on the African continent represents only 0.9 pct of world production. For this reason, African countries are not represented in the database.

The two most populated countries are Nigeria and South Africa. In Nigeria, paper production is a mere 20,000 tons, whereas paper consumption is 281,000 tons. South Africa, of course, has a sizeable paper industry and is an important pulp producer. Even so, it produces less than 0.7 pct of world paper (2.1 million tons).

Tanzania and Kenya have paper industries of domestic importance. These countries are major producers of sisal. For that reason, we will discuss their scope in paper in a separate paragraph.

table 7.20 *paper in East Africa* [1]

year		1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
newsprint	p	36,440	346,540	35,350	40,270	45,320	39,320	38,220	39,170	40,400	41,000	24,000	24,000	
	i	21,818	17,071	16,888	16,878	18,365	16,374	13,533	28,916	22,832	30,389	45,431	51,725	
	e											61	323	
	ac	58,258	51,611	52,238	57,148	63,260	55,657	51,704	67,905	63,080	71,237	69,370	75,402	
other p&w	p	49,800	54,800	44,900	38,200	44,000	50,000	33,600	33,000	30,300	30,000	28,200	28,600	
	i	30,141	32,929	34,155	37,355	42,293	37,169	40,933	22,902	29,972	34,460	51,799	70,775	
	e	100	1	155	155	583	507	284	493	2,188	2,361	1,648	2,504	
	ac	79,841	87,728	78,900	75,400	85,710	86,662	74,249	55,409	58,084	62,099	78,351	96,871	
packaging	p	68,600	73,600	64,000	63,000	134,000	133,700	86,600	90,400	107,800	107,800	95,300	95,600	
	i	36,400	28,000	30,000	30,000	14,286	17,567	24,959	22,032	30,500	30,500	11,200	10,100	
	e	2,600	2,600	2,600	2,600	9,809	1,009	955	1,767	1,669	1,669	0	0	
	ac	102,400	99,000	91,400	90,400	138,477	150,258	110,604	110,665	136,631	136,631	106,500	105,700	
paper total	p	232,240	241,840	224,250	221,070	302,020	295,620	232,420	239,370	255,400	256,100	166,200	173,900	
	i	126,027	114,500	121,281	124,871	124,599	112,090	108,573	120,542	129,584	118,032	137,397	178,145	
	e	6,900	6,801	6,955	6,955	23,661	1,719	1,525	5,981	9,808	10,807	1,112	602	
	ac	351,367	349,539	338,576	338,986	402,958	405,991	339,468	353,931	375,176	363,325	302,485	351,443	n.a.
chemical pulp	p	77,500	78,500	81,100	82,300	99,300	114,300	87,300	97,300	97,300	97,300	119,400	119,400	
	i					10,288	9,415	4,173	11,756	11,776	13,659	9,163	6,736	
	e					18	10	13	132	108	36	173	173	
	ac	77,500	78,500	81,100	82,300	109,570	123,705	91,460	108,924	108,968	110,923	128,390	125,963	
mechanical pulp	p	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	
	i					1,972	101	2,000	2,000	1,803	1,203	1,000	1,000	
	e													
	ac	10,000	10,000	10,000	10,000	11,972	10,101	12,000	12,000	11,803	11,203	11,000	11,000	
total pulp	p	87,500	88,500	91,100	92,300	109,300	124,300	97,300	107,300	107,300	107,300	129,400	129,400	
	i					12,260	8,516	6,173	13,756	13,579	14,862	10,163	7,736	
	e					18	10	13	132	108	36	173	173	
	ac	87,500	88,500	91,100	92,300	121,542	133,806	103,460	120,924	120,771	122,126	139,390	136,963	n.a.
waste	p	66,000	69,000	55,970	55,900	62,840	67,000	73,900	74,800	74,800	74,800	51,500	46,500	
	i	5,626	2,114	7,674	7,674	12,833	4,268	9,762	19,709	21,802	20,929	14,268	8,774	
	e			26	26	386	4,548	2,505	2,556	1,999	2,324	505	879	
	ac	71,626	71,114	63,618	63,548	75,287	66,720	81,157	91,953	94,603	93,405	65,263	54,395	n.a.

[1] *includes Kenya, Tanzania, Uganda, Burundi/Rwanda/Congo, Malawi/Mozambique/Zambia, Sudan/Somalia/Ethiopia*

table 7.21 nutshell view of paper production in sixteen African countries

	population	*paper mills*	*capacity*	*app consumption*
source : faostat, ppi	*million*	*number*	*FMTPY average 1998-2000*	
Kenya	30.0	5	148,600	156,600
Tanzania	32.2	4	27,400	23,800
Uganda	21.3	1	3,000	10,400
Sudan	28.5	2	2,400	13,600
Ethiopia	61.1	1	9,400	21,000
Mozambique	19.3	2	600	10,000
Madagascar	15.5	1	2,400	10,500
Malawi	10.6	-	0	5,600
Zambia	9.0	1	2,900	9,000
Nigeria	108.9	2	62,600	434,000
Zimbabwe	11.5	4	78,000	101,000
South Africa	43.0	17	1,834,000	2,073,000
Algeria	30.2	4	48,400	220,000
Egypt	67.2	12	309,200	954,000
Morocco	28.0	5	110,000	285,000
Tunisia	9.3	9	96,800	175,000

7.11 East Africa

Products from Tanzania and Kenya reach the other east African countries by road and sea. Both countries export paper to the interior. Paper exports to Uganda are significant, most comes from Kenya and some from Tanzania. The consumption of paper in Uganda is steadily increasing. Uganda has a small paper mill, where locally generated waste and imported pulp are used (*tables 7.21 and 7.22).*

Other countries within the zone are Burundi and Rwanda (one small paper mill), where most paper is also imported from Tanzania and Kenya. Further afield are Malawi (no paper mills), Mozambique (one small mill) and Zambia (some paper mill capacity). The latter three countries are far away, in the sphere of influence of South African trade. Some paper reaches the central African countries by road, through Tanzania and Uganda.

table 7.22 paper production in twelve East and Central African countries

annual volume in metric tons	*production*	*trade*
source : faostat, ppi	*average 1994-2000*	
Kenya	119,750	22,283
Tanzania	25,000	2,614
Uganda	3,000	3,712
Burundi & Rwanda	-	4,724
Malawi, Mozambique, Zambia	1,750	11,961
Ethiopia, Somalia, Sudan, Congo	10,780	18,348

Average production statistics in East Africa (ref *table 7.20*) are in *table 7.22.*The quantities of paper consumed outside Tanzania and Kenya not large. Tanzania and Kenya each have one large paper mill, plus some small mills. The large mills in Tanzania and Kenya produce primarily for their respective domestic markets, and have marginal exports.

7.12 *Tanzania and Kenya*

Kenya and Tanzania have paper mills that produce for the domestic market. They also export paper to countries in the region. The export volumes are limited. The *officially published statistics* have been collected and are reproduced in *tables 7.21.* The data may not always represent the true situation.

In Tanzania four paper mills are in operation. The major mill, in Iringa, has a considerable capacity of 85,000 tons, sufficient for the country's domestic consumption and some export. The statistics suggest that production from the mill has been around 25,000 tons on average in recent years. Several explanations are offered for the discrepancy between capacity and output.

The mill is well designed and fully equipped to process wood, hardwood as well as softwood. It is capable of producing good quality wood cellulose. It is not equipped to process sisal. The mill has experienced various difficulties in obtaining pulpwood, despite the fact that large forest plantations of pine and eucalypt exist nearby. It is unfortunate that the mill is located far away from the populated areas. The mill's restricted output is detrimental to the price of paper in Tanzania. The location of the mill is too far away from the sisal plantations in Tanga and Arusha, to be supplied with sisal fiber.

The mill in Moshi produces matchboard and other paperboard from softwood pulpwood, paper waste and imported pulp. The mill has a separate production line, producing sisal pulp. Sisal fiber is procured from nearby plantations with the same ownership as the mill. Sisal pulp is exported, most of it is sold to Japan. There have been unsuccessful attempts to sell in Europe.

The Moshi mill has a well equipped paper and pulp laboratory, where it would be possible to investigate sisal pulping and testing methods, with very little additional investment. In addition, the mill is well placed for pilot runs on new fiberisation and pulp process methods. This would require only limited additional investment.

The two other paper mills in Tanzania operate on waste, one producing board, the other tissue.

In Kenya, five paper mills are in operation, including the important PanAfrican Paper Mills, located in Webuye, northwest of Nairobi, a fully integrated pulp and paper mill complex of well regarded technical standing and expertise. The mill's capacity is 70,000 tons of paper and 62,000 tons of pulp. There are important softwood (pine) and hardwood plantations in the area. The mill uses softwood and hardwood for pulping and papermaking, and, in addition, it uses imported pulp and paper waste. Similarly to the mill in Iringa, it is not equipped to handle sisal.

The PanAfrican mill has considerable experience in pulping and testing research. Regarding sisal, the mill has done extensive evaluations of sisal pulping and pulp testing, a fact which testifies to their interest in alternative fibrous raw materials. Just as the Iringa mill, the mill is not equipped to process sisal fiber into pulp.

The other paper mills in Kenya are small operations, using paper waste and occasional quantities of imported pulp. Two mills produce tissue from recycled paper, one produces various wrapping and packaging papers, and one makes paperboard.

There are two small sisal pulp mills in Kenya, both idled at the time of reporting. It would be worthwhile to review their situations and restart operations at either mill, possibly trying out new fiberisation and pulp process methods (*chapter 2*) on a pilot scale.

7.13 sisal pulp manufacture in Tanzania and Kenya

This subject encompasses four topics :

[i] the small scale manufacture of specialty sisal cellulose
[ii] sisal pulp for domestic paper production
[iii] large scale production of sisal pulp for export, for instance for reinforcement
[iv] bole fiber

7.13.1 production of sisal pulp in Africa

Tanzania produces and exports sisal pulp in small quantities, in the mill in Moshi. The pulp mill is located in a paper mill, where matchboard is produced. The pulp mill was idled for some years but is back in production.
Until some years ago, there were two mills in operation in Kenya, also producing small quantities of sisal pulp for export.

7.13.2 small scale production of sisal pulp

A bird's eye view suggests that the small scale production of sisal cellulose in Tanzania and Kenya can be a very profitable business.

In Kenya, one or even both sisal mills could be revitalised by attracting entrepreneurial capital. Considerable investment is needed, which however could be very profitable.

An inventory of the Moshi mill, made in 1998, showed that the sisal pulp mill is in acceptable condition, but that mill operations need better process and quality control. A limited but cost effective investment should improve process flow. Another improvement might be to equip the mill for bleaching.
If the process and quality control systems can be improved, pulp sales can be focussed more effectively on relationships with overseas clients. This could recapture the fortunes of former days ; something which would not be difficult or expensive to achieve.

For all the existing sisal pulp mills, new process technology in fiber extraction and pulping (*chapter 2*) will boost their performance and can help them to regain a position of prominence. For this to materialise, it is required that company management or investors recognise the potential of such technologies and are willing to undertake the investment. A provisional calculation suggests that for a 2,000 tons pulp operation a 32 pct IRR is feasible.

7.13.3 bole fiber

The exploitation of residual bole from end-of-cycle sisal fields has been discussed at length. There are inexpensive ways of producing mechanical pulp from bole. This requires a fiber processing plant and a facility to produce mechanical pulp. Both are satisfactory as small scale operations, if a consumer for the pulp is nearby. There are two disadvantages.
The ratio of the cost of usable fiber in the raw material (wet bole) to the price of the product (mechanical pulp) is excessive. The logistics in the processing sequence are unfavorable : transportation, fiber and fines content, product sale. The short fiber content in the bole center is an additional draw back for pulp quality. The pulp can be improved by eliminating the short fiber fraction, but this augments the cost. Locally produced mechanical pulp from bole cannot compare in quality with imported long fiber cellulose or with mechanical pulp, and would have to be deeply discounted in price.
Nevertheless, mechanical pulp from the bole may be considered a useful component for coarse paperboard, such as in Moshi. If the processing and transportation economics were better, the

Iringa mill might also be able to absorb bole fiber from end-of-cycle plantations. In both cases, the volume of available bole and their processing economics appear to be ill matched.

7.13.4 *pulp import substitution*

Tanzania and Kenya import long fiber pulp from traditional world market sources (Scandinavia and North America) at considerable cost. The freight, shipping charges and import duties add about 40 pct to the price tag. The suggestion has been made that the existing (domestic) paper mills use sisal waste instead of imported pulp.
This requires that the pulp mills be converted from wood to sisal, or that an additional pulp line be set up. Both options are expensive in terms of investment. The existing mills were designed to process wood and cannot handle sisal fiber.
Another objection is that sisal fiber would compete with coniferous pulpwood, available in the inmediate surroundings of the mills. As we shall see in *chapter 10*, the logistics of a sisal fiber-to-pulp chain deteriorate as the size of operations increases, whereas those of pulpwood-to-pulp improve with larger capacities.

7.13.5 *large scale sisal pulp*

A large scale sisal pulp export project, to be located close to shipping ports in Tanzania or Kenya, is a third possibility. The feasibility of such a scheme should be analysed, using conservative (prudent) estimates of manufacturing cost and market response. The latter aspect is the realm of a market feasibility analysis, the provisional elements for which were collected during this study. They should be given focus in the market analysis, scheduled to follow this first phase of study.

The former Tanzania Sisal Authority has proposed the idea of a sisal export pulp mill, to be located in Tanga, in the heart of the sisal growing region of the country. Some years ago, a feasibility study was made which suggests that a 50,000 ADMTPY mill scheme is feasible. We have examined the information and conclusions on market aspects in the reports.

Incidentally, it is always a prudent idea to reconsider and re-work previous feasibility considerations in the light of recent information. The feasibility exercise can easily be repeated or updated and confirmed, and is usually worth the effort which it takes.

The feasibility reasoning pre-supposes certain cost and market conditions, which in our opinion are not assured over the full depreciation life of the scheme. A change in conditions, any assumed volume or cost factors for instance, means that the calculated outcome changes. Some of the assumed conditions may not be valid at all times during the active period of the project. If so, this affects the conclusions. A negative change causes a downward adjustment in the appreciation for the project, for as long as the change is valid.

Relatively mild changes in certain price or cost factors can produce sharp swings in the bottom line results. For an example, refer to the *graphs 8.1* and *8.2* which illustrate the price development of NBSK, the bench mark reinforcement pulp. Calculations show that, if the bench mark price movements change with the frequency and amplitude as the graphs show, the financial feasibility of the proposed scheme is only assured for half the depreciation interval. This means that the project might experience hardship, even financial loss during some years.

The market study has collected and review market related information, for the purpose of ascertaining the reliability of assumptions, made in feasibility analyses. The procedure is consistent with conservative estimates of manufacturing cost estimates and market response. The latter aspect, of course, was the major target of this market study.

NBSK is the price leader in reinforcement pulp. The price of sisal reinforcement pulp, exported to the European or North American markets, would be influenced by the price movements of bench mark NBSK. Indeed, sisal pulp would follow the NBSK price. An independent price level for sisal reinforcement pulp is impossible, at the expense of grave fluctuations in buffer stock, which then needs to be financed.

The comparison of cost and price elements in NBSK and sisal cellulose, referenced against the time fluctuations in the NBSK price, are unfavorable for a sisal scheme of the proposed capacity. The risk is too large, compared to the possible reward. Said in other words : there may be time intervals during the life of the project, where the financial feasibility is negative. Therefore, the outlook for the 50,000 ADMTPY scheme is not satisfactory. This is largely due to the size of the proposed project and its logistics. See also *chapter 10.*

7.14 a note on sisal in developing countries

There are few softwood species that are indigenous to tropical areas. The exotic coniferous plantations have been confined to the subtropical zone. It is difficult or impossible to establish coniferous plantations in the tropical zone.
Most populated countries in the tropics are developing countries, in dire need of economic and social development. The availability of paper is one of the key elements in alphabetisation and industrial activity. Poor countries can ill afford to import all their basic needs. Paper mills in developing countries rely usually on few locally available fibrous raw materials : straw or other short fiber sources are used out of necessity. Short fiber furnish, however, limits the speed, therefore the capacity of paper machines. If available, long fiber pulp could debottleneck some capacity without the need for capital investment to modernise the mills.
By coincidence, many areas in developing countries are suitable to grow sisal. Sisal is the *one* species, adapted to dry humid climates and semi-dry soils (*rainfall* 400 to 900 mm), frequently found in countries in the tropics.

The results in the present sisal project are of great interest to other developing countries. The technology of growing and processing sisal leaf, and new pulp process technology, should be made available freely to the developing world.

table 7.23 paper statistics on Kenya

year		1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
newsprint	p	8,200	6,300	6,000	11,000	16,000	16,000	13,000	14,000	14,000	14,000	14,000	14,000	
	i	7,100	5,047	965	965	956	298	1,006	5,315	2,400	7,610	21,000	21,000	
	e					10			4					
	ac	15,300	11,347	6,965	11,965	16,946	16,298	14,006	19,311	16,400	21,610	35,000	35,000	n.a.
other p&w	p	34,000	38,000	28,000	32,000	32,000	32,000	17,000	18,000	18,000	18,000	18,000	18,000	
	i	1,000	8,576	5,600	4,344	4,344	9,545	8,166	3,641	6,700	12,241	17,000	17,000	
	e	100	1	155	20	20	105	105	105		145	1,500	1,500	
	ac	34,900	46,575	33,445	28,445	36,324	41,440	25,061	21,536	24,700	30,096	36,500	36,500	n.a.
packaging	p	52,000	57,000	51,000	49,000	120,000	120,000	73,000	75,000	91,000	91,000	91,000	91,000	
	i	5,800	5,800	5,800	5,800	14,286								
	e	2,600	2,600	2,600	2,600	7,150	11	896	98					
	ac	55,200	60,200	54,200	52,200	112,850	119,989	72,104	74,902	91,000	91,000	91,000	91,000	n.a.
paper total	p	100,200	108,300	93,000	92,000	176,000	176,000	108,000	113,000	129,000	129,000	129,000	129,000	
	i	25,600	31,123	24,065	24,065	15,200	20,099	20,651	18,813	20,400	30,863	53,000	53,000	
	e	2,700	2,601	2,755	2,755	7,180	116	1,001	207		273	1,700	1,700	
	ac	123,100	136,822	114,310	113,310	184,020	195,983	127,650	131,606	149,400	159,590	183,700	183,700	184,300
chemical pulp	p	55,000	56,000	56,000	58,000	75,000	90,000	63,000	66,000	66,000	66,000	66,000	66,000	
	i					2,231	262	263	1,375	5,003	3,794	3,200	3,200	
	e					18	10	1	25	1	1			
	ac	55,000	56,000	56,000	58,000	77,213	90,262	63,262	67,350	71,002	69,793	69,200	69,200	n.a.
mechanical pulp	p													
	i					1,972	101	103	103	103	103			
	e													
	ac	0	0	0	0	1,972	101	103	103	103	103	n.a.	n.a.	n.a.
semichemical pulp	p													
	i													
	e													
	ac		0	0	0	0	0	0	0	0	0	0	0	n.a.
total pulp	p	55,000	56,000	56,000	58,000	75,000	90,000	63,000	66,000	66,000	66,000	66,000	66,000	
	i					4,203	363	366	1,478	5,106	3,897	3,200	3,200	
	e					18		1	25	1	1			
	ac	55,000	56,000	56,000	58,000	79,185	90,363	63,365	67,453	71,105	69,896	69,200	69,200	70,000
waste	p	30,000	36,000	27,000	26,000	26,000	26,000	37,000	38,000	38,000	38,000	38,000	38,000	
	i	4,000	299			4,689		3,028	4,175	1,100	187	4,600	4,600	
	e			26	26									
	ac	34,000	36,299	26,974	25,974	30,689	26,000	40,028	42,175	39,100	38,187	42,600	42,600	43,000

faostat statistics 2001

table 7.24 paper statistics on Tanzania

year		1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
newsprint	p	9,000	9,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	
	i	116	1,552	212	212	725	4,200	400	1,487	1,300	1,868	8,282	8,569	
	e					217							188	
	ac	9,116	10,552	8,212	8,212	8,508	12,200	8,400	9,487	9,300	9,868	16,282	16,381	
other p&w	p	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	
	i	2,881	2,659	1,163	1,163	461	1,700	2,600	313	600	998	4,095	5,793	
	e						11	11	11	11	11	11	762	
	ac	8,881	8,659	7,163	7,163	6,381	7,689	8,589	6,302	6,589	6,987	10,084	11,031	
packaging	p	13,000	13,000	11,000	11,000	11,000	11,000	11,000	11,000	11,000	11,000	11,000	11,000	
	i	10,000	10,000	10,000	10,000	2,047	1,235	1,235	1,208	1,100	1,100	1,100	1,155	
	e					475	19	19	1,629	1,629	1,629	1,629	1,629	
	ac	23,000	23,000	21,000	21,000	12,572	12,216	12,216	10,579	10,471	10,471	10,471	10,526	
paper total	p	28,000	28,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	
	i	17,997	19,211	16,375	16,375	3,233	7,135	4,235	3,008	3,000	5,160	16,809	23,540	
	e					772	30	30	1,640	1,640	1,640	28	1,128	
	ac	45,997	47,211	41,375	41,375	27,461	32,105	29,205	26,368	26,360	28,520	41,781	47,412	n.a.
chemical pulp	p	25,000	25,000	44,000	44,000	44,000	44,000	44,000	44,000	44,000	44,000	44,000	44,000	
	i					121	438	438	56	56	30	4	78	
	e						10	10	10	10	10	150	150	
	ac	25,000	25,000	44,000	44,000	44,121	44,428	44,428	44,046	44,046	44,020	43,854	43,928	
mechanical pulp	p	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	
	i												2	
	e													
	ac	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,002	
semichemical pulp	p													
	i													
	e													
	ac	0	0	0	0	0	0	0	0	0	0	0	0	
total pulp	p	35,000	35,000	54,000	54,000	54,000	54,000	54,000	54,000	54,000	54,000	54,000	54,000	
	i					121	438	438	56	56	30	4	78	
	e						10	10	10	10	10	150	150	
	ac	35,000	35,000	54,000	54,000	54,121	54,428	54,428	54,046	54,046	54,020	53,854	53,928	n.a.
waste	p	0	0	0	0	0	0	0	0	0	0	0	0	
	i					1,088	141	141	2,091	3,600	2,030	7,450	3,513	
	e												141	
	ac	0	0	0	0	1,088	141	141	2,091	3,600	2,030	7,450	3,372	n.a.

faostat statistics 2001

THEME B

chapter 8 long fiber cellulose and reinforcement pulp

overview	the supply aspects of softwood reinforcement cellulose and price histories are reviewed

In the previous chapters, we have found the following information on long fiber cellulose :

million tons	*year 2000*	*year 2010*
total long fiber cellulose	75	87
total reinforcement cellulose	50	58
market reinforcement pulp	17	24

8.1 forest resources

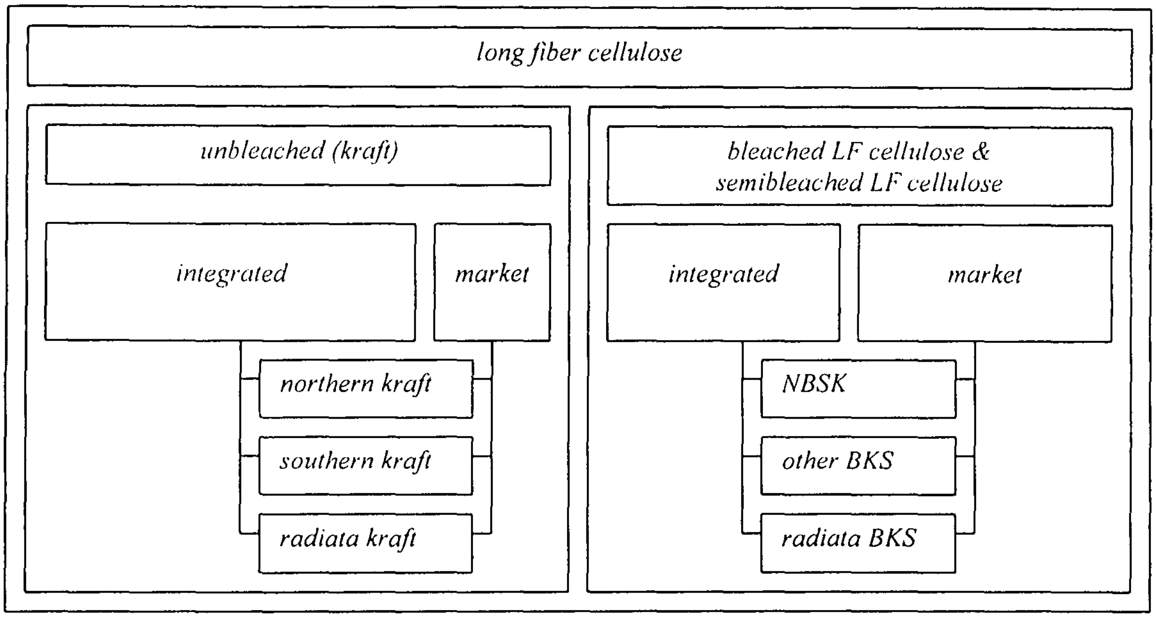
Coniferous forest reserves abound in the cold and temperate zones of North America, Europe, Russia and Siberia. As it gets warmer, softwood species occur more occasionally, more often in mixed forest stands or in patches. In the tropical and subtropical zones, conifer species are also found, but these rarely form massive forests as in the northern softwood belt.

In Europe and Scandinavia, the coniferous forests are exploited on a sustained basis and produce lumber, wood products and pulp. Those in the United States are also fully exploited, and the same is true of the accessible forests in Canada. Beyond these, to the northern interior, Canada has massive softwood reserves. Russia is in a similar position. The enormous potential of Siberia is almost untouched as yet.

Indigenous conifer forest reserves exist in some of the tropical and subtropical zones. They can be found in Central America (Honduras, Guatemala, Nicaragua), Mexico, Brasil and Argentina, and Chile ; in Asia Minor, in the Himalayas, China, the Mekong delta and Japan ; in Indonesia (Sumatra), the Philippines (Luzon), Taiwan, Papua New Guinea, and in New Zealand. In most of these, pine species are found, but some harbor exotic Gymnospermae species like Araucaria and Agathis.
Where these forests have been accessible, they have usually been exploited, indeed over-exploited. The remaining softwood forests are dispersed, inaccessible, not exploitable, the reasons that they have survived in the first place.

In Mexico and Central America, several pine species are found that occur in large natural habitats although widely dispersed. Certain of these, Pinus radiata in particular, have been adopted for forestation schemes elsewhere. Massive plantations have been established in Chile, South Africa and New Zealand. The growth rates of radiata pine in Chile have been five or six times those of temperate conifer species. In the subtropical climate of Chile, radiata pine has been a huge success. The potential for more radiata plantations in Chile is very considerable.
In other countries, like Argentina, Uruguay and southern Brasil but also in the Venezuelan Andes, exotic pine plantations have been fairly successful. Elsewhere, exotic pine species were unsuccessful, invariably because the climatic conditions were not compatible. Pine species are prone to diseases, if the climate is not favorable, as the experience in Spain and Argentine has demonstrated.
In the wet tropical lowlands, the true tropical pine species (indigenous to the Mekong delta and eastern Himalayas) have been unsuccessful in exotic plantations.

figure 8.1 provenances of long fiber cellulose for paper



8.2 softwood cellulose

Softwood market pulp owes its success to a combination of circumstances. The conifer forests are uniform over large areas, the forests are accessible, and the consumers of lumber and pulp were nearby. The trees are easy to harvest, the crop is uniform and is easily transported. The conversion into wood products has been practiced for a long time. As far as papermaking is concerned, the major wood pulp processes were invented long ago, between 1800 and 1885, and improved in the hundred years that followed. In the end, the sulphate process won. The major long fiber market pulps are bleached sulphate and kraft.

As to the origin of pulpwood, there were four phases in which softwood cellulose developed. The first was when wood in the temperate softwood forest reserves in Scandinavia and North America was used. This phase lasted almost hundred years. In the fifties, the southern pine forests (in the United States) were unlocked. Only some decades ago, the potential of pine plantations in subtropical countries like Chile and New Zealand was recognised. Simultaneously, the large scale use of sawmill waste was adopted. This underlined that the age of wood has a distinct influence on pulp quality. Meanwhile, saw mill waste has become a valuable raw material in North America and Scandinavia. This has underlined the experience that young and mature wood produce different qualities of pulp.

There are important differences in papermaking characteristics between the pulps from all these provenances. We need to distinguish these because their pulp properties are not alike. This fact is not habitually mirrored in the price statistics. We have also seen that the use of pulp is changing over time (*chapter 7*). Observations such as these provide us with the proper perspective on the questions, which differentiate reinforcement pulps.

A second consideration is the cost of using reinforcement pulp. We have previously noted that producers of coated wood content paper use some of the world's most expensive reinforcing pulp (NBSK), and that they do so for cost economies.

The future availability of reinforcement pulp depends not only on the physical availability of softwood but also on the price of pulp. Standard reinforcing pulp is increasingly substituted by alternative grades, where this is acceptable and cost effective. The result is that more reinforcement pulp is available for critical applications, where the best reinforcing grade is necessary and at the same time cost effective.

Ultimately, the answers to above questions are helpful in determining the best value of sisal cellulose, for reinforcement or other applications.

8.3 long fiber cellulose and reinforcement pulp

Long fiber pulp and reinforcement cellulose are different products. We have seen in *chapter 7* that the volume of reinforcement cellulose is half of the volume of long fiber pulp.

Long fiber pulp, such as kraft, is used in packaging paper to *reinforce* the strength properties, but this is *not* reinforcement pulp. We have seen that half of the world's volume of softwood cellulose is unbleached kraft, used for packaging paper. Ninety percent of this is integrated. This pulp has a cost well below the price of reinforcement market pulp : normally 30 or 35 pct less, occasionally more than 40 pct lower. The pulp yield, absence of bleaching and lower cost of pulpwood explain the cost difference. The integrated operation brings additional economies.

The other half of softwood pulp is bleached long fiber pulp ; and most of it is used in printing paper, for reinforcement. The volume of reinforcement pulp is fairly evenly divided between integrated and market cellulose (*chapter 6*).

Purchased cellulose is more expensive in comparison with integrated pulp. The cost elements of drying, sales and transportation make the pulp necessarily more expensive ; the difference ranges from 80 to 140 dollars. Therefore, integrated paper mills will use their own and not purchase any market pulp. Likewise, captive pulps also are lower cost pulps.

The question, therefore ('whether sisal reinforcement pulp is a viable export product') is confined to the reinforcement market pulp segment. The volume of this segment is approximately half of the world volume of reinforcement pulp.

8.4 pulp manufacture

Pulp producers need a reliable and cost effective supply of pulpwood. They like to have control over their raw material base. For such and other reasons, they are located in forest areas, away from the urban areas where most paper is consumed. Pulp mills produce either long fiber or short fiber pulp. The dominant wood type, where the mill is located, determines the product, which the mill produces. We will limit the discussion to reinforcing pulp.

Reinforcement pulp is produced from softwood species by the sulphate process and multistage bleaching. The qualities of pulp differ considerably and are determined by the wood species, age, the growth conditions and whether thinnings or sawmill waste are used.

Canadian spruce and fir produce the best reinforcement cellulose. Pine and spruce are the common species in Scandinavia and produce comparable qualities. Most pulp from southern pines (US) is packaging grade, but some is bleached, and some of it is used in specific reinforcement situations such as tissue. Radiata market cellulose from Chile is used for reinforcement applications and packaging ; cellulose from New Zealand and South Africa is used for the same purposes.

Large scale manufacture of pulp is now the rule. The major 'world class' market pulp mills in the northern hemisphere enjoy scale and other cost economies. Greenfield mills of 400,000 to

500,000 ADMTPY are commonplace. To feed such a mill requires a constant flow of wood, and a considerable area of forest.
Most of the major producers are found in Canada and Scandinavia. Others are found in the southeast of United States, and in the in the forest plantation areas of Chile, South Africa, Spain and New Zealand.

8.5 scale economies

The scale economy curves of softwood pulp mills flatten out at around 300,000 to 400,000 tons capacity (*figure 2.2*). Beyond 400,000 tons or so, other cost factors assume a growing influence. The supply logistics are consequential. The daily flow of wood to a mill of such size is considerable : 8,000 tons or more of fresh wood need to be transported to the mill every working day.
A mill of this size needs an extensive forest reserve on which it can count for many years. The necessary forest area depends on the climate and the growth rate : 260,000 to 400,000 ha of northern temperate forest, compared to only 60,000 ha or so in Chile. Naturally, the cost of logging and hauling increases as the forest area is larger. In any case, the cost of wood and those in society are related. The countries in the northern hemisphere have the highest cost of living in the world. This is just one of the reasons why favorable greenfield sites in the northern hemisphere are now difficult to find. Together with other factors such as the cost of land, this explains why the migration of the industry to low cost locations may be unavoidable in the end.

8.6 differentiation in pulp characteristics

As the climatic zones vary, so does the wood. Softwood pulps differ considerably according to the wood and the climate.
Northern bleached sulphate is the preferential grade for reinforcement in printing paper, and southern pine bleached kraft is best for packaging purpose. The subtropical pines of Chile and New Zealand produce pulps that are acceptable for both.
Not all NBSK pulps are the same. The strongest pulps are produced from the very slow growing trees of western Canada. There are significant differences between coastal and inland locations, even within British Columbia. Canadian and Scandinavian pulps also differ in fiber length, count of fiber per gram of pulp, wet entanglement and wet strength. Nevertheless, all NBSK is priced at the same level, the highest priced bulk paper grade pulp on the market.

Premium NBSK is produced in the northern countries : Canada, Sweden, Norway, Finland and Russia. This pulp is stronger than the other softwood pulps produced in the USA, South America or New Zealand. It commands a price premium of around $30 over US southern pine sulphate, or $10-20 over Chilean radiata pine.

8.7 North American and European softwood pulp producers

North America has a large and important forest industries sector, in which pulpwood exploitation is an essential part forest exploitation. The softwood pulp industry has a well established base in the temperate coniferous forests of east and west Canada, northern and western United States and in the southeast forest belt.
The North American forests have sustained the development of pulp and paper operations in a generous way, but these are sometimes thought to be approaching mature commercial exploitation. In any case, the extensive forest reserves are capable of supporting the present operations, while the vast untouched forest reserves -in northern Canada- remain untapped.

In Europe, the situation has been different. Sweden and Finland have been traditional suppliers of long fiber pulp and long fiber content paper to continental Europe. Opinions differ whether the nordic forests are now fully exploited. There is some consensus that intensive management can expand the wood supply by one or two percent annually for the foreseeable future. The additional wood volume can at best support capacity increases in existing mills. On balance, the export volume of softwood cellulose from Scandinavia will decrease, because these countries will produce additional paper themselves.
The forests of nearby Russia and the Baltic states export pulpwood and constitute an important reserve for greenfield mills in the future. Other important forest patches in eastern Germany and Russia also are possible locations for greenfield mills.

Chile is busily expanding its forest plantations in the south, and more plantations in Uruguay and Argentina are in the planning stage.
Some very large plantation schemes in China are under way ; although these are for domestic consumption, they will alleviate pressure on the world market (*paragraph 7.6*).

The notable absentees are the countries in southeastern Asia, where softwood plantations have failed for climatic reason, although these have been tried in the Philippines and Thailand. The conifer forest reserves in northern Sumatra are insufficiently large to support growing demand for reinforcement pulp in Indonesia, but more capacity in New Zealand is potentially available.

8.8 industry profile

There are currently 85 pulp mills in operation, where long fiber market cellulose is produced. Their sizes and unit manufacturing costs are compared in *figure 8.4*, and their cost profiles are presented in *figure 8.5* at the end of this chapter.

Interesting conclusions can be drawn about the profiles of low cost producers, the likely course of future pulp prices and the pulp supply situation in the coming years.
For our purpose, we limit ourselves to establishing the price horizons of reinforcement pulp. We shall need these as the reference in assessing the position of sisal reinforcement pulp, in *chapter 10*. Some conclusions on unit cost may be helpful in establishing the feasibility limits of sisal pulp.

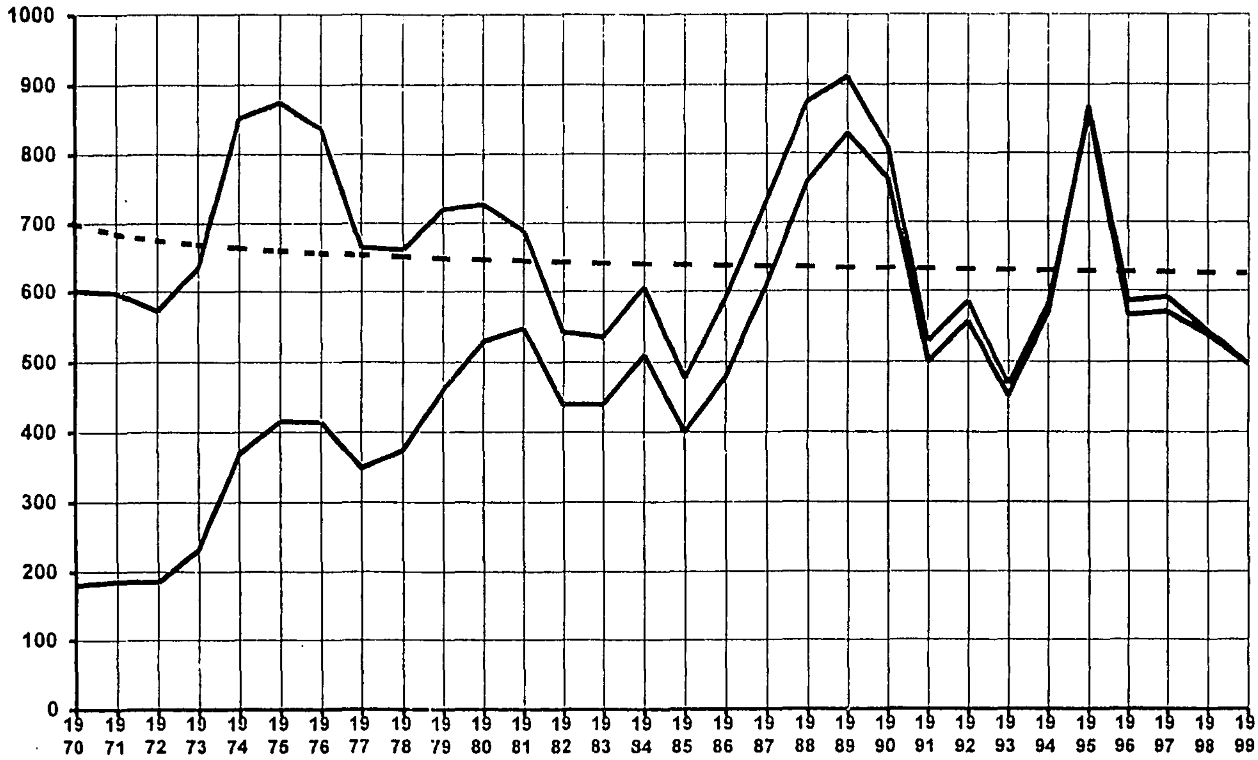
In market softwood kraft, fiber cost per ADMT of pulp oscillates between 120 dollars (in Chile) and 265 dollars (Scandinavia). The apparently acceptable maximum fiber price is 240 dollars ; but beware : this information is only relevant in relation to mill size.
Chemical cost is fairly even. Labor fluctuates between 20 and 100 dollars. Supplies and materials is fairly even, and so are sundries and taxes.
The cost of energy diverges widely, from 10-14 to 50-110 dollars. Of course, these depend on the heat and energy balances of individual mills. The cost of wood and the energy content in wood are intimately related. The efficiencies in recovery, heat and energy cycles and in situ chemicals generation are in play. Only their balance is seen from the energy cost figures. The cost of energy is unequal between North America and Europe, and this explains the difference in energy efficiencies and cost.

8.9 reinforcement cellulose - price and cost aspects

Actual prices for NBSK from 1970 to 1999 and real prices in 1999 US dollars are shown in *figure 8.2* on the next page. Actual prices are the recorded prices for the period of 1970 to 1999 and real prices are the *recalculated* prices in constant 1999 dollars for the same period.

figure 8.2 *current and constant dollar prices of NBSK from 1970 to 1999*

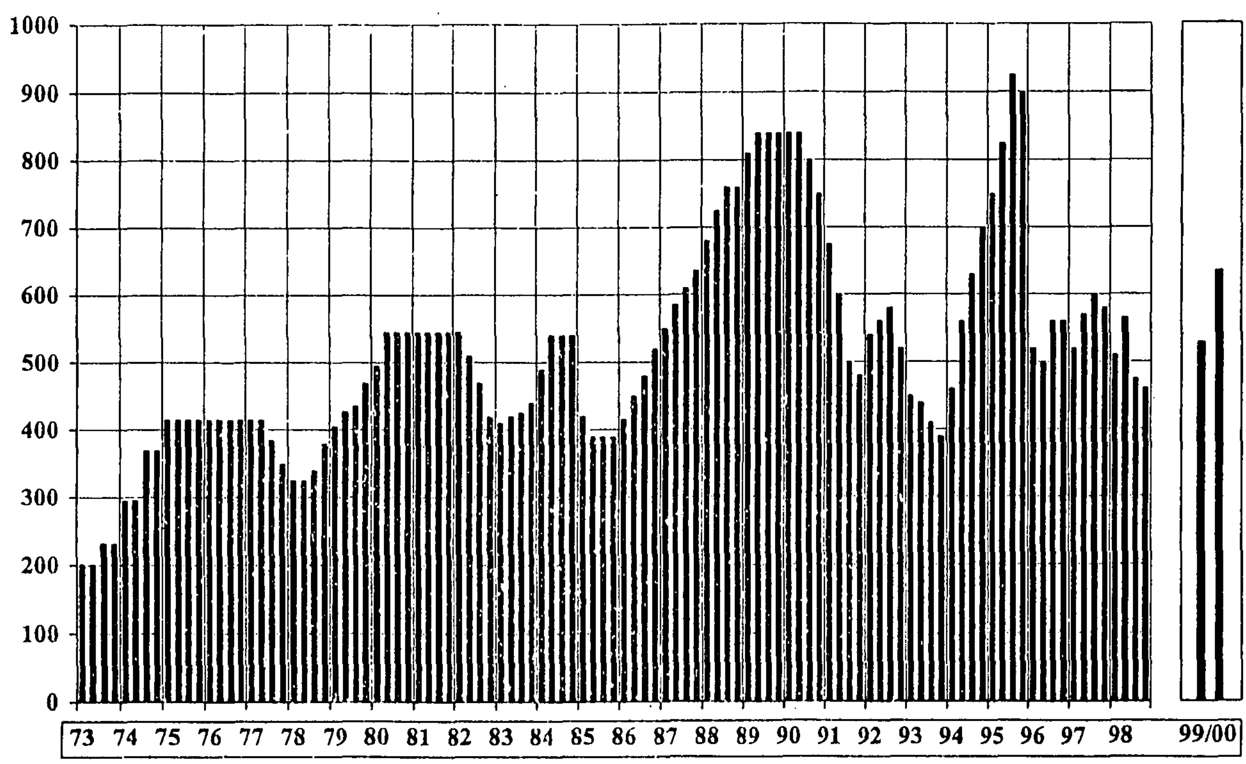
usdr per ADMT – US domestic



current prices — *top line* constant 1999 dollars — *bottom line* long term base line — *dotted line*

figure 8.3 *quarterly current price of NBSK from 1973 to 1999, cif northern Europe*

usdr per ADMT – cif northern Europe - current prices



The long term price trend for NBSK in the US has decreased from 700 dollars to 625 dollars (dotted line). The long term base line was 625 dollars just two years ago. The last two years, the price line has continued to decrease, despite various mill closures as a result of the market downturn in 1998. In theory, capacity reduction should support the long term upward movement in price, but this has not been the case.
The trend line is expected to touch 580 dollars in the current decade. Incidentally, the recent price fluctuations (1998 to 2001) will accelerate the long term price adjustment downwards. The long term descent is the result of a combination of longer term factors : scale economies, the mature technology, the gradual shift in fiber use (cf *chapter 5*).

The actual prices of NBSK by quarter since 1973 are illustrated in *figure 8.3*. This shows that the price of NBSK fluctuates widely, falling as low as 400 usdr per ton and rising as high as 1000 usdr per ton for short periods. The short term fluctuations are cause by pulp inventories. The fluctuations in price present an additional risk for greenfield mills, unless they can operate at lowest cost. A significant observation from the graphs is that price volatility has increased dramatically in recent years.

⌘ Most grades of pulp were over-supplied in 1998 and 1999, when the NBSK spot price had fallen to a low of around 460 usdr for some months. The price came back to 520 dollars in the second quarter of 1999, and slowly recovered to the more normal level of 625/650 dollars by the end of that year. Since then, the market rebounded even further, with the mid-year price around 700 dollars, where market resistance was met. The situation deteriorated again in the first half of 2001, as the benchmark NBSK price again fell to 460 dollars.

Conclusions :
The long term price trend is in a long term descent, reflecting scale economies, technological change and market saturation.
The short term movements do not affect the long term price trend. However, the short term fluctuations are important signs, signaling increased investment risk. The extent of risk should be considered in the feasibility profile of a greenfield project. Refer to *chapter 10*.

8.10 will long fiber cellulose be in short supply in the future ?

We are interested whether the supply of softwood cellulose for reinforcement purpose is reasonably assured in the future. The question has two aspects : will the conifer forest reserves be able to supply sufficient pulpwood, and will there be adequate additional capacity in pulp. In other words : is a shortage in these pulps in the future likely ?

We have seen that the slow growing coniferous species (spruce, fir, pine) of the cold northern hemisphere are the best raw material for reinforcement pulp. We have also seen that greenfield mills in nordic climates require vast tracts of forests. The accessible forests are fully exploited, and will not support additional greenfield mills, although they are able to support expansions at existing mills. It is difficult to identify equally good investment opportunities in the traditional pulp producing countries.

The industry has been getting accustomed to using other softwood pulps, which it has found in the southern states of the US and overseas, in Chile, South Africa and New Zealand. The information in *figures 8.4* and *8.5*, which we used to profile the industry in *paragraph 8.8*, is equally useful to compare greenfield opportunities. It allows us to compare the cost factors of alternative pulp (such as sisal) with established industries.

8.11 *future long fiber pulp supply - where ?*

The world paper production will increase by 107 million tons in ten years' time, but the additional volume of long fiber pulp for papermaking is only 12.6 million tons (*table 8.1*). This includes 4.7 million tons of integrated pulp and 7.9 million tons of market pulp, two thirds of which is bleached cellulose. The additional reinforcement pulp is 5.4 million tons.

The additional volume of market pulp can be generated by a combination of two approaches, expansion in existing mills and greenfield mills.

table 8.1 growth of long fiber pulp requirements between the years 2000 and 2010

million tons annually	*2000*	*additional pulp volume required*	*2010*
total fiber balance, long fiber pulp	74.53	12.61	87.14
bleached	38.51	5.76	44.27
kraft	36.02	6.85	42.87
integrated pulp			
bleached	19.95	0.21	20.16
kraft	33.10	4.46	37.56
market pulp			
bleached	18.56	5.55	24.11
kraft	2.92	2.39	5.31

Existing mills will debottleneck and can add around 1 pct each year. The volume is about 5 million tons of market and integrated bleached long fiber pulp in ten years.
New bleached long fiber pulp mills in Chile, Russia, the Baltic States, Germany and China should account for the rest. A number of possible projects are in planning (*table 8.2*) ; there is sufficient lead time to meet the market. Feasibility studies are at various stages of completion in all these areas. New plantations in Chile will mature in the decade and the softwood forest reserves in eastern Germany and the Baltic states are available inmediately.

The supply side could be restricted by closures of existing bleached pulp mills, especially in North America. This was a very real possibility three years ago, when very challenging effluent limitations were proposed by the US government. The proposed limits were increased which largely removed the threat of widespread mill closures. In the last two years, several Canadian bleached pulp mills were suffering financially. There have been several ownership changes but no substantial loss of productive capacity.
Whereas North America and Scandinavia are now the major suppliers of bleached long fiber pulp for reinforcement, they will decline in importance, because integration or acquisition of paper mills will diminish the available volume of market pulp. New supplies are likely to come from Russia, eastern Germany, the Baltic States and Chile. The preferences for reinforcement pulp will change, as the new pulps have properties that do not quite match the present NBSK.

The principal constraint concerning new capacity is not wood availability, but the capital, necessary for the investment. None of these projects has the necessary finance in place. Lenders have become extremely cautious about investing in pulp capacity after dismal financial returns during most of the 1990 decade. Nonetheless, history learns that, if shortages of pulp are in prospect, prices increase to encourage investment.

In any case, new capacity will be constructed along the principle of least cost first. In this respect, it is recalled that production cost economies are available from two approaches : capacity addition to existing mills or greenfield mills. In both cases, scale economies are an important decision element.

In concluding, we believe that no long term world shortage of reinforcing pulp should be assumed in the next fifteen years. The world supply of reinforcement and long fiber pulp is balanced. Regional dislocations in supply may occasionally occur and are difficult to predict.

History has shown that supply usually leads demand by two to three years, keeping prices depressed into the future. Any sisal pulp project for reinforcement pulp for the world market will need to be measured against other pulp producers and will be confronted with the risk of price variations.

table 8.2 announced greenfield capacities in long fiber cellulose [1]

[1]	Zellstoff Stendal, Germany (500,000 ADMTPY)	final permits have been received and much of the financing is in place - needs an industrial partner
[2]	Wittenberge, Germany (550,000 ADMTPY)	preliminary planning permission has been received - needs an industrial partner - Södra Cell of Sweden and Metsäliitto of Finland review the viability of both German projects
[3]	Poronaysk, Russia (360,000 ADMTPY)	potential greenfield mill on Sakhalin Island in eastern Russia - Hansol of South Korea was involved - the project is on hold due to the Asian crisis
[4]	Lithuania (800,000 ADMTPY)	joint venture between the Lithuanian Economic Ministry and the Japan International Cooperation Agency - feasibility study started april 1999
[5]	Latvia (600,000 ADMTPY)	the Latvian State Forest Service has selected Södra Cell and Metsäliitto as strategic investors in this project - feasibility study is underway
[6]	Estonia (500,000 ADMTPY)	discussions are being held with investors - a site in N.E. Estonia has been selected
[7]	Forestal Terranova (Chile) (430,000 ADMTPY)	pine plantations are available in the region - negotiations carried out with potential partners
[8]	Arauco (Chile) (550,000 ADMTPY)	advanced project, delayed by environmental problems - wood is available in Valdivia (pine and some eucalyptus)
[9]	Pan Pacific Paper (China) (400,000 ADMTPY)	potential pine pulp mill in Jiangsu based on plantations in An Hui province

[1] *FAO listings show additional expansion and greenfield projects (many of uncertain status) in a periodic publication : projected pulp and paper mills in the world, FAO, Rome ; 1973 - 1999, annually*

8.12 conclusions

[i] the demand for market reinforcement cellulose, presently 17 million tons annually, will grow to 24 million tons in the decade

[ii] the softwood forests in the northern temperate hemisphere, as far as accessible, are being fully exploited

[iii] there are enormous softwood forest reserves, especially in Canada and Siberia, but these are presently inaccessible physically and for reasons of cost

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[ii] the softwood forests in the northern temperate hemisphere, as far as accessible, are being fully exploited

[iii] there are enormous softwood forest reserves, especially in Canada and Siberia, but these are presently inaccessible physically and for reasons of cost

[iv] apart from the existing forest plantations in subtropical zones (for example in Chile), considerable land reserves can be found where softwood species might be grown in the future at competitive cost

[v] future availability of softwood pulpwood, therefore, is restricted by price, not physical limits

[vi] the database contains 85 market pulp mills in operation where reinforcement cellulose is produced, and the major producers are in Canada, Scandinavia, United States and Chile

[vii] the increase in demand for reinforcement pulp in the 2000 to 2010 decade will be met by capacity increases in existing mills, *plus* additional capacity in east Europe and Russia, Chile and China ; further potential exists in Chile, South Africa and New Zealand

[viii] the constraint on new capacity is the necessary capital for greenfield mill investment, not the wood supply

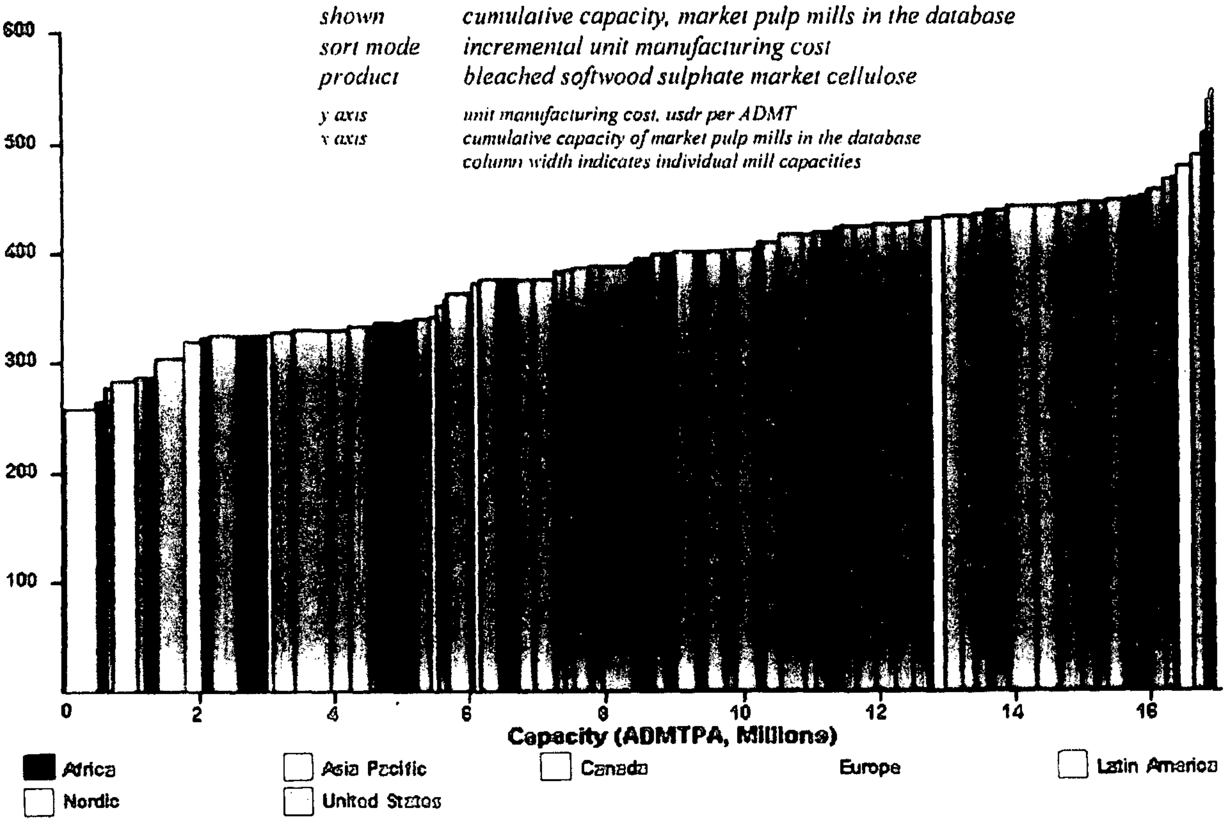
[ix] the long term price line for reinforcement pulp will reach 580 dollars in the decade, descending from 625 dollars presently and 700 dollars twenty years ago

[x] the short term fluctuations in price augment the risk especially in greenfield mills

[xi] a worldwide shortage in wood for reinforcement pulp is not expected in the intermediate term to 2015

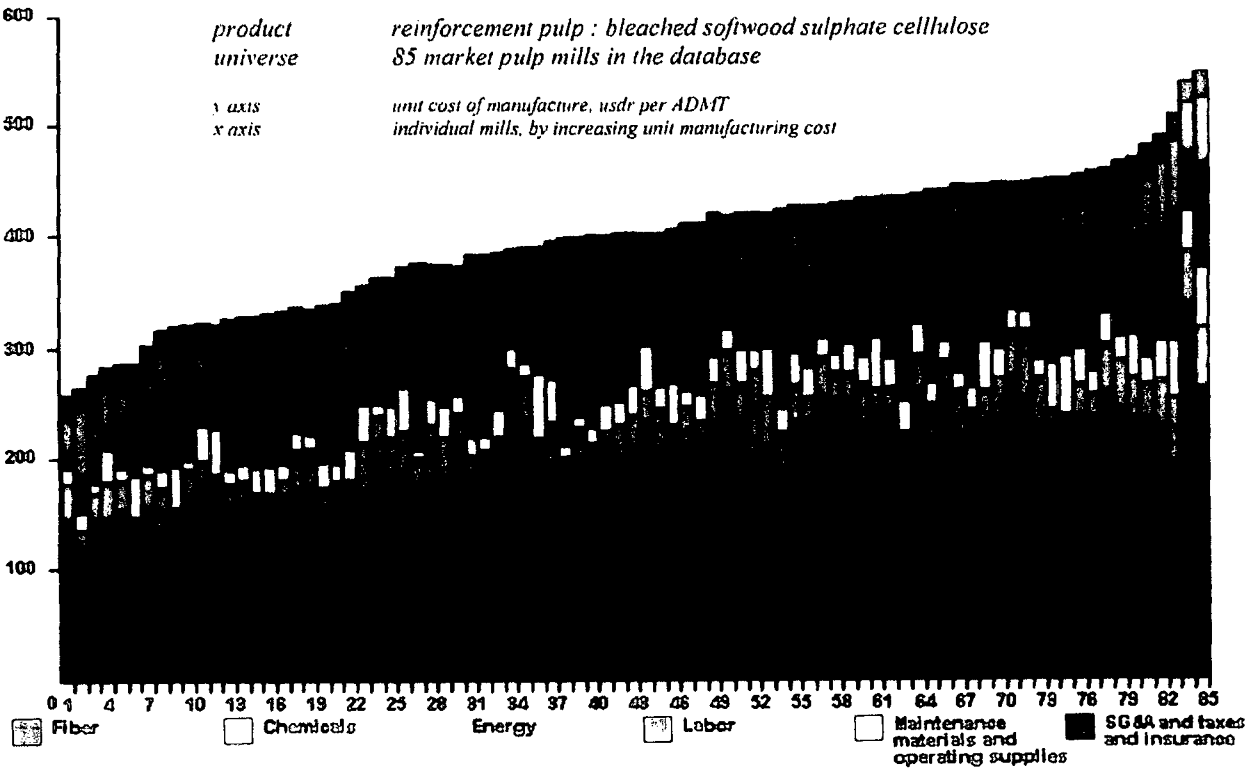
[xii] sisal pulp for reinforcement will need to compete with softwood reinforcement pulp in price and availability

figure 8.4 universe of BSK market pulp mills, differentiated by unit cost of manufacture



number of mills Africa 1 – Scandinavia 23 – Asia and Pacific 3 United States 16 – Canada 32 – Europe 4 – Latin America 6 – total 85

figure 8.5 cost profiles of BSK market pulp mills



THEME B

chapter 9 *statistical interpretation of queries on reinforcement practice*

overview	Paper mill operators were interviewed and questioned about paper production practises in relation to fiber furnish compositions. The information was evaluated by statistical means. The results are presented. The discussion focuses on reinforcement pulp.

So far, we have established the broad patterns of long fiber pulp use in the manufacture of paper. Reinforcement is practised widely for printing papers and tissue. The volumes of reinforcement pulp worldwide are considerable. The most important reinforcement grade (NBSK) is also the most expensive ; at the same time, it is also the most cost effective.

The production statistics from the past (1995 to 2000) and the projections for the current decade (2000 to 2010) have given us the volumes of reinforcement pulp, present and future. The shift in using other long fiber cellulose (radiata BKS) has also been noted. Further, we have also seen that there are considerable regional differences in the fiber furnishes for paper. Finally, the price and cost structures of reinforcement pulp have been reviewed.

The information in this (the present) chapter has been collected from interviews and queries, by a more personal approach involving paper mill executives and operators, research scientists, engineers and consultants.
The queries were focussed on reinforcement and long fiber use in paper mills, for various paper grades. Production routines as well as attitude on reinforcement were recorded. The findings have been evaluated by statistical means.
The discussion describes and determines the relationships between the use of long fiber pulps, paper grades, the extent of reinforcement, attitude and cost, and the possible replacement of softwood reinforcement cellulose by sisal pulp.

9.1 *introduction*

So far, we have established that reinforcement is widely practiced in the manufacture of printing papers and tissue, where wet web cohesion (during sheet formation) is often insufficient, caused by the fiber furnishes that need to be used. It is believed that paper recycling adds to the demand for reinforcement pulp.

The annual quantities of reinforcing pulp have been established to great detail in previous chapters (*chapters 3 to 6*) from past and current production statistics. We have found that the volume is considerable, and is increasing year by year. There are differences in the use of reinforcing pulp between regions, even between countries (*chapter 7*). Some people believe that reinforcement pulp will be in short supply in the future.

Practically all reinforcing pulp is bleached and semibleached softwood sulphate cellulose.
The preferred reinforcing grade is NBSK (Canada, Scandinavia), seconded by radiata BKS and, least attractive, BKS from southern pines. The most expensive reinforcement pulp is NBSK, and it is also the most effective (*chapter 8*).

The information, so far collected and evaluated, has confirmed the importance of reinforcement and established the volumes and price levels of reinforcement pulp. By itself, this information is insufficient to determine whether sisal pulp can replace softwood reinforcement cellulose. It is necessary to chart the attitude of paper producers concerning change in fiber furnishes for their papers. The replacement of softwood cellulose by sisal pulp poses a cost as well as a technical problem.

This, in a nutshell, is the subject of the queries and interviews, analysed in *annex report three* and discussed below.

The approach has been to explore the attitude of paper producers on reinforcement practice. The underlying issue was which role sisal might have, the reinforcing properties of sisal pulp, what price level would be acceptable in comparison to softwood pulp. Refer to *paragraph 9.3*.

9.2 paper mills throughout the world

There are 4,900 paper companies (*table 9.1*) in operation throughout the world, and approx. 10,200 paper machines are in regular production. Among these, three quarters are fourdrinier machines, and 20 pct are cilinder machines. (These figures exclude China.)

The large capacity machines are in North America and Europe. Most of these are state-of-art and fast running paper machines, and are found in Europe and North America.

The question was : since we are interested in reinforcement, where is it practised ? The reinforcement problem is best identified on fast running fourdriniers, producing low basis weight paper. It is also manifest on machines, trailing this group. These have been the primary targets of the present analysis. Reinforcement in developing countries is a separate subject.

table 9.1 number of paper mills and their capacities throughout the world

	source	*pulp mills*	*paper mills*	*paper capacity*	*population*
		number		*million tons*	*millions*
Europe	*ppi*	299	1,349	107.8	781
North America	*ppi*	237	622	113.4	303
Latin America	*ppi*	58	370	17.4	506
Japan	*ppi*	44	477	34.1	127
China	*ppi*	5,000	4,750	33.0	1,267
other Asia	*ppi*	233	1,152	40.3	2,215
Australia/New Zealand	*ppi*	17	27	3.7	23
Africa	*ppi*	28	86	3.8	751
world including China	*ppi*	5,916	8,833	353.5	5,979
world excluding China	*sasa*	916	4,903	320.5	4,712
database 30 countries	*NLK*	*5,757*	*7,805*	*313.7*	*3,752*
reinforcement queries			*paper mills*	*paper capacity*	*population*
initial selection	*sasa*		*1,600*	*162.0*	*3,82*
secondary selection	*sasa*		*1,080*	*128.0*	*3.82*
rif questionnaires	*sasa*		*917*	*116.0*	*3.76*
interviews & other info	*sasa*		*68*		

A significant feature is that the number of mills and machines is gradually declining. Between 30 and 40 machines are shut annually, and between 8 to 14 mills cease operation. Especially obsolete machines and mills are closed out.
Marginal machines are refurbished, or exchanged for new machines. The effect is that paper capacity augments each year. Measures to improve production efficiency have a similar effect. In the present economic climate, it is more effective to modernise existing machines and upgrade production. This explains the capacity expansion, taking place despite mill, closures.

⌘ On average, paper capacity has increased by 2.8 pct annually in the last ten years. It will increase by 3.3 pct in the current decade 2000 to 2010. This represents an annual addition of 10.6 million tons in paper on average. The comparable figures for virgin pulp are 3.5 million tons, and only 1.1 million tons for long fiber chemical cellulose. The balance is waste.

9.3 the query process : selection of paper mills

A selection procedure was established to focus on paper mills where reinforcement is believed to be significant. From among 5,000 possible contacts, 985 targets were questioned. The selection was accomplished in two stages, with confirmatory checks in the second stage.

The preliminary selection of paper mills was based on criteria such as mill size, machine capacities, geography, and representative paper grades. Packaging, printing and tissue mills were earmarked proportionately. Integrated mills and paper mills were earmarked in equal numbers. All together, 1,600 mills were identified, one third of all the paper mills throughout the world. Mills in China were excluded for practical reasons.

The initial universe (1,600 mills) was a fair cross section of the industry, but not representative for the reinforcement problem.
A stricter selection was necessary. This secondary selection was made by allowing preferences such as the following : printing papers and tissue, greenfield mills, fast running paper machines and the group trailing these, non-integrated and partially integrated mills.

The grade groups in the fiber furnish analysis (database, *chapter 4*) were also used to classify the mills in the sample universe, which the secondary selection produced.
In this selection, white paper mills and recycled paper mills were over-represented. Non-integrated and partially integrated paper mills were also over-represented.
Integrated white paper mills and packaging paper mills were under-represented, because their raw material base makes it less likely that they would be interested in market pulp. This was confirmed by the returns.

Presently, there were 1,080 mills identified. At this point, preview queries were conducted, which helped to establish the definite criteria for the questionnaire program. About 100 targets were eliminated, because they now appeared less relevant for our purpose.

The query efforts were divided between mail questionnaires, in certain cases followed up by interviews. The queries were conducted with mill managers and operators throughout the world. Interviews were held by telephone or in person. Information from engineering and consulting sources was also gathered. All the responses were tallied in electronic worksheets in *annex reports three* and *six*.

The strategy was to question *production management* with questions of increasing complexity. The queries were questions about production practice, paper grades, mill capacities, fiber furnish profiles, paper machine details, the use and cost of pulp. Specific questions were about the use of softwood cellulose, market and integrated. The objective was to chart the reinforcement routine of mills and find reinforcement alternatives. The questioning procedure was equally focussed on attitude for change. For a change in manufacturing practice, different furnish profiles for example, the attitude of mill managers and machine operators is crucial.

⌘ Specialty mills, 480 in total, were selected and approached separately, refer to *chapter 11*.

Summarising : from among the 1,600 targets initially identified, 917 mills were approached. Prototypes of query forms were pre-tested twice, followed by phone questioning to ensure that the procedure was understood. Separately, 68 interviews were held with people in corporate research, engineering and with consultants.

9.4 response status

Out of the 917 mills in the universe, the returns from 743 mills form the basis for the statistical evaluation in the paragraphs that follow (invalid returns were 174). Refer to *table 9.2*.

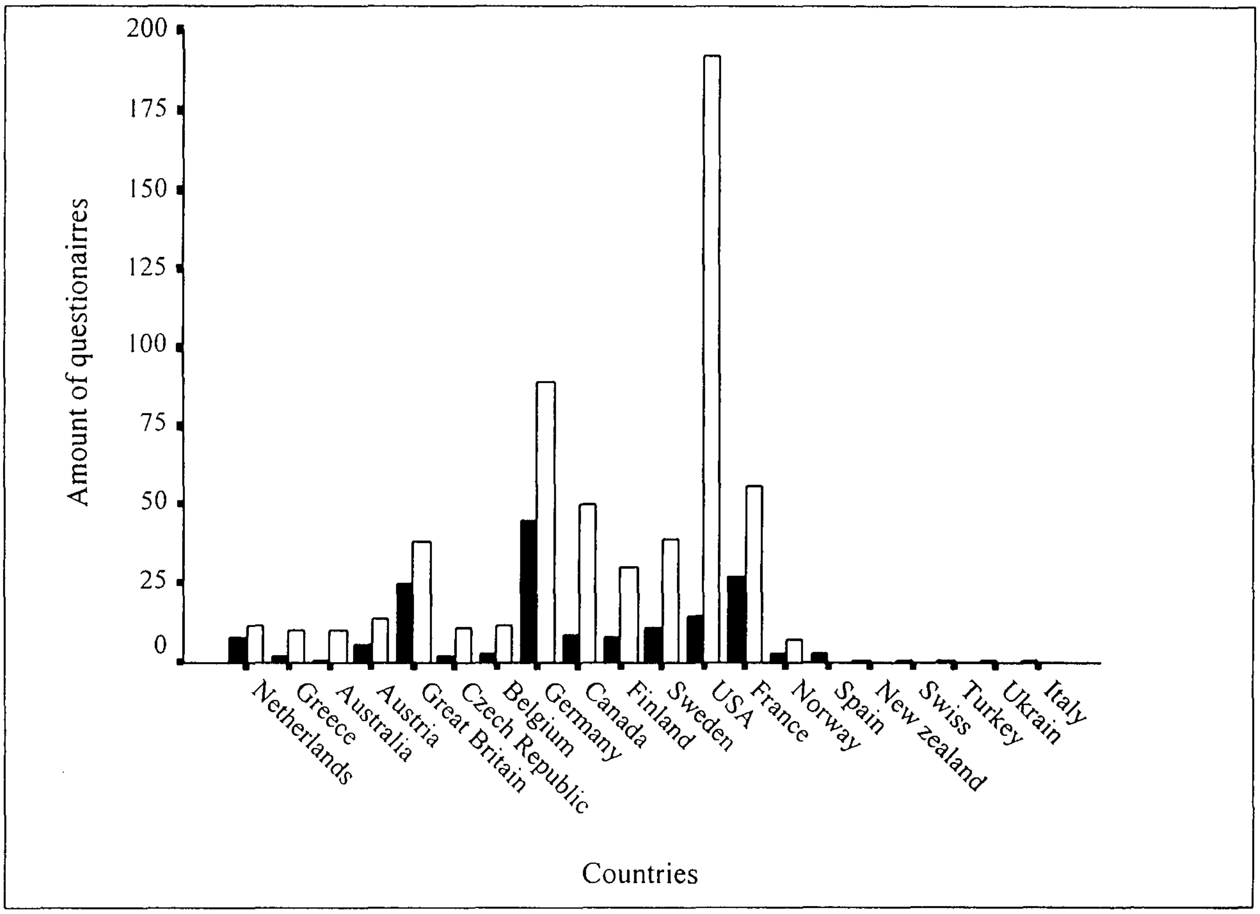
Among the 228 returns in the reinforcement sector, 178 were quantitative of which 108 were positive, and 70 were negative. The qualitative responses (50) were tallied, as far as possible. The largest numbers of returned questionnaires came from Germany, Britain and France, and only few mills in America showed interest (*figure 9.1*). The 'forest' countries Canada, Finland, Sweden provided most of the negative responses, as expected.

The universe (917 mills) reflects that certain sectors were over-represented ; this fact, of course,

table 9.2 reinforcement queries to paper mills

initial selection	*selected*	*done*				
selected targets	1,600					
paper mills	1,560					
reinforcement mills	1,080	917				
specialty mills	480	418				
corporate research, consulting	40	24				
secondary selection	*selected*	*done*	*response*			
try out	40	28	22			
reinforcement situations	1,080	917	228			
specialty situations	480					
interviews	28	20	18			
reinforcement questionnaires		*sent*	*responses*	*positive*	*negative*	*qualitative*
worldwide		917	228	108	70	50
Europe		535	171	88	61	22
North America		254	45	17	9	19
Latin America		24	0			4
Africa, Asia & Pacific		104	8	3	0	5
evaluation (this chapter)	*universe*	*valid*	*tallies*			
tallies	917	743	228	108	70	50
response rate, pct	*24.9*	*30.7*		*60.7*	*39.3*	

figure 9.1 questionnaires and responses



■ *returns* □ *questionnaires out* | *total out 917, valid 743 (81 pct), missing 174 (19 pct)* |

is mirrored in the returns. Out of the universe of 917 mills, 174 were invalid returns. In the paragraphs that follow, the responses from 743 mills will be analysed.

9.5 responses

9.5.1 response rate

The response rate was 31 pct ; this excludes invalid returns. All the answers were recorded in the tallies in *annex reports three* and *six*.

One third of the positive returns (74) were further questioned to refine their comments. The comments, together with other information from interviews, were also recorded in the tallies.

The query process proved to be more difficult than foreseen. Operators in the commodity paper mills often admitted having insufficient knowledge about sisal pulp. On the other hand, in the interviews we were often unable to answer specific questions on reinforcing behavior of sisal. Such information does not exist. Of course, data sheets on sisal cellulose were provided along with the query forms, but the information was insufficient to answer production-focussed questions on fiber blending, stock preparation, wet sheet cohesion of the furnish on the wire, runnability on paper machines. Production oriented information on sisal needs to be generated by research, undertaken jointly with the industry.

Recommendation : the project should initiate such research (refer to *chapter 12*).

9.5.2 subdued response

The response from commodity paper mills has been subdued. There were few surprises. On the key questions of reinforcement and replacement, the responses were conservative.

9.5.3 short term outlook

The economy began to show signs of a retreat by the end of 1997, aggravated by the Asia crisis, and continued depressed during the following year. The market for paper began to deteriorate by early 1998 and only stabilised in late 1999. Weak demand sent paper inventories up sharply, in turn affecting the demand for pulp. Prices for paper were abysmal. Those for pulp followed. Eventually, prices of eucalypt cellulose dipped below 380 dollars, and those for NBSK touched 400 dollars. There were down times in pulp mills in North America and Europe, even closures of pulp capacity in Canada, and paper machines were idled in North America and Europe. The downturn of the market added to the already unfavorable outlook for the industry, which has found it hard to attract capital for investment plans. The outlook became more positive from the middle of 2000 onwards. By the end of that year, pulp prices had recovered to 620/630 dollars ; they touched 680/700 dollars briefly but retreated to their former levels as the year 2001 went on, with an uncertain outlook for the remainder of the year.

The questioning and interviews for the market study took place in 1998 and early 1999. By hindsight, it is coincidental that these occurred in the midst of the downturn cycle. Quite often in interviews, operators demonstrated lukewarm interest, referring to the state of the industry. Considering this, the response rate of 31 pct is surprisingly high, the ratio of positive responses encouraging. In previous querying work, we invariably noticed that the inmediate outlook over-colors the reactions in interviews.

9.5.4 pulp shortage

Previously, we have seen that the demand and supply of long fiber pulp are fairly balanced and appear to remain so in the foreseeable future.
From the interviews, we have established that paper producers expect no shortage in softwood pulp. The supplies will remain balanced, even with increased use of waste and the continuing shift towards short fiber pulp use. In other words, the price differential between short and long fiber cellulose remains stable and small.
If a scarcity in softwood for pulp would develop and eucalypt pulp would remain plentiful, pulp prices should drift further apart. This is not the case. Therefore, we may assume that not physical wood scarcity but other factors drive the supposed scarcity of softwood for pulp.
Our respondents indicate clearly that a worldwide shortage of long fiber cellulose is not expected. This contrasts with the view that on some local markets, with controversial conditions, ad hoc shortages from local sources might occur at times, although these will be offset by deliveries from elsewhere.

9.5.5 comments from large mills

Operators of large machines are least inclined to consider alternatives to NBSK, something which they regard as risky. The leading commodity printing paper producers operate their machines to precise standards and say that any change in reinforcing alternatives is unaffordable. Other arguments are sharp on price, supply and the reliability of supply and pulp specifications. Respondents emphasise that pulp must be available from a reliable market source. Responses from white paper mills were particularly keen. Integrated mills will not consider a market pulp alternative in any, but this is obvious.

It has been obvious from the responses, that mill operators, with few exceptions, have little knowledge about sisal pulp characteristics. Mills are quick to conclude that sisal pulp and NBSK should have the same price, but some mills will *consider* a 10 pct premium. Apart from sheet properties, sisal pulp should have the same runnability as NBSK. A reliable supply and wide availability are other critical conditions to the success of sisal.

From the interviews, it obvious that the leading paper mills with mass commodity paper *refuse* to consider reinforcement alternatives, about which they know little and trust less.
Their reluctance is in so far justified, that sisal pulp is not a market commodity, not presently available, an unknown product, not even samples are available for testing.
Considering these arguments, a surprising number of respondents, nevertheless, confirmed their willingness and interest in laboratory testing of sisal pulp.

9.5.6 small mills more positive

In contrast to the large state-of-art mills, smaller mills were more responsive. Small mills usually operate a few machines at least, and are often more flexible.
Mills with smaller machines are likely to produce more diversified paper grades, or higher value added paper. They were found to respond more positively, and are more willing to consider alternatives. Not all these mills are in the niche or semi-specialty sectors. Indeed, most are common grade mills, often characterised by having 'dated' and updated machinery. The mills or machines have been rebuilt, renewed, reoriented or in some other way have escaped from obsolescence. Frequently, they are profitable because their investment cost is low. Of course, quite a few mill were 'saved' because they were converted to specialty grades.

Conclusion : even in this category, approaching niche operations, most respondents know little about the virtue of sisal pulp. Outside the 'true' specialty mills (*chapter 11*), few operators grasp the potential of inexpensive sisal pulp.

Recommendation : it should be made the aim of the project to initiate wider acceptance of sisal among the papermaking fraternity.

9.5.7 mills in Kenya and Tanzania

Mills in Tanzania and Kenya are nearby candidates for replacing imported long fiber pulp with sisal. These countries were not included in the world database, because their production volumes are marginal on the world scale.
From interviews, it was established that the paper producers in these countries do not foresee a role for sisal pulp in their mills. We might add that imports of long fiber pulp in both countries are erratic. The official statistics provide few clues on matters concerning production or imports. Refer to *chapter 7*.

9.5.8 quotes from interviews

- *'supposedly superior properties'*
- *'any replacement pulp should have properties, comparable to NBSK'*
- *'should have the same price as NBSK'* ✱ *'widely available'*
- *'purchase from reliable source'* ✱ *'reinforcement pulp is traded in large volumes'*
- *'an untried and unproven fiber, about which nothing is known'* ✱ *'risky and unaffordable'*

9.6 statistical evaluation

The universe of 743 active targets was used in the statistical evaluation that follows. Note that (as mentioned previously) the universe over-represents certain sectors such as printing papers.

The respondents did not always provide all the answers to all questions ; in some cases, some answers were irrelevant. For such reasons, the statistical bases for the probes may vary.

The aspects, that were evaluated, are discussed below. They include mill and machine capacities, furnish components and paper grades, printing papers, price of reinforcement pulp, price premium for sisal pulp.

9.7 *mill capacities, machine types*

Mill sizes were classified according to capacity and paper machines. Mill size is the total capacity of all paper machines in operation. The classifications are :

[i] less than 50,000 tons annually
[ii] 50,000 to 100,000 tons
[iii] 100,000 to 200,000 tons
[iv] 200,000 to 400,000 tons
[v] more ham 400,000 tons annually

Small mills, less than 50,000 tons annually, are over-represented in the database (31 pct). Large and very large mills were under/represented, because the preview revealed that their interest was likely to be low, for technical reasons (state-of-art paper machines).

Nearly half of the mills (46 pct) that have fourdrinier paper machines produce less than 50,000 or between 50,000 and 100,000 tons annually. The other half of fourdrinier mills are fairly evenly distributed in the 100,000 to over 400,000 tons brackets. State-of-art paper mills are invariably 'one grade mills' between 200,000 and over 400,000 tons and larger.
Most mills with cilinder machines are in the higher volume brackets, because of the basis weight of paperboard.

Mills in the 50,000 to 100,000 tons range most often showed interest in sisal pulp. Another finding : most mills with interest in sisal pulp have two paper machines (38 pct).
State-of-art mills were least interested in sisal reinforcement pulp. State-of-art mills use over 60 pct of the reinforcement softwood pulp volume. Paperboard (cilinder machine) mills showed little interest in sisal pulp.

Most paper is produced on fourdrinier paper machines, especially the low and medium basis weight papers (including printing papers). About 80 pct of paper machines are fourdriniers. Cilinder machines are found less frequently, about 15 pct of the machines counted. Most of the world's paper of higher basis weight is produced on multi-cilinder machines ; for example packaging grades, but also printing board. Naturally, their production share in total paper is much higher than their machine count, over 35 pct.
Paperboard output from cilinder machines should not be confused with those specialty papers of lower basis weight, which are produced on single cilinder machines. Typically also is that tissue is manufactured *either* on fourdrinier wire machines *or* on single vat (cilinder) machines, although the former accounting for most of the world's tissue output.

The question was to identify the mills that might be interested in sisal pulp for reinforcement. A surprising 88 percent of mills, operating fourdrinier machines, expressed interest, notably among the small and medium size mills.
On the other hand, only 7 pct of mills, operating cilinder machines, and 5 pct of mills, operating both machine types, were interested. This is easily understood because cilinder machines operate at slower speeds, so that wet sheet cohesion is much easier maintained.

A note of caution : these results characterise the way the mills were sampled, they are not typical for the industry as a whole.

Conclusions :

[i] most mills with interest in sisal as a reinforcement component are small size and the majority have two paper machines in operation.
[ii] the smaller mills (less than 100,000 tons annually) with two machines (sometimes one) were most responsive
[iii] at the same time, the smaller size mills are the best targets for sisal try-out

9.8 mill capacity and paper machines

The mills in the database have various characteristics, like size, number and type of paper machines and types of paper grade produced.

Mills were classified according to size : total machine capacity in each location. As explained above, small mills are over-represented in the database (31 pct) ; sizes of less than 50,000 tons annually. Most mills with interest have two paper machines (38 pct). So, most mills with interest in sisal as a reinforcement component are small size and have two paper machines in operation.
Among these positive respondents, 88 pct operate fourdrinier machines, whereas only 7 pct have cilinder machines and 5 pct have both. Nearly half of the responding mills (46 pct) with fourdrinier paper machines produce less than 50,000 or between 50,000 and 100,000 tons annually. This is not a characteristic cross-section of the industry, but of the sample.

Conclusion : smaller mills (less than 100,000 tons annually) with two machines (sometimes one) were most responsive and at the same time are the best targets for experimental try-out of sisal in papermaking.

9.9 printing paper and production size

The majority of mills in the sample produce mostly printing paper ; some produce packaging . (*figure 9.2*). Mean annual capacity for the two paper grades is shown for all mills in the database, as a function of total paper output annually. In particular if mills produce more than 400,000 tons paper annually and their production is divided between printing and packaging, their capacity is higher for printing paper. State-of-art mills most often produce one type of paper, in the 200,000 to 400,000 tons range. Tissue and specialty paper grades are produced in such small quantities that the relation between these grades could not be ascertained.

9.10 fiber furnishes and long fiber cellulose (figure 9.3)

9.10.1
Reinforcement is widely practised, especially in printing paper manufacture. The standard reinforcement pulp is NBSK, northern bleached softwood kraft. The respondents foresee no shortage of long fiber pulp.
Mills are hesitant to substitute a proven and reliable reinforcement pulp, with which they are familiar. More than 35 pct of respondents refuse to consider substitution. This means that 62 pct accept the suggestion that substitution is possible.

figure 9.2   *mill size and paper types*

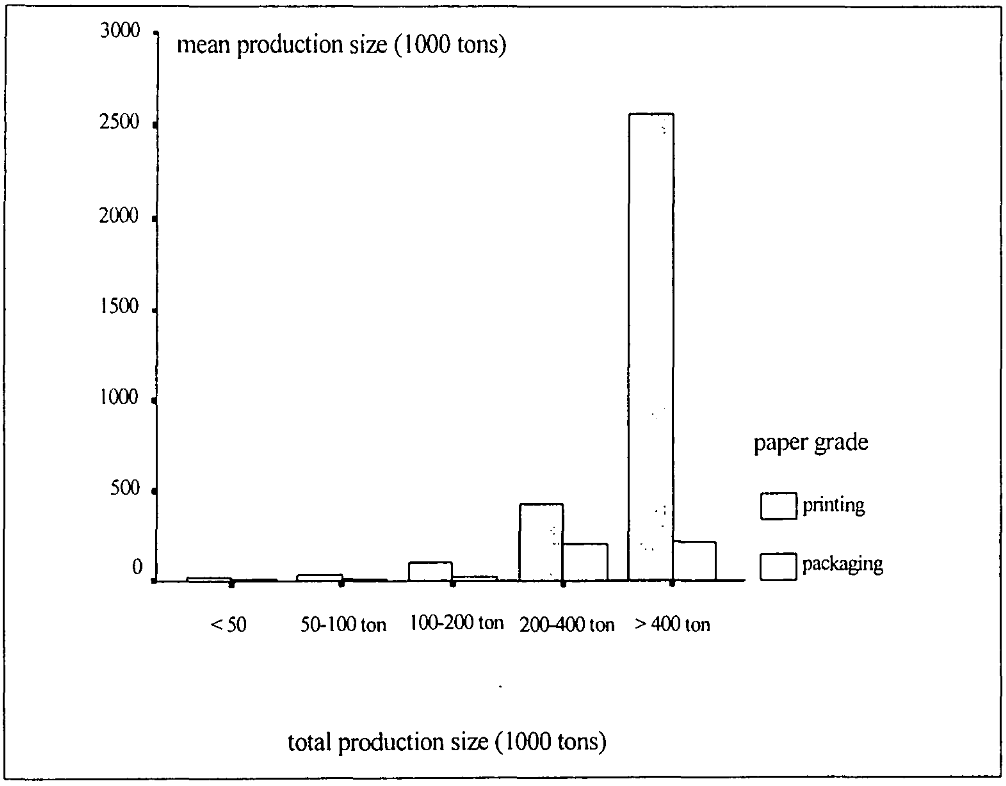


figure 9.3   *mill size and pulp provenance*

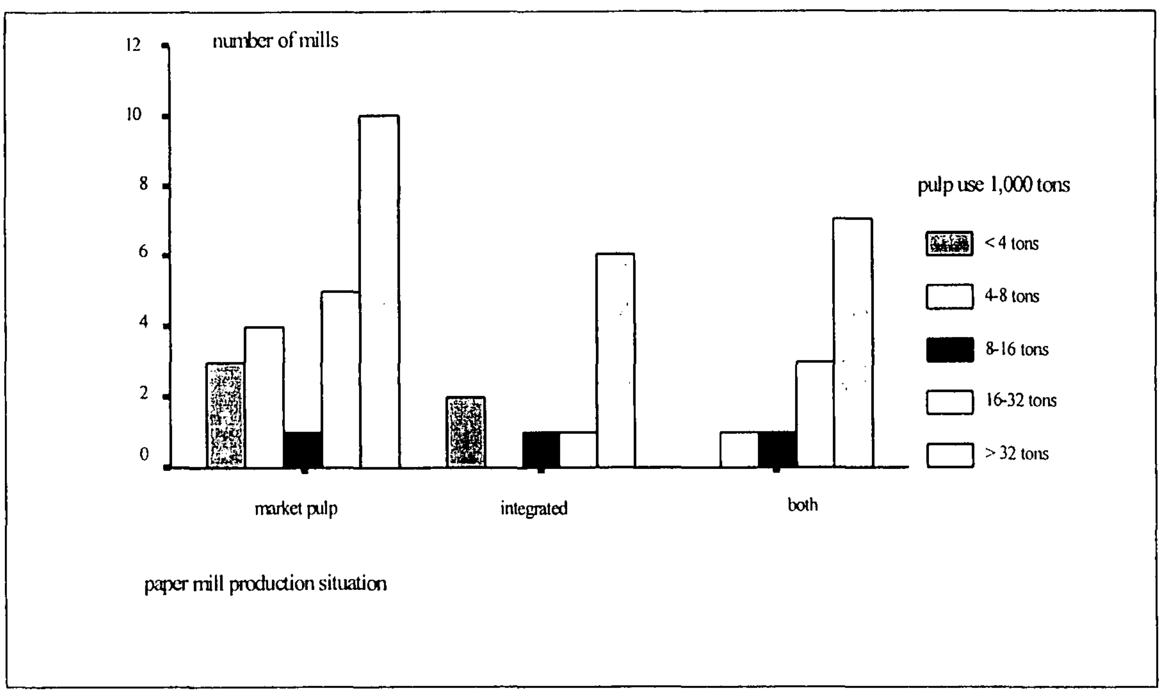


figure 9.4 *furnish sources*

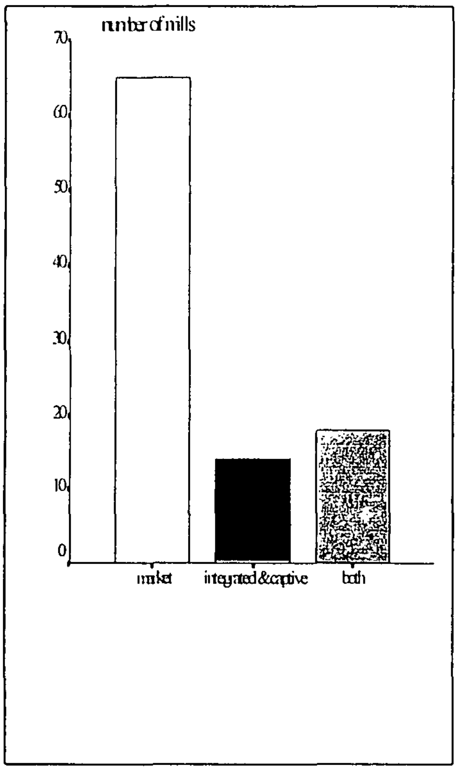
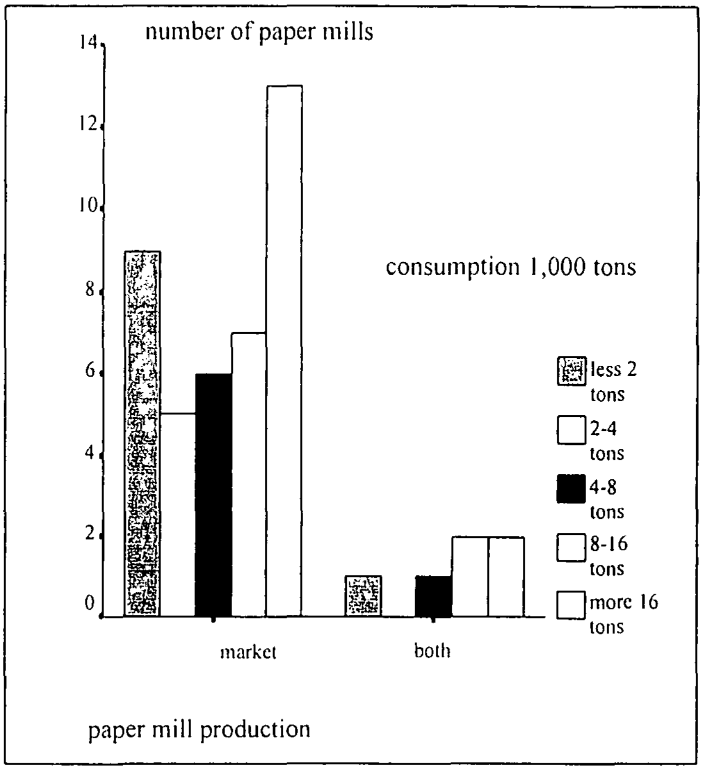


figure 9.5 *paper mill size and furnish sources*



It has been of course impossible to establish how many of these are seriously interested in committing themselves. Many respondents have placed other conditions on their eventual acceptance, such as price and supply.
Notwithstanding, 49 mills (45 pct of respondents) have asked for fiber or pulp samples for evaluation (*paragraph 9.13* and *chapter 12*). And half of all the respondents were positive about sisal pulp in one way or other and requested technical and project progress information.

9.10.2
More than half of the interrogated paper mills purchase pulp. Only one fifth of the mills use integrated or captive pulp, and the remainder rely on both sources (*figure 9.3*).
Each possible situation (*market, captive or integrated*) has been analysed for the amount of pulp, which mills use annually. The results differ for mills in the small and large groups.

All the small paper mills rely on market pulp, partly or fully. Therefore, small mills are frequent consumers of market pulp (*figure 9.3*). Forty mills from the total of 46 mills (or 87 pct of all small mills) rely solely on market pulp (refer to *table 2* and *figure 4* in *annex report three*). Only 13 pct of mills are partially integrated, although these are in the large category classes of their group.

Large mills show more diversity. Most of the large mills consume market pulp and do so in considerable volume : 35 mills, which is 78 pct (*table 3* and *figure 5, ibidem*). Among the large mills, only 10 mills (22 pct) are fully integrated or captive. The captive mills are in North America. Few mills (12 mills or 27 pct) purchase *and* produce pulp ; if they do, mechanical pulp or short fiber cellulose are produced and reinforcement pulp purchased (12 mills or 27 pct). Usually, mills with captive and integrated pulp are state-of-art mills or belong in the category inmediately below these. They are least inclined to consider market pulp alternatives.

Of course, the largest mills in the 'large mills' group dominate the market scene. They purchase most of the market reinforcement pulp : 56 pct of mills each buy 32,000 tons or more of pulp annually. And, although 93 pct of the large mills in the 'small mills' group each buy 16,000 tons or more, their volume is only 15 pct of the market reinforcement pulp volume.
Despite this, the 'small mills' group appears more suitable because the group has more mills and mill operations are more flexible.

Mills resort to purchase, because they have no other access to pulp, or, more significantly, they need pulp of certain characteristics, pulp which they do not produce themselves. Access to market pulp is vital, especially in the white sector. This is an important observation, because it confirms that key elements of furnish components are procured in major quantities on the market. An identical conclusion was previously drawn from analysing the fiber furnish data in *annex report two* (refer to *chapter 6*). This implies that it is realistic to approach paper mills with an alternative product, for instance sisal pulp. This would be hypothetical if the industry as a whole relies on integrated pulp. Integrated mills are not amenable to purchasing pulp.

9.10.3 type of long fiber cellulose and consumption rate

For reinforcement, white paper mills use bleached or semibleached softwood cellulose. Most mills use bleached pulp.
Over half of bleached long fiber pulp is traded, less than half is integrated. If partially integrated, the missing fiber types are purchased : these are bleached cellulose.

9.10.4

Long fiber pulp types have been classified by their annual volume, in order to identify the quantities that sisal pulp might replace. The following results are shown separately for small and large mills and refer to *all* long fiber pulp, not just reinforcement pulp.
Small paper mills purchase more bleached than unbleached long fiber cellulose. A substantial number of small mills use *both* bleached and unbleached long fiber cellulose : ten mills (22 pct) do so. Large mills use predominantly *bleached* long fiber cellulose (*table 9.4*).

Because unbleached sisal pulp is easy to produce, an obvious possibility is to substitute the unbleached cellulose in mills that purchase both types of pulp. This does not valorise sisal pulp to the full extent. Bleached cellulose is a higher value added product.

Most mills, that purchase bleached long fiber cellulose, question the brightness of sisal pulp. For a limited co-furnish, this should not pose a problem, whereas paper strength and the runnability are enhanced, an important advantage which sisal pulp can contribute.

9.11 price

9.11.1 benchmark NBSK

The benchmark reinforcement pulp is NBSK. This is the grade that printing paper mills use preferentially and to which they refer for comparison. It is the most expensive pulp grade for common paper manufacture. Other reinforcing pulps (BKS) are priced at a discount to NBSK.

9.11.2

Our further analyses were focussed on price aspects. Questions concerning price were posed in various ways. An analysis was made whether mills are inclined to pay a premium for sisal pulp, the amount acceptable and the conditions for sisal pulp to be purchased at such price.
In an accompanying data sheet, information on sisal pulp was presented. The superior

9.11.8
Since mid 1999, when the market study was issued in draft form, pulp prices have rebound sharply. By the third quarter of 2000, some spot prices for NBSK had overshot the 710 dollars. This would indicate that the prospects for sisal are rather good momentarily and also that the outlook for sisal would have been better if the market study had been done in 2000.
Since then, however, the market has experienced another retreat. From mid 2000 onwards, NBSK contract prices have stabilised on the 620 to 640 dollar level. The first half of 2001 saw continuously deteriorating prices. Paper mills have taken downtime in the face of waning demand, caused by the uncertain outlook for the economies. The short term NBSK price has retreated to 480 dollars (mid 2001), with an uncertain prospect of stabilising in the 540 to 590 dollar area. A possible sisal project will face more risk from the possible downturn of pulp prices from time to time.

Conclusions :

[i] rather than looking forward to price stabilisation in the 590 dollar level (*graph 8.3*), we conclude that sharp price fluctuations in the 500 to 600 dollar range are likely to dominate in the near and intermediate future
[ii] sharp fluctuations pose additional risk to a sisal-for-reinforcement investment scheme.

9.12 geography, regional differences, price premium, volume (*figure 9.6*)

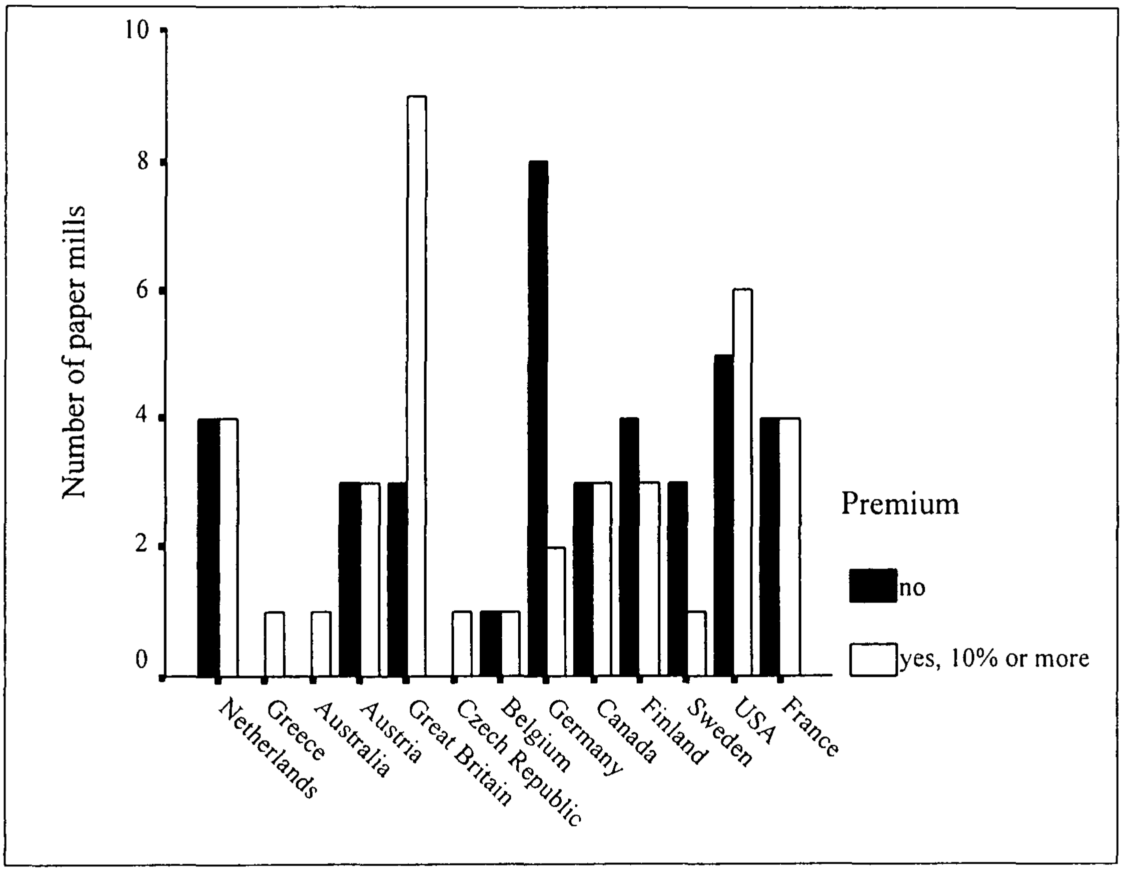
9.12.1 regional differences
Next we investigated whether regional differences exist in the views on price premium.
There might be a relationship between the geographical location of mills and their perception on price.
We found that on average, half of the mills worldwide do not accept a price premium, although a modest premium of 10 pct is acceptable to 35 pct of the mills.

More than half of the mills in Britain and the USA accept a premium of 10 pct or more, and nearly half of the mills in Canada, Netherlands, France and Finland accept the same. This coincides well with the results from the regional analysis. The pulp deficit countries are more inclined to consider a premium. Canada and Finland are anomalies.

9.12.2 mill size
Next, the consumption rates of mills in different countries were compared. Mills that accept any price premium were transferred into new database and were analysed for their annual pulp demand. The new database comprises 39 mills, which had responded to the question concerning the price premium (*tables 6-8* in *annex report three*).
Small mills (22 in the group) consume over 16,000 tons annually (32 pct, *see table 7*). For large mills, the volume is of course higher (56 pct consumes more than 32,000 tons annually, *table 8*). It should, however, be said that the number of large mills, which responded to this question and offer a 10 pct price premium or more, is not large (14 cases).

9.12.3 price premium
Nevertheless, the conclusion is that half of the mills in the worldwide sample accept *some* price premium. They have control over an appreciable volume of purchased pulp.

figure 9.6 price premium geography



In conclusion : paper mills, which accept some price premium use important quantities of market, pulp : 16,000 tons for small mills or 32,000 tons or more for large mills. These offer the most inmediate prospect for sisal reinforcement pulp in paper ; a better prospect than mills that buy less pulp.

9.13 evaluation of sisal pulp : cooperation with paper mills

9.13.1 expressions of interest

Paper mills were asked to indicate their interest in further information about the project, either for general information about sisal fiber and sisal cellulose, or about their willingness to evaluate fiber and pulp samples in their laboratories.

A surprisingly large number of mills (80) indicated to be interested in information. These range from vague expressions to commitments on sample testing.
There were 49 mills, showing interest to receive samples of fiber and pulp, for in-house testing. These numbers were more than was expected. They show a keen interest to learn about alternative fibrous raw materials. Of course, the commitment to testing carries no guarantee that paper mills will adopt sisal pulp in their paper. In any case, the willingness to share in test evaluations is a positive result from the queries.

The mills that have expressed some form of interest have been identified in *annex report six.*

Although it was too early to get firm commitments, most of the interviewed mills indicated that they would share the results from their test evaluations. As the industrial testing gets underway and testing results come forward, it is possible to explore the possibilities for further cooperative research (*next paragraph*).

The expressions of interest are presented in *table 9.4* whereas the responses from specialty paper producers are discussed in *chapter 11*.
The cumulative results indicate that 97 respondents have expressed interest in testing samples. This justifies to pursue the experimental testing of sisal samples and initiate phase two of the market study.

9.13.2
The results show that even in bad market conditions the attitude of mill operators towards sisal is positive. The response from mills about testing is encouraging.
The prospect of sisal pulp for reinforcement is positive, on the condition that price and supply expectations are met. By comparing this result with the forecast findings, we must conclude that the outlook for sisal as a reinforcement component is only positive for a limited number of mills, and only in certain countries. A further restriction is that replacement of sisal in these mills is only cost effective when the NBSK price is in its very upper range (*graph 8.2*) ; certainly not when this price is depressed. In other situations, the risk to introduce sisal is too great.

9.13.3
A separation has been made between mills, interested in sisal (mills which have indicated some interest in further information) and those, that would commit themselves to evaluate fiber or pulp samples.

All the mills with 'some interest' and those interested in samples were identified in *annex report six*. Their count is summarised in *table 9.4* (see also *chapter 12*). Among 'sample 'mills, there are 17 interested in fiber testing, including *pulp cooks* and *pulp evaluation*. Another 32 mills are interested in pulp evaluation : *pulp properties, beater runs, handsheet testing*. Therefore, there are sufficient mills in the reinforcement group, interested in laboratory testing of sisal fiber and pulp. There is no guarantee that all the mills will indeed carry out all testing and share the results.

Conclusion : mills from the 'sample' groups (49 total) should be invited for phase two of the project. Our estimate is that 12 to 18 mills would accept and share test results with the project.

table 9.4 *expressions of interest in sisal testing : reinforcement queries*

number of requests from respondents = 108				
requests		*project progress*	*info on sisal*	*data on sisal*
		83	56	32
requests for samples	*total*	*fiber*	*pulp*	*fiber and pulp*
	49	17	32	9

9.13.4
As the sisal project is proceeding and mills have pledged their cooperation, price fluctuations in NBSK may still result in more or lesser numbers of mills that will take part in the testing phase of the project. If all the expressions of interest are counted, then mill laboratory testing for reinforcement requires 650 kg of properly prepared sisal fiber *plus* 800 kg of air dry sisal pulp (for all pulp process configurations), *or* 280 kg of pulp (testing a single standard process pulp).

9.14 further development

Finally, some recommendations are offered concerning further development in sisal market research and sisal cellulose evaluation.

The query responses have shown that people in most commodity paper mills have little or no knowledge about sisal pulp. Naturally, mills hesitate to engage in something with which they are unfamiliar from the production viewpoint.

The positive responses indicate a lot of interest among the industrial fraternity to consider and probe something with which they are unfamiliar. If sisal is to find its rightful place in paper manufacture, a lot of groundwork is needed for the industry to get convinced. Laboratory research alone will not achieve this. The more effective approach is to have the potential applications of sisal cellulose probed and verified by a cooperative effort in the industry itself. There are some encouraging examples of industrial research cooperation, which the sisal project might choose to follow.
Within the worldwide paper industry, ESPPRI, the Empire State Pulp and Paper Research Institute in Syracuse (USA) is an example of industry funded cooperative research.
Another famous example is the Tun Abdul Razak Laboratory (in Britain), the former research institute of the Malaysian Rubber Producers' Research Association, where producers and processors of latex work on research and development concerning rubber.

It is suggested that the sisal project initiates and initially coordinates such activity. If this is accepted, such a program of applied research and dissemination should be initiated soonest.

A certain coordination during the evaluation phase (*task two* of the market study) is foreseen anyway. This can be used to initiate a participants' group, at little extra expense.
The dissemination workshop, scheduled at the end of the sisal project, comes too late to forge this cooperative research effort.

Unido's role would be to initiate and initially coordinate such an effort among the participants. The latter are easily identified among the respondents to the queries (refer to *annex report six*).

THEME B

chapter 10 reinforcement and the role of sisal pulp

overview	Sisal cellulose has reinforcing properties, superior to softwood cellulose. However, sisal pulp is unsatisfactory for other reasons. In fact, replacing softwood reinforcement pulp with sisal pulp is not recommendable.

In this chapter, we will review the arguments *pro and contra* the use of sisal for reinforcement and in ordinary paper.

10.1 reinforcement

Reinforcing cellulose is used in the furnish of printing paper and tissue, to achieve production economies that are otherwise unobtainable.

The paper types where reinforcement is most needed are the low basis weight grades and those with weak bonding furnishes, for example coated printing papers. A reinforcing network is necessary to hold the weak components together. The elements with poor bonding are mechanical pulp, short fiber cellulose, mineral fillers, sizing and coating additives. These largely determine the printing properties of paper, or the absorbent properties in tissue.

Reinforcement cellulose needs to have superior properties in fiber entanglement and wet sheet strength, especially on fast running paper machines, while sheet formation takes place.

10.2 reinforcement market pulp volume

The world volume of market reinforcement pulp was 17 million tons in 2000, and will rise to 24 million tons in the decade. North America and Europe take 80 pct of this, the other important parties are in Japan, Brasil, Australia and southeast Asia.

The leading pulp producers are mills in the 200,000 to 500,000 ADMTPY range. Most mills in this range have operating costs below or equal to 420 dollars per ADMT, and only one third of these are in the 100,000 to 160,000 ADMTPY range.
Only 26 mills, less than one third in the universe of market pulp mills, representing 2.1 million tons capacity, have unit manufacturing costs that surpass 420 dollars. Some of these mill will cease operation in due time, others will expand to meet future minimum criteria or convert to integrated mills.

The leading pulp producers typically have the ability to market reinforcing pulp in volumes of 200,000 ADMTPY. The leading pulp buyers purchase annual quantities of 100, 000 to 200,000 tons or more. Of course, pulp producers will service smaller buyers, but the leading pulp users set the tone.

The most important buyers are the leading producers of coated paper on both sides of the Atlantic. Other buyers of reinforcement pulp are tissue mills (North America) and printing paper mills in the afore- mentioned countries.

The pulp buyers purchase shiploads, not container loads, and they do so on a regular basis. They purchase pulp parallel with their output of paper, and prefer just in time delivery. Overshoots on either side are costly, but those on the short side are not tolerated.

In any case, for a sisal reinforcement pulp mill on the export market to be a viable partner, size is a major criterion. The provisional feasibility profiles for sisal pulp (*par 10.6*) suggest that as very large sisal pulp project, in the order of 100,000 to 200,000 ADMTPY, is confronted with cost elements that, contrary to wood pulp, are no longer in their minimal ranges. However, wood pulp mills in the 100,000 to 200,000 tons range were found to confront an uncertain outlook, as the base price line of NBSK will erode further.

10.3 relationship with reinforcing pulp producers

Pulp buyers also emphasise the importance of reliable deliveries over time. The reliability of suppliers of pulp is continuously monitored for two vital aspects : quality control *plus* constant quality, and on time deliveries.
Paper mills, which purchase pulp, maintain close and mutually confidential relationships with a limited number of pulp producers which they trust and rely on. Untried producers will be offer one time opportunities but not a continuing liaison.

10.4 potential for sisal reinforcing pulp

It is self-evidently impossible to quantify the potential for sisal pulp until the product development and paper mill trial stages are completed. A realistic idea is required about how sisal pulp performs with a wide variety of other raw materials on a commercial scale. When we know the price that will be required in order to stimulate investment on a full scale sisal pulp mill, then we will be able to assess the potential demand for sisal pulp in each major world region.
However, even at this early stage, it is possible to draw some qualitative conclusions from this preliminary analysis :

[i] there is a growing demand for reinforcing fibers in most regions of the world

[ii] there is a limited future potential to increase the supply of traditional reinforcing fibers, particularly NBSK, from the nordic countries and Canada

[iii] more NBSK will become available from new mills in Germany and the Baltic states, and from refurbished mills in Russia

[iv] this means that purchasers of reinforcing pulp will be gearing themselves up to test new sources and establish relationships with new suppliers, while their traditional suppliers are merged into bigger groups or closed down or getting integrated
a positive atmosphere into which to introduce an innovation such as sisal pulp

[v] competitiveness is the key to survival for all paper mills and, in spite of their conservative attitude, they will investigate any realistic way of achieving competitive advantage

[vi] the accepted way to introduce a new grade of pulp is first to offer a price advantage and then to demonstrate its real value
eucalyptus pulp was for years regarded as a cheap alternative to Scandinavian birch, but is now recognised as the hardwood market leader
Chilean radiata pine was similarly regarded as an alternative to US southern pine, but is now a real challenge to NBSK

[vii] it will be difficult to promote sisal pulp at a price, substantially higher than NBSK, and only if it is can be shown to perform better, a higher price will be attainable in time
this comment applies to sisal pulp as reinforcing fiber in bulk paper, not specialty paper

[viii] by the time a commercial sisal pulp mill can be started up, the average price of NBSK will probably be around $600 and oscillate between $400 and $800

if sisal pulp is offered to the market at the same price as NBSK, or preferably 10 pct below, then we would expect potential users to run serious trials to evaluate it ; we see no reason why sisal pulp would not compete for a share of the reinforcing fiber market at such a price

[ix] if sisal pulp can be introduced at an average price of around $600 CIF, and provided it proves to be a better reinforcing fiber than NBSK, then we would expect the price to move up to reflect its advantages

[x] any sisal pulp producer will have to be financially strong enough to live with the pulp price cycle as well as to survive with a rather low price while the pulp is evaluated on full scale paper machines

[xi] if sisal pulp can be produced in regions which lack softwood resources (large parts of Asia and South America), then distribution dynamics will work in its favor and these countries will be able to develop mechanical grades of paper which would otherwise have to be imported from North America, Japan or Europe, or made from imported reinforcing fibers.

10.5 the prospect for sisal pulp as a reinforcement component

It is significant to this project that paper producers will pay a premium price for the best reinforcing pulp, because it enables them to maximise their use of cheaper minerals and mechanical pulps and reduce the overall cost of the complete paper furnish. In principal, if an even better reinforcing pulp than NBSK becomes available in sufficient volume, it will attract a premium price over NBSK *provided* the overall furnish cost can be further reduced *and* there is no reduction in product quality or machine runnability.

Our telephone interviews and meetings with buyers of reinforcing pulps have provided important qualifications to the above statement, namely :

[i] paper furnishes are established over long periods of experimentation, research, development, and fine tuning of paper machines, and are not changed without good reasons

[ii] paper producers are notoriously conservative and resist change (*'if' it works, don't fix it'*)

[iii] the only way to evaluate a new pulp comprehensively is to introduce significant quantities into the furnish on the paper machine and to operate at full speed for long enough to reach a steady state

laboratory samples are always required in the first instance, but can only be indicative of product potential and open the way to machine trials

[iv] producers of similar grades of paper do not require the same combinations of tear and tensile in their reinforcing pulps ; their individual requirements change over time

the best reinforcing pulp is determined by the characteristics of each paper machine, other raw materials in the furnish and the stock preparation for developing the properties of the pulp immediately prior to use

[v] considerable importance is attached to long term relationships between pulp buyers and sellers and it is not easy for new suppliers to establish a market share in developed countries (less imperative in developing countries)

[vi] pulp buyers prefer to purchase similar grades of pulp from more companies and geographical locations

buyers *dislike* to deal with a single supplier of any grade of pulp, because this weakens their negotiating position in price discussions and leaves them vulnerable to supply disruptions

[vii] buyers are constantly seeking competitive advantage and will normally agree to test samples of new grades of pulp provided adequate volumes of such pulp are expected to be available in the foreseeable future

mechanical paper producers purchase tens of thousands of tons reinforcing pulp each year from each of a number of suppliers

10.6 cost of reinforcement pulp

A critical factor in reinforcement pulp is the *cost* of using it. The *cost* is a function of the *price* in relation to the efficiency of the particular pulp in reinforcing behavior.

A higher price reflects scarcity. Price pressure, on the other hand, proves that there is ample supply for paper mills to satisfy their needs.

NBSK is the most expensive mass grade papermaking pulp. The base line price of NBSK, presently 625 dollars (*figure 8.2*), will probably reach 580 dollars in the future. This seems to preclude scarcity, except for short periods or in market patches.

In *chapter 8*, we have seen that a shortage in reinforcement pulp or pulpwood is unlikely. The worldwide production of softwood pulp will, on average, follow the expansion of paper. The additional capacity in pulp will be found in the expansion of existing mills and in greenfield mills, for which the raw materials bases are in place. The gradual shift in demand, from NBSK to BKS, is inspired by cost economies, not by scarcity of pulpwood. The use of other BKS augments the reservoir of available NBSK.
In any case, NBSK has the highest price among common papermaking pulps, and this sets a cap on alternative pulps, including sisal cellulose.

As observed elsewhere, 'papermakers use some of the most expensive softwood pulp (NBSK)' in their effort to achieve production economies. NBSK is cost effective as the network in which the lower cost furnish elements are embedded.

Papermakers will replace NBSK, for instance with lower priced BKS, if this is equally cost effective - product specifications permitting. In all other instances, paper producers resist a higher price for alternative pulp. For sisal pulp to be accepted, it must meet this criterion.
The interviews and returns on the queries (*chapter 9*) have provided clues on the attitude of paper producers to consider alternative reinforcement pulp.
Broadly, the responses indicate that half of the paper mills *will not* consider a higher price for any reinforcement pulp, regardless of the effect, and that the other half *will* consider a price premium, usually 10 pct over NBSK. This sets a limit of 700 dollars on sisal reinforcement pulp, likely to go to 640 dollars in the current decade.

The price suggestions do not take account of the presumed higher reinforcing efficiency of sisal pulp. Producers have little or no knowledge about sisal cellulose, which is outside their experience.
Producers decline to accept the suggestion that sisal pulp is superior until proof is available. If the CFC/UNIDO sisal project is serious about introducing sisal pulp for reinforcement, this proof must be forthcoming. A suggestion for this was given in *paragraph 10.x*.

10.7 pilot runs with sisal reinforcement pulp

Papermaking characteristics are usually determined from laboratory beater curves and handsheet properties. In comparison to reinforcement softwood pulp, sisal cellulose samples are superior in many sheet properties, for example tear and wet cohesion.

This suggests that sisal pulp could be a superior reinforcement pulp, but this is *not* supported by evidence from production conditions. The suggested replacement ratio is 7 (sisal) to 10 (softwood cellulose), the calculated outcome from a comparison of strength properties in laboratory handsheets.
We have commented previously that this is not a valid comparison, since the true effect must be measured under the dynamic conditions of a fast running paper machine (*chapter 2*). The reinforcing efficiency cannot be measured from laboratory measurements.

Pilot runs offer a compromise solution. This requires that sisal pulp is available for a trial run. The *minimum quantity* of sisal pulp for duplicate runs on a coated paper machine of moderate size is 30 or 40 ADMT. The trial requires the cooperation of a pulp mill, where sisal pulp can be produced, and a paper mill with a suitable and stock preparation line. The minimum size of a suitable paper machine is likely to be 300 tons of paper per day. A suitable paper mill can be found among the respondents in the market survey (*annex report six*) and a suitable pulp mill can also be identified.

10.8 feasibility of sisal reinforcement pulp

The interviews and queries clearly establish that sisal market reinforcement pulp will be referenced to the NBSK benchmark price. This sets cost limitations on the manufacture of sisal reinforcement pulp.

A large greenfield sisal reinforcement pulp mill will need to have comparable operations in raw fiber supply, mill scale, infrastructure and support, financial resources. It must survive in a competitive market with well established pulp producers and meet the NBSK price profile during its entire depreciation cycle. Short term price fluctuations (*graph 8.3*) add considerable short term risk to a sisal reinforcement pulp project.

The characteristics of sisal production and processing differ from those of pulpwood. Sisal and softwood pulp have their own cost elements, some of which are not comparable. This gives both raw materials their proper feasibility profiles.

The feasible range of capacity for a sisal reinforcement pulp mill is governed by scale economies (along similar lines as in wood based mills, *chapter 2*), but also by other factors. Other production factors, such as logistics, assume a dominant role as size increases.

The new greenfield softwood pulp mills have capacities in the 400,000 to 500,000 ADMTPY, they require up to 1.5 million tons of fresh wood annually and need 1.0 to 1.4 billion dollars for investment.
In comparison to possible process economies, available with fresh sisal, this would compare to a 160 to 180,000 ADMTPY sisal pulp mill.

In tropical conditions, the logistics of sisal growing, fiber processing and fresh fiber pulping do not always converge. Large scale day-to-day field operations are not possible everywhere.
The alternative is dry fiber pulping, but fiber drying adds considerably to fiber cost. Besides, a dry sisal fiber pulp mill has different process economics from fresh fiber pulping, and requires

additional mill circuits, as in wood pulping. A dry fiber sisal pulp mill with a unit manufacturing cost to match NBSK would have to be in the 300,000 ADMTPY range, and would require 460,000 tons of dry sisal fiber delivered annually, a rotational area of 132,000 ha. This feasibility outlook changes entirely when a sisal pulp price in the 800 to 1,000 dollars range is considered, but this is outside the price range of reinforcement pulp (*chapter 11*).

The production cost elements in pulp manufacture, were sisal has a distinct advantage, are typically available in smaller size operations, not on the scale of NBSK.

10.8 scale economies in NBSK and sisal reinforcement pulp

We do not need to analyse the complete NBSK and sisal pulp feasibility profiles to identify the crucial differences between these. Briefly, these are the following :

[i] the logistics of raw fiber production, harvesting, transportation and fiber extraction, compared to wood

[ii] the heat and power economies available from wood

[iii] the established user profiles of softwood pulp, the experimental profiles of sisal pulp

ad [i] Whereas softwood and sisal crops have comparable raw fiber yields per year per hectare, the fiber densities at harvesting time differ very considerably. Fiber density is the amount of fiber per hectare. The moisture contents also differ. Moisture is the amount of water in the biomass as it is harvested and transported.
Sisal is at a disadvantage because the fiber content in the biomass is only 6 pct, compared to 80 pct in the harvested biomass of wood. The moisture content in sisal leaf is 84 pct, compared to 45 pct in fresh wood. The difference causes higher harvesting and transportation cost for sisal.

The harvest cycle for pulpable sisal fiber is 4 years (proposed), and the crop yield is 400 metric tons of biomass, containing 24 tons of equivalent oven dry fiber and 40 tons of the oven dry equivalent of organic material, of which 55 pct is fermentable.
This means that the harvesting and transportation of one hectare of sisal crop, yielding 24 tons of oven dry fiber, entails the lifting of 400 tons of biomass in which 40 tons of combustible material (as oven dry equivalent) are contained. The combustible mass is proportionally lower in calorific value.

If we take radiata wood in Chile, the harvest cycle is 24 years and the crop yield is 180 to 200 metric tons of biomass, of which 160 tons is equivalent oven dry fiber, from which 87 ADMT of pulp are produced. Even though the cost of harvesting and transportation is not fully comparable, it is evident that pulpwood has a lower delivered cost than sisal.

ad [ii] The pulp yield from softwood is 50 pct, calculated on oven dry wood, and 40 pct of the oven dry equivalent of the biomass is combustible organic material, available for heat and power.
The comparable figures for sisal are 66 to 68 pct on oven dry fiber, and 26 to 30 pct combustible material. The lower combustibles content in sisal means that exterior heat must be provided. The cost of exterior energy is largely compensated by the higher yield in pulp. The sisal route is more profitable with a higher price for sisal cellulose.

The fermentation route differs from the recovery of soluble wood solids in the wood pulp process route. Both are capital intensive, but the capital cost in wood pulping can be charged to multiple uses through heat and chemicals recovery, and the accompanying combined heat and energy cycle, customary in wood pulping.

ad [iii]
Sisal reinforcement pulp is a new and unproven product which competes with well known wood cellulose, available from established producers, leaders in the industry.

10.8 sisal pulp in developing countries

Short fiber plant species and hardwood species are the common raw materials for paper manufacture in most tropical countries. Bagasse, and sometimes bamboo, are the nearest 'long fiber' raw material, but are not always available. Coniferous forests are not compatible with the climate ; they occur in few and isolated patches, which are not exploitable (with only *two* exceptions throughout the entire tropical zone). The few tropical pine species that exist have been tried for exotic plantations but have been unsuccessful. Very few mills elaborate the waste from long fiber plant species (jute, kenaf, hemp, crotalaria, and -yes- sisal) into paper, but these are rare cases.

By consequence, paper machine capacity is under-utilised. It would be possible to improve the production efficiency of domestic paper mills if they can acquire suitable long fiber raw material at local prices. The *domestic* raw material is compatible with locally produced paper ; with imported pulp, this is often not so. This viewpoint was underlined in the interviews with overseas mill managers, notably in Asia : 'suitable technology from the project can benefit our mills for *add-on* pulp'.

Most of the populated tropical countries have dry monsoon to semi-arid climates, where certain sisal species can be grown. This possibility is not widely recognised. Of course, it depends whether fallow land is available to establish plantations on a large scale ; this is not always the case. Frequently however, that small farmers can have benefits from cash crops. In areas around paper mills, growth conditions permitting, sisal can be a cash crop. Fiber extraction techniques are available for small size leaf processing into staple fiber, suitable for pulp manufacture. The scale economies are almost flat down to fiber extraction at the village level. A scheme such as this depends on paper mills, interested in processing the fiber into pulp. The most favorable cost economics are when fiber is processed fresh and wet.

10.9 conclusions

Sisal reinforcement pulp has superior papermaking properties, and would be a desirable reinforcement component for printing paper or tissue. As a market export commodity however, sisal reinforcement pulp is not feasible for other reasons :

- [i] NBSK and BKS are well established commodity pulps and enjoy very considerable scale economies
- [ii] sisal reinforcement pulp needs to compete with NBSK pulp
- [iii] the scale economies of wood pulping are not available for sisal pulping
- [iv] the logistics of sisal growing and processing are counter-effective to large scale pulp manufacture
- [v] dry sisal fiber pulping will not enjoy the process economies of fresh sisal fiber pulping, nor those in wood pulping
- [vi] sisal reinforcement pulp will not be available in the volumes that reinforcing paper mills expect

THEME C

chapter 11 sisal pulp for specialty paper manufacture

overview	Specialty paper mills were questioned about their fibrous raw material use ; the results are presented. A plan of action is unfolded.

11.1 specialty paper mills

The distinction between ordinary and specialty paper is rather arbitrary. We will try to characterise the specialty paper mills' group by common treats and illustrate these with some examples. A broad specter of specialty papers is in *table 11.1.*

Specialty mills produce paper types of high added value in restricted quantities ; they meet a narrow demand for a specific purpose. In a wider sense, a superficial classification is the price of paper : specialties are invariable more expensive than their common counterparts.
A common characteristic is that specialty mills are always smaller in size, and have smaller paper machines, than the larger counterparts in comparable paper classes (however, the reverse is not generally true). On all other aspects, it is difficult to identify specialty papers : they exist in all categories of printing and industrial grades.

In the realm of common paper, a specialty paper is a paper that deviates in some property or use from the established largest volume grade. There are paper types, regarded as specialties, which are manufactured from mechanical pulp, even from waste. *Examples* : multiplex, bookbinder board, set up board. *Examples* : newsprint specialties, directory grade, catalogue, other groundwood content specialties ; printing multiplex board, and many others.

The 'true' specialty paper mills remain the domain where specialty nonwood pulps are most often consumed. Specialty pulps are long fiber bleached celluloses from fibrous plant species such as cotton, hemp, flax, kenaf, jute, sunn hemp, abaca, and -indeed- sisal. Each of these fibrous raw materials have their specific areas of papermaking application. *Some examples* : banknote paper, blotting paper, artist paper (*sisal pulp*), laboratory filtration paper, other porous paper (*sisal pulp*), cigarette tissue, condenser tissue, transformer board, gasket paper.

The more mundane specialty papers are increasingly made *with*, even *from* wood cellulose. The

table 11.1 overview of some specialty papers

printing grades	*office grades*	*tissue*	*convenience paper*	*nonwovens, porous paper*	*packaging*	*industrial paper*
bible *air newsprint* *colored paper* *photographic* *artist* *drawing* *ledger* *set up*	*airmail* *onion skin* *inkjet*	*industrial* *optical* *septic* *wipes* *dissolve* *food* *edible* *battery sep*	*banknote* *authenticated* *watermark* *document* *erasable* *security paper* *fraud proof* *ticket*	*medical* *filtration* *filter paper* *porous board*	*fruit wrap* *aluminised* *antistatic* *rust* *prevention* *lubricated* *water* *repellant*	*cigarette* *condenser* *conductive* *transformer* *gypsum* *board* *abrasive* *bookbinder* *cartridge* *laminating* *extensible* *tape base*

use of nonwood specialty pulp is being limited for cost reason. Examples are specialty papers made with wood pulp : automotive filter paper, cigarette paper, coffee filter, rope paper, cartridge, ledger, office stationary.

Most frequently, we see that the share of wood pulp has encroached on the nonwood pulp furnish. This is due to the unflagging pressure on price ; and facilitated by the over-engineered character of many papers. Mills in the true specialties' paper group have succeeded in resisting such pressure. *One example* : banknote paper continues to be made from cotton, even as cotton waste is largely being replaced by cotton linter.

Conclusions : the group of specialty paper mills is not sharply defined ; the criteria are diffuse, the classification is arbitrary. When the mills were selected, their possible use of sisal pulp was taken into account.

11.2 specialty pulp

The specialty nonwood pulps are manufactured from the long fiber plant species or plant residues that were mentioned previously : cotton waste and cotton linters ; hemp, flax and kenaf ; sunn hemp, ramie ; abaca and sisal.

Specialty cellulose as a market pulp is manufactured by dedicated pulp mills. Cotton linter pulp is a commercially available market cellulose, by far the most important grade in volume. North America is the leading producer. World linter cellulose capacity is in excess of 400,000 tons annually. Whereas cotton linter cellulose is a volume commodity, cotton textile waste (*filter, clippings*) is a true specialty and -in most cases- elaborated by the banknote mills themselves.

All the other fibers are processed in mills of smaller capacity, either dedicated mills or -in specific cases- integrated mills. Hemp, flax and kenaf pulps are available from market pulp mills, specialised in processing nonwood fibers.

Abaca and sisal pulps are processed in small, specialty pulp mills in the on the market in comparable small volumes, are produced in dedicated specialty pulp mills but also in some of the specialty paper mills where these fibers are used.
All the other nonwood pulps can be ordered from specialty pulp mills, of which few remain that sell on the world scale. They will elaborate flax, hemp, kenaf, sisal and abaca. In India and China, some paper mills operate successfully on a furnish with nonwood fiber waste, jute cuttings for example, and produce their own pulp, but these are common type paper mills.

The important consumers of long fiber specialty pulps (flax, hemp, abaca, sisal) are the specialty paper mills in Europe, North America and Japan that produce highly specialised paper such as tea bag, filter, cigarette, tissue and nonwoven specialties. Many of these purchase raw fiber and produce their own pulp, the remaining mills maintain liaison with dedicated specialty pulp producers.

Abaca and sisal pulps are broadly comparable as long fiber pulps, often complementary, sometimes interchangeable. Both have elevated prices and are low volume pulps. Both are used for specific applications. Sisal pulp is perhaps more versatile, and more often used as co-furnish.

11.3 statistics

Pulp and paper statistics on specialty grades are unavailable from national accounts, and their published information is not relevant for our purpose. The published statistical data (*faostat,*

eurostat, afpa, jppa) have no references to specialty subgroups or the paper specialty group. The *faostat* data carry fair detail on nonwood cellulose, but are not differentiated ; they show nothing on specialty paper. The leading specialty producers have considerable information, which is kept confidential. It is fairly uncomplicated to collect meaningful data from user sources, although much time is required to do so.
Statistics on the furnish of specialty paper are similarly unavailable, and difficult to ascertain. Refer to *paragraph 11.6*.

11.4 specialty long fiber pulps

The export and import volumes of abaca and sisal fiber are found in the trade statistics. The volumes of pulp can be estimated from trade data. Certain paper mills in Europe, North America and Japan use these in *very limited volume* in their papermaking.
The annual consumption of sisal pulp is 14,000 tons ; equivalent to 25,000 tons sisal fiber. About half of this volume is integrated pulp. The remainder is purchased from dedicated pulp mills, which will process various specialty fiber types to clients' specifications.
The market price of sisal pulp is in the range of 1,400 to 2,800 dollars. Naturally, the *cost* of producing sisal pulp in *integrated mills* is less. The major expense is for fiber. Integrated paper mills use UG grade and tow for their pulp.

11.5 fiber furnish

Paper mills continuously try different furnish formulas, in their effort to improve product quality, meet client standards and decrease cost of manufacture. While most grades have specific formulas, gradual change is possible in some cases, if some improvement can be found. The research, referred to in *paragraph 9.9*, should consider whether to cooperate with mills that are interested in furthering the cause of specialty paper.

11.6 specialty paper database

Just as has been done for reinforcing pulp, a database on specialty paper production and fiber furnish will be set up by assembling the relevant information from paper mills. This work (not part of the current market study) is expected to be finalised in two years' time.
The database will store information on 128 specialty paper mills in the same countries as before (*paragraph 2.2*). It will endeavor to identify the fiber balance in various specialty papers and produce estimates on the specialty pulp volumes by regions and the world.

11.7 the query process : specialty paper

For the present study, it was necessary to collect information from specialty paper mills on their use of specialty pulps and their attitude concerning sisal pulp. A universe of small scale and specialty paper mills was established by screening the worldwide paper mill database for multiple criteria including product palette, pulp use, mill and machine size.

The paper mill database showed 718 entries for nonwood based mills.These were matched against a provisional selection of mills with the above criteria.
The first selection produced a list of 480 mills, far more than the number of 'true' specialty paper mills. The second screening delivered 418 mills. These were accepted for questioning.

The mills were selected in the following categories :

[iv] sharing technical and market research results with interested specialty pulp and paper mills

[v] identify a universe of paper mills, interested in sharing and funding further development in research on fiber and pulp properties

[vi] prepare the feasibility analyses on pulping, sisal fiber and -pulp markets and produce the bankable documents for a project on sisal fiber processing

appendices

apex 1 glossary and abbreviations

glossary

paper	*indicates paper and paperboard, unless specified otherwise*
pulp	*indicates cellulose and pulp for papermaking, unless specified*

abbreviations

cb	*cross & bevan cellulose*
csf	*canadian standard freeness*
iso	*international standards organisation*
lf	*long fiber*
ml	*milliliter*
n.a.	*not available, not applicable*
pct	*percent*
sf	*short fiber*
tcf	*total chlorine free bleaching*
ADMT	*air dry metric tons, 10 pct moisture, for pulp, by definition*
FMT	*finished metric tons, for paper*
GDP	*gross domestic product*
IRR	*internal rate of return*
OD	*oven dry*
PA, PY	*per year*
AFPA	*American forest & paper association*
afpa	*id*
CEPI	*European paper federation*
cepi	*id*
faostat	*FAO statistics database*
ppi	*Pulp & paper international statistics*
tappi	*Technical association of the pulp and paper industry*

apex 2 annex reports one through six to this market report

the annex material has been issued in six separate reports

annex report one
Gill Clarke & Richard A Cockram
Bleached paper and paperboard furnishes 1995 to 2010 in worldwide paper manufacture, user manual
ver 1.3 march 1999
NLK Consultants, Vancouver & *sevenhuijsen associates, driebergen, netherlands 1999*

annex report two
Richard A Cockram, Michel R Lauer & Erik J van den Ent
Fiber furnishes and fiber balance in paper manufacture 1995 to 2010
ver 2.1 apr 99
NLK Consultants, Vancouver & *sevenhuijsen associates, driebergen, netherlands 1999*

annex report three
Michel R Lauer
Statistical interpretation of responses to questionnaires on paper mills and reinforcement pulp
ver 2.2 apr 99
sevenhuijsen associates, driebergen, netherlands 1999

annex report four
Richard A Cockram
Punya B Chaudhuri & Erik J van den Ent, editors
Reinforcement pulp in paper manufacture, the role of reinforcing pulps in world paper furnishes
ver 2.1 apr 99
NLK Consultants, Vancouver & PB Systems Norrkoping
sevenhuijsen associates, driebergen, netherlands 1999

annex report five
Erik J van den Ent, editor
with contributions from
Joseph E Atchison, Punya B Chaudhuri, Richard Cockram, Mich E Lauer, Erik J van den Ent
Sisal cellulose for specialty paper manufacture,
the use of sisal cellulose in niche and specialty paper mills
review report on mill queries, status jul 99
ver 2.3 july 99
sevenhuijsen associates, driebergen, netherlands, 1999

annex report six
Erik J van den Ent & Mich E Lauer
Response tallies from paper mills, identification of paper mills,
questionnaires about reinforcement and specialty papermaking
ver 1.1 apr 99 - ver 2.2 may 2001
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sevenhuijsen associates, driebergen, netherlands 1999-2001