Ministry of Agriculture Fisheries and Food
Agri – Industrial Materials

Research & Development Report

THE USE OF NATURAL FIBRES IN NONWOVEN STRUCTURES FOR APPLICATIONS AS AUTOMOTIVE COMPONENT SUBSTRATES

February 2000
Reference NF0309

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APPENDICES

THE USE OF NATURAL FIBRES IN NONWOVEN STRUCTURES FOR APPLICATIONS AS AUTOMOTIVE COMPONENT SUBSTRATES

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1. SUMMARY

Objective

The prime objective of the study is to determine the current status of knowledge and commercial usage of natural fibres (specifically flax, hemp, jute and kenaf) in the pan-European automotive components industry, and to identify present constraints and future market opportunities.

Project Content

Section 3 comprises an analysis of the structure of the European automotive components market, its supply chain as pertinent to natural fibres, and its principal decision points.
Section 4 is a summary and analysis of published European technical literature and sources on the subject, including publicly funded research projects, papers by research institutes, universities and companies operating in the sector, and papers presented at technical conferences.
Section 5 summarises current attitudes towards the use of natural fibre composites in the automotive components industry.
Section 6 provides detailed information and analysis on the principal issues affecting natural fibres in the sector.

- Their suitability for current automotive process technology.
- The comparative physical and performance characteristics of the bast fibres.
- Current present and potential applications as automotive components.
- Essential automotive performance specifications and requirements.
- Market opportunities and constraints for natural fibres in the automotive sector.
- Estimated European market size and characteristics, and analysis of current commercial usage and supply chain in each country.
- Technical status and research priorities.

Information, estimates and opinions are provided by The Textile Consultancy on an E & OE basis, and are based upon a series of personal, fax and telephone interviews carried out during the course of the project by TTC, and its subcontractor Nova-Institute, Germany

Appendix 1 forms a comprehensive listing of companies and market contacts in the automotive sector and its supply chain.
Appendix 2 summarises published research work in the project sector.

Whilst every effort has been made to check facts and opinion, they remain the responsibility of the respondents.

2. INTRODUCTION

The use of natural fibre composites for automotive interior components is a phenomenon that has appeared and developed only during the last five years. The principal fibres now being used for this purpose belong to the bast fibre group – flax and hemp, grown in the temperate climates of Western Europe, and the sub-tropical fibres, jute and kenaf, mainly imported from the Indian subcontinent.

In view of the important potential of re-growing and sustainable industrial crops, and the suitability of flax and hemp to European agricultural production, an informed analysis of key end-use applications is essential. The analysis can be used to plan fibre production and processing, and to determine the direction of future research.

This scoping study aims to provide this information in respect of potential in the growth sector of automotive components. The overall objective is to determine the current status of knowledge and commercial use of bast fibres on a pan-European basis, and to identify current constraints and future market opportunities.

It became apparent early in the research programme that the study would be incomplete without the inclusion or expansion of two specific factors:

- The original processing technology to be considered was solely nonwoven (mainly needlepunch) technology, which is the normal production precursor to compression moulding of components. However innovations in process technology are now beginning to allow the use of natural fibre granulate composites for injection mouldings.
- Since it is apparent that Germany occupies a totally dominant market position in terms of product innovation, research, and commercial production, additional research effort has been put into detailed analysis in this geographical market.

The market structure of the components industry is examined in detail. Although the car producers (OEMs) and their principal (Tier One) components suppliers operate on a truly global basis, the upstream supply chain tends to be national (nonwoven producers) or regional (fibre producers), although a significant number of companies trade transnationally.

Research work relevant to the project has been collated from many European sources. No attempt has been made to reproduce original documents, because of bulk and language factors. Research titles, sources and content matter are summarised in Appendix 2. Some research and innovative commercial activity remains confidential and inaccessible. A number of subjects which would benefit from further research project work have been identified.

From the detailed information provided in this study, it is apparent that the market for natural fibre composites has grown from zero to a considerable industrial infrastructure during the last five to ten years. The study predicts continued growth in both existing and innovative applications and processes, with few potential constraints.

3. THE STRUCTURE OF THE AUTOMOTIVE COMPONENTS MARKET

The important elements of the automotive components industry, insofar as they are relevant to natural fibre supply, are:

- **OEMs (Original Equipment Manufacturers) –** the principal familiar car and vehicle brands.

- **Tier One Suppliers –** suppliers of specialised components for assembly by the OEMs. For the purposes of this study, interest is confined to specialists in car interior systems.

- **Substrate Suppliers –** mainly nonwoven producers in the wider textile industry, but also plastics producers in the case of the new natural fibre granulate technology.

- **Natural Fibre Suppliers –** of flax, hemp, jute, kenaf and sisal, which are the principal focus of this study.

For the most part, the links in the above supply chain are relatively compartmentalised, with very few exceptions. For example, Ford and General Motors respectively own the Tier One suppliers Visteon and Delphi Automotive Systems. A few Tier One suppliers such as Empe-Findlay and Borgers also have vertical operations which include nonwoven plant.

Similarly, few natural fibre producers have downstream processing capability. Known exceptions are HVG Hanfprodukt Nord-West at Westerstede in Germany, and a vertical plant currently under construction for Mollerplast at Kalletal in Germany.

In order to influence specification and usage of natural fibres, the suppliers must work with all parts of the supply chain.

Although the actual customers for natural fibres are the substrate/nonwoven producers, the principal innovators in automotive components are the principal global Tier One suppliers. Their research and product selection decisions will be the main determining factor in the growth of the natural fibre sector.

The supply chain is analysed below in more detail, and the principal European market contacts and research centres are shown in Appendix I.

1. OEMs (Original Equipment Manufacturers)

The automotive industry is one of the truly global industries, and it is now the case that despite US or Japanese ownership, a high proportion of product innovation is centred upon Europe. This is particularly evident in the case of interior components based on natural fibres.

Market Size – Global Automotive Production Summary 1998, total production of cars and light trucks – 52.7 million units (see Fig.1).

In fact, the market in 1996 was 55.1 million vehicles, but the crisis in Far Eastern markets is responsible for the reduction of 2.35 million units. Industry forecasts suggest that it may be 2001 before market conditions recover to previous levels.

Market Growth – At present, only about 10% of cars are produced in emerging countries, but this is forecast to change radically in the next 5–10 years. In view of the global economic slowdown, the overall market growth has been revised downwards to 4–5% up to 2005. However, growth rates in excess of 40% are forecast for Eastern Europe, South America,

India, and particularly China, whose forthcoming membership of the WTO should open the market to sophisticated consumer products.
The effect is likely to be an accelerated trend towards local manufacture, or at least local assembly. However, R & D is likely to remain centred in Europe.

Market share Fig.2 (See over page).

Other significant producers are Daewoo, who are gaining market share, and the BMW Group (including Rover), who have a reputation for innovation in natural fibres.

The Nonwoven Car (see over page)

Typical applications which are possible for natural fibre-based substrates are shown above. Various estimates have been made of the potential use of such substrates, ranging from 15 to 30kg per vehicle.

The potential global market is therefore very large indeed – for 53 million vehicles, the maximum natural fibre consumption (for 50:50 natural:synthetics) could be as high as 800,000 tonnes, in the unlikely event that every vehicle used every possible application.

- **OEMs – Market Trends**

  Consolidations and mergers – following Daimler/Chrysler, Renault/Nissan and Ford/Volvo, other mergers and acquisitions are likely, with the financially troubled Daewoo Group the next probable target. Indeed Bob Eaton, Chairman of Chrysler, believes in an eventual industry of just 8 multinationals, exploiting the economies of shared R&D and distribution costs and common model platforms.

  - Assembly will continue to locate in low wage cost countries, particularly those where the strongest market growth is forecast, as above.

  - The principal OEMs will continue to concentrate on a reducing number of Tier One suppliers – Chrysler has already cut its suppliers from 3,000 to under 1,000 in 3 years.

  - For interior systems, which are relevant to natural fibres, there is an increasing tendency to contract the entire interior to one major Tier One supplier, who will then subcontract individual items such as seats to a specialist “competitor”.

2. Automotive Tier One Suppliers

As previously noted, Tier One interior systems suppliers are critical to the widespread acceptance of natural fibres in composites and nonwoven substrates. This industry has seen an unparalleled growth rate during the second half of the last decade. It is no coincidence that many of the trends seen in the OEMs, such as globalisation, aggressive expansion by acquisition, specialisation, and establishment in emerging countries, are mirrored in the components industry.

The principal Tier One suppliers now operate wherever cars are assembled. Because of the sophisticated JIT requirements of the OEMs, plants must be located on adjacent industrial parks such as Speke (Pelzer for Ford) or Sunderland (Magna Kansei & R-Tek for Nissan). This pattern is repeated in emerging countries.

Tier One interior specialists usually have a comprehensive range of production technologies, of which the most important for natural fibres are:

- Compression Moulding (both thermoplastic and thermoset) for medium/long fibre reinforced composites, incorporating deep-draw mouldings for door panels etc. These components are generally based upon needlepunched nonwoven mats.

- Injection Moulding techniques, including co-extrusion and low pressure back-moulding are now becoming possible for short fibre reinforced granulate compounds, but commercial use and volume production is still at an early stage.

Industry opinion is that by 2005–2010, the automotive components industry will be dominated by no more than 5-6 major groups, each with a minimum turnover of at least $5 billion. Economies of scale are necessary for the high levels of plant and research investment required. A comprehensive listing of Tier One suppliers European operations is provided in Appendix I, but below is a brief summary of the current principal players.

- **Johnson Controls Inc** based in Milwaukee, is US owned, was founded in 1885, and 1998 sales were $12.6 billion.

  The company has 275 plants worldwide, with 52 in Europe alone, and specialises in auto seats, headliners, batteries and integrated interiors. Significant acquisitions in recent years include:

  1995 Roth Freres (Fr)
  1996 Prince and JDI (UK)
  1998 Becker Gp (Ger) and Fibrit (Fr)
  1999 Benecke-Kaliko (Ger)

- **Lear Corporation** based in Detroit, is US owned, was founded in 1917, and 1998 sales were $9.1 billion.

  The company has over 200 production plants and sales offices worldwide, and acquisitions in recent years include:

  1995 Automotive Industries UK
  1996 Masland Corpn and Borealis
  1997 Empetek, Dunlop-Cox, Kieper Seating (Ger) & JV with Donnelly
  1998 Pianfei and Strappazini (Italy) Delphi (seating interests)
  1999 UT, Polovat and Ovatex

- **Magna International** is a Canadian-owned company, with 1998 sales of Canadian $9.19 billion. It is active in the supply of interior and exterior moulded components, instrument panels and window and door mechanisms.

  The company employs 40,000 in about 140 plants, mainly in North America and Europe, and has also embarked on a series of acquisitions in recent years including:

  1995 Marley automotive (UK)
  1996 Douglas & Comerson (USA) Ebyl Krems (Aust)
  1997 Tricom (UK) Emfisint (Sp) Ymos (Ger)

  The company is also unusual in its ownership of nonwoven producers, Georg Naher and C H Sandler (Ger) since most Tier One suppliers outsource nonwovens.

- **Rieter Group** is based in Winterthur, and is Swiss-owned.
  Rieter has 2 divisions, Textile Machinery and Automotive, the latter accounting for nearly two thirds of group sales in 1998 of SF 2,640 million.

  The company specialises in automotive carpeting/floorpans and automotive insulation NVH materials (noise/ vibration/harshness) and integrated interior systems. Mergers and acquisitions in recent years include:

1996 Fimit (It)
1997 Ello (Brazil)
1998 Magee Carpet (USA) Erkurt (Turk) Hirotani (Malay) – the latter 2 as joint ventures.

- **Delphi Automotive Systems** is based in Troy, Michigan, and is owned by General Motors.

  Delphi sales amount to over $12 billion, with 200,000 employees in nearly 200 plants.

  The group is primarily concerned with dynamics, propulsion and electronic systems rather than moulded interiors.

- **Bertrand Faure Group** is based at Boulogne-Billancourt, France, and is 27% owned by the PSA Group of Peugeot/Citroen. It is one of the world leading manufacturers of automotive seats, with 1997 sales of nearly FF 3 billion.

Tier One Suppliers – Market Trends

- Major growth in the last 5-10 years by merger, joint venture or acquisition.

- Consolidation to specialised areas of expertise, by divesting non-core activities.

- The capability to offer complete interior module systems.

- Increasing concentration of R&D facilities in Europe.

- Increasing interest in natural fibres.

Substrate Suppliers

For the purposes of this study, substrate suppliers are considered to be primarily the European nonwoven producers who supply nonwoven mats to the Tier One suppliers for compression moulding into components.

The most common nonwoven process is the oldest and most proven technology, based on carding, web formation, crosslapping and needlepunching, with or without ancillary bonding by thermal oven or calender. This ancillary technology can produce extra strength or rigid or lightweight forms. However, although not in common use at present, it is also known that alternative nonwoven technologies can produce comparable substrates.

Hydroentanglement can produce lightweight substrates up to 150 g.s.m., and airlaying techniques can economically produce high loft mats.

Nonwoven mats for automotive use can be 100% natural fibre, for thermoset resin impregnation, or blends with synthetic fibres, for thermoplastic components. The polymers most commonly used are polypropylene or polyesters, in varying proportions depending on the required performance characteristics.

In Europe alone, there are well over 500 nonwoven producers. The industry is characterised by a diverse product range serving many industrial sectors, even in the output of an individual company. Very few producers indeed specialise only in natural fibres. The industry is predominantly based on synthetic fibres, and there is a general reluctance to process bast fibres. Even with segregated lines and sophisticated extraction systems, natural fibres are perceived as “dirty” and “contaminant”.

Appendix I contains a comprehensive listing of producers presently or potentially willing to process natural fibres.

Granulation technology for short fibre-reinforced composites (in order to produce injection mouldings) works on an entirely different market structure. The principal suppliers of granule to the industry are chemical-based multinationals such as Hoechst, BASF, Dupont, DSM, Lucky Polymers, Eastman and Amoco.

Since three of the four known natural fibre development projects in this field have still to be scaled up to commercial production, this market structure is excluded from further analysis.

Natural Fibre Suppliers

The European market structure of the supply chain for hemp and flax is well established. Owing to growing interest in these crops, which can be grown well in the temperate European climates, much effort has been put into improving processing techniques:

- in the UK by the Fibrelin and Fibreclean projects and by work at the Biocomposites Centre.
- in France and Spain by the major producers Van Robaeys Freres and CELESA.
- in Sweden by Swefibre.
- particularly in Germany where several large decortication plants have been established with funding from the EC and the German Federal States.

Fibre producers are well aware of the possibilities offered by the automotive industry and are making efforts to improve yields and fibre quality accordingly.

By contrast, the supply chain for kenaf and particularly the more abundant jute, is difficult and fragmented. The jute industry in Europe, formerly centred upon Dundee and Belgium, has all but disappeared. Jute fibre is available through a diverse network of growers, weavers, merchants and middlemen in the principal producer countries of Bangladesh and India.

Apart from the disproportionate costs of container shipment, there is an unsatisfactory lack of consistency in price quotations because of middlemen's margins, and no reliable database of suppliers.

In terms of the availability of natural fibres in the supply chain, a comparison of the temperate and sub-tropical fibres is interesting:

- European production of flax and hemp is estimated at just under 200,000 tonnes, of which two thirds is flax and one third hemp. Of this total, 62,000 tonnes is exported, mainly to China and Eastern Europe for conversion to thread and traditional woven apparel fabric. There is no other significant trade in the fibres outside Europe, except imports of about 9,000 tonnes from Lithuania and Egypt.

  European cultivation of flax and hemp has grown exponentially in recent years, because of the attractive subsidies available under the CAP scheme, from about 24,000 hectares in 1994 to about 240,000 hectares for the 1999/2000 marketing year.

  Spain alone is growing 138,000 hectares, mainly of flax, and even in the UK, the acreage given over to flax has expanded tenfold from 2,000 to 20,000 hectares.

  If adopted in its present form, the drastic reduction of subsidy now proposed under amending Council Regulation would threaten the economic viability of fibre production, and the proposals face concerted European opposition

- By contrast, world production of jute and kenaf amounted to 3.325 million tonnes in 1996/7 and 3.507 million tonnes in 1997/8, of which about 86% is jute. The principal producer nations are Bangladesh, followed at some distance by India, China, Thailand and Nepal.

  It is estimated that 10-12 million peasant farmers depend at least partially on jute. Most jute fibre is used in India, for traditional and declining woven applications as sacking, hessian and carpet secondary backing, but the industry is very interested in new nonwoven end uses for the fibre.

There has also been interest, particularly from Southern European countries like Spain, Greece, Portugal and Italy, in starting up cultivation of kenaf. It is known that US OEMs are interested in kenaf, because it can be domestically grown in Texas and Kentucky.

Indeed, Kafus Industries is now building a vertical composites plant in Indiana, in collaboration with Ford's Visteon components division.

4. EUROPEAN TECHNICAL LITERATURE

Sources of Published Information

In excess of 100 publicly funded projects and published papers have been identified. The source, the numbers per source and the Appendix to this report in which details appear are listed below:

- Manual

  Automotive plastics and Composites – Worldwide Markets and Trends to 2003 – Dick Mann/Ian Helps – Elsevier Science Ltd 1995

- Publicly Funded Project

  Showing Authority/Funding Sources, Number of Appendix Papers

  EU, 14, 11a

  EU IENICA Project – due Jan/Feb 2000

  House of Lords Science and Technology Committee, Sub-Committee on Industrial Crops Report – published Dec 1999

  Bundesministerium für Ernährung Landwirtschaft und Forsten (BML), Germany, 20, 11b

  Land (Various), Germany, 11, 11b

  Bundesamt für Landwirtschaft (BLW), Switzerland, 2, 11b

  Commond Fund for Commodities (CFC)/ International Jute Organisation (IJO), 3, 11c

- Published Papers

  Institutes/Universities/Companies

  Deutsche Bundesstiftung Umwelt (DBU), Germany, 3, 11b

  Various Institutes, Germany, 7, 11d

  Swedish Institute for Composites Various, 11e

  Institute Textile de France, 1, 11d

  OEM's, 5, 11d
  Tier One Suppliers, 4, 11d

- Conferences

  MAFF Meeting 1997, London, 2, 11f

  Techtextil Symposium 1997 and 1999, Frankfurt, Germany, 4, 11f

  INDEX '99 Congress, Geneva, Switzerland, 4, 11f

  Automotive Composites Workshop, 1998, Brands Hatch, UK, The Institute of Materials, 3, 11f

  2nd International Wood and Natural Fibre Composites Symposium 1999, Kassel, Germany, 10, 11f

  SAMPE Europe Conference 1998, Paris, 1, 11f

  Drylaid Nonwovens Conference 1998, Wakefield, 1, 11f

  Natural Fibres Performance Forum, May 1999, Copenhagen, Denmark, IENICA Conference, 13, 11g (+ 34 Poster Abstracts)

Publicly Funded Projects

- European Union

  14 relevant EU funded projects have been identified under the 2nd, 3rd and 4th Framework Programmes (FWP). Project

details under the 5th FWP will be published from January 2000.

Advanced notification of a 5th FWP project has been obtained. The project title is Eco-efficient Technology and Products Based on Natural Fibre Composites. The project is a four-year project starting 1 January 2000, and will be undertaken by a consortium, known as Ecofina. This is headed by Professor Kenny, University of Perugia and includes OEM's and Tier 1 suppliers, including Fiat and Saab.

Information on EU projects is available on the website at http://www.cordis.lu/ or from Dr Johannes Klumpers, European Commission, DGX11, Brussels.

Details of 13 of the projects have been printed from the Cordis website and 1 from the NF2000 website and they form Appendix 11a of this report.

An IENICA (Interactive European Network for Industrial Crops and their Applications) Project Report is due January/February 2000. This will cover activity in the 15 member states of the European Union.

Melvyn Askew is the co-ordinator of the IENICA Project and is located at the Central Science Laboratory, Sand Sutton, near York.

A report is due from a sub-committee of the House of Lords Science and Technology Committee early in 2000.

- German & Swiss Publicly Funded Projects

BML and Land (various) Germany are the Federal and State (various) Ministries of Agriculture in Germany.

BLW is the Swiss Ministry of Agriculture.

Copies of project reports are available by writing to the respective organisations. The reports are published in German.

Details of the projects and a summary of their contents, in English, form Appendix 11b of this report.

- CFC/IJO

Three projects have been undertaken for the International Jute Organisation (IJO), funded by the Common Fund for Commodities.

Details of these projects form Appendix 11c of this report.

Published Papers

- Institutes/Universities

Various Institutes, Germany

DBU is a German Environmental Foundation. Papers from DBU are listed in Appendix 11b, numbers 32–34.

Papers from the following German Institutes are listed in Appendix 11d, numbers 10–16:

Faserinstitut Bremen e.V (FIBRE), Bremen.

Thüringisches Institut für Textil – und Kunststoff-Forschung e.V, Rudolstadt.

Deutsche Forschungsanstalt für Luft – und Raumfart e.V (DLR), Braunschweig.

Fachhochschule Lippe, Lemgo.

Innovative Verbundwerkestoffe Realisation und Vermarktung neuer Technologien GmbH (INVENT), Braunchsweig.

Universität GH Kassell, Kassel.

Universität Hamburg, Hamburg.

Copies of the papers are available by writing to the Institutes. The papers are published in German.

Details of the papers and a summary of their contents, in English, are included in the Appendices noted above.

Swedish Institute for Composites

A listing of Technical Reports published by this Institute forms Appendix 11e of this report. Reports are available for Skr100 (approx. £7.40) each.

Institute Textile de France

A European study on automotive textiles has been produced by the French Textile Institute. The report is available, in English, for Ecu 1000 (approx £615). Contact Jean-Jaques Conroux at jjconroux@itf.fr. Details of this study are listed in Appendix 11d of this report.

- Companies

Papers from the following OEM's are listed in Appendix 11b, numbers 1-5:

Audi AG, Ingolstadt

Daimler-Chrysler AG, Stuttgart

BMW AG, München

Ford AG, Köln

Opel AG, Rüsselsheim

Papers from the following Tier 1 suppliers are listed in Appendix 11b, numbers 6–9:

Johnson Controls Interiors GmbH, Grefrath

Findlay Industries GmbH, Geretsried

Julius Haywinkel GmbH, Osnabrück

Sommer-Allibert-Lignotok GmbH, Sassenburg.

Conferences

- MAFF Meeting 1997, London

A MAFF meeting was held in February 1997 which discussed the industrial aspects of the introduction of new fibres crops into the UK.

Two papers have been identified as directly relevant and are listed in Appendix 11f of this report.

- Techtextil – Symposium

The Techtextil Symposium is held every 2 years and is organised by Messe Frankfurt, Germany. Papers are included in Volumes, under subject headings. Volumes are available for DM 86.25 (approx £28).

Four papers have been identified as relevant and are listed in Appendix 11f of this report.

- INDEX

The INDEX Congress is held every 3 years and is organised by the European Disposables and Nonwovens Association (EDANA), Brussels. Papers are included in Volumes, under subject headings. Volumes are available for Ecu65 (approx £40).

Four papers have been identified as relevant and are listed in Appendix 11f of this report.

- Automotive Composites Workshop

This workshop is held every 2 years at various venues and is organised by The Institute of Materials, London. Proceedings of the workshop are available for £44.99. The next workshop will be held in December 2000 at the Ford plant in Essex.

Three papers from the 1998 Workshop have been identified as relevant and are listed in Appendix 11f of this report.

- 2nd International Wood and Natural Fibre Composites Symposium.

  Ten papers from the 1999 forum have been identified as relevant and are listed in Appendix 11f of this report.

  A number of the papers listed here also appear in Appendix 11d.

- SAMPE Europe Conference, Paris 1998

  A conference is held by the Society for the Advancement of Materials and Process Engineering (SAMPE), alongside an Exhibition, Journe European Composites (JEC), in Paris annually. The society is based in California. The President of the conference and exhibition is Professor Kenny, University of Perugia.

  One paper has been identified of direct relevance. The details are contained in Appendix 11f of this report.

- Drylaid Nonwovens Conference 1998, Wakefield

  One paper presented at this conference has been identified of direct relevance. The details are contained in Appendix 11f of this report.

- Natural Fibres Performance Forum

  This conference was organised by Melvyn Askew as part of the IENICA Project brief. Papers were presented under the headings limitations, new design opportunities, realising the full performance potential of plant fibre products and the future/next steps.

  Details of the 13 most relevant papers are included in Appendix 11f of this report.

Other Conferences

Papers from other conferences/symposiums were examined but did not include information of direct relevance to this report.

These included:

- Nonwovens Technical Conference – Berlin ’98, Copenhagen ’99. Organised by Marketing Technology, Kalamazoo, Michigan.

- International Nonwovens Conference, Manchester. Organised by UMIST.

- World Textile Congress, Huddersfield. Organised by Huddersfield University.

- Annual Veneto Agricolura, Padua, Italy. Organised by Societa Italiana di Agronomia.

Subject Matter of Published Information

Projects and published papers have been analysed and listed below by main subject matter. Detailed references can be found in Appendices 11a–11f.

General – Europe

- EU IENICA Project

- EU-Financed Research on Non-Traditional Industrial Uses of Biological Fibres: Past Projects and Future Plans. Dr Klumpers, EC-DGXII E2 Brussels

- Institut Textile de France European Study.

General – United Kingdom

- House of Lords Science and Technology Committee, Sub-Committee on Industrial Crops Report

Flax

- EU FAIR 950195
- EU BRST965032
- EU CR175091/BRE21269
- EU CR144691/BRE21140
- EU FMB1972376
- BML Appendix 11b, Nos 1-15, 19-20
- Land Bayern Appendix 11b, Nos 21-23
- CARMEN Appendix 11b, No 24
- Land Sachsen Appendix 11b, No 25
- Land Baden-Wurttemberg Appendix 11b, No 27
- Land Schleswig-Holstein Appendix 11b, No 28
- Opel AG, Russelsheim Appendix 11d, No 5
- Findlay Industries GmbH, Geretsried Appendix 11d, No 7
- Thüringisches Institut für Textil–und Kunststoff-Forschung e. V, Rudolstadt Appendix 11d , No 11

Hemp

- EU FAIR950195
- EU FAIR950396
- EU BRST965032
- EU BRST970597
- EU CR175091/BRE21269
- EU CR144691/BRE21140
- BML Appendix 11b, No 19
- Land Nidersachsen Appendix 11b, No 29
- Land Nordrhein-Westfalen Appendix 11b, No 31
- DBU Appendix 11b, No 32
- BLW Appendix 11b, No 36
- Audi AG, Ingolstadt Appendix 11d, No I
- Ford AG, Koln Appendix 11d, No 4
- Opel AG, Russelsheim Appendix 11d, No 5
- Findlay Industries GmbH, Geretsried Appendix 11d, No 7
- FIBRE Appendix 11d, No 10
- Thüringisches Institut für Textil-und Kunststoff-Forschung e. V, Rudolstadt Appendix 11d, No 11
- Fachhochschule Lippe, Lemgo Appendix 11d, No 13
- RTM Hemp Fibre-Reinforced Composite Automotive Components G Sebe, N S Cetin, C A S Hill
- Life Cycle Studies on Hemp Fibre Reinforced Components and ABS-epoxy-resin for Automotive Parts K Wötzel, R Wirth, M Flake, Technische Universitt Braunschweig

Jute

- Jute based Composites for Packing and Automotive Applications, Dr Roger Davidson, AEA Technology Ltd, Harwell, United Kingdom.
- Development of Pilot-Line Technology, Dr Martin Snijder, ATO/DLO, Wageningen, Netherlands.
- Development and Commercialisation of Jute Based Nonwovens, Eddleston, Ellison & McNaught, the Textile Consultancy Ltd, Dalgety Bay, United Kingdom.
- Opel AG, Russelsheim Appendix 11d, No 5.

Nettle

- DBU Appendix 11b, No 33.
- Thüringisches Institut für Textil-und Kunststoff-forschung e. V, Rudolstadt Appendix 11d, No II.
- Universität Hamburg, Hamburg Appendix 11d, No 16.

Fibre Treatments/Processing

- EU FAIR950195
- EU BRST970580

- BRST965032
- BRST970597
- EU CR175091/BRE21269
- EU AGRE0050
- EU AIR3-CT94-2000
- BML Appendix 11b, Nos 6-8, 14-15, 20
- Land Bayern Appendix 11b, No 21.
- CARMEN Appendix 11b, No 24.
- Land Niedersachsen Appendix 11b, No 29.
- Optimisation of Methods of Fibre Preparation from Agricultural Raw Materials. Dr J E G van Dam, ATO-DLO, Netherlands.

Vertical Projects

- EU FAIR950195
- EU FAIR983919
- EU BRST970580
- EU BRST965032
- EU BRST970597

Bonding/Interface Characteristics

- EU FMB1972376
- EU AIR3-CT94-2000
- BML Appendix 11b, Nos 8, 11
- BLW Appendix 11b, No 35
- Universität GH Kassel, Kassel Appendix 11d, No 15.
- Transcrystallisation in Natural-Fibre-Polypropylene Composites. Mildner, Bledzki, Universität GH Kassel.
- Optimisation of the Bond Strength of Natural Fibre-Reinforced Polyurethane at the Fibre Matrix Interface Gassan, Bledzki, Universität GH Kassel.
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5. CURRENT ATTITUDES TOWARDS THE USE OF NATURAL FIBRE SUBSTRATES

The history of use of natural fibre nonwovens is relatively recent, a phenomena of this decade only, starting in 1994/5 with use of jute-based door panels in the Mercedes E class. Since then, use of natural fibre substrates has become relatively common in European cars, without having replaced the use of moulded polypropylene or resinated wood composites. These substrates still account for an estimated 60% of the available market (TTC estimate).

The main reasons influencing the steady growth of natural fibres in this sector include:

- Comparative weight reduction of 10–30% in comparable parts.
- Good mechanical and manufacturing properties.
- The possibility of forming complex components in a single machine pass.
- Relatively good impact performance, with high stability and minimal splintering.
- Occupational health advantages in assembly and handling compared to glass fibre, where airborne glass particles can cause respiratory problems.
- Moulding offcuts can be re-used unlike fibreglass.
- No emissions of toxic fumes when subject to heat.
- Good “green” credentials, as a sustainable renewable raw material resource.
- Superior environmental balance during material and energetic use.
- Recycling possibilities by incineration with energy recovery or by regrinding.
- Relative cost advantages compared to conventional constructions.

Constraining factors which are preventing the more widespread adoption of natural fibre substrates include:

- Concerns over the consistency of quality of the bast fibre supply – this is equally true for hemp, flax and jute.
- Concerns over the long term availability of fibre.
- Persistent technical problems, mostly connected with either fibre quality from batch to batch, or grouped as emission problems (fogging and odour).

The above positive and negative factors are examined in more detail in section 6 below. Certain features of the market attitudes are, however, quite apparent.

The quality German manufacturers, Mercedes (Daimler/Chrysler), BMW, and Audi/Volkswagen are considerably more pro-active in the specification of natural fibre substrates than the mass market marques. They have built up a considerable body of knowledge in this field, and accordingly, a high proportion of European research and development in this field is of German origin.

Mercedes and BMW, taken the possible technology one stage further by initiating in-house research into short fibre/polypropylene granulation processes for injection moulding applications.

Because these companies use the same group of Tier One suppliers as the mass market marques such as Ford and Opel, they recognise that the expertise which they have pioneered will filter down through Tier One. However they are quite content with the technical lead which they continue to enjoy. All BMW and Mercedes models now use natural fibres as the base for components such as door liners, boot liners and parcel shelves. These OEMs are now making more sophisticated modifications (such as blends of flax with sisal for extra strength) or looking at new possibilities such as lightweight headliner structural substrates.

There is now a strong imperative in the automotive industry to replace glass fibre reinforced substrates on grounds of expense, recyclability and workplace health considerations. Recent work with jute seems to offer a viable low cost alternative. Jute/PES substrates are under test at three leading Tier One suppliers under IJO sponsored work.

By contrast, the volume manufacturing OEMs, Ford and Opel in Germany, and Renault. Peugeot and Citroen in France, appear content to approve, rather than specify, natural fibre substrates. These substrates are developed and offered by their respective Tier One suppliers.

By the filtering down process referred to above, natural fibre nonwovens are now reaching the volume market – for instance, Opel Vectra door panels are now flax-based, although the same Astra component is still woodstock. In France, use of natural fibres is not so advanced – Renault Clio door panels and parcel shelves are made of natural fibres. Generally, France and the UK lag behind Germany in the use of natural fibres.

There is a surprising degree of either ignorance or misinformation about the use of natural fibres – between OEMs and their Tier One suppliers, and between different installations of the same Tier One company.

- For instance, the Centro Ricerche Fiat at Ordassano is aware of research on the subject, but says that no natural fibre is used in production. However, Fiat's principal supplier of door panels, Johnson Controls, state that both long and short fibre is used as reinforcement as a matter of routine, and specifically that jute/pp cofibre composites are used in the Alfa 146. The technical department at Ford Koln is similarly unaware which Ford production models are now using natural fibre nonwoven substrates.
- Equally, in the experience of the Textile Consultancy, research centres of Johnson Controls are unaware of sampling and prototype development work which has taken place at other group research centres, such as Schweighouse on jute lightweight headliner material. Some product development work at Lear Corporation, Ebersberg, is known to have been carried out in isolation. The rapid expansion of the Tier One suppliers by takeover has evidently outstripped co-ordination of research activities in some instances.

It is also evident that the Tier One suppliers lack a comprehensive knowledge of the European nonwoven industry which supplies natural fibre mats as roll goods for compression moulding. Possibly this is because there has not been a strong traditional interface between the automotive and textile industries. The Tier One centres are remarkably open to approach from new nonwoven suppliers, and equally open–minded in respect of which fibre they may consider using – flax, hemp or jute.

Of the major Tier One suppliers, the attitudes of Johnson Controls especially, and Lear Corporation are most positive towards the use of natural fibres. Johnson Controls have particular centres of research excellence at Grefrath and in Italy, and the Lear research centre at Ebersberg has strong interest in further developments – both companies are already producing volume compression mouldings, mainly flax and jute based.

Rieter are less advanced in production terms, but the research centre at Aubergenville is well aware of current research. The fourth European major player, Magna International, has yet to develop the use of fibre-based substrates, and production is presently geared towards woodstock (resinated wood chip or flour) products. Short fibre flax blends with woodstock are now in production.

In Germany in particular, there is a significant infrastructure of secondary Tier One suppliers, some (such as Empe-Findlay, Johann Borgers, TTO, and Heywinckel) using increasing volumes of natural fibres. Others, including the largest independent, H P Chemie Pelzer, have yet to adopt natural fibre technology.

At present, in the most important market, Germany, there is a distinct preference for the use of flax, and a growing tendency to consider hemp as prime raw material. The reason is thought to be local availability of an established fibre supply chain, and the heavy investment in improved fibre processing in recent years.

Mercedes are known to encourage use of local raw material, with jute used in India, and current research on indigenous fibres in co-operation with a South African supplier.

6. NATURAL FIBRES – PRINCIPAL ISSUES

Fibre Suitability for Automotive Process Technology

In technical terms, the most common use of bast fibres in automotive applications involves compression moulding technology, usually using medium-long fibres in the form of a nonwoven mat or felt. The mat can be produced by airlaying, or even in recent developments by hydroentanglement, but the usual nonwoven bonding method at present is needlepunching.
Natural fibres on their own cannot be thermoformed, and require the addition of polymers to act as binders, either by blending prior to needling, or by coating/impregnating a 100% natural fibre mat with duromeric (thermoset) resins.

- In the first or thermoplastic process, the most commonly used polymer is polypropylene in a 50:50 blend. For special applications where additional strength is required, the more expensive polymer polyester is sometimes used, or even bicomponent polyester where lower processing temperatures are required. Typically, the melt points are about 165°C for polypropylene, 260°C for polyester, and 115-135°C for bicomponent, so that both heat and pressure are required to produce the component.

- In the second or thermoset process, the natural fibre mat is coated or impregnated with duromers such as epoxy resins or polyurethane. It is then moulded into the finished component. Experiments have taken place using natural resins, but without significant success.

The principal Tier One suppliers use both technologies, typically in such applications as door liners, parcel shelves and boot liners. These applications can now be extended to include headliners, seat backs and floorpan substrates. Compression moulded components (mainly based upon flax and jute) are in commercial production throughout Europe.

Generally, the bast fibres jute, flax and hemp can all be used to produce thermoplastic or thermoset compression moulded components. For these process technologies, medium/long fibre of 80–90mm staple length is generally used. The detailed differences are examined below. Kenaf was introduced to the market about 3 years ago, but because of the dusty, extremely short fibre structure, the fibre was sandwiched between two needled layers of polypropylene.It is no longer in common use, produced by only one German manufacturer, J J Marx.

More recent developments now offer the possibility of producing injection moulded composites, reinforced by short natural fibres. For the first time, it may be possible to produce external components such as spoilers and fenders, although the hydrophilic absorbent properties of bast fibres may continue to restrict external applications where moisture is present. Injection moulding is also used for “hard” internal items such as dash and instrument panels. In this process, short fibre flax, hemp or jute of a staple length of 4–6mm is processed with polypropylene in a single or twin- screw extruder, either to produce granulate for injection moulding, or for continuous processing resulting in moulded parts.

- Several research projects have focussed on this technology in recent years, notably at ATO/DLO in the Netherlands, at the NIRJAFT Institute in Calcutta and at in-house projects at BMW and Daimler/Chrysler.

- Commercial scaled-up applications are now operational at Perstorp in Sweden (also intended to produce computer casings) and at Johnson Controls in Italy.

The following table summarises the most common processes for natural fibres. It includes conventional composites based on wood fibres – although woodstock is outside the scope of this study, bast fibres are in competition for this established market, just as they are in competition with petroleum-based polymers and glass fibre.

1. FIG 3 – Compression Moulding Process

BASE	**BINDER**	**PROCESS**	**COMMERCIAL EXAMPLES**
Ground Wood Chip	Natural Resin, Acrylate	Slurry	Fibrit
Shredded steamed wood	Phenolic-Formaldehyde	Needled	Lignotock, Isowood
Wood flour 50%	Polypropylene 50%	Extruded sheet	Polywood, Woodstock
Natural Fibre – Flax,) Flax/Sisal) Medium/) Hemp) Long Fibre – Jute) Short Fibre – Kenaf)	Polypropylene (or polyesters) 3 layer sandwich	Needled (or airlaid) Needled	Isoflax, New Jute LoPreFin
Natural fibre as above	Epoxy, Unsat PE or Phenolic resin	Needled	PNM
Natural fibre as above	Polyurethane	Needled	Fibropur
Natural fibre as above	Pre-melted polymer	Needled	EXPRESS
Long fibre jute	Polypropylene	Needled sheet form	Cofiber
Cotton Waste	Polypropylene	Needled	*

* Although strictly outside the prime subject matter of this study, it is known that needled recycled cotton waste substrates, for use in the floorpans of the Volvo C70 and VW Golf C4 are being produced by Borgers in Germany. Cotton is also cellulosic, and recycled cotton is cheap, costing about 0.70 DM per kg.

2. Injection Moulding Process

Wood flour – mixed) wood or Eurcalyptus) Jute Flax or hemp)	Polypropylene with MAH PP compatibiliser	Co-injection Co-Extrusion	Coexil
Short Natural Fibre	Polypropylene	LP Backmould	

Comparable Fibre Characteristics

Jute, flax, hemp and kenaf are all lignocellulosic fibres with a global production of some 4 billion tons, about 60% from agricultural crops and 40% from forests. * They thus represent a vast and sustainable raw material resource. In practical terms, production of the European indigenous fibres, flax and hemp, amounted to about 200,000 tonnes of fibre in 1998/9, including EC production and imports. Subtropical production of jute and kenaf, mainly in Bangladesh and India, is about 3,500,000 tonnes.

*P O Olesen/D V Plackett – Perspectives on the Performance of Natural Plant Fibres (1999).

In fact, availability of any of the fibres is not a real issue, except in terms of consistency and sustainability of dedicated industrial grades.

It should be noted that despite industry efforts, jute, kenaf and hemp are not suitable for apparel end use. However, a high proportion of European flax is grown for conversion into thread or woven linen fabric, and much of the hemp crop is used for papermaking. The reliability of supply for this reason has caused some concerns about flax to the automotive industry. These concerns are rather unjustifiable, in view of the demonstrable ability to increase production since 1994. As industrial fibres, the bast group share common but varying physical characteristics – key elements are shown below:

FIG 4

Fibre Type	Length mm Average (range)	Width mm Average (range)	Chemical Cellulose	Composition Hemi Cellulose	Lignin	Pectin
Flax (bundles)	(250-1200)	(0.04-0.6)	)68 – 85	10 – 17	3 – 5	5– 10
Flax (single fibres)	33 (9-70)	0.019 (0.005-0.038)	))			
		(0.5-5.0)	)68 – 85	10 – 17	3 – 5	5– 10
Hemp (Bundles)	(1000-4000)	0.025	))			
Hemp (Single fibres)	25 (5-55)	(0.01-0.05) -	)70 – 75))	12 – 15	10 – 15	1
Jute (fibre strands)	(1500-3600)	0.020 (0.010-0.025)				
Jute (single fibres)	(2-5)					

Olesen/Plackett – Perspectives on the performance of Natural Plant Fibres.

The cellulosic microfibrils of bast fibres impart enormous tensile strength (at best similar to Kevlar), and the lignin content gives rigidity and a degree of hydrophobia. Lignin also becomes thermoplastic, softening at 90°C and flowing at about 170°C. The combined effect of the chemical composition is to impart properties which are useful as benefits for industrial fibres:

- High strength – tensile strength and tenacity (50cN/Tex for jute).
- Low extension at about 2%.
- High modulus of Elasticity (1 Mpa at 250cN/Tex).
- High coefficient of Friction giving anti-slip characteristics.
- Excellent heat, sound and electrical insulating properties.
- Biodegradability through fungal/ bacterial action.
- Combustibility – in automotive applications, bast fibres generally meet flammability tests but this property allows disposal by incineration with energy recovery.
- Harsh feel and handle.
- Reactivity – the cell wall hydroxyls allow for absorption of water or chemicals, useful in resin impregnation processes.

The principal differences between the individual fibres are:

- Fibre qualities – Use of inferior grades (cuttings and recovered or "pulled" fibre) has diminished the recent reputation of jute in automotive circles. However, the ideal raw material is designated as Tossa Grade D, which has undergone an intermediate carding process in Bangladesh to eliminate waste and dirt, and to produce sliver. This can also be guillotine or rotary cut to a consistent staple length (+/- 90mm for optimum blending) and re-compressed into bales for economical container shipment.

  Although comparable data for kenaf are not available in the table above, processed kenaf fibre is very short staple, and contains much dust.

  The equivalent secondary processing method for flax and hemp is decortication, and despite recent improvements in processing, particularly in Germany, flax and hemp generally contain up to 12% "shive" or woody content, which is considered a drawback in some quarters where smoothness of the moulded component is important.

- Lignin content – Jute has a significantly higher lignin content than flax or hemp. Although there is a lack of authoritative research on the subject, this may be a factor in the distinctly inferior performance of unprocessed jute-based mats in automotive Fogging Tests (see below).

- Odour – all bast fibres have a residual smell, but anecdotally, flax is generally agreed to be worse than hemp or jute. Jute is known to meet Ford Enose standards.

- Natural/synthetic fibre interface – Flax, hemp and jute are all reported to have periodic problems of compatibility with intimate binding with polypropylene, which can lead to substandard mouldings. This may be a result of inconsistent fibre quality, and it can lead to impact failure, as in the case of Concargo Ford Transit components. It is now known that "compatibilisers" based on MAPP (maleic anhydride polypropylene) in the form of granule or emulsion may improve surface fibre adhesion.

  Various research projects have included consideration of this factor (see papers listed on page 17 – Bonding/Interface Characteristics, also FAIR 1-CT95-0195 and "New Products and Processes for the Automotive Industry" – Mark Sudol, Concargo – Nov 1999).

Generally, the benefits shared by the bast fibre group for the automotive industry include:

- Abundant global supply, accessible to car assembly locations.

- Renewable and sustainable plant fibre resources.

- Recyclability – presently the emphasis is on incineration with energy recovery, but to meet forthcoming EU legislation, it should be economically feasible to regrind natural fibre based components and re-use the composite with upgraded additives.

- Weight reduction – this factor is of paramount importance to the automotive industry, and as a generalisation, the expected weight saving on comparable synthetic components can vary between 12 and 30%. On the current Mercedes E class, a reduction of 20% was achieved by substituting flax/sisal thermoset doorpanels for similar wood fibre based product.

- Cost reduction – cost saving techniques are the second principal driving force in the automotive industry, and are said to be responsible for transforming Ford's entire European operations into profitability. Indeed, Tier One suppliers (and, in turn, their nonwoven suppliers) are expected to produce cost downs of 3–5% annually, and can rarely expect payment terms of less than 60 days.

  The most commonly used polymer in the automotive industry is polypropylene. Drake Fibres estimate Western European consumption for all moulded products (not just automotive) to be 2.8 million tonnes. The current cost of PP fibre is about 85-90p per kg.

  The European market for fibreglass composites is about 300,000 tonnes, approximately one third for automotive applications, at a cost of about £5.50 per kg for mats.

  At current market prices of 30-35p per kg, the use of natural fibres in composite blends can confer significant cost reduction possibilities.

Given the marketing advantages conferred by the above factors, it is perhaps surprising that the use of natural fibres for substrates does not figure more prominently in the sales literature of the more committed car manufacturers. Only BMW produce a multi-lingual explanatory coloured brochure on the subject.

Automotive Applications

The range of potential nonwoven applications for the average production car can be seen in the graphic in Section 3 above. It should be noted that natural fibre-based nonwovens are not appropriate for all the applications shown.

However, the development of short fibre reinforced granulate for injection moulding will also open up other commercial applications, not just in the automotive market, but in the wider sector of injection-moulded plastics.

Generally, natural fibre nonwovens can be used as both fillers and reinforcement for interior components. Current applications, with typical weights of natural fibre used, include:

- Front door liners 1.2 – 1.8 kg
- Rear door liners 0.8 – 1.5 kg
- Boot liners 1.5 - 2.5 kg
- Parcel shelves up to 2.0 kg.

The above applications are now well established for natural fibres, but other end uses are now becoming a realistic possibility, including:

- Seat backs 1.6 – 2.0 kg
- Sunroof sliders up to 0.4 kg
- NVH material min 0.5 kg
- Headliners avge 2.5 kg
- Floorpan not known.

The approximate figures shown above are confirmed by BMW. Current 3, 5 and 7 series models use about 20–24 kg of natural fibre, although over 16 kg comprises coconut/sisal seat padding bonded with natural latex.

From the standpoint of the natural fibre producer, the automotive market is also attractive because the model platform life is usually a minimum 5 years, and often 7–8 years. Although such long-term contracts are attractive, there also appears to be the opportunity to change component specifications in mid-model. Even the industry market leaders, Mercedes and BMW, will allow their Tier One suppliers to substitute materials provided that they meet or improve upon cost parameters and technical performance standards.

The form of nonwovens supplied for the above applications is still in a dynamic state of development. New fibre blends and production techniques of increasing sophistication can provide enhanced performance or meet initial production problems. The most common current nonwoven types and forms of delivery are shown below.

- Composition – nonwoven mats, either airlaid or more commonly needlepunched.
  - Either 100% flax, jute or hemp, as the base substrate for embedding in a resin matrix applied by spray or pressure impregnation to produce thermoset composites. BMW are now using an 80:20 flax/sisal blend for increased strength and impact performance.
  - Or flax, jute or hemp blended with polymer which acts as a binder under heat and pressure to form thermoplastic composites. The usual binder is polypropylene in a 50:50 blend with the natural fibre. There are also variants such as pre-melted PP for the EXPRESS technology or LoPreFin, which comprises kenaf bonded to two external thin layers of needled PP.
- The above nonwoven mats are usually felts, but recent work by the Textile Consultancy has also produced successful commercial trials of high strength, lightweight or semi-rigid substrate material. The composition is 70% jute blended with more expensive polymers such as polyester or bicomponent (low melt) polyester, particularly for use as structural headliner substrate (this is now in production in USA for the Chrysler Minivan. For this purpose, needlepunched felts are subjected to ancillary bonding processes, utilising either oven or heated calender bonding.
- Weight – for use in the first generation of natural fibre components such as door liners, nonwoven mats are usually supplied to Tier One in the range 800–2000 g.s.m. Just as blended mats 50:50 have become standard, the most common weights for compression moulding are 1800 g.s.m. and 1200 g.s.m.

  In the developing sector of headliners, lightweight calendered sheet material of 75–80 g.s.m. appears to meet industry specifications.

- Thickness – for thermoplastic components, natural fibre mats at delivery point are usually specified to be in the range of 8-12.5mm thick, dependent on the application, and 10mm (which compresses by at least half) has become a standard startpoint.

  Suitable headliner substrate is 0.6mm for dry processing, and 0.9mm for wet processing

- Form of Delivery – Most nonwoven producers despatch roll goods at a usable width of 1.5–2.0 metres. This tends to be a function of the width of the needle bed, and on modern plant, widths up to 6 metres are not uncommon. At the wider widths the resulting mat can be longitudinally slit. Widths under 1.5 metres are not commercially viable.

  Some companies offer the facility of die cutting mats to approximate compression mould dimensions, and by using calendered blends incorporating polyester, it is also possible to supply die-cut semi rigid board.

Automotive Performance Specifications

The automotive industry requires that materials and substrates used in components should meet a wide range of performance tests, many of which are quite specialised and expensive. Perhaps for this reason, centres with the full range of testing equipment are widely spread – some facilities are available at the OEM, some at Tier One, but few are owned by nonwoven producers. In the UK, MIRA at Nuneaton, LTC at Leyland and Laboratory 2000 at Automotive Insulations at Rugby are independent laboratories capable of carrying out most of the requisite tests.

However, it is in the area of performance tests that natural fibre composites encounter most problems. It is also an area of a good deal of uncertainty, principally because of a lack of comparative and authoritative data on the intrinsic and comparable qualities of the different natural fibres available.

The range of performance requirements vary slightly between different OEMs. A typical Lear Corporation Material Specification is shown below.

- Pre-Conditioning (to DIN 50 014) before testing for minimum 24 hours at standard atmosphere – 23 +/- 2°C, 50 +/- 6% humidity.

- Material Structure – Natural Fibre – fibre length 50mm +/- 5%: shive content< 5%.
  Polymer (PP) – fibre length 50mm +/- 5%: titre 6.7 dtex: MFI 8–10: crimp 4.5-5.5/cm: Melt Point 160-170°C: density 0.91 g/cm3.
  Bonding – specified method with conditions.
  Moisture content on delivery – maximum 4.5%.

- Area Weight – e.g. 1000 g.s.m. +/- 5% (to DIN 53 854).

- Roll Width and Diameter – according to order, tolerance +10mm.

- Thickness at Preload – according to order, tolerance +/-1mm.

- Ultimate Breaking Force (to DIN 53 857 page 2) measured with samples 5cm wide. Speed of travel 100mm/min: free distance between grips = gauge length 100mm. Lengthwise – e.g. 1000 g.s.m. material: 750N.
  Crosswise: 1250N.
  The relation between lengthwise and crosswise should be better than 1:2.

- Bending test (to DIN EN 63).
- Percentage Elongation at Break measured with samples 5cm wide.
  Lengthwise – e.g. 1000 g.s.m. material: 70 +/-10%.
  Crosswise: 60 +/-10%.
  The relation between lengthwise and crosswise should be better than 1:2.
- Odour Characteristics (to VDA 270 Methode C2) – maximum mark: 3.
- Fogging Characteristics (to DIN 75 201).
  Procedure A – Fog Mass or Condensate value should not exceed 1.0mg.
  Procedure B – Average Percentile Fog Number.
- Mildew Growth (to Opel specification GM 9128P) Plates with a density of 0.8g/cm3 are used with additional requirements of 14 days duration at a temperature of 38 +/-1°C, using a lidded 1 litre container, with 50ml of water beneath the sample (80mm dia).
  There must be no mildew growth or related odour.
- Flammability (to DIN 75 200) using plates with a density of 0.8g/cm3.
  Maximum burn rate of 100mm/minute
- The nonwoven blended substrate should also be capable of withstanding compression moulding process temperatures of 200–220°C with a dwell time during pre-heating of about 40 seconds. This is not a problem for the bast fibres, which begin to char at 260°C.
- Acoustic Absorption Coefficient using Standing Wave Tube apparatus, graphing maximum and minimum sound pressure levels through given octave bands from 250 to 2500 Hz. This is an optional performance standard for specific applications.
- Impact Strength.

There are a number of additional tests for headliner material, such as abrasion resistance, flex modulus tests to 7N under warm (104°C) humid conditions and light fastness. Tests for VOC (Volatile Organic Compounds) are sometimes required. Additionally, both nonwoven producers and fibre producers should be prepared to certificate a Hazardous Substances declaration.

In general, there are no particular problems for natural fibre based nonwovens in meeting the industry standards, except in three areas:

a) Flax and hemp fibre need a credible international standard of measurement and grading, so that there is a general lack of confidence in the consistency of quality from batch to batch. There is also no agreed system of measuring fibre quality.

   The USA has now taken the lead by setting up an ASTM Committee to determine reproducible standards for trash (shive) content, colour, and fibre strength, length and fineness.

   Jute has an internationally recognized quality grading system comprising White (A–D), Tossa (A–D) and cuttings, in descending order. The principal quality problem for jute is the ease of substituting inferior grades to increase margin, notably pulled or recovered jute, which contains many residues and dyes and is quite unsuitable for automotive applications.

b) Emissions are the greatest problem for the bast fibre group, comprising mildew growth, odour and particularly fogging. The major OEMs have different priorities in this respect – Opel have the highest tolerance for fogging, but mildew growth is paramount, and odour is said to be particularly important to Audi, but not VW.

- The generally accepted standard for fog mass condensate is 1.0mg, (although Opel allow 2.0mg), and at this level, batches of hemp/PP and flax/PP sometimes fail, whilst jute/PP almost always fails, reaching levels of up to 15.0–16.0mg prior to thermoform processing.

  This distinction is important, because even though the Tier One suppliers usually require Fogging tests to be carried out on the virgin fibre nonwoven mats, the only real relevant testing procedure, according to Ford Koln, is to test the finished moulded component, complete with laminated layers such as soft PU foam, warp knit decorative face fabric etc. It is also evident that test results improve dramatically where the nonwoven mat is impregnated with resin, or laminated to foil or PU/PE film as in seat back applications.

  Even at high level in the OEMs and first rank Tier One suppliers, rumour and hearsay abound about fogging on natural fibres. The Textile Consultancy have been unable to discover any research which definitively compares fogging (and other) relevant automotive test results for similar constructions in the different fibres.

- Odour is also a problem, particularly for flax. Johnson Controls at Grefrath report that flax/PP mats retain a distinct smell for 2–4 weeks after delivery. Ford at Koln have developed the eNose 5000 system of electronic/computer evaluation of odour, with samples conditioned for 16 hours at 40°C in a 3 litre jar. Grade 1 has no smell, Grade 2 is detectable but acceptable, Grade 3 is detectable but unacceptable, and Grade 4 is severe and objectionable. Jute, even cuttings, ranks acceptable or better.

Now, however, all odour testing is carried out in the form that the component appears in the car.

- Impact strength has also been a problem for natural fibre substrates, occurring quite unpredictably, possibly as a result of inferior fibre batches or poor cohesion between the natural fibre and its polymer binder (see section 6 above).

c) As for all automotive interior materials, recycling issues present real challenges for natural fibre composites in the new millenium, particularly in view of forthcoming European legislation (Directive for Recycling End-of-Life Vehicles). The policy aims to "depollute" all scrapped cars – about 10 million each year, avoid hazardous waste, and reduce landfill to a maximum 5% per car by 2015.

   The fact that bast fibres are renewable resources has no specific relevance to recycling issues – indeed, their inherent biodegradability is a potential negative factor in the automotive life cycle. Biological degradation, or rotting of the component, is prevented by the protection of intimate binders or resins.

   Therefore, specific recycling methods have been devised for such composites, including:

   - Regrinding stripped thermoset components in a cylindrical grinder for subsequent re-use – this recovered material, however, can only be used for production of similar or lower specification parts, even with the addition of enhanced additives.

- Melting down and re-granulating thermoplastic components, with similar provisos.

- Chemical decomposition of the original binder constituent.

- Incineration to generate energy, with minimal residues. Glass fibre cannot be disposed of in this manner. In the case of bast fibres, there is a positive $CO^2$and energy balance because of the solar energy absorbed by the plant during growth.

Once again, German car manufacturers have led the way in recycling issues, including the design of single material components for ease of recycling, and the establishment of regional recovery units. Opel, for example, has a nationwide waste management scheme through its 2500 dealers, and the Astra has over 40 components which use recycled material – such items as fender liners and sound absorbent fillers. Fiat and Renault are also pro-active, and Renault is building an energy-recovering incinerator at Douai with a capacity of 36,000 tonnes per year.

In general terms therefore, natural fibre composites are somewhat more "green" than conventional plastics, and considerably more than fibreglass, because of their derivation from sustainable resources rather than fossil fuels. In terms of recycling techniques, there is very little apparent difference, but because of their intrinsic positive CO^2 and energy balance, the use of natural fibre-based composites is positively encouraged by the German Economic Recycling Act.

Natural Fibres for the Automotive Industry – Opportunities and Constraints

Opportunities

The market for bast natural fibres has expanded considerably in the last 5 years (see Section 6 below) to the extent that most European car producers now use natural fibres for interior components. The type of fibre used is, to some extent, interchangeable, dependent upon particular performance requirements and the prevailing current fibre costs. Opportunities for all four bast fibres can thus be classified under three headings:

- Mature Products

Use of natural fibres in blended thermoplastic or resinated thermoset compression mouldings is now generally accepted for applications as door liners/panels, parcel shelves and boot liners. The following producers and models are known to incorporate natural fibres for such components to a greater or lesser extent:

Volkswagen:	Golf, Passat, Bora.
Audi:	A3, A4, A6, A8, A4 Avant, Roadster.
Mercedes:	all models including A Class, C Class, E Class, S Class.
Opel GM:	Vectra, Astra.
Ford:	Mondeo, Focus.
Fiat:	Punto, Brava/Marea, Alfa Romeo 146, 156.
Renault:	Clio.
Peugeot:	new 406.
Volvo:	C70, V70.

Use of natural fibres for these components can be expected to increase steadily with increased model penetration

- Developing Products

Using similar nonwoven and process technology, the use of natural fibres can also be expected to extend into components such as seatbacks, sunroofs, floorpan substrates and NVH/acoustic absorption materials.

Using supplementary calender bonding, the market is beginning to open for lightweight natural fibre reinforced substrate for structural headliners, as a replacement for glass fibre.

There are increasing possibilities for customised blends of natural fibres to optimise binder saturation and resultant performance – such as flax/sisal or possibly flax/jute.

- New Products

Although outside the detailed scope of this study, which focuses upon nonwovens, it is apparent that considerable opportunities may be opening up for injection moulded components based upon short fibre reinforced polymer granule. At present, this technology has yet to be scaled up to full commercial production and marketing.

In this technology, which is equally suitable with jute, flax or hemp, a new range of hard interior components can be targeted. Subject to continuing research to mask the hydrophilic properties of bast fibres, a range of semi-structural exterior components may also come under consideration.

It should also be noted that the same injection moulding technology may bring wider opportunities in the plastics market for items such as computer, audio and TV casings.

Constraints

In interviews with decision formers at the principal OEMs and Tier One suppliers, reference is always made to factors of cost and performance, when discussing future prospects for natural fibres in the automotive industry. Many of these issues have been examined in detail in preceding sections, but are summarised below.

- Performance factors

The principal limitations to further growth are:

- Compliance with required performance standards for emissions, particularly fogging, followed in importance by odour and mildew growth. It is believed that these problems are not insurmountable, but there is a lack of authoritative test data on truly comparable substrates, in finished format, in the different fibres available. The consequence is misinformation and speculative hearsay.

- Consistency of quality from batch to batch, particularly for flax and hemp, and injudicious substitution of inferior grades for jute.

- The lack of an internationally recognised grading and quality system for flax and hemp fibre. The automotive industry is now demanding better and more reproducible fibre qualities, independent of climatic and processing variables.

- Consistent availability of fibre is still seen as a problem, although it is demonstrated above that these concerns are groundless, with almost unlimited supplies of jute, and increased European production of improved grades of flax and hemp.

- Natural fibre suppliers need to adapt continually to the evolving processing technologies in the automotive industry.

- The continuing reluctance of mainstream European nonwoven producers to process natural fibres, on the grounds that they are dirty, that waste and dust clog up the carding lines and contaminate adjacent synthetic lines.

  However lines can be isolated, and with improved fibre qualities and sophisticated extraction systems, more nonwoven producers are willing to consider processing. Additionally, there are now a significant number of producers with lines dedicated to natural fibres.

- Cost Factors

  As a volume consumer of raw materials, the automotive industry is particularly concerned with actual and potential cost reduction measures. Although this attitude has opened the market to natural fibres in competition with petroleum-based polymers, the supply chain will not tolerate wide cost variations and expects cost-downs.

- The accepted market price for natural fibres in Germany (by far the most important – see Section 6 below) has become established at DM1.00 per kg +/- 5–10 Pfennigs.

  At present, with some reservations, each of the competitive bast fibres considered in this study can meet this target figure, but in each case, there is some uncertainty over future price trends.

  It is vital within the industry that long-term contracts are entered into with price down agreements. Dedicated industrial fibre must meet these parameters.

- Flax, with an estimated 70% of the current natural fibre market, is most subject to considerable price fluctuations, between DM0.90 and DM1.50 per kg. This is partly because of yield, and partly because of temporary supply shortfall or oversupply resulting from fashion demands for linen.

  Market price is also determined by heavy EU area subsidies of Euro 815 per hectare. The CAP subsidy was originally designed to bridge the gap between average production costs estimated at Euro 3000 per ha and income calculated at Euro 2000 per ha.

  The proposed Commission Amendment to Council Regulations, designed primarily to prevent abuses in the expansion of short fibre growing area, would render flax and hemp totally uncompetitive, if adopted in the present draft form. *

- Jute, having been at the forefront of early developments, has become of secondary importance in the last few years. However, in late 1999 there is now renewed interest in the improved qualities now available.

  World Bank projections for raw jute fibre continue to show a decreasing price to about $200 per tonne, but raw jute is unusable to the nonwoven industry in this form.

  Semi-processed (carded) fibre in the form of breaker card sliver (cut to 90mm staple and recompressed into bale) is eminently suitable for automotive mats and is now available. Taking into account container costs from Bangladesh, the fibre can reach Rotterdam CIF for about $500 per tonne, equating to about DM0.94 per kg.

  The major problem in jute supply is the wide price variation resulting from the complicated infrastructure of producers, merchants and weavers, and the lack of a reliable supplier database.

Many European nonwoven producers have misconceptions about jute prices, and believe that the market cost of even inferior grades, such as cuttings, is DM1.20–DM1.30 per kg.

Jute also suffers from quality problems caused by use of recovered jute or cuttings, neither of which are appropriate for automotive quality standards.

- Hemp is a growth fibre for the automotive industry, and its commercial use in full-scale production began only in 1998, in Germany. Recent developments have improved crop yields and quality, and at present, hemp fibre is traded to nonwoven producers at DM1.00–DM1.20 per kg.

  Like flax, European production of hemp fibre is subject to EU subvention subsidies amounting to Euro 662 per hectare.

  As for flax, the Commission Amendment, to be phased in over the next 3 years, would reduce the area subsidy to cereal levels, whilst adding a graduated straw processing subsidy and imposing national acreage quotas.*

- Kenaf, imported from Bangladesh, is also available on the European market in the price range DM1.00–DM1.20 per kg. In Europe however, unlike USA, its use most recently in the automotive industry has begun to decline.

Most nonwoven producers justifiably consider it as a relatively dirty, short staple fibre, which requires masking layers of PP, bonded by adhesives.

Nevertheless, interest was shown in cultivating kenaf in the Mediterranean countries, Spain, Portugal, Italy and Greece, and an EU funded AIR Project reported in 1996 – the economics were thought to be questionable.

*At recent meetings in November 1999 in London and Germany, the proposed EU Amendment to Council Regulations (on subsidy revisions for flax and hemp) has met with concerted opposition. Current industry opinion is that the proposals as formulated would destroy the growing fibre industry. Fibre producers intend to lobby Brussels for the adoption of less damaging measures.

FIG. 5

Summary of Market Prices for Natural Fibres

Fibre	Main Sources	Market Price Range DM/kg
Flax	France, Spain, Belgium, Lithuania, UK	0.90 – 1.20
Jute	Bangladesh, India	0.95 – 1.25
Hemp	Germany, UK, France and possibly Romania	1.00 – 1.20
Kenaf	Bangladesh	1.00 – 1.20
Sisal	South Africa, South America	1.20 – 1.30

Market Size and Current Market Usage

Market Size and Forecast

The use of natural fibres in the automotive industry, for interior components, dates back only to about 1994. During the last five years, with steadily increasing interest and the gradual development of the supply chain, use for a limited range of components has become commonplace.

Consumption is expected to increase substantially during the next 5 years, from current consumption estimated at about 22,000 tonnes to at least 35,000 tonnes. Some industry authorities (Kinkel 1999) put the figure even higher, up to 45,000 tonnes.

The estimates in this study have been produced by the Textile Consultancy Ltd and Nova-Institut GmbH on the basis of some 200 personal/telephone/fax interviews with respondents and decision formers at the principal OEMs, Tier One suppliers, nonwoven and fibre suppliers. Much of the data obtained is commercially confidential, since the technologies are both innovatory and competitive.

At present, it is believed that Germany alone is responsible for over two thirds of European production of natural fibre composite components, followed by Italy, France, UK and Sweden. In this context, Ford is considered German whether assembly is in Genk or Speke.

FIG 6.

Estimated automotive consumption of Natural Fibres in tonnes

Fibre	1996		1999		2000 (Projected)
	Germany	Rest of Europe	Germany	Rest of Europe	All Europe
Flax	1,800		11,000	4,900	+2 – 10%
Jute	1,800	300	2,000	1,400	+3 – 15%
Hemp			1,100	600	+3 – 20%
Kenaf	400		900		0 to – 3%
Sisal			500		0 to – 3%
Totals	4,000	300	15,500	6,900	23,000 – 25,000

For the year 2000, when European growth in car sales is expected to be 5% or under, many component contracts are already in place, and most OEMs have new models recently introduced. In ensuing years, according to Kinkel, demand may rise by 500–3,000 tonnes of natural fibre per annum with new model changes.

Flax is still the first choice fibre for the German automotive industry, although growth of the fibre is relatively minimal in Germany. An ambitious programme to stimulate growth of flax was introduced in the 1980s at a cost of DM 60 million, but met with relative failure. Most of the flax used in the German automotive industry is imported from either France, Spain or Belgium, from trading companies such as Saneco and Procotex, and fibre is now being imported from the Baltic States.

In Germany, most production and research effort in recent years has been put into hemp. With existing and planned capacity, the German hemp industry could provide up to 10,000 tonnes in the near future; fibres from Vernaro at Gardelegen represent the best quality so far from short fibre lines. Other supply sources include Hemcore in UK and imports from France and the Netherlands. Major investment has also taken place in Romania.

After a few years when jute lost market share, for reasons previously given, there is now a strong renewal of interest in improved, semi-processed fibre, which is surprisingly clean in nonwoven operations. There is also the prospect of abundant supply and long term competitive cost, if the industry can get its act together.

Kenaf was produced by J J Marx and is being trialled by others. However, due to supply difficulties, J J Marx may now be considering other fibres.

Current Commercial Usage By Market

- <u>United Kingdom</u>

  The United Kingdom is one of the least developed European markets for automotive developments in natural fibres, perhaps because the car industry, with the exception of a few specialist and racing marques, is overseas-owned – most R & D facilities are in mainland Europe. The present supply chain can be summarised below.

  - Fibre production – in 1998, about 15,000 ha, a sevenfold increase on 1993, was sown to flax and hemp, mainly short fibre varieties. The principal producers are British Fibres Ltd, processing Robin Appel flax, Flax UK Ltd, processing Lintex flax, and Hemcore Ltd, processing hemp.

  - Nonwoven producers – in the UK, the principal companies with experience of natural fibres for the automotive industry are Gaskell Textiles Ltd, W E Rawson Ltd and on a smaller scale, JB Plant Fibres. Several other companies with appropriate technology and potential interest are listed in Appendix 1C.

  - Tier One suppliers – all the principal groups are represented in the UK, although development, for the most part, is carried out offshore. There are also a few separate companies, such as Midland Industrial Plastics (now Textron) and the part Japanese-owned R Tek.

  - The UK acreage is stable at a modest level of production.

- France

  Although France is one of Europe's principal fibre producers, with over 50,000 ha of flax and 10,000 ha of hemp under cultivation, use of these fibres in the automotive industry has been minimal until last year. France, however, is the principal flax supplier to the German industry – an estimate from the fibre producer, Seneco, is about 10,000 tonnes.

  - Fibre producers – Etablissements Van Robaes Freres claim to be the largest processor of flax in Europe, with their output sold through Seneco in Lille. Another major processor is La Chanvriere de l'Aube at Troyes, also selling in Germany – this company is also contemplating the processing of jute, besides hemp.

  - Nonwoven producers – few needlefelt companies are interested in processing natural fibres. The principal known players are Silac at La Rochefoucauld, Tharreau at Chemille, and a processor associated with La Chanvriere.

  - Tier One suppliers – the principal groups, with the exception of Magna, are represented in France, and the Rieter Group research unit specialising in natural fibres is located near Paris. There are also two major French-owned groups, Sommer Alibert (Sommer Masland and SAL) and ECIA. – ECIA is known to be interested in natural fibre composites, originally through a FAIR project.

  - OEMs – the two French car manufacturers, Renault and PSA (Peugeot/Citroen) are relatively secretive about their use of natural fibre composites, but a few models are known to contain such components. Overall however, it is believed that the French automotive industry is a long way behind Germany in this field.

- Scandinavia

  About 35,000 ha of flax is grown in Sweden, traditionally for textile use, and perhaps because of the importance of this crop, there are two particular centres of research excellence in natural fibres, SICOMP at Pitea and the Swedish Institute for Fibres and Polymers (IPF). Together with Tier One, Saab and Volvo, they have formed the Green Car Consortium.

  - Fibre producers – the principal company is Swefibre at Halmsted, supplying flax to the German automotive industry.

  - Nonwoven producers – Dexter Nonwovens have expressed interest in natural fibre developments, but no other companies are active in this field.

  - Tier One suppliers – Lear Corpn and Collins & Aikmann (formerly Perstorp) operate.

  - OEMs – Volvo are using flax/PP composites, but Saab still use woodstock and glass fibre, without any plans to use natural fibres at present.

  - There are no relevant natural fibre/automotive activities in Norway, Finland and Denmark, although the Royal Veterinary and Agricultural University in Copenhagen is a recognised authority on bast fibres, and has produced related research work.

- Iberia

  In 1999, Spain was responsible for cultivation of 126,000 ha of short fibre flax, primarily for subsidy – the largest European producer, and one of the prime reasons for the proposed limitation legislation. (See Appendix 12).

  - Fibre producers – CELESA (Cellulosa de Levante) is the prime processor and grower of genuine industrial grades of flax and hemp, and has also begun processing imported jute. The principal end uses are as pulp for papermaking, and fibre is also exported to Germany for automotive end use.

  - Nonwoven producers – little research has been carried out, but companies active in the automotive industry, not necessarily with natural fibres, include CATENSA, Autotex, and Emfisint (now owned by Rieter).

  - Tier One suppliers - Lear Corpn and Johnson Controls have plants in Spain, and the major European group, Antolin Irausa is Spanish-owned. Irausa supply Opel and Renault, and are Ford's principal supplier of headliners – they have experience in moulding flax/PP mats imported from Belgium and Germany and have renewed interest in jute.

  - OEMs – SEAT is owned by Volkswagen, and all R&D development is centred in Germany.

  - Research – the main research organisation in the automotive industry is CIDAUT, Valladolid, and several institutes, such as Keninter, Madrid, and the Universidad de Leon specialise in fibre research, including work on kenaf.

  - There are no relevant natural fibre/automotive activities in Portugal except a Ford/VW joint venture assembling various Ford models – there is, however, no supporting infrastructure.

- Belgium

  Although Belgium is a significant flax producer and trading nation, with over 10,000 ha under cultivation, most of the natural fibre automotive developments are for German or French based customers, since Belgium is the location of major assembly plants such as Ford, Genk.

  - Fibre producers – one of the largest European flax processors and traders, Procotex (Belgalin) is based at Gent, with modern vertical nonwoven plant supplying the automotive industry in Germany, and the textile industry with yarn.

  - Nonwoven producers – there are a number of needlefelters with current automotive business in jute, flax and hemp, mainly exporting to Germany – they include Wattex, La Zeloise, Procotex, FDR and Elco/EAC, a US joint venture with a plant in Poland.

  - There are no independent Tier One producers – the exception is Vitalo, Meulebeke, which has divisions specialising in Acoustics, components for trucks and computer casings.

- Italy

  Despite a previous history of growing hemp and flax in the Po Valley, there is currently no significant growing of industrial crops in Italy, and until recently, the dominant Fiat Group has been reluctant to specify natural fibre composites because they lacked evidence of cost savings. Fiat however, pioneered use of Brome fibre composites for Tipo tailgates. This situation is now changing. There are no significant fibre producers.

- Nonwoven producers – there is a well-established and sophisticated nonwoven infrastructure serving the Italian car industry, but few with any experience of processing natural fibres.

- Tier One suppliers – the principal players are Johnson Controls, Rieter (Fimit) and Lear Corpn, who have acquired the Italian companies Pianfei and Strappazini. Johnson Controls, but not Lear, have current natural fibre contracts using both flax and jute.

- OEMs – attitudes at Fiat are now changing, with the introduction of natural fibre composites into several models, and Fiat are understood to be actively interested in new technologies, fibres (specifically jute) and new applications.

- Austria

There are now plans to produce hemp on a commercial scale in Austria. The only significant Austrian player in natural fibres/automotive is one of the largest automotive nonwoven producers, Funder Industrie at Kuhnsdorf, with an additional plant near VW in Germany. Funders output is reported to be about 10,000 tonnes, including Isowood (wood flour composite) and Isoflax (needled flax/PP).

- Germany

The situation in Germany has already been examined in some depth in the preceding sections, since it holds a position of European market dominance in research and development, specification, infrastructure and actual production of natural fibre composites for the automotive industry. Indeed, based on TTC/Nova estimates, Germany alone is responsible for nearly 70% of activity in this sector.

Since the car manufacturers Mercedes (Daimler/Chrysler) BMW and Audi/VW originated developments in composites, it is not surprising that a competent infrastructure has grown around them, importing raw and semi-processed material from throughout Europe. Nor is it surprising that these manufacturers are still at the leading edge of technological development. In Germany converters tend to be located adjacent to decortication plants, helping to minimise non-productive fibre costs, notably transport

- Full details of fibre producers, nonwoven producers specialising in natural fibres, Tier One suppliers and the principal OEMs can be found in Appendix 1.

- Figure 7 shows the locations of the principal fibre producers and specialist nonwoven producers in Germany.

Technical Status and Research Priorities

Section 4 of this report contains a comprehensive listing of European research work on the subject of natural bast fibres in automotive applications. Publications are listed by country of origin, the type and funding source, and by the principal subject matter.

- It should be noted that there is a further body of research, not listed here, which addresses issues relating to the improvement of fibre species and primary processing techniques. In the jute industry alone, the consultancy is aware of at least 12 projects of this nature, concerning subjects such as retting, improved carding methods, and the type of oils used as lubricants in processing.

Such research is not within the Terms of Reference, and is excluded because it is fibre industry-specific, without direct relevance to the automotive industry.

- The consultancy specialises in economic and marketing issues, and does not profess the specialist scientific knowledge to evaluate the research work listed, in terms of content or subject coverage; indeed, in most cases, only a brief synopsis of the content and results has been accessed.

  However, from the survey of research material, and interviews with academics and executives in the automotive supply chain, the consultants were able to draw the following conclusions:

- Detailed research has already been carried out in recent years on most aspects of primary and secondary processing of natural fibre nonwovens for the automotive industry. Research findings are generally publicly available, at a cost, primarily from several German institutes, and from specialist institutes such as ATO/DLO (Neths) and SICOMP/IPF (Sweden).

  These sources and their publications are listed in Appendix II, and new research proposals should be checked against such extant research work.

- In Europe, future research and development is likely to remain focussed upon the bast fibres, flax, hemp and jute. This is not the case in USA, where kenaf is becoming important through the joint interests of Kafus Industries and Visteon (Ford).

  European OEM and Tier One specifiers are currently open-minded upon the subject of fibre selection. The key criteria are simply cost and performance.

  Information already exists on the comparative physical properties and characteristics of the three principal fibres (summarised in Section 6 above), but is lacking in comparative performance data.

- There is no authoritative data, for instance, on controlled tests for fogging, moisture absorption, mildew growth and odour, carried out on identical nonwoven substrates based on flax, hemp and jute and blends thereof. Lightweight calendered nonwovens have only been produced using jute.

- There is no work on the subject of blends of natural fibres to obtain the optimum characteristics from each fibre. On an empirical basisonly, BMW are now using flax substrates incorporating sisal for increased strength.

- In view of reported substrate failures owing to lower mechanical performance (especially brittleness upon impact), there may be scope for further work in compatible resins systems for an improved fibre/matrix interface.

  Work by ATO/DLO suggests that maleic anhydride polypropylene may improve surface fibre adhesion. SICOMP have also produced research on the subject, and these sources should be the base point for future research.

- Some European research has been carried out on fibres other than flax, hemp and jute, notably work on nettles and miscanthus. Daimler/Chrysler have a Brazilian indigenous fibre under active consideration, and pineapple fibre is said to be a possible filler material. However, such fibres are considered to be a diversion, given the requirement of the automotive industry for continuity, quality and reliability of supply.

- Reference has already been made (Section 6 page 35) to the need to set reproducible quality standards for flax in terms of shive content, colour, and fibre strength, staple length and denier. This is also necessary for hemp, to meet the demands of the automotive industry and to improve confidence.
  The current work of the US ASTM sub-committees should be the base point before future research is undertaken.

- There is no strong interest in the automotive industry for the use of recovered or secondary plant fibre waste materials. The reasons cited are supply uncertainties, and issues related to quality – lack of reproducibility, indeterminate composition, and possible contaminants such as dyes etc.

  The use of such regenerated material has declined in recent years. Pulled clothing is no longer widely used even as underbonnet insulation/filler, and there have been adverse experiences with components based on recovered jute. The exception is nonwoven cotton waste impregnated with phenolic resin, used as a floorpan substrate in the Mercedes A Class.

- The perceived advantages of bast natural fibres in recycling could provide the subject of further research. However, with the current focus on regrinding rather than incineration, resources for collection and processing could only be provided by the car manufacturers themselves.

- Finally, great importance is forecast for the relatively recent technology of fibre-reinforced granule for injection moulding. Each of the principal bast fibres seems suitable for this process if short staple fibre is used. The process is technically beyond the scope of this study, which focusses upon nonwoven industry technology.

  However, the consultancy is aware of European developments in this field. Mercedes and BMW have carried out in-house research, and similarly restricted information is available from Perstorp in Sweden (the main application is understood to be computer casings).

  Pilot line work, using both hemp and jute, has been carried out by ATO/DLO (Neths), and is in the public domain. These sources would be a useful start point for future research, perhaps to scale up the technology.

  The consultancy, however, has reservations about some marketing aspects of this technology. The principal suppliers of polymer granule at present are thought to be multinational chemical companies – the “dilution” of their product, and contamination of their lines are unlikely to attract their marketing effort.

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APPENDIX I: Supply Chain Market Contacts

SUPPLY CHAIN MARKET CONTACTS

1.A. ORIGINAL EQUIPMENT MANUFACTURERS OEMs

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Gunther Stengel Dept 8360

Audi Volkswagen
Ingolstadt, Germany Tel: 0049 841 8939091
Thomas Schmidt/Herr Kinkel

BMW Group
Location 1: Munchen, Germany
Tel: 00 49 89 382 48298 Fax: 89 382 43690
Roland Madlener
Location 2: Rover – Gaydon, UK
Tel: 01926 646416 Fax: 01926 646707
Ray Hedges/Derek Wilkins (Care project)

Daimler Chrysler (Mercedes)
Ulm, Germany Tel: 0049 731 5052897
Fax: 731 5054213
Drs Schlosser/Ralph Greiner/Thomas Schuh
Dept FT4/TP

Fiat Group
Orbassano, Torino, Italy
Tel: 0039 011 9083776 Fax: 011 9083666
Enrico Indino/Enrico Mangino

Ford
Location 1: Koln-Merkenich, Germany Tel 0049 221 9033752 Fax: 221 9032760
Wolf-Peter Schmidt/Frau Schafforth
Koln Tel: 221 9037042 Fax: 221 9032543
Monika Sauerbier (Advanced Vehicle Technology)
Koln Tel: 221 9013429 Fax: 221 9012995
Dr Jorg Sassmannshausen (Technical)
Location 2: Laindon, UK Tel: 01268 403204
Fax: 01268 404765
Alan Harrison

Honda
Swindon, UK Tel: 01793 831183
Jurgen van der Goot

Jaguar
Whitley, Coventry, UK Tel: 01203 216518
Fax: 01203 301561
Ken Reece

Nissan
Location 1 : European Tech Centre, Cranfield, UK Tel 01234 755555 Fax: 01234 755712
Dave Brown/Peter Eastland
Location 2 : Eur Technology Centre, Gent, Belgium Tel: 0032 10 482355
Anne Debaut

PSA Group (Peugeot/Citroen)
La Garenne Colombes, France
Tel: 0033 141 366000
M Lattree/Josiane Fatet

Renault
Guencourt, France Tel: 0033 134 959352
Fax: 134 959702
Mme Brevaut

Saab (General Motors)
Trollhaten, Sweden Tel: 0046 520 85318
Fax: 520 84100
Mark Widen

Toyota Group
Osmaston, Derby, UK Tel: 01332 283400
Harry Hatori

Volvo
Gothenburg, Sweden Tel: 0046 31 596020
Fax: 31 594379
Ulf Kleist/Harald Pettersen

1.B. TIER ONE SUPPLIERS

Lear Corporation
Location 1: European HQ – Coventry, UK
Tel: 10203 301005 Fax: 10203 639662
Management structure in process of change
Location 2: European R & D – Ebersberg, Germany Tel: 0049 8092 233776
Fax: 8092 20193
Konrad Hartmann/Rainer Ankele (Components)/Richard Muhlbacher (Headliners)

Johnson Controls
Location 1: European HQ – Burscheid, Germany Tel: 0049 2174 650825
Fax: 2174 65209
Location 2: Headliners – Schweighouse, France
Tel: 0033 388 734444 Fax: 388 733325
Guy Ludwiler/G Maentz/Marie-Christine Knorr
Location 3: Components – Grefrath, Germany
Tel: 0049 2158 919221
Dr Kleinholz/Andre Dupont
Location 4: Seats – Strasbourg, France
Tel: 0033 388 405151
M Lalagu
Location 5: Prince APG, Coventry, UK
Tel: 01926 333000
Kevin Bamford
Location 6: Benecke Headliners – Uberherrn, Germany Tel: 0049 6836 470190
Herr Gerecke
Location 7: Fibrit Components – Harnes, France Tel: 0033 321 773377
Fax: 321 497065
Jean-Pierre Demey/Pascal Zavard
Location 8: Becker Trucks – Wuppertal, Germany Tel: 0049 202 342237
Fax: 202 341107
Vince Churchfield

Magna International
Location 1: European R & D – Magna Eybl, Ebergassing, Austria Tel: 0043 2234 7540
Richard Hahnekamp
Location 2: UK HQ – Maidstone, UK
Tel: 01622 686311 Fax: 01622 625070
Bob Startup

Rieter Group
Location 1: European R&D – Gundernhausen, Germany Tel: 0049 6071 4910
Fax : 6071 491425
Jurgen Opfermann
Location 2: Materials – Aubergenville, France
Tel: 0033 130 950960 Fax: 130 953042
Didier Dumas
Location 3: Carpet/Insulation – Heckmondwike, UK Tel: 0870 6066608
Fax: 01924 401128
Marion Zimmermann/Chris Cawthra/John Dowson

Empe Findlay (Findlay Industries USA)
Geretsried, Germany Tel: 0049 8171 3810
Fax: 8171 381729
Matthias Lorincz/Rudiger Poltrock
Empe also produce nonwovens in Germany at Ebersdorf and in Poland

H P Chemie Pelzer
Location 1: European HQ – Witten, Germany
Tel: 0049 2302 668215 Fax: 2302 668227
Herr Gerlach/Jurgen Beissner
Location 2: Speke, UK Tel: 0151 448 2383
Paul Garner/Dieter Loewe
Pelzer is the largest independent Tier One supplier, with factories in Europe and USA

Johann Borgers
Location 1: Bocholt, Germany
Tel: 0049 2871 3450 Fax: 2871 345291
Hans Segbert/Klaus Menke
Location 2: Telford, UK Tel: 01952 670345
Fax: 01952 670123
Mr Stephens

Julius Heywinckel
Osnabruck, Germany Tel: 0049 541 5849142
Fax: 541 5849130
Udo Hausler

R & S Stanztechnik
Offenbach Tel: 0049 69 8900020
Ernst Spengler

TTO Techtextil
Oschatz Tel: 0049 3435 622041

Two further vertical plants (i.e. nonwoven mats to compression-moulded components) are under construction in Germany – **Mollerplast** at Kalletal, and **Sprengstoffwerk** at Gnaschwitz.

Sommer Masland
Mouzon, France Tel: 0033 324 277503
Fax: 324 261665
Michel de Bettignies/Annie Bock
Also operating in UK and Germany as SAL (Sommer-Alibert-Lignotock)

ECIA (Equipements et Composants pour l'Industrie Automobile)
Audincourt, France Tel: 0033 381 376748
Fax: 381 376840
M Bergeret/J Barge

Vitalo
Meulebeke, Belgium Tel: 0032 51 480048
Fax: 51 485131
Yves Boonen/Dominiek Claerbout

EAC Technologies (JV with Astechnologies USA)
St Pieters Lieuw, Belgium
Tel: 0032 2 3710130 Fax 2 3780999
John Stoll

Grupo Antolin Irausa
Headliners – Madrid-Irun, Spain
Tel:0034 947 477700 Fax: 947 484363
Yolanda Gonzalez (Ingeneria Investigacion)

Midland Industrial Plastics (owned by US Textron Group)
Stourport-on-Severn, UK Tel: 01299 827676
Fax: 01299 827033
Richard Lindoe/Harry Harris

Collins & Aikmann
Newcastle-under-Lyme, UK
Tel: 01782 712299 Fax: 01782 715772
Phil Marks/Tony Pearce/Cliff Kemp

R-Tek (JV of Plastic Omnium, France & Japanese ownership)
Washington, UK Tel: 0191 415 7000
Fax: 0191 415 0063
John Stephenson

Automotive Insulations
Rugby, UK Tel: 01788 578300
Fax: 01788 579700
Peter & Robert Harris

Linpac Automotive
Billericay & Southend ,UK Tel: 01702 349481
Fax: 01702 343982
Ian Roberts/ David Barr/Tony Wallace

T-Mat Engineering
Loughborough, UK Tel: 01509 610099
Pete Stocks

Concargo, Western-Super-Mare
Tel: 01934 628221 Fax: 01934 417623
Mark Sudol

Perstorp
Trelleborg, Sweden Tel: 0046 410 40190
Dr Laurence Mott/Peter van Smirren

1.C. ACTUAL OR POSSIBLE PRODUCERS OF NATURAL FIBRE NONWOVENS

UK

Gaskell Textiles
Accrington Tel: 01254 872525
Fax: 01254 231166
Peter Forrester/Stuart Ainsworth/ Mike Pfeiffer

W E Rawson
Wakefield Tel: 01924 373421
Fax: 01924 290334
Mr Mycroft/Malcolm Roberts

J B Plant Fibres
Anglesey Tel: 01248 361129
Fax: 01248 355594
Gary Newman/James Bolton

Ledatec (Cosmopolitan Textile Group)
Blackburn Tel: 01254 56413
Fax: 01254 682723
Andrew Leather/Bob Worthington

John Cotton
Mirfield Tel: 01924 496571
Fax: 01924 498831
John Uttley

R A Irwin Co
Portadown Tel: 01762 336215
Fax: 01762 350310
Ian Irwin

BFF Nonwovens
Bridgewater Tel: 01278 428500
Fax: 01278 429499
John Abercrombie

Marling Industrial Felts
Stonehouse Tel: 01453 824444
Fax: 01453 821255
Brian Fuller

France

Tharreau Industries
Chemille Tel: 0033 241 715555
Fax: 241 715578
Michel Tharreau/Florence Vallat

Silac (Groupe Chaignaud)
La Rochefoucauld Tel : 0033 545 24020
Fax: 545 242089
M Constant/Bodo Meuter

Agrofibretextil/La Chanvriere de l'Aube
Troyes Tel: 0033 325 923192
Fax: 325 273542
M. Brunet

Belgium

Wattex
Buggenhout Tel: 0032 52 331111
Fax: 52 334655
Mr van Roy/Mr G Guns

Procotex Corpn
Gent Tel: 0032 9 2236436 Fax: 9 2240240
Yves Wuyts/M Douchy

Elco/EAC Technologies
Nonwoven producer/Moulder – see section 1B.

La Zeloise
Zele Tel: 0032 52 449241 Fax: 52 449248
Filip Haegens

FDR Automotive (recently had major fire – may be out of business)
Gent Tel: 0032 9 2261778 Fax: 9 2365104
M L Belpeer/Johann Plaetinck

Dexter International Corpn (US owned)
Brussels Tel: 0032 2 6750510 Fax: 2 6750363
Guy Lanier
Also operate plant for automotive industry in Sweden

Germany

Polyvlies Franz Beyer
Horstel-Bevergem Tel: 0049 5459 931040
Fax: 5459 931050
Thomas Guthe/Herr Hallaman
J J Marx
Lambrecht Tel: 0049 6325 9610
Fax: 6325 961183
Herr Maier

Oertel
Kulmbach Tel: 0049 9221 84094
Fax: 9221 2016
Harald Oertel

J H Ziegler
Achern Tel: 0049 7841 20270
Fax: 7841 202799
Peter Hartwig

Rowa Rothmund
Aalen Tel: 0049 7361 98720
Gunther Jagerhuber

Seeber Systemtechnik
Gernsbach Tel: 0049 7224 61301
Fax: 7224 61320
Herr Mickus

Tangerding
Bocholt & Nordlingen Tel: 0049 9081 50710
Fax: 9081 23687
Herr Hartle/Adolf Schneeweiss

Gebr Roders
Soltau Tel: 0049 5191 6040 Fax: 5191 60426
Peter Gronwald

Hildener Filz Produktion
Hilden Tel: 0049 2103 750

HVG Hanfprodukt Nord-West
Westerstede

Muhlmeier
Barnau Tel: 0049 9635 920200
Fax: 9635 920669
Herr Maubege

Austria

Funder Industrie
Kuhnsdorf Tel: 0042 32 4949191
Fax: 32 4949199
Wilhelm Bierbaumer/Hermann Gitschthaler
Funder also operate plants in Germany

Italy

Orsa (Crespi Group)
Goria, Varese Tel : 0039 0331 609111
Fax: 0331 604646
Alberto Baroni

Vigano Pavitex
Curno Tel : 0039 035 617979
Fax: 035 617940

ORV/Ovatex (Maurizio Peruzzo Group)
Grantorio Tel: 0039 049 9421600
Fax: 049 9490101
Mauro Montelli
The Peruzzo Group also owns the CTDMF plant in China, making automotive substrates

Texno
Briga Novarese Tel: 0039 0322 913600
Fax: 0322 956342
F Godi

Italfeltro
Prato Tel: 0039 0574 624101
Fax: 0574 624104
M Pini

NB:

This is a fast developing industry; therefore ownership of individual companies is changing as consolidation by the major players takes place.

1.D. MAJOR FIBRE PRODUCER/PROCESSORS

Hemcore (Hemp)
Great Dunmow Tel: 01279 504466
Fax: 01279 755395
John Hobson

British Fibre (Flax – Robin Appel)
Waltham Chase Tel: 01489 896300
Fax: 01489 896602
Harry Gilbertson

Flax UK (Flax – Lintex)
Kings Lynn
Robert Bateson

Swefibre (Flax)
Halmsted, Sweden Tel: 0046 430 17755
Fax: 430 17759
Jens Elmegren

APPENDIX IIA: EU Funded Projects

1.	Project No:	FAIR950195
	Title:	Annual Fibre Reinforced Polypropylene Composites for Industrial Applications: Development of a Quality Controlled Fibre Production Chain.
	Principal Contractor:	ATO-DLO Agrotechnological Research Institute, 6700 AA Wageningen, Netherlands Dr Thea Van Kemenade
	Duration:	01.12.1995 – 30.11.1998
2.	Project No:	FAIR950396
	Title:	Hemp for Europe – Manufacturing and Production Systems
	Principal Contractor:	Agricultural Development and Advisory Service (ADAS), Winchester SO21 1AP, United Kingdom Prof. H T H Cromack
	Duration:	01.02.1996 – 31.1.1999
3.	Project No:	FAIR983784
	Title:	Optimisation of the Production Chain for High Performance "Light Natural Sandwich Materials" (LNS) as a Basis for Scaling-up
	Principal Contractor:	Danish Institute of Agricultural Sciences, 8830 Tjele, Denmark Dr Kai-uwe Schwarz
	Duration:	01.07.1998 – 30.06.2001
4.	Project No:	FAIR983919
	Title:	New Functional Biopolymer – Natural Fibre – Composites from Agricultural Resources
	Principal Contractor:	Fraunhofer-Gesellschaft sur Forderung der angewandten Forschung e.V., 85354 Freising, Germany Dr Gregor Katzschner
	Duration:	01.06.1998 – 31.05.2001

5.	Project No: Title: Principal Contractor: Duration:	BRST970580 Development of Thermoplastic Composites Based on Upgraded Ligno-Cellulose Fibres for Improved Durability and their Processing for Components Atlas Acomfa B.V., 2210 GG Noordwijkerhout, Netherlands 01.10.1997 – 01.04.1998
6.	Project No: Title: Principal Contractor: Duration:	BRST965032 New Materials Deriving from Cellulosic Fibres, Agricultural Commodities and Waste Tecnologia Materiali Compositi Srl, 80022 Arzano Napoli, Italy Gennaro Pedato 01.01.1997 – 31.12.98
7.	Project No: Title: Principal Contractor: Duration:	BRST970597 The Use of Hemp in Cars Polyvies GmbH & Co KG, 48472 Horstel-Bevergen, Germany Franz Beyer 01.10.1997 – 01.04.1998
8.	Project No: Title: Principal Contractor: Duration:	BRPR980766 Nonwovens Forming Process with Spunlaced Fibres & New System (h/w & s/w) to Achieve such a Process Comerio Ercole Spa, 21052 Busto Arsizio, Italy Renato Lualdi 01.09.1998 – 31.08.2001
9.	Project: Title: Principal Contractor: Duration:	BRPR950039 Production of Fibreboard Through High-Speed Refining, Double-Wire Pressing & High-level Intelligent Control Funder Industrie GmbH, 9300 St Veit-Glan, Austria 01.12.1995 – 31.12.1998

10.	Project No: Title: Principal Contractor: Duration:	CRI75091/BRE21269 New Materials Deriving from Cellulosic Fibers Crops, Agricultural Commoddities and Wastes Tecnologia Materiali Compositi Srl, 80022 Arzano, Napoli 01.05.1994 – 31.07.1994
11.	Project No: Title: Principal Contractor: Duration:	CRI44691/BRE21140 Structural Resin Transfer Moulding (SRTM) of Reinforced Phenolics Research Consultants Ltd, Melton Mowbray, LE14 2UX, United Kingdom 01.05.1994 – 31.07.1994
12.	Project No: Title: Principal Contractor: Duration:	FMB1972376 Development of High Quality Engineering Materials Based on Natural Fibre Composites by Optimising the Interface Characteristics Imperial College of Science Technology and Medicine, London SW7 2BP, United Kingdom 27.10.1997 – 26.10.1999
13.	Project No: Title: Principal Contractor: Duration:	AGRE0050 Fibre and Pulp Production from Unconventional Biomass Fibre-Plastic Blending Trials and Applications Centro Ricerche Fiat Spa, 10043 Orbassano, Italy Augusto Balestrini 01.07.1991 – 30.06.1994
14.	Project No: Title: Principal Contractor: Duration:	AIR3-CT94-2000 High Performance Biocomposites with Improved Durability and Dimensional Stability from Non-Toxic Chemically Modified Lignocellulosic Fibres Chalmers University of Technology Department, Forest Products, Sweden Prof. Rune Simonson 01.12.1994 – 30.11.1997

APPENDIX IIB: Authoritative summary of published research and technical/academic sources of information on the use of natural fibres (flax, hemp, kenaf, jute) in the automotive industry in the German speaking countries (Germany, Austria, Switzerland)

Summary of published research and technical/academic sources:

(I) Publicly funded R&D projects

1.	**Authority & Funding:**	**BML – Bundesministerium fur Ernahrung, Landwirtschaft und Forsten, Bonn (GERMANY)** **FNR – Fachagentur Nachwachsend Rohstoffe, Gulzow (GERMANY)**
	Project No.:	**0319442A**
	Original Title:	Einsatz von Flachs in Reibebelagen. Teilvorhaben: Entwicklung und Erprobung von Verfahren zur chemischen und thermischen Vorbehandlung von Flachsfasern fur den Einsatz in Brems- und Kupplungsbelagen.
	Translated Title:	Use of flax fibres in friction linings. Partial project: Development and testing of chemical and thermal pre-treatment methods of flax fibres for use in brake and clutch linings.
	Principle Contractor:	ECCO Gleittechnik GmbH, Mr Hensel, Seeshaupt
	Duration:	01.03.1990 – 28.02.1993
	Objectives and Results:	Production of modified short staple fibres from flax fibres for application in friction linings using different chemical-physical pre-treatment. Suitable types of flax fibres were developed which satsify the requirements for friction linings. Additionally, specific testing equipment for brake tests was developed.
2.	**Authority & Funding:**	**BML – Bundesministerium fur Ernahrung, Landwirtschaft und Forsten, Bonn (GERMANY)** **FNR – Fachagentur Nachwachsende Rohstoffe, Gulzow (GERMANY)**
	Project No.:	**0319442B**
	Original Title:	Einsatz von Flachs in Reibebelagen. Teilvorhaben: Einsatz von Flachsfasern in PKW-Trommelbremsen.
	Translated Title:	Use of flax fibres in friction linings. Partial project: Use of flax fibres in drum brakes for automotive applications.
	Principle Contractor:	Rutger Pagid AG, Dr Melcher, Essen
	Duration:	01.07.1990 – 30.06.1993

	Objectives & Results:	Use of flax fibres in friction linings and drum brake linings. Development of substitutes for currently used fibres such as glass, mineral, and acrylonitrile fibres. Forty different types of flax fibres were characterised and tested in drum brake linings. Nine suitable drum brake linings were then field tested in automobiles and one quality – close to industrial manufacturing quality – was chosen as a sample for the automotive industry.
3.	**Authority & Funding:**	**BML – Bundesministerium fur Ernahrung, Landwirtschaft und Forsten, Bonn (GERMANY)** **FNR – Fachagentur Nachwachsende Rohstoffe, Gulzow (GERMANY)**
	Project No.:	**0319442C**
	Original Title:	Einsatz von Flachs in Reibebelagen. Teilvorhaben: Verwendbarkeit von Flachs in Scheibenbremsbelagen.
	Translated Title:	Use of flax in friction linings. Partial project: Suitability of flax fibres in disk brake linings.
	Principle Contractor:	TEXTAR GmbH, Dr Gondrum, Leverkusen
	Duration:	01.07.1990 – 30.06.1994
	Objectives & Results:	Use of untreated or modified flax fibres in composites as a substitute for organo-synthetic fibres (polyaramide) for use in friction lining of disk brakes. Generally, flax fibres are suitable for use in disk brake linings. However, inadequate abrasion performance and the substantive investment requirements in testing systems and processing technologies constitute barriers to scale-up and mass production.
4.	**Authority & Funding:**	**BML – Bundesministerium fur Ernahrung, Landwirtschaft und Forsten, Bonn (GERMANY)** **FNR – Fachagentur Nachwachsende Rohstoffe, Gulzow (GERMANY)**
	Project No.:	**0319442D**
	Original Title:	Einsatz von Flachs in Reibebelagen. Teilvorhaben: Eignungsuntersuchungen und Selektierung neu zu entwickelnder Faserprodukte auf Flachsbasis zur Verstarkung und Verbesserung der Prozesseigenschaften von Trommelbremsbelagen.
	Translated Title:	Use of flax fibres in friction linings. Partial project: Suitability tests and choice of new products based on flax fibres for reinforcement and performance improvement of drum brake linings.
	Principle Contractor:	FERODO BERAL GmbH, Dr Emmett, Marienheide
	Duration:	01.07.1990 – 31.12.1994

	Objectives & Results:	Development of large-scale drum brake linings for commercial vehicles. All results (physical & mechanical properties, flammability, noise test, abrasion etc.) indicate that drum brake linings based on flax fibres show no performance advantages compared to conventional fibres. These results and the lack of any financial benefits make these products hardly acceptable for serial production.
5.	**Authority & Funding:**	**BML – Bundesministerium fur Ernahrung, Landwirtschaft und Forsten, Bonn (GERMANY)** **FNR – Fachagentur Nachwachsende Rohstoffe, Gulzow (GERMANY)**
	Project No.:	**0319442F**
	Original Title:	Einsatz von Flachs in Reibebelagen. Teilvorhaben: Untersuchung und Bewertung der Einsatzmoglichkeit von Flachs als Armierungs- und Prozessfaser bei armierten und regellosen, organisch gebundenen Kupplungsbelagen.
	Translated Title:	Use of flax in friction linings. Partial project: Investigation and evaluation of the suitability of flax fibres for reinforcement in armoured and irregular, organically bonded clutch linings.
	Principle Contractor:	RAYBESTOS – Industrie-Produkte GmbH, Dr Lawatsch, Morbach
	Duration:	01.05.1991 – 31.12.1995
	Objectives & Results:	Use of flax fibres and flax yarns for development of asbestos-free clutch linings. The level of abrasion – especially at high temperatures – was 2.5 times higher than with conventional fibres. Despite the use of flame retardants no reduction of abrasion could be achieved. Overall, the results are promising, but additional experiments are necessary regarding the improvement of properties.
6.	**Authority & Funding:**	**BML – Bundesministerium fur Ernahrung, Landwirtschaft und Forsten, Bonn (GERMANY)** **FNR – Fachagentur Nachwachsende Rohstoffe, Gulzow (GERMANY)**
	Project No.:	**0310027A**
	Original Title:	Einsatz von Flachs in faserverstarkten Kunststoffen und Biopolymeren. Teilvorhaben: Modifizierung von mechanisch aufgeschlossenen Flachskurzfasern fur den Einsatz in faserverstarkten Kunststoffen.
	Translated Title:	Use of flax in fibre-reinforced plastics and biopolymers. Partial project: Modification of mechanically processed short staple flax fibres for the use in reinforced plastics.
	Principle Contractor:	Thuringisches Institut fur Textil- und Kunststoffverarbeitung e.V. (TITK), Dr Mieck, Rudolstadt

	Duration:	01.02.1992 – 31.01.1995
	Objectives & Results:	Modification of mechanically processed flax fibres regarding their flotation properties and suitability for extrusion processes. Development of physical and chemical treatments for enhanced bond strengths of flax fibre composites. The report does not list any results regarding the suitability of flax fibres for extrusion processes. Instead, needle-punched flax fibre mats were produced. Trials with different surface pre-treatments of the mats – with silanes or polypropylene – lead to better bond strengths of the composites compared to untreated mats. Final results: Strength and stiffness of the flax fibre composites were comparable to glass fibre composites.
7.	**Authority & Funding:**	**BML – Bundesministerium fur Ernahrung, Landwirtschaft und Forsten, Bonn (GERMANY)** **FNR – Fachagentur Nachwachsende Rohstoffe, Gulzow (GERMANY)**
	Project No.:	**0319490B**
	Original Title:	Einsatz von Flachs in faserverstarkten Kunststoffen und Biopolymeren. Teilvorhaben: Untersuchungen zum Herstellen und Verarbeiten von flachsfaserverstarkten Kunststoffen.
	Translated Title:	Use of flax fibres in reinforced plastics and biopolymers. Partial project. Investigation of production and processing of flax fibre-reinforced plastics.
	Principle Contractor:	RWTH Aachen, Prof Dr Michaeli, Aachen
	Duration:	01.02.1992 – 31.01.1995
	Objectives & Results:	Modification of processing technologies for flax fibre-reinforced plastics to improve the properties of semi-finished and finished products. A) Reinforcement of thermoplasts (polypropylene): Flax fibre ribbons (card slivers) were fed through a modified twin-screw extruder. Results regarding tensile strength, bond strength, and elastic modulus of the reinforced plastics were promising. B) Reinforcement of duroplasts (epoxy resin): the “bulk moulding compound” (BMC) technology was found a suitable technique for the production and processing of flax fibre reinforced duroplasts.
8.	**Authority & Funding:**	**BML – Bundesministerium fur Ernahrung, Landwirtschaft und Forsten, Bonn (GERMANY)** **FNR – Fachagentur Nachwachsende Rohstoffe, Gulzow (GERMANY)**
	Project No.:	**0310102A**

	Original Title:	Einsatz von Flachs in faserverstarkten Kunststoffen und Biopolymeren. Teilvorhaben: Biologisch abbaubare, flachsfaserverstarkte Polymerwerstoffe auf der Basis nachwachsender Rohstoffe (Aufbereitung).
	Translated Title:	Use of flax fibres in reinforced plastics and biopolymers. Partial project: Biodegradable flax fibre reinforced plastics based on renewable resources (processing).
	Principle Contractor:	Universitat Stuttgart, Prof Dr Fritz, Stuttgart
	Duration:	01.04.1992 – 31.10.1995
	Objectives & Results:	Development of a suitable processing technology for biodegradable reinforced plastics based on flax fibres and starch. Evaluation of the properties of flax fibre starch composites. An equipment configuration for the production of "thermoplastic starch" (TPS) flax fibre composites was developed. Particularly the inhomogeneous distribution of flax fibres lead to a low bond strength of the investigated composites.
9.	**Authority & Funding:**	**BML – Bundesministerium fur Ernahrung, Landwirtschaft und Forsten, Bonn (GERMANY)** **FNR – Fachagentur Nachwachsende Rohstoffe, Gulzow (GERMANY)**
	Project No.:	**10544A**
	Original Title:	Einsatz von Flachs in faserverstarkten Kunststoffen und Biopolymeren. Teilvorhaben: Entwicklung eines statisch belastbaren Refenzformteils aus flachsfaserverstarkten Duromeren.
	Translated Title:	Use of flax in reinforced plastics and biopolymers. Partial project: Development of a statically robust composite from flax fibre reinforced duroplasts.
	Principle Contractor:	Kunststoffe Werner Thieme GmbH & Co. KG. Dr Kapischke, Teningen
	Duration:	01.01.1993 – 31.12.1995
	Objectives & Results:	Use of flax fibres for reinforced duroplasts (foamed polyurethane and epoxy resin). Sandwich composites were produced from flax fibre mats from another project (TITK – No. 0310027A) with a modified "resin-transfer-moulding" (RTM) technique. The final results indicated good bond strength of the composites.
10.	**Authority & Funding:**	**BML – Bundesministerium fur Ernahrung, Landwirtschaft und Forsten, Bonn (GERMANY)** **FNR – Fachagentur Nachwachsende Rohstoffe, Gulzow (GERMANY)**
	Project No.:	**10545A**

	Original Title:	Einsatz von Flachs in faserverstarkten Kunststoffen und Biopolymeren. Teilvorhaben: Naturfaserverstarkte Kunststoffe fur automobil-technische Anwendungen.
	Translated Title:	Use of flax fibre in reinforced plastics and biopolymers. Partial project: Reinforced plastics with natural fibres for applications in the automotive sector.
	Principle Contractor:	Daimler Benz AG, Dr Folster, Ulm
	Duration:	01.01.1993 – 31.12.1994
	Objectives & Results:	Development of a production technology for flax-fibre/polypropylene composites for automotive applications. A combined technology for extrusion and compression-moulding – the “EXPRESS Technology” was developed. The final results indicate similar properties of composites reinforced with flax fibre and glass fibre mats.
11.	**Authority & Funding:**	**BML – Bundesministerium fur Ernahrung, Landwirtschaft und Forsten, Bonn (GERMANY)** **FNR – Fachagentur Nachwachsende Rohstoffe, Gulzow (GERMANY)**
	Project No.:	**0310048A**
	Original Title:	Einsatz von Flachs in faserverstarkten Kunststoffen und Biopolymeren. Teilvorhaben: Mikromechanik und Mikrostrucktur der flachsfaserverstarkten Kunststoffe.
	Translated Title:	Use of flax fibres in fibre-reinforced plastics and biopolymers. Partial project: Micromechanics and microstructure of flax fibre reinforced plastics.
	Principle Contractor:	Technische Universitat Berlin, Prof Dr Hinrichsen, Berlin
	Duration:	01.02.1992 – 31.01.1995
	Objectives & Results:	Investigation of the physical properties and surface characteristics of flax fibres and fibre-reinforced composites. Improvement of the fibre-matrix bond strength and optimisation of the film-stacking technology. Treatment of flax fibres with maleic anhydride-treated polypropylene and silane resulted in increased shearing strength. Additionally, moulding temperatures of 190^{o}C combined with a moulding pressure of 75 bar (flax-fibre content of 35%) increased the tensile strength of the composites.
12.	**Authority & Funding:**	**BML – Bundesministerium fur Ernahrung, Landwirtschaft und Forsten, Bonn (GERMANY)** **FNR – Fachagentur Nachwachsende Rohstoffe, Gulzow (GERMANY)**
	Project No.:	**96NR062-F**

	Original Title:	Optimierung der Produktion, der Verwertung und des Recycling von technisch nutzbarem Kurzfaserlein. Teilvorhaben: Entwicklung und Optimierung von Verarbeitungsverfahren zur Herstellung flachsfaserverstarkter Kunststoffbauteile.
	Translated Title:	Optimisation of production, utilisation, and recycling of short-staple flax fibres for technical uses. Partial project: Development and optimisation of the processing technology for the production of flax fibre-reinforced components.
	Principle Contractor:	Daimler Benz AG, Dr Knothe, Ulm
	Duration:	01.08.1996 0 31.05.1999
	Objectives & Results:	Continuation of project 10545A. Optimisation of processing technologies for composites based on nonwoven natural-fibre mats, such as the “sheet-moulding-compound” (SMC) or the “EXPRESS Technology”. Development of a new technology for the production of natural-fibre reinforced granulates for injection moulding. Flax fibre mats with defined properties were tested with different moulding techniques (SMC, EXPRESS). Additionally, a variety of technologies for the production of granulates were tested.
13.	**Authority & Funding:**	**BML – Bundesministerium fur Ernahrung, Landwirtschaft und Forsten, Bonn (GERMANY)** **FNR – Fachagentur Nachwachsende Rohstoffe, Gulzow (GERMANY)**
	Project No.:	**96NR062-F**
	Original Title:	Optimierung der Produktion, der Verwertung und des Recycling von technisch nutzbarem Kurzfaserlein. Teilvorhaben: Vliesherstellung.
	Translated Title:	Optimisation of production, utilisation, and recycling of short staple flax fibres for technical uses. Partial project: Production of nonwoven mats.
	Principle Contractor:	Tangerding Sud GmbH & Co. KG, Mr Kern, Nordlingen
	Duration:	01.08.1996 – 31.12.1998
	Objectives & Results:	Adaption of the processing technology for the production of nonwovens from flax fibres. Determination of the basic correlation between fibre quality, processing parameters, and the properties of nonwovens. At present, no results are available.
14.	**Authority & Funding:**	**BML – Bundesministerium fur Ernahrung, Landwirtschaft und Forsten, Bonn (GERMANY)** **FNR – Fachagentur Nachwachsende Rohstoffe, Gulzow (GERMANY)**
	Project No.:	**93NR105-F**
	Original Title:	Einsatz von Flachs fur Duromer-Formteile.

	Translated Title:	Use of flax fibres for duroplasts.
	Principle Contractor:	(1) Schock GmbH, Schorndorf (2) Fachhochschule fur Technik und Wirtschaft, IAF – Institut fur angewandte Forschung Reutlingen, Prof Dr Kohler, Reutlingen.
	Duration:	01.11.1995 – 31.10.1998
	Objectives & Results:	Production of finished and semi-finished, flax-fibre reinforced acrylic resin components. Adaptation and modification of the processing technology and the natural properties of flax fibres. The final tests indicate that the best results – regarding the mechanical properties (particularly bond strength) – can be achieved with DDA (steam-explosion)-treated, very fine flax fibres.
15.	**Authority & Funding:**	**BML – Bundesministerium fur Ernahrung, Landwirtschaft und Foresten, Bonn (GERMANY)** **FNR – Fachagentur Nachwachsende Rohstoffe, Gulzow (GERMANY)**
	Project No.:	**95NR053-F**
	Original Title:	Anbau, Ernte und Aufbereitung sowie Verwendung von Hanf.
	Translated Title:	Cultivation, harvesting, processing and use of hemp.
	Principle Contractor:	Universitat Kiel, Prof Dr Hanf, Kiel
	Duration:	01.09.1995 – 31.05.1996
	Objectives & Results:	Investigation of the technical and economical conditions for sustainable cultivation, processing, and use of industrial hemp in Germany. The study concluded that about 10% of the total use of technical fibres in the automotive sector in Germany could be replaced with hemp fibres within the next 10 years. In that case, to satisfy demands, ca. 8,000-10,000 ha needed to be cultivated in Germany.
16.	**Authority & Funding:**	**BML – Bundesministerium fur Ernahrung, Landwirtschaft und Forsten, Bonn (GERMANY)** **FNR – Fachagentur Nachwachsende Rohstoffe, Gulzow (GERMANY)**
	Project No.:	**96NR050-F**
	Original Title:	Verbundvorhaben: Strukturoptimierte naturfaserverstarkte geschaumte und ungeschaumte Polymere fur hoher belastbare, leichte Fahrzeuginnenbauteile. Teilvorhaben 1: Verbund- und Bauteilentwicklung.
	Translated Title:	Combined project: Optimised structures of foamed and non-foamed, reinforced natural-fibre polymers for chargeable and light weight automotive components. Partial project 1: Composites and components.
	Principle Contractor:	Universitat Gesamthochschule Kassel – Institut fur Werkstofftechnik, Kunststoff- und Recyclingtechnik, Prof Dr Bledzki, Kassel
	Duration:	01.08.1997 – 31.07.2000

	Objectives & Results:	Not yet available (will include the development of composites and components for automotive applications). At present, no results are available.
17.	**Authority & Funding:**	**BML – Bundesministerium fur Ernahrung, Landwirtschaft und Forsten, Bonn (GERMANY)** **FNR – Fachagentur Nachwachsende Rohstoffe, Gulzow (GERMANY)**
	Project No.:	**97NR050-F**
	Original Title:	Verbundvorhaben: Strukturoptimierte naturfaserverstarkte geschaumte und ungeschaumte Polymere fur hoher belastbare, leichte Fahrzeuginnenbauteile. Teilvorhaben 2: Cellulosische Verstarkungsfasern.
	Translated Title:	Combined project: Optimisation of structures of foamed and non-foamed reinforced natural fibre polymers for chargeable and light-weight automotive components. Partial project 2: Cellulosic fibres for reinforcement.
	Principle Contractor:	Fraunhofer Gesellschaft – Institut fur Angewandte Polymerforschung, Dr Fink, Teltow
	Duration:	01.08.1997 – 31.07.2000
	Objectives & Results:	Not yet available (will include the investigation of cellulosic fibres for automotive applications).
18.	**Authority & Funding:**	**BML – Bundesministerium fur Ernahrung, Landwirtschaft und Forsten, Bonn (GERMANY)** **FNR – Fachagentur Nachwachsende Rohstoffe, Gulzow (GERMANY)**
	Project No.:	**97NR051-F**
	Original Title:	Verbundvorhaben: Strukturoptimierte naturfaserverstarkte geschaumte und ungeschaumte Polymere fur hoher belastbare, leichte Fahrzeuginnenbauteile. Teilvorhaben 3: Bauteilfertigung.
	Translated Title:	Combined project: Optimised structures of foamed and non-foamed reinforced natural fibre polymers for chargeable and light-weight automotive components. Partial project 3: Production of components.
	Principle Contractor:	Johnson Controls Interiors GmbH, Dr Promper, Grefrath
	Duration:	01.08.1997 – 31.07.2000
	Objectives & Results:	Not yet available (will include the production of components for automotive applications).

19.	**Authority & Funding:**	**BML – Bundesministerium fur Ernahrung, Landwirtschaft und Forsten, Bonn (GERMANY)** **FNR – Fachagentur Nachwachsende Rohstoffe, Gulzow (GERMANY)**
	Project No.:	**97NR066-F**
	Original Title:	Leichtbau-Konstrucktionsbauteile auf Basis von Polymer/Flachs- bzw. Polymer/Hanf-Verbunden.
	Translated Title:	Light-weight construction based on polymer-flax or polymer-hemp composites.
	Principle Contractor:	Fraunhofer Institut fur Zuverlassigkeit und Mikrointegration, Prof Dr Bauer, Teltow
	Duration:	01.01.1999 – 31.12.2000
	Objectives & Results:	Not yet available.
20.	**Authority & Funding:**	**BML – Bundeesministerium fur Ernahrung, Landwirtschaft und Forsten, Bonn (GERMANY)** **FAL – Forschungsanstalt fur Landwirtschaft, Braunschweig (GERMANY)**
	Project No.:	**201070940005**
	Original Title:	Aufbereitung von Flachs aund anderen Naturfasern fur technische Anwendungen u.a. in Faserverbundwerkstoffen.
	Translated Title:	Processing of flax and other natural fibres for technical applications in fibre-reinforced composites.
	Principle Contractor:	Institut fur Technolgie der Bundesforschungsanstalt fur Landwirtschaft, Mr Vorlop, Mr Dernedde, Braunschweig-Volkenrode
	Duration	1994 – 1997
	Objectives & Results:	Investigation of the correlation of harvesting technology, processing technology, the final fibre quality and suitability of fibres for technical applications. The properties of natural fibres, e.g. flax fibres and other natural fibres, were tested regarding their suitability for composite-materials. Furthermore approaches of surface-modification of natural fibres were explored and evaluated by microscopic examination.
21.	**Authority & Funding:**	**Land Bayern (District Bavaria) (GERMANY)**
	Project No.:	**FZ00004**
	Original Title:	Lieferung von Flachsstroh zu Versuchszwecken.
	Translated Title:	Supply of flax straw for testing.
	Principle Contractor:	(1) Bayerische Flachsproduktion Management GmbH, Merching (2) EMPE-Werke GmbH, Geretsried.
	Duration:	1991
	Objectives & Results:	Processing of flax straw for use in technical applications, particularly for automotive components. No results are available.

22.	**Authority & Funding:**	**Land Bayern (District Bavaria) (GERMANY)**
	Project No.:	**FZ00007**
	Original Title:	Entwicklung von Formteilen aus Flachsfaservliesen fur den Autombilinnenausbau.
	Translated Title:	Development of moulded components based on nonwoven flax fibre mats for automotive interiors.
	Principle Contractor:	EMPE-Werke GmbH, Geretsried
	Duration:	1991 – 1993
	Objectives & Results:	Development of a processing technology for the production of automotive components based on nonwoven flax fibre mats. No results are available.
23.	**Authority & Funding:**	**Land Bayern (District Bavaria) (GERMANY)**
	Project No.:	**FZ00008**
	Original Title:	Erschlieβung des technischen Marktes fur Flachs, Entwicklung von Flachsfaservliesen fur die Formteilherstellung zur Verwendung im Automobil-Innenausbau.
	Translated Title:	Development of a market for technical applications of flax fibres, production of nonwoven flax fibre mats for moulded components automotive interiors.
	Principle Contractor:	(1) B. und J. Vliesstoff GmbH, Memmingen (2) EMPE- Werke GmbH, Geretsried.
	Duration:	1991 – 1993
	Objectives & Results:	Investigation of the potential flax fibres in automotive compnents. Development of a suitable processing technology for the production of nonwoven flax fibre mats and development of new applications. Production of flax-fibre reinforced components. No results are available.
24.	**Authority & Funding:**	**C.A.R.M.E.N. – Centrales Agrar-Rohstoff-Marketing- und Entwicklungs-Netzwerk, Rimpar (District Bavaria) (GERMANY)**
	Project No.:	
	Original Title:	Flachsfaservliese im Automobilinnenausbau.
	Translated Title:	Nonwoven flax fibre mats for automotive interiors.
	Principle Contractor:	EMPE FINDLAY INDUSTRIES GmbH, Geretsried
	Duration:	Since 1996
	Objectives & Results:	Design and construction of a flax-fibre processing line for automotive components for the new BMW 3-series in Nordhalben (Bavaria). Improvement of the use of new sustainable raw materials and technologies as well as sustaining and creating jobs in Bavaria. Regional aids in the amount of DM 1.4 mio. were spent for the design and construction of a production facility for automotive components (total investment DM 8.5 Mio.) with an output capacity of 1.3 mio.kg flax fibres per year. Twenty-five new jobs were created.

25.	**Authority & Funding:**	**Land Sachsen (District Saxony) (GERMANY)**
	Project No.:	**LD-SS/1.1.5 (FZ00291)**
	Original Title:	Technische Vliesstoffe aus Flachs.
	Translated Title:	Nonwoven flax fibre mats for technical applications.
	Principle Contractor:	Sachsische Faser- und Werkstoffrecycling GmbH, Neukirchen
	Duration:	1992 – 1994
	Objectives & Results:	Not available.
26.	**Authority & Funding:**	**Land Brandenburg (District Bradenburg) (GERMANY)**
	Project No.:	
	Original Title:	Faserverstarkte Kunststoffe fur den Leichtbau in Brandenburg, vorzugsweise fur den Fahrzeug- (und Flugzeug-)bau.
	Translated Title:	Reinforced plastics for light-weight constructions in Brandenburg, especially for applications in automotives and aeroplanes.
	Principle Contractor:	Fraunhofer Institut fur Angewandte Materialforschung, Teltow
	Duration:	1997 – 2000
	Objectives & Results:	Development of light-weight construction materials also based on natural fibres for components in tautomotives and aeroplanes. At present, no results are available.
27.	**Authority & Funding:**	**Land Baden-Wurttemberg (District Baden-Wurttemberg) (GERMANY)**
	Project No.:	**LD-BA-WUE-ML 22-89.45 (FZ00663)**
	Original Title:	Einsatzmoglichkeiten von Flachs im nichttextilen Bereich – Naturfaserverbundwerkstoffe.
	Translated Title:	Potential for the use of flax in non-textile applications – natural-fibre reinforced composites.
	Principle Contractor:	IAF – Institut fur Angewandte Forschung Reutlingen, Prof Dr Wurster, Reutlingen.
	Duration:	1989 – 1991
	Objectives & Results:	Investigation of the properties of flax fibres compared to cotton, glass, carbon, and aramide fibres. Investigation of suitable applications for flax fibres. Results are not available.
28.	**Authority & Funding:**	**Land Schleswig-Holstein (District Schleswig-Holstein) (GERMANY)**
	Project No.:	**FZ00825**
	Original Title:	Verwendung von Flachsfasern als Erganzung zu Glasfasern beim Einsatz in Polyesterharzen, insbesondere in Hinblick auf das Abwicklungsverhalten in Fasermatten.
	Translated Title:	Addition of flax fibres to glass fibres in polyester resin, particularly with respect to the performance in nonwoven fibre mats.

	Principle Contractor:	(1) Holstein Flachs GmbH, Mr Heger, Mielsdorf (2) Fachhochschule Kiel, Kiel
	Duration:	1991
	Objectives & Results:	Not available.
29.	**Authority & Funding:**	**Land Niedersachsen (District Lower Saxony) (GERMANY)**
	Project No.:	
	Original Title:	Hanffasererzeugung fur Fahrzeugbauteile. Qualitatsmanagement und Qualitatssicherung bei der Hanferzeugung und –aufbereitung.
	Translated Title:	Hemp fibre for automotive components. Quality management and quality assurance in production and processing of hemp fibre.
	Principle Contractor:	(1) Johnson Control Interiors GmbH, Dr Promper, Grefrath (2) DLR – Deutsches Zentrum fur Luft – und Raumfahrt e. V., Mr Riedel, Braunschweig (3) FIBRE – Faserinstitut Bremen e. V., Prof Dr Harig, Bremen
	Duration:	1995 – 1998 (with DLR) 1999 – 2001 (with FIBRE)
	Objectives & Results:	Not available.
30.	**Authority & Funding:**	**Land Niedersachsen (District Lower Saxony) (GERMANY)**
	Project No.:	
	Original Title:	RIKO – Realisierung innovativer Konstruktionswerkstoffe aus nachwachsenden Rohstoffen.
	Translated Title:	RIKO – Development of innovative construction materials based on renewable resources.
	Principle Contractor:	(1) INVENT GmbH, Braunschweig (2) Sauer & Sperlich Consulting GmbH, Gottingen
	Duration:	1998 – 2001
	Objectives & Results:	Support for development and market penetration of innovative materials based on renewal resources, e.g. development of a communication platform (data collection and dissemination of results via an internet service centre), development of research projects, and consulting activities for companies.
31.	**Authority & Funding:**	**Land Nordrhein-Westfalen (District North Rhine-Westphalia) (GERMANY)**
	Project No.:	
	Original Title:	Optimierung der Faserqualitat von Hanf fur den Einsatz bei technischen Teilen (Verbundwerkstoffe) und Dammstoffe.
	Translated Title:	Optimisation of the fibre quality of hemp for use in technical parts (composites) and insulation materials.
	Principle Contractor:	Moller Plast GmbH, Mr Beckmann, Bielefeld

	Duration:	01.07.1999 – 30.06.2001
	Objectives & Results:	Not available.
32.	**Authority & Funding:**	**DBU – Deutsche Bundesstiftung Umwelt, Osnabruck (GERMANY)**
	Project No.:	
	Original Title:	Das Hanfproduktlinienprojekt (HPLP) – Erarbeitung von Produktlinien auf Basis von einheimischem Hanf aus technischer, okonomischer und okologischer Sicht.
	Translated Title:	The Hemp Product Line Project – development of product lines based on German hemp – technical, economical and ecological aspects.
	Principle Contractor:	Nova-Institut GmbH, Mr Karus, Hurth
	Duration:	1996
	Objectives & Results:	Identification of product lines based on German hemp with the greatest prospects for short and medium term implementation under economic, technical and environmental considerations. The study concluded that German hemp fibres for automotive applications may be produced for 0.50-0.60 Euro per kg. At this price, hemp fibres are competitive with other natural fibres and also synthetic fibres for automotive interior applications – under economical as well as technical aspects. The study anticipates that within a time period of about five years about 4,000 tons of fibres per year could be replaced with hemp fibres in the automotive sector.
33.	**Authority & Funding:**	**DBU – Deutsche Bundesstiftung Umwelt, Osnabruck (GERMANY)**
	Project No.:	
	Original Title:	Die Fasernessel (*Urtica dioica* L.) als nachwachsender Rohstoff zur Substitution von Flasfasern bei verstarkten Kunststoffteilen.
	Translated Title:	Nettle fibres (*Urtica dioica* L.) as a renewable resource for the substitution of glass fibres in reinforced plastics.
	Principle Contractor:	(1) Julius Heywinkel GmbH. Osnabruck (2) Thuringisches Institut fur Textil- und Kunststoff-Forschung, Dr Mieck, Rudolstadt (3) Universitat Hamburg, Institut fur Angewandte Botanik, Hamburg
	Duration:	01.07.1996 – 30.06.1999
	Objectives & Results:	Not yet available.
34.	**Authority & Funding:**	**DBU – Deutsche Bundesstiftung Umwelt, Osnabruck (GERMANY)**
	Project No.:	
	Original Title:	Substitution von Glasfasen in Spritzgieβteilen durch Pflanzenfasern – Aufbau einer technologischen Linie.

	Translated Title:	Substitution of glass fibres in injection moulded parts with plant fibres – set up of a technological (processing) line.
	Principle Contractor:	(1) Sprengstoffwerk Gnaschwitz (MOLAN-Gruppe), Schlungwitz (2) Carl Pohl Textil- und Thermplastenherstellung, Forst (3) Universitat Halle-Wittenberg, Halle-Wittenberg
	Duration:	01.03.1999 – 28.02.2002
	Objectives & Results:	Development of a technology for the processing and production of injection moulded parts reinforced with hemp and flax fibres. At present, no results are available.
35.	**Authority & Funding:**	**BLW – Bundesamt fur Landwirtschaft (SWITZERLAND)**
	Project No.:	
	Original Title:	Biologisch abbaubare Verbundwerkstoffe.
	Translated Title:	Biodegradable composites.
	Principle Contractor:	FAT – Eidgenossische Forschungsanstalt fur Agrarwirtschaft und Landtechnik, Mr Keller, Tanikon (CH)
	Duration:	1999 – 2000
	Objectives & Results:	Improvement of the fibre-matrix bonding strength between natural fibres and bioplastics. Adaptation of existing processing lines for plant fibres and the development of new processing technologies. Currently the final results are not available.
36.	**Authority & Funding:**	**BLW – Bundesamt fur Landwirtschaft (SWITZERLAND)**
	Project No.:	
	Original Title:	Maktanalyse fur Faserprodukte aus Chinaschilf, Flachs, Hanf und Kenaf in der Scheweiz.
	Translated Title:	Market analysis for fibre products based on miscanthus, hemp and kenaf in Switzerland.
	Principle Contractor:	(1) FAL – Eidgenossische Forschungsanstalt fur Agrarokologie und Landbau, Mr Mediavilla, Zurich (CH) (2) Institut fur Umweltschutz und Landwirtschaft, Lieberfeld-Bern (CH)
	Duration:	1999
	Objectives & Results:	Finally the study indicates that in Switzerland is actually no market for natural fibres in the automotive sector. Due to the fact that in Switzerland is no separation plant respectively no processing line for flax or hemp for automotive applications there is actually no supply and also no demand for natural fibres in the automotive sector. The study forecast a short-term market potential of 1,000 to 1,600 t/a for reinforced plastics and composites in 2002.

APPENDIX 11C: CFC/IJO Projects

1.	Project No:	
	Title:	Jute-based Composites for Packaging and automotive Applications
	Principal Contractor:	AEA Technology Ltd, Harwell, United Kingdom Dr Roger Davidson
	Duration:	01.10.1994 – 30.06.1998
	Objectives & Results:	Part of their work programme included the development of a resin-impregnated thermoset jute parcel tray for the Ford Transit, in conjunction with Concargo Ltd, Weston-super-Mare and J B Plant Fibres, Anglesey
2.	Project No:	
	Title:	Development of Pilot-Line Technology
	Principal Contractor:	ATO/DLO, Wageningen, Netherlands Dr Martin Snijder
	Duration:	01.10.1994 – 30.06.1998
	Objectives & Results:	Development of pilot-line technology for granulation techniques using up to 40% short staple jute fibre with polypropylene for injection mouldings in packaging, and potentially automotive applications
3.	Project No:	
	Title:	Development and Commercialisation of Jute-based Nonwovens
	Principal Contractor:	The Textile Consultancy Ltd, Dalgety Bay, United Kingdom, in association with BTTG, Manchester, United Kingdom E Philip Eddleston
	Duration:	01.06.1996 – 31.12.1999
	Objectives & Results:	The project included product developments in floorings, footwear components and thermoplastic automotive components – prototype blended substrates developed for European Tier 1 suppliers and scaled up into production by commercial nonwoven producers

APPENDIX 11D: Other Relevant Research and Technical/Academic Sources

Due to the fact that there are hundreds of sources in the field of natural fibre composites, only the most recent sources relevant to the automotive sector were summarized in the following chapter.

1.	**University/Institute or Company:**	**Audi AG, Ingolstadt (GERMANY)** **Technische Universitat Braunschweig – Institut fur Geookologie, Mr Flake** **Technische Universitat Munchen – Institut fur Energiewirtschaft und Kraftwerkstechnik, Dr Fleiβner**
	Authors:	Mr Fischhaber (Audi), Mr Wotzle (TU Braunscheig), Mr Wirth (TU Braunschweig), Mr Flake (TU Braunschweig), Mr Fleiβner (TU Munchen), Mr Oppermann (Seeber Systemtechnik KG), Mr Wirth (Seeber Systemtechnik KG).
	Original Title:	(1) Untersuchung und Bewertung der okologischen Vorteilhaftigkeit des Einsatzes von Automobilkomponenten aus nachwachsenden Rohstoffen. (Fischhaber/Flake/Fleiβner) *In: 2nd International Symposium "Werkstoffe aus nachwachsenden Rohstoffen" 01 September 1999 – 02 September 1999 in Erfurt.* (2) Anwendung von Naturfasern am Beispiel der Herstellung einer Innen-Seitenverkleidung fur den PKW Audi A3. (Oppermann/Wirth) *In: 2nd International Symposium "Werkstoffe aus nachwachsenden Rohstoffen." 01 September 1999 – 02 September 1999 in Erfurt.* (3) Vergleichende Lebensweganalyse von Verkleidungsbauteilen fur den Automobilbereich aus ABS-Spritzguβ und einem Naturfaserverbundwerkstoff. (Wotzle) *In: MarktInnovation Hanf – Verbundwerkstoffe mit Hanffasera.* *19 May 1999 in Bremen.* (4) Life cycle studies on hemp fibre reinforced components and ABS for automotive parts. (Wotzel/Wirth/Flake) *In: 2nd International Wood and Natural Fibre Composites Symposium. 28 June 1999 – 29 June 1999 in Kassel.*

	Translated Title:	(1) Investigation and evaluation of environmental benefits of automotive components based on renewable resources. (2) Use of natural fibres exemplary for the production of door panels for the Audi A3. (3) Comparative life-cycle-analysis of panel components for automobiles from ABS-epoxy-resin versus a natural fibre reinforced composite. (4) Life cycle studies on hemp-fibre reinforced components and ABS-epoxy-resin for automotive parts.
	Date:	(1) – (4) 1999
	Objectives & Results:	Investigation of the environmental characteristics of natural fibre composites (flax/hemp-polypropylene composites for the AUDI A3 and AUDI A4) in comparison to conventional components (e.g. injection-moulded ABS). Results indicate that natural fibre composites are environmentally preferable regarding the energy and resources consumption compared to conventional components.
2.	**University/Institute or Company:**	**Daimler Benz AG (respectively DaimlerChrysler AG, Stuttgart), Ulm (GERMANY)**
	Authors:	Mr Schloβer, Mr Knothe, Mr Schafer, Mr Kubler, Mr Diener
	Original Title:	(1) Naturfaserverstarkte Fahrzeugteile. (Schloβer/Knothe) *In: Kunststoffe 87, p. 1148-1152, 1997.* (2) Einsatz und Potential naturfaserverstarkter Kunststoffe in der Automobilindustrie. (Schafer) *In: FNR – Gulzower Fachgesprache "Nachwachsende Rohstoffe – Von der Forschung zum Markt" 25 May 1998 – 26 May 1998 in Gustrow.* (3) Anwendungspotentiale nachwachsender Rohstoffe in der Automobilindustrie. (Kubler) *In: 2. Handelsblatt Agrarkongreb. Zukunftsforum Agribusiness.* *27 May 1999 – 28 May 1999 in Berlin.* (4) Short natural fibre reinforced plastics in the interiors of automobiles-preparation and processing. (Schafer) *In: 2nd International Wood and Natural Fibre Composites Symposium. 28 June 1999 – 29 June 1999 in Kassel.* (5) Environmental comparison between NMT- and GMT-components. *In: 2nd International Wood and Natural Fibre Composites*

		Symposium. 28 June 1999 – 29 June 1999 in Kassel.
	Translated Title:	(1) Automotive Parts reinforced with natural fibres. (2) Use and potential of natural fibre reinforced plastics in the automotive industry. (3) Potential for use of renewable resources in the automotive industry. (4) Short natural fibre-reinforced plastics in the interiors of automobiles-preparation and processing. (5) Environmental comparison between NMT (NFRT)- and GMT (GRFT)-components.
	Date:	(1) 1997 (2) 1998 (3)-(5) 1999
	Objectives & Results:	The results demonstrate the suitability of plastics reinforcement with natural fibres for a variety of parts in various automotive applications. The range of potential applications includes large foamed panels for interiors and compact exterior structural parts. Despite the necessary increased amount of fibres, a definite weight reduction of the parts can be achieved. Depending on specifications of the part and its corresponding fibre/matrix ratio, a material-cost reduction of up to 25% may be achieved. Additionally, the use of natural fibres in fibre reinforced plastics considerably improves the recycling potential of the parts. Furthermore, the environmental comparison on NFRT (natural fibre reinforced thermoplasts) to GFRT (glass fibre reinforced thermolplasts) indicates advantages for natural fibre-reinforced components. In the future it will be essential to optimise the entire value-added chain to make large volume production feasible.
3.	**University/Institute or Company:**	**BMW AG, Munchen (GERMANY)**
	Author:	Mr Madlener
	Original Title:	Anwendung und Potentiale von Naturfasern im Automobil. *In: MarktInnovation Hanf – Verbundwerkstoffe mit Hanffasern.* *26 May 1999 – 27 May 1999 in Wolfsburg.*
	Translated Title	Use and Potential of natural fibres in automobiles.
	Date:	1999
	Objectives & Results:	At present, BMW uses various natural fibre reinforced components for automotive interiors in the BMW 5 and 3-series. So far, the experiences with natural fibre reinforced components are very positive. Advantages of natural fibres are the suitability for light-weight construction, good life-cycle-analysis, price and recycling

		advantages. The report strongly points out the demand for production optimisation in light of the inconstant and irreproducible quality of natural fibres.
4.	**University/Institute or Company:**	**Ford AG, Koln (GERMANY)**
	Author:	Dr Schmidt
	Original Title:	Untersuchung zum Einsatz hanffaserverstarkter Bauteile im Fahrzeugbau. *In: Zukunftsmarkt Nachwachsende Rohstoffe. 24 June 1999 in Saarbrucken.*
	Translated Title:	Investigations regarding the use of hemp fibre-reinforced components in automobiles.
	Date:	1999
	Objectives & Results:	Investigation of hemp fibres under technical and environmental considerations for the use in automotive components. Results of the life-cycle-analysis indicate environmental advantages for hemp fibre-reinforced components compared to glass fibre-reinforced components. Also, the testing of mechanical properties showed promising results. However, one of the biggest obstacles for the use of hemp fibres in interiors is their particular odour and the persisting drug-image of hemp (critical obstacle for the US market). In an odour test with an e-nose, the smell of hemp fibres in interiors was recognised. Currently, the use of hemp fibres is tested for an exterior application as a protective covering of the underside (cover undershield) of the new FOCUS.
5.	**University/Institute or Company:**	**Opel AG, Russelsheim (GERMANY)**
	Author:	
	Original Title:	Bio-Stoffe im neuen Compact Van Zafira – Nachwachsende Rohstoffe contra Glasfasern. *In: Kunststoffe. No. 1456, p. 6, 16 August 1999*
	Translated Title:	Bio-materials in the new compact van Zafira – renewable resources versus glass fibres.
	Date:	1999
	Objectives & Results:	The comparison of natural fibres (sisal, flax, jute, hemp, and wood) and glass fibres for automotive interiors (car door panels and car ceilings) indicates a variety of advantages for natural fibres. Advantages include environmental aspects as well as better sound insulation, better or similar mechanical properties, and also the lower weight of natural fibres. At present, sisal, flax, hemp and jute-fibres are used for interiors as ceilings and panels in the Astra and the Vectra. In the new Zafira the ceiling is made from sisal fibres and the car door panels are based on wood fibres.

6.	**University/Institute or Company:**	**Johnson Controls Interiors GmbH, Grefrath (GERMANY)**
	Authors:	Mr Beckmann, Mr Kleinholz, Mr Dupont
	Original Title:	(1) Zukunftschancen harzgebundener Naturfaser-Formpreβteile. (Dupont). *In: MarktInnovation Hanf – Verbundwerkstoffe mit Hanffasern.* *26 May 1999 – 27 May 1999 in Wolfsburg.* (2) Demands on natural fibres from the viewpoint of an automobile supplier for interior components. (Beckmann/Kleinholz) *In: 2nd International Wood and Natural Fibre Composites Symposium. 28 June 1999 – 29 June 1999 in Kassel.* (3) Chancen und Risiken von Naturfasern fur PKW-Innenraumteile. (Beckmann/Kleinholz) *In: 2nd International Symposium "Werkstoffe aus nachwachsenden Rohstoffen." 01 September 1999 – 02 September 1999 in Erfurt.*
	Translated Title:	(1) Future prospects of epoxy-resin bonded, pressure-moulded components with natural fibres. (2) Demands on natural fibres from the viewpoint of an automobile supplier for interior components. (3) Prospects and risks of natural fibres for automotive interiors.
	Date:	(1) – (3) 1999
	Objectives & Results:	At present, Johnson uses natural fibres, e.g. flax, hemp, or jute for automotive interiors. The prospects and risks for the use of natural fibres are associated with the properties of natural fibres, the optimisation of processing technologies and quality management, as well as the technical requirements for automotive components. Compared to glass fibres, there are considerable advantages for natural fibres with respect to price and potential for light-weight constructions. But there are also disadvantages regarding risks due to the inconstant and irreproducible quality of natural fibres.
7.	**University/Institute or Company:**	**Findlay Industries GmbH, Geretsried (GERMANY)**
	Author:	Mr Poltrock
	Original Title:	Verbundwerkstoffe mit Hanffasern – Marktentwicklung bei Naturfaser-PP-Formpreβteilen. *In: MarktInnovation Hanf – Verbundwerkstoffe mit Hanffasern.* *26 May 1999 – 27 May 1999 in Wolfsburg.*
	Translated Title:	Composites with hemp fibres – market development for natural fibre-reinforced, pressure-moulded PP-components.
	Date:	1999
	Objectives & Results:	At present, Findlay uses flax fibre nonwoven mats fur duroplastic and thermoplastic automotive interiors. Replacement of flax fibres with

		hemp fibres is not feasible due to the lack in price-stability, delivery and quality ensurance for hemp fibres.
8.	**University/Institute or Company:**	**Julius Heywinkel GmbH, Osnabruck (GERMANY)**
	Author:	Ms Luck
	Original Title:	Anwendungen von Naturfasern im Fahrzeuginennbereich. *In: MarktInnovation Hanf – Verbundwerkstoffe mit Hanffasern.* *29 May 1999 in Bremen.*
	Translated Title:	Use of natural fibres in automotive interiors.
	Date:	1999
	Objectives & Results:	Heywinkel is a producer of automotive interiors based on natural fibres (e.g. flax) and PP or PES. At present, Heywinkel produces interiors for Audi, Volvo, and VW. Compared to glass fibres, the advantages of natural fibres include their lower weight, lower price, good mechanical properties, environmental aspects, as well as an improved potential for recycling.
9.	**University/Institute or Company:**	**SAL Automotive – Sommer-Allibert-Lignotock GmbH, Sassenburg (GERMANY)**
	Author:	Ms Seurig-Franke
	Original Title:	Nachwachsende Rohstoffe in Autombilinnenraum-Komponenten. *In: IGLU Workshop – "Wertschopfungsketten zur industriellen Nutzung der Rohstoffpflanze Hanf in Niedersachsen." 29 April 1999 in Wolfsburg.*
	Translated Title:	Renewable resources in automotive interior components.
	Date:	1999
	Objectives & Results:	Based on a current market research SAL a producer of automotive interiors gives an overview of all currently known components in automotive interiors based on natural fibres. Actually most European automobile producers use natural fibres in interiors. The following producers are mentioned in the report: Volkswagen (Golf, Passat, Bora), Audi (A3, A4, A6, A8, A4 Avant, Roadster), Ford (Mondeo, Focus), Opel (Vectra, Astra), GM (Saab), BMW (5-series, 3-series), Mercedes (S-class, C-class, A-class), Volvo and Renault (Clio etc.).
10.	**University/Institute or Company:**	**FIBRE – Faserinstitut Bremen e. V, Bremen (GERMANY)**
	Authors:	Prof Dr Harig, Mr Mussig
	Original Title:	(1) Heimische Pflanzenfasern fur das Automobil. (Harig/Mussig) *In: Harig/Langenbach (Hrsg): Neue Materialien fur innovative Produkte.* (2) Beurteilung der Einsatzes von Hanffasern im Automobilbereich aus technischer Sicht. (Harig/Mussig) *In: MarktInnovation Hanf – Verbundwerkstoffe mit Hanffasern.*

		19 May 1999 in Bremen.
	Translated Title:	(1) Domestic plant fibres for automobiles. (2) Evaluation of the suitability of hemp fibres in the automotive sector under technical aspects.
	Date:	(1) + (2) 1999
	Objectives & Results:	Domestic plant fibres such as nettle, hemp, and flax are interesting alternatives for the use of import fibres in automotive components. At present, domestic plant fibres such as hemp are competitive with sisal, jute, or kenaf. For the future, the study recommends better quality management and co-operation with the automotive industry along the entire value-added chain from cultivation through processing to the finished product.
11.	**University/Institute or Company:**	**Thuringisches Institut fur Textil- und Kunststoff-Forschung e.V. Rudolstadt (GERMANY)**
	Authors:	Dr Mieck, Dr Reuβmann
	Original Title:	(1) Stand und Entwicklung des Einsatzes von Naturfasern und umweltfreundlich hergestellten Cellulosefasern fur Composites. (Mieck). *In: 2nd International Symposium "Werkstoffe aus nachwachsenden Rohstoffen." 01 September 1999 – 02 September 1999 in Erfurt.* (2) Verfahrensentwicklung zur Herstellung von Langfasergranulat aus Stapelfasermischungen. (Reuβmann/Mieck) *In: 2nd International Symposium "Werkstoffe aus nachwachsenden Rohstoffen." 01 September 1999 – 02 September 1999 in Erfurt.* (3) Nesselfaserverbundwerkstoffe fur Fahrzeuginnenteile. (Mieck/Reuβmann) *In: 2nd International Symposium "Werkstoffe aus nachwachsenden Rohstoffen." 01 September 1999 – 02 September 1999 in Erfurt.*
	Translated Title:	(1) Status and development of the use of natural fibres and environmentally friendly produced cellulosic fibres for composites. (2) Development of a processing technology for the production of fibre-blended granulates based on staple fibre mixtures. (3) Nettle fibre composites for automotive interiors.
	Date:	(1) – (3) 1999
	Objectives & Results:	Natural fibres such as flax, hemp, or nettle in combination with polymers are competitive with synthetic fibres for reinforcement. Nettle fibre-reinforced composites show a better mechanical flexibility as flax fibre-reinforced composites. At present, it is no longer a problem to produce natural fibre nonwoven mats based on hemp and flax with good mechanical properties for composites (e.g.

		with PP). The production of nettle fibre nonwoven mats requires an adaptation of the processing technology. To widen the field of applications in the future, the development of fibre blended granulates for injection moulding will be crucial. One possible approach is the production of fibre blended granulates based on staple fibre mixtures, e.g. with mixtures of glass, aramide, and natural fibres.
12.	**University/Institute or Company:**	**DLR – Deutsche Forschungsanstalt fur Luft- und Raumfahrt e. V., Braunschweig (GERMANY)**
	Authors:	Dr Herrmann, Mr Riedel, Mr Nickel, Mr Gensewich
	Original Title:	(1) Bio-composites – new construction materials derived from biomass. (Nickel/Riedel/Herrmann) *In: 10th European Conference and Technology Exhibition – Biomass for Energy and Industry. 8 June 1998 – 11 June 1998 in Wurzburg.* (2) Pultrusion of construction materials from renewable raw materials (Gensewich/Riedel) *In: 2nd International Wood and Natural Fibre Composites Symposium. 28 June 1999 – 29 June 1999 in Kassel.* (3) Natural fibre reinforced biopolymers as construction materials – new discoveries. (Riedel) *In: 2nd International Wood and Natural Fibre Composites Symposium. 28 June 1999 – 29 June 1999 in Kassel.*
	Translated Title:	(1) Bio-composites – new construction materials derived from biomass. (2) Pultrusion of construction materials from renewable raw materials. (3) Natural fibre-reinforced biopolymers as construction materials – new discoveries.
	Date:	(1) 1998 (2) + (3) 1999
	Objectives & Results:	Bio-composites made entirely from biodegradable resources showed promising properties for structural parts, e.g. DLR in co-operation with Becker-Group Europe produced a biodegradable car door interior paneling. Preliminary data reveal that these parts have comparable mechanical properties as GFRP (Glass Fibre-Reinforced-Plastics). Especially the pultrusion technology seems to be a very promising method for the production of more complex construction materials based on natural fibres. Tests with flax fibres and Lyocell filament fibres reinforced biodegradable plastics showed promising results regarding their mechanical properties. The development of new fibre/matrix combinations and environmentally friendly flame retardants as well as the option of designing biodegradable as well as

		non-biodegradable bio-composites will considerably widen the field of applications in the automotive sector.
13.	**University/Institute or Company:**	**Fachhochschule Lippe, Lemgo (GERMANY)**
	Author:	Prof Dr Hesch
	Original Title:	Hanf – Perspektiven fur eine okologische Zukunft.
	Translated Title:	Hemp – Prospects for an environmental future.
	Date:	1996
	Objectives & Results:	In general, hemp fibres are technically and economically suitable for the use in automotive components, especially in compression-moulded parts. At present, one of the main obstacles for the use of hemp in injection moulded components is the lack of flotation of hemp fibres. The study indicates that the mechanical properties of hemp fibres and their suitability for light-weight constructions in automotive components may create a market potential of about 25,000 tons of natural fibres per year.
14.	**University/Institute or Company:**	**INVENT – Innovative Verbundwerkstoffe Realisation und Vermarktung neuer Technologien GmbH, Braunschweig (GERMANY)**
	Authors:	Dr Hanselka, Dr Sperlich
	Original Title:	(1) Faserverbundwerkstoffe aus nachwachsenden Rohstoffen fur den okologischen Leichtbau. (Hanselka) *In: Materialwissenschaft und Werkstofftechnik, No. 29, p. 300-311, 1998.* (2) Fibre-reinforced construction materials from renewable raw materials – concept of realisation from the state of Niedersachsen. (Hanselka/Sperlich) *In: 2nd International Wood and Natural Fibre Composites Symposium. 28 June 1999 – 29 June 1999 in Kassel.*
	Translated Title:	(1) Fibre composites based on renewable resources for light-weight construction. (2) Fibre-reinforced construction materials from renewable raw materials – concept of realisation from the state of Niedersachsen.
	Date:	(1) 1998 (2) 1999
	Objectives & Results:	Natural fibres owe their potential as outstanding reinforcement in light-weight structures to their low density. Because most natural fibres are hollow they also may increase flexural stability. A completely renewable and, if desired, biodegradable composite can be created by imbedding natural fibres as a substitute for conventional, petroleum-based products in organic polymers. At present, car door linings or instrument panels do not provide a

		supporting function in the structure of a car. A future generation of cars may achieve weight reduction by giving these elements reinforcing functions through and integration of hollow, natural fibres aligned along the main loading directions.
15.	**University/Institute or Company:**	**Universitat GH Kassel, Institut fur Werkstofftechnik, Kunststoff- und Recyclingtechnik, Kassel (GERMANY)**
	Authors:	Prof Bledzki, Dr Gassan, Dr Mildner
	Original Title:	(1) Alkalisierung von Naturfasern zur Optimierung der Eigenschaften von naturfaserverstarkten Kunststoffen. (Gassan/Mildner/Bledzki) *In: Technische Textilien, No. 41, p. 74-76, 1998.* (2) Probleme der Grenzflachenhaftung bei Naturfaserverbundwerkstoffen. (Bledzki) *In: MarktInnovation Hanf – Verbundwerkstoffe mit Hanffasern. 29 May 1999 in Bremen.* (3) How to control strength and impact toughness in natural fibre reinforced thermosets. (Bledzki/Gassan) *In: 2nd International Wood and Natural Fibre Composites Symposium. 28 June 1999 – 29 June 1999 in Kassel.* (4) Transcrystallisation in natural-fibre-polypropylene composites. (Mildner/Bledzki) *In: 2nd International Wood and Natural Fibre Composites Symposium. 28 June 1999 – 29 June 1999 in Kassel.* (5) Die Faser-Matrix-Grenzschict zur Optimierung der Verbundfestigkeit und –zahigkeit naturfaserverstarkter Polyurethane. (Gassan/Bledzki) *In: 2nd International Symposium "Werkstoffe aus nachwachsenden Rohstoffen." 01 September 1999 – 02 September 1999 in Erfurt.* (6) Transkristallisation in naturfaserverstarktem Polypropylen bei unterschiedlichen Faserbehandlungen. (Mildner/Bledzki) *In: 2nd International Symposium "Werkstoffe aus nachwachsenden Rohstoffen." 01 September 1999 – 02 September 1999 in Erfurt.*
	Translated Title:	(1) Optimisation of natural fibre reinforced plastics properties by alkalinization of natural fibres. (2) Problems regarding the interfacial bonding of natural fibre composites. (3) How to control strength and impact toughness in natural fibre reinforced thermosets.

		(4) Transcrystallisation in natural fibre polypropylene composites. (5) Optimisation of the bond strength of natural fibre-reinforced polyurethane at the fibre matrix interface. (6) Transcrystallisation in natural fibre polypropylene composites following different treatments.
	Date:	(1) 1998 (2) – (6): 1999
	Objectives & Results:	Natural fibre reinforced plastics combine good mechanical properties with a low specific weight. However, their low wettability with plastics as well as inadequate fibre matrix bonding prevent a wider use of natural fibres in new applications. The use of bonding agents such as MAH-PP-Copolymer (maleic anhydride polypropylene copolymers) for polypropylene, epoxy-functionalised or amino-functionalised silane for epoxy-resin and isocyanate-functionalised or diamine-functionalised silane for polyurethane resulted in increased bonding strength. An alkalinization of natural fibres resulted in an increased stiffness of the natural fibres and the composites but also lead to lower bond strength in the matrix.
16.	**University/Institute or Company:**	**Universitat Hamburg – Institut fur angewandte Botanik, Hamburg (GERMANY)**
	Author:	Mr Dreyer
	Original Title:	Fibre nettle (*Urtica dioica* L.) as an industrial fibre crop for composites? *In: 10th European Conference and Technology Exhibition – Biomass for Energy and Industry. 8 June 1998 – 11 June 1998 in Wurzburg.*
	Translated Title:	Fibre nettle (*Urtica dioica* L.) as an industrial fibre crop for composites?
	Date:	1998
	Objectives & Results:	The fibres of fibre nettle are remarkable for their high tensile strength, fineness, and the fact that their cell walls are not lignified. Available data regarding technical characteristics of nettle fibres indicate a potential for use in fibre-reinforced composites instead of glass fibres. The most important bottle-neck for using fibre nettle is the nearly non-existing local fibre processing infrastructure and the resulting lack of competitiveness.
17.	**University/Institute or Company:**	**Institute Textile de France, Lyon, France**
	Authors:	
	Original Title:	Etude Europeene sur les Textiles dans l'Habicle Automobile
	Translated Title:	European Study on Automotive Textiles.
	Date:	1999
	Objectives & Results:	The study analyses the following applications: seats, door lining,

		package trays, floor covering, trunk lining, noise absorption, roof covering, nonwoven textiles. For each application, the following items were studied: nature of textiles used and their main characteristics, share of the European market in m2 and tons, the main actors in the production chain, new application possibilities for textiles in the automotive industry.

APPENDIX IIE: SICOMP Technical Reports

Number	Title	Author
1990		
TR 90-001	Transverse matrix cracking in glass fibre epoxy composites, A review	S Ostlund
TR 90-002	Fatigue of glass fibre reinforced plastic (GRP)	R. Bredemo
TR 90-006	Permeability of unidirectional reinforcements for RTM	R Gebart
TR 90-007	First order analysis of stiffness reduction due to matrix cracking	P Gudmundson S Ostlund
TR 90-011	Fatigue loading of glass fiber/epoxy, laminates of different matrix ductility	T Johannesson
TR 90-015	An evaluation of the program WINDTHICK for simulation of filament winding	W Zang
TR 90-018	Thermoelastic properties of composite laminates with matrix cracks	P Gudmunson S Ostlund
TR 90-020	Principer for injicering av fiberkompositer	C Lundemo
1991		
TR 91-001	A micromechanical analysis of the permeability of fibrous preform	S Lundstrom
TR 91-014	Euromech 277	P Gudmundson S Ostlund R Talreja
TR 91-016	Numerical analysis of matrix crack induced delaminations in [-+55^{o}] GFRF laminates	P Gudmundson S Ostlund
TR 91-017	Development of a processing facility for research in composites processing	C Lundemo
TR 91-020	An experimental investigation of the compaction behaviour of RTM-reinforcements	C Lundemo T Serrander
TR 91-023	An evaluation of alternative injection strategies in RTM C Lundemo	R Gebart P Gudmundson
TR 91-024	Void formation in RTM	R Gebart S Lundstrom C Lundemo
TR 91-027	Process simulation of wet filament winding and curing of thick walled cylinders	K Olofsson
TR 91-028	Local stresses and thermoelastic properties of composite laminates containing micro cracks	P Gudmundson S Ostlund
TR 91-029	On flexural and tensile strength for composites manufactured by resin transfer moulding	A Holmberg
TR 91-030	How to avoid blister formation during compression moulding of SMC	S Halvarsson

TR 91-031	Calculation of stresses and strains in composite tubes and pressure vessels containing cracks	PA Hallin
1992		
TR 92-001	Damage development during unaxial fatigue of filament would tubes	R Bredemo
TR 92-002	Biaxial fatigue of filament would tubes	R Bredemo
TR 92-003	An evaluation of the mould filling simulation code TIMS	R Gebart S Lundstrom
	92-004 har ersatts av 93-007	
TR 92-005	Recycling of SMC	J Pettersson
TR 92-006	Thermoforming of continuous fiber mats	L Lundstrom
TR 92-007	A universal model for thermoelastic properties of micro cracked composite laminate	P Gudmundson W Zang
TR 92-008	SICOMP/TCV-A suite of computer programs for material characterisation and simulation of cure and heat transfer	R Gebart
TR 92-009	SICOMP composite toolbox, user’s guide	S Lindmark
TR 92-010	Kostnadsanalys av produktionsprocesser for polymera kompositmaterial	A Edlund
TR 92-011	Reduction of blister formation in SMC by control of internal mould pressure and charge weight	S Halvarsson
TR 92-012	Damage evolution and thermoelastic properties of composite laminates	W Zang P Gudmundson
TR 92-013	Measurement of in-plane permeability of anistropic media	P Lidstrom
1993		
TR 93-001	Critical parameters for heat transfer and chemical reactions in thermosetting materials	R Gebart
TR 93-002	Influence from different process parameters on void formation in resin transfer moulding	S Lundstrom R Gebart
TR 93-003	About impact	R Bredemo
TR 93-004	Mechanical behaviour of epoxy resins in uniaxial and triaxial loading	L Asp LA Berglund P Gudmundson
TR 93-005	Application of Weibull theory on random fibre composites	A Holmberg
TR 93-006	Manufacturing analysis of wet filament wound pipes and pressure vessels	K Olofsson
TR 93-007	Process analysis of wet filament winding	K Olofsson R Langstrom S Lindmark
TR 93-008	The tensile strength of composites after low velocity impact	W Zang
TR 93-009	Effect of perturbation of fibre architecture on permeability inside fibre tows	S Lundstrom R Gebart

TR 93-010	Tillverkning av hogpresterande kolfiber epoxiror mha fiberlindning	R Bredemo
TR 93-011	Micro crack – a Fortran program for composite laminates containing micro cracks	W Zang
TR 93-012	Void formation and transport in RTM	S Lundstrom
1994		
TR 94-001	Concurrent engineering improve damage tolerance after low velocity impact	R Bredemo
TR 94-002	(Andrad till Confidential Report)	
TR 94-003	Impact resistance of carbon/epoxy pipes A case study	W Zang R Bredemo
TR 94-004	Research done by SICOMP – NOKOS	K Olofsson T Serrander R Lamgstrom
TR 94-005	Process induced defects in resin transfer moulding A Strombeck	A Holmberg S Lundstrom R Gebart
TR 94-006	Studie av andra tekniker for Glass Mat Thermoplastics (GMT)	S Halvarsson
TR 94-007	Principles of resin transfer moulding	A Strombeck R Gebart E Sandlund L Lundstrom
TR 94-008	Process optimisation for filament winding Final project report	K Olofsson R Langstrom S Lindmark
TR 94-009	Temperature predictions in thick polymer composites subjected to low initial cure temperatures	K Olofsson
TR 94-010	Optimering av formpressning	S Halvarsson
TR 94-011	Wetting between resin and reinforcement in reinforcement in fibre composites	M Dahlback
TR 94-012	Forformning av glasmatteforstarkt termoplast (GMT)	S Halvarsson
TR 94-013	Monitoring of Process Variables (MPV)	S Halvarsson
TR 94-014	Project 130: Failure criteria based on constituent material properties	A Holmberg R Lundstrom
TR 94-015	Project 120: Process optimisation for resin transfer moulding – final report	A Strombeck E Sandlund
TR 94-016	Preliminary calculations on the Atlas barrel TRT support structures	JO Aidanpaa R Lundstrom R Gebart
TR 94-017	Project 140: Resin flow in the presence of fibres	R Gebart S Lundstrom
1995		
TR 95-001	Project 180: Recycling fibre reinforced thermosets	J Pettersson

TR 95-002	Evaluation of mould filling simulation for RTM	A Strombeck S Lundstrom
TR 95-003	Curing Stress – A FORTRAN program for stress analysis during cure	W Zang
TR 95-004	A new method for the measurement of in-plane permeability in fabrics for RTM	R Gebart E Sandlund
TR 95-005	Atervinning av hardplastkompositer	J Pettersson A Hedlund-Astrom M Skrifvars
TR 95-006	An approximate analysis of the springback phenomenon (Tidigare registrerad som CR 95-011)	A Holmberg
TR 95-007	U-beams manufactured by RTM – I: Experimental results and initial analysis (Tidigare registrerad som CR-95-012)	A Holmberg
TR 95-008	Out-of-plane strength of RTM-laminates with sharp corners	A Holmberg
TR 95-009	Temperature predictions in thick composite laminates at low cure temperatures	K Olofsson
TR 95-010	Stress development in filament wound pipes	K Olofsson
TR 95-011	Forstudie – “Kunskapsinsamling inom omradet vakuuminjiceringsteknik for battillverkning”	L Liljenfeldt P Nilsson T Serrander R Gebart
TR 95-012	A new approach to cure optimisation for unsaturated polyester	A Strombeck R Stenberg S Lindmark
TR 95-013	A method to measure wetting between resin and reinforcement	M Dahlback S Lundstrom
TR 95-014	Principles of liquid composite moulding A Strombeck	R Gebart
TR 95-015	Mechanical recycling of fibre-reinforced thermosets in spray-up applications Part II a: Comparison of mechanical properties of core materials	J Pettersson P Nilsson
TR 95-016	Fran “hydda” till “rymdkapsel” – fiber-kompositer I ett teknikhistoriskt perspektiv samt miljoaspekter	J Pettersson
TR 95-017	Fibre orientation analysis by digital simulation of Fraunhofer diffraction J Krispinsson	N Jekabsons R Gebart
TR 95-018	Grinding of fibre-reinforced thermosets for mechanical recycling	J Pettersson P Nilsson
TR 95-019	Bestamning av totala reaktionsvarmen (Htot) for ett omattat polyestersystem	R Stenberg
TR 95-020	Stiffness of barrel-TRT modules (CERN)	JO Aidanpaa

TR 95-021		
TR 95-022	Specimen preparation and image analysis of fibre orientation in compression moulded parts	J Krispinsson R Gebart N Jekabsons
TR 95-023	U-beams manufactured by RTM – II: Additional experimental results and analysis (Tidigare registrerad som CR 95-035)	A Holmberg
TR 95-024	A method for measuring delamination strength in polymer composites during cure	G Nilsson
TR 95-025	Effects of moulding pressure on mechanical properties of glass mat reinforced thermoplastics (GMT)	A Hedberg
1996		
TR 96-001	SimRTM. Interim Technical Report. Non destructive determination of void content in fibre reinforced polymer composites	S Lundstrom
TR 96-002	SimRTM. Final Technical Report. Non destructive testing: Experiments with ultrasonic attenuation	S Lundstrom R Stenberg D Norris
TR 96-003	SimRTM Interim Technical Report. Introductory study on void formation in RTM	S Lundstrom
TR 96-004	Evaluation of stiffness and strength in adhesively bonded carbon fiber bars	A Andersson
TR 96-005	Development of injection equipment (Tidigare registrerad som CR 95-005)	E Sandlund
TR 96-006	Undersokning av material avsedda for forlorade karnor vid tillverkning av fiberkompositer (Tidigare registrerad som CR 95-024)	T Made
TR 96-007	NORDTEST – Projekt 1229-95. Slutrapport. Hardningsoptimering for komposit-processer	R Stenberg S Lindmark A Strombeck S Slotte (Neste)
TR 96-008	Practical recycling of thermoset composites; New boat concept Proc. JEC Composite Manufacturing, France, April 24-26, 1996	J Pettersson P Nilsson
TR 96-009	Manufacturing of carbon fibre U-beams by RTM	P Nilsson
TR 96-010	U-beams manufactured by RTM – III: Microstructural characterisation	A Holmberg
TR 96-011	Brottojning pa komposit av atervunnet material	Y Vilander J Harder
TR 96-012	Krypsimulering av GMT- och GMT/Plytronbalkar	G Nilsson JO Aidanpaa M Ericsson
TR 96-013	Strength evaluation of a vinyl-ester resin during cure	A Koscher
TR 96-014	Manufacturing and performance of RTM U-beams, Revision 2	A Holmberg LA Berglund

TR 96-015	Measurement of in-plane permeability: Test of equipment	F Gaude
TR 96-016	Effects of voids and beam radius on RTM U-beam failure	A Holmberg LA Berglund
TR 96-017	Forstudie: Energiutvinning ur kompositavfall. Lokala forutsattningar samt tekniska och ekonomiska konsekvenser	A Johansson, ETC (JP)
TR 96-018	Micromechanisms of delamination failure in RTM U-beams. Revision 2	A Holmberg LA Berglund
TR 96-019	SimRTM. Bubble transport through constricted capillary tubes with application to fibre reinforced polymer composites	S Lundstrom
TR 96-020	Cure kinetics characterisation of four thermoset resins (tva parmar, del I och II)	R Gebart R Langstrom R Stenberg
TR 96-021	SimRTM. Final Technical Report. Measurement of void collaps during resin transfer moulding	S Lundstrom R Langstrom
TR 96-022	Effects of processing conditions on residual stresses in PP-based fibre composites	A Eriksson
1997		
TR 97-018	Technical Report on research done by SICOMP and ABB Plast during 96/97 in the NoKoS-project "Manufacturing of high-performance composite and sandwich components. Subproject: Filament Winding	K Olofsson R Langstrom T Serrander R Scott, ABB
TR 97-019	Recycling of composites in spray-up applications	J Pettersson P Nilsson
TR 97-020	Recovery of composites waste Proc.: NESCO, Stockholm, Oct. 1997	JA Larsen J Pettersson
TR 97-021	A model for the vacuum infusion moulding process. Revision 2	A Hammami R Gebart
TR 97-022	(Andrad till Technical Note)	
TR 97-023	Composites manufactured by RTM	A Holmberg
TR 97-024	The influence of recipe, curing temperature and styrene content on the chemical shrinkage in thermoset resins	R Stenberg S Slotte A Holmberg
1998		
TR 98-001	Experimental investigation of the vacuum infusion moulding process	A Hammami R Gebart
TR 98-002	Thermoplastic Composites Based on Natural Fibres	K Oksman
TR 98-003	Initial testing of Symalit GM4OPP and pure PP	A Holmberg P Nilsson
TR 98-004	Vidhaftning av hardplastkompositer pa termoplastytor	G Hyllander
TR 98-005	Kompositer av naturliga ravaror	K Oksman
TR 98-006	Vacuum Infusion Moulding of Natural Fibre Composites	K Oksman E Sandlund

TR 98-007	Tool Influence on RTM Plate Manufacturing	K Olofsson B Jozefowicz
TR 98-008	Factors affecting shape distortions A survey	M Svanberg A Holmberg
TR 98-009	Manufacturing Parameter Influences on Production Cost	K Olofsson A Edlund
TR 98-010	Creep Testing of Symalit GM40PP and pure PP	A Holmberg M Megnis J Varna
TR 98-011	Elements of the Linear Visco-Elasticity Theory	J Varna M Megnis A Holmberg
TR 98-012	Processvariablers inverkan pa dimensions-forandringar hos formpressad PP	G Nilsson
TR 98-013	Processvariablers inverkan pa dimensions-forandringar hos formpressad GMT	G Nilsson A Holmberg
TR 98-014	Fibre Structure and Anisotropy of Glass Reinforced Thermoplastics	MA Dweib F Vahlund CM O Bradaigh
1999		
TR 99-001	Process simulation of multiple material filament wound pipes	K Olofsson
TR 99-002	Jamforelse av styrenavgang vid tillverkning av bat med sprutning och med vakuum-injicering	M Lindgren
TR 99-003		
TR 99-004	Evaluation of HBP modified woven laminates using static and Fatigue Acoustic Emission monitoring	D James
TR 99-005	Comparison of styrene emissions during manufacturing of boats with spray-up and vacuum injection	M Lindgren
TR 99-006	Influence from cure schedule on shape distortion of RTM composites	M Svanberg A Holmberg
TR 99-007	Kompositmaterial av naturliga fibrer Slutrapport	K Oksman
TR 99-008	High quality flax fibre composites manufactured by Resin Transfer Moulding process	K Oksman
TR 99-009	Mechanical properties of resin transfer molded natural fiber composites	K Oksman
TR 99-010	Liquid composite moulding of natural fibres	K Oksman

APPENDIX IIF: Conferences

MAFF MEETING 1997, LONDON

1.	Title:	UK Grown Non-Wood Fibres: Meeting the needs of Industry
	Author(s):	1 paper by Richard Lindoe, MIP 1 paper by Harry Gilbertson, Natural Fibres Organisation

TECHTEXTIL – SYMPOSIUM 1997

1.	Title:	Hybrid Materials from Natural Fibres and Thermoplastics – New Developments for Production of Composites.
	Author(s):	K P Mieck, R Lützkendorf, Th Reussmann, Thüringisches Institut für Textile – und Kunstoff – Forschung, Rudolstadt

TECHTEXTIL – SYMPOSIUM 1999

1.	Title:	New Trends in the use of Natural Fibres for Technical Textiles and Composites
	Author(s):	Dr Ryszard Kozlowsky, Institute of Natural Fibres, Poland
2.	Title:	Needled Glass Fibre Mats for use in Automotive Construction
	Author(s):	Dr L Chou, BFG Industries, Greensboro, NC, USA
3.	Title:	Optimized Textile Techniques for Advanced Composites
	Author(s):	C H Sigle, A S Herrmann, A Pabsch, Deutsches Zentrum für Luft – und Raumfshrt, Braunschweig

INDEX 99

1.	Title:	Needs of the Transportation Industry Regarding Fibre Compositess Products
	Author(s):	Dr K Drechsler, Daimler-Chrysler
2.	Title:	Technical Requirements of Automotive Applications of Nonwovens as Textiles or as Substitutes for Other Materials
	Author(s):	W Fung, Collins & Aikman
3.	Title:	Nonwoven and PUR-foam – Competition or Complement?
	Author(s):	Dr P Hartwig, J H Zeigler, Germany
4.	Title:	Biocomposites from Needlefelt Nonwovens
	Author(s):	J Nickel, U Riedel, A S Herrmann, DLR

AUTOMOTIVE COMPOSITES WORKSHOP 1998
THE INSTITUTE OF MATERIALS, BRANDS HATCH

1.	Title:	RTM Hemp Fibre-Reinforced Composite Automotive Components
	Author(s):	S Gebe, N S Cetin, C A S Hill

2.	Title:	Plant Fibres – A Growing Interest for Automotive Composites
	Author(s):	M Sudol
3.	Title:	Injection Moulding of Natural Fiber Reinforced Plastics (NFRP)
	Author(s):	M Sauerbier, M Colberg

2ND INTERNATIONAL WOOD AND NATURAL FIBRE COMPOSITES SYMPOSIUM 1999 INSTITUT FUR WERKSTOFFTECHNIK, KASSEL

1.	Title:	Vegetable Fibres in automotive Interior Components
	Author(s):	A Magurno, Johnson Controls Interiors
2.	Title:	Demands on Natural Fibres from the Viewpoint of an Automotive Supplier for Interior Components
	Author(s):	Beckmann, Kleinholz, Johnson Controls Interiors
3.	Title:	Prospects and Risks of Natural Fibres for Automotive Interiors
	Author(s):	Beckmann, Kleinholz, Johnson Controls Interiors
4.	Title:	Life Cycle Studies on Hemp Fibre Reinforced Components and ABS-epoxy-resin for Automotive parts
	Author(s):	K Wötzel, R Wirth, M Flake, Technische Universität, Braunschweig
5.	Title:	How to Control Strength and Impact Toughness in Natural Fibre Reinforced Thermosets
	Author(s):	Bledzki, Gassan, Universitat GH Kassel
6.	Title:	Short Natural Fibre Reinforced plastics in the Interiors of Automobiles – Preparation and Processing.
	Author(s):	Schäfer, Daimler Chrysler
7.	Title:	Environmental Comparison Between NMT – and GMT – Components
	Author(s):	Diener, Daimler-Chrysler
8.	Title:	Transcrystallisation in Natural-Fibre-Polypropylene Composites
	Author(s):	Mildner, Bledzki, Universität GH Kassel
9.	Title:	Optimisation of the Bond Strength of Natural Fibre-Reinforced Polyurethane at the Fibre Matrix Interface
	Author(s):	Gassan, Bledzki, Universität GH Kassel
10.	Title:	Transcrystallisation in natural Fibre Polypropylene Composites following Different Treatments
	Author(s):	Mildner, Bledzki, Universität GH Kassel

SAMPE EUROPE CONFERENCE 1998, PARIS

1.	Title:	Composite Materials with Vegetable Fibres for Automotive Applications
	Author(s):	Guido Contrafatto, Fiat Auto Pre Indus. –Innovazione, Enrico Indino and Anna Benenti, Centro Ricerche Fiat, Jose Kenny and Anna Grandinetti, Universita di Perugia

DRYLAID NONWOVENS CONFERENCE 1998, WAKEFIELD

1.	Title:	Nonwovens in Automotive
	Author(s):	Paul Bamber, Cosmopolitan Textile Co Ltd, Northwich

NATURAL FIBRES PERFORMANCE FORUM 27 – 28 MAY 1999, COPENHAGEN

1.	Title:	Perspectives on the Performance of Natural Plant Fibres
	Author(s):	P O Olsen, D V Plackett, Royal Veterinary and Agricultural University, Denmark
2.	Title:	Renewable Materials for Automotive Applications
	Author(s):	Dr Thomas, G Schuh, Daimler-Chrysler
3.	Title:	High Performance Applications of Plant Fibres in Aerospace and Related Industries
	Author(s):	Ulrich Riedel, Jorg Nickel, Axel Siegfried Herrmann, DLR
4.	Title:	Plant Fibre Supply – Opportunities and Current Limitations
	Author(s):	Gary Newman, JB Plant Fibres
5.	Title:	Green Fibres – Present State and Future Prospects for the Next Millenium
	Author(s):	Dr Ryszard Kozlowsky, Institute of Natural Fibres, Poland
6.	Title:	New Design Opportunities for Plant Fibre Products
	Author(s):	Lars Thogersen, CPH Industriel Design, Copenhagen
7.	Title:	Design Potential of Plant Fibres
	Author(s):	Jorn E Behage, Proterra, Netherlands
8.	Title:	Optimisation of Methods of Fibre Preparation from Agricultural Raw Materials
	Author(s):	Dr J E G van Dam, ATO-DLO, Netherlands
9.	Title:	Improvement of Fibre Performance in Composites and Related Materials
	Author(s):	Dr Mark Lawther, The Royal Veterinary and Agricultural University, Denmark
10.	Title:	EU-Financed Research on Non-Traditional Industrial Uses of Biological Fibres : Past Projects and Future Plans
	Author(s):	Dr Klumpers, EC-DGXII.E2, Brussels
11.	Title:	Strategy for a Sustainable Future of Fibre Crops
	Author(s):	R W Kessler, R Kohler, M Tubach, Institut für Angewandte Forschung, Reutlingen
12.	Title:	Perspectives on the Utilisation of Natural Binders in Composite Materials
	Author(s):	Claus Felby, Novo Nordisk AS, Denmark
13.	Title:	The Limits of Design Potential in Plant Fiber Products
	Author(s):	Roger M Rowell

APPENDIX 12: Statistical Data on Flax

Flax Cultivated Area [ha]

	1994	1995	1996	1997	1998	1999
AUSTRIA	1300*	1346*	1105*	700*	635*	
BELARUS	82650	96800	78500*	73600		
BELGIUM	11178*	11052	11188	11654*	11202*	12000*
BULGARIA	11178	350	300	200		
CHINA	15000*	130000*				
CZECH REPUBLIC	11046	10076	7300	2155	4117	
DENMARK	500*	150	200	57*	44*	
EGYPT**	11941	15714	9676	8714		
ESTONIA	850	300		200		
FINLAND	300	112	490	944	800*	
FRANCE	48570*	53069*	44556*	45096	43708*	48000*
GERMANY	1704*	3370	4500	1362*	416*	3500
IRELAND				42	1*	
LATVIA	1520		1240	1500		
LITHUNIA	9800	13200	5600	6100		
NETHERLANDS	4539*	4430*	3823*	4089*	3320*	3560*
POLAND	9500	13742	4383	2660	2548	2500
PORTUGAL				1125*	1500*	
RUSSIA	135000	177300	135000	113100		
SPAIN		11300	44000	49045*	87727*	100000*
SWEDEN				47*	320*	1350
UKRAINE	78700	95800	54500	39975	31200	
UNITED KINGDOM	17000	17500	20500	19080*	16700*	15000*

Source: Data provided by relevant countries.