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April 2004

# Thermoplastic Composites in Europe to 2025

## Foresight Study into Future Research Needs

Thermoplastic Composites Infrastructure Cooperation Network - Coronet

Output from Task 3.2: Foresight Activity
***Final Version After Validation***

Coronet is a European Research Infrastructures Network
funded by the European Commission under the Framework 5 research programme
Contract No. HPRI-CT-2001-40029
www.coronet.eu.com

# Contents

# 1 Introduction

Over the last 10-15 years European industry has generally been far more receptive to thermoplastic composites than other world regions, primarily due to environmental concerns and legislation in areas such as processing emissions and end-of-life recycling.

Partly because of these factors, the growth rate of thermoplastic composites is widely reported as being twice that of thermoset composites[1], and the last 5 years have therefore seen significantly increased interest and activities in thermoplastic composites outside of Europe, particularly in North America.

This foresight report views the future direction of thermoplastic composites, particularly in relation to future research and research infrastructure requirements within the industry. Conventional foresight methods are used to present an overall picture of the expected research and infrastructure needs, giving recommendations on future research activities.

This report forms the output from Task 3.2: Foresight Activity, of the Thermoplastic Composites Infrastructure Cooperation Network – Coronet, an Infrastructure Cooperation Network funded by the European Commission.

The previous task, Task 3.1, compares the current and planned research activities and infrastructures in Europe with those in North America and the rest of the world. The following task, Task 3.3, brings together the results of Task 3.1 and 3.2 to map Europe's thermoplastic composites research and infrastructure against future research requirements.

This then gives a clear picture of the gaps in Europe's research portfolio and infrastructure, with which the European thermoplastic composites community can effectively plan for the future to maintain its position in this fast-growing technology.

# 2 Methodology

There are a wide range of techniques and tools that are appropriate for foresight exercises, and foresight programmes have successfully been undertaken using combinations of many of these techniques.

When trying to gain an understanding of where Europe should be focussing its research efforts over the next 10-20 years, it is important to look at the thermoplastic composites industry as a whole, rather than just looking at research in isolation. Only by capturing the views of the wider industry and looking at the future of the industry as a whole can Europe's future thermoplastic composite research activities be accurately aligned with long-term industrial needs. For that reason this study examines the overall thermoplastic composites industry, drawing from it specific conclusions that are pertinent to future research activities and future research infrastructures.

In undertaking the planning for this foresight study, an investigation was carried out into the available methods for capturing high-quality information, as well as the techniques that should be used to identify the issues affecting thermoplastic composites, and hence the future direction of Europe's research activities.

Whilst the authors of this report have previous experience in the formulation and implementation of foresight exercises[2,3,4], a number of supporting documents were used to ensure the validity of the methodology used. In particular, 2 well-regarded publications were consulted as general sources of information and guidance during this foresight exercise:

- Handbook of Knowledge Society Foresight[8]
- Foresight for Trade Associations and Other Member-based Organisations - a guide for running effective sectoral foresight exercises[5]

The first of these documents has been endorsed by DG RTD Foresight Unit K2 and the IPTS of the European Commissions JRC[6], whilst the second is a publication of the UK Government – the only known national guide to sectoral-based exercises of this type.

All of the available information sources were used to assess the following methods available to us.

## Available Methods

Methods for looking to the future range widely from highly creative thinking through to the structured use of expertise, with a range of methods in between. These two extremes can be placed at two corners of a triangle, with the third apex representing alignment of differing views through interaction. In foresight studies a combination of methods is usually used

This variety of methods is illustrated in the foresight triangle[7], shown in Figure 2.1 below.

In structured foresight exercises, highly creative methods such as science-fiction writing, brainstorming and 'genius forecasting' are very rarely used. Instead, more ordered methods are used, such as surveys, workshops and technology scanning.

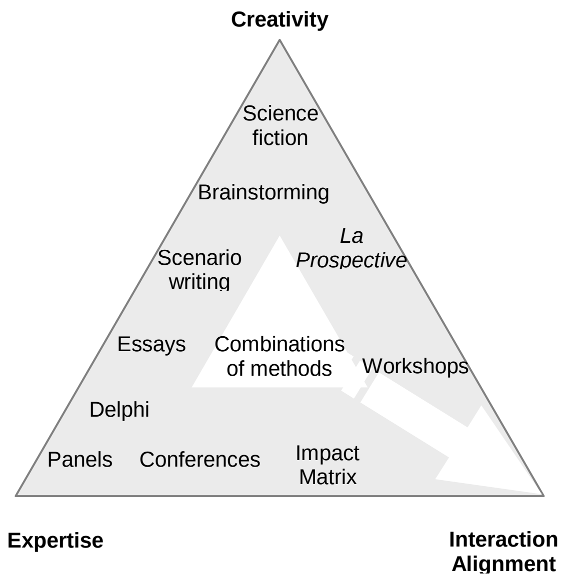


**Figure 2.1: The Foresight Triangle[7]**

Expert inputs are usually central to these types of foresight exercises, and are particularly important where activities are highly specialised and not widely understood[8].

Key methods that were considered in this exercise are detailed below.

**Technology Scanning**

Scanning involves the systematic analysis of documentary sources, and media coverage of issues is commonly used[8]. For science and technology areas, bibliometric approaches can be used to track the number of journal articles on a particular theme or the active areas of research in a particular technology area.

**Delphi Method**

The Delphi method is widely identified with foresight and involves a survey of opinion. In a true Delphi survey the respondents receive the same set of questions at least twice, the respondents in later rounds also receiving feedback on the structure of responses in previous rounds. The idea is that respondents can modify their judgements and see how far their forecasts correspond to the wider pool or respondents.

However, it is worth noting that many foresight activities, including some national foresight programmes, do not use this method[8]. For example, in Europe the Netherlands national foresight programme did not use Delphi[9].

**Non-Delphic (Issue) Surveys**

Issue surveys are used to consult a wider range of opinion than can readily be accommodated in face-to-face meetings[8], and such surveys provide useful background information.

These surveys can be open-ended, but a more structured approach is common, asking respondents to comment, in their own words, on issues, drivers and shapers in the area of interest. This type of approach was used successfully in the UK foresight programme in the mid 1990s.

In a mature market, a survey can be targeted so that the number and type respondents are broadly matched to the breakdown of the industry as a whole. For foresight activities in immature industries, such as thermoplastic composites, targeting the survey respondents in this way can restrict the useful forward-looking information that is gathered as it can lead to the exclusion of applications and sectors that do not currently exist but which might do in 10-20 years. For this reason, it is more common for foresight surveys to have a less structured approach than, for instance, market surveys, to encourage creative thinking.

**Workshops**

Workshops are a unique form of meeting, where the aim is to achieve a consensual output through active group participation[5]. The workshop participants should represent a cross section of relevant views and it is important that the workshop is well-structured and the workshop itself should be effectively facilitated to encourage participation and the expression of different viewpoints.

Depending on the nature of the foresight exercise, brainstorming and SWOT analysis are among the methods that can be used in workshops, and prioritisation of issues can also be effectively carried out within a workshop environment.

**SWOT Analysis**

SWOT stands for Strengths, Weaknesses, Opportunities and Threats and SWOT analyses are often used within foresight. Foresight activities such as workshops may conduct SWOT analyses and it is also common for surveys to ask respondents to identify SWOT issues, for example to compare the responses of different regions[8].

**STEEP Analysis**

A useful technique for identifying the factors that affect a sector is the STEEP analysis, where external factors are grouped into five areas[5]:

- Sociological factors: For example, changes in consumer markets and demographic trends
- Technological factors: Anticipated advances in current technology
- Economic factors: For example, global competition and financial cycles
- Environmental factors: Factors such as the effects of global warming, waste disposal and recycling
- Political factors: Changes in local and national government, policies and legislation

STEEP analyses are usually undertaken within a workshop format, although questionnaires and surveys can also be used[5].

**Other Methods**

A number of other methods, including techniques such as trend extrapolation and relevance trees were also considered in outline. However, these techniques were either found to be more appropriate for more targeted problem solving, or required accurate historical quantitative data that was not available for the thermoplastic composites research community. Each of the available techniques is able to offer alternative viewpoints and in practice a combination of techniques is usually used in a sectoral foresight exercise such as this. A combination of methods was therefore also chosen for this study, the actual methods used detailed below.

## Methods Used

A combination of three main methods was used to gather the information needed for this exercise:

- Technology scanning
- Facilitated workshop
- Non-Delphic (issue) survey

Outputs from each of these methods were used to formulate the following sections of this report, from which overall conclusions could be drawn:

- STEEP Analysis
- SWOT Analysis
- Key Trends
- Major Issues

Details of each method and its outputs are as follows:

**Technology Scanning**

Activities in this area encompassed systematic examination of published information from a number of sources, including:

- Online composites technology media and worldwide news services
- Scientific publications covering developments in composites technology
- Trade publications
- Conference proceedings

A comprehensive list of the sources used in this part of the exercise is shown in Annex 1.

This activity was used as one of the inputs into assessing the key trends in thermoplastic composites, detailed in Section 5 of this report.

**Workshop**

A facilitated workshop was used to brainstorm the main drivers affecting thermoplastic composites, as well as the strengths, weaknesses, opportunities and threats facing

European thermoplastic composites industry and research.

In selecting the workshop participants, it was considered important to draw on a representative sample of expertise directly relevant to thermoplastic composites research and application in a cross-section of end use sectors. It was also felt essential that, wherever possible, the workshop participants should have a broad role in the industry, so that they could present the viewpoint of thermoplastic composites as a whole, rather than just the narrow perspective of their own organisation.

The Coronet partnership itself had already established this breadth of expertise, so the workshop participants were drawn from within the Coronet partnership. The workshop was chaired by a facilitator experienced in foresight activities and in managing workshops of this type. Details of the workshop participants are given in Annex 2.

This activity was used as the input into the STEEP analysis, detailed in Section 3 of this report, and as one of the inputs into the SWOT analysis, outlined in Section 4.

From the STEEP analysis, the factors affecting thermoplastic composites were grouped into categories, each containing issues affecting the industry in a positive manner as well as those that affect it in a negative way. These categories were then to help formulate the survey, used as suggested topic areas in the when respondents were asked to comment on factors that affected thermoplastic composites.

**Issue Survey**

The relatively narrow field of study in this foresight exercise, coupled with the fact that the survey respondents were knowledgeable in thermoplastic composites, meant that a non-Delphic issue survey was considered appropriate. Any potential added benefit as a result of a second (Delphic) iteration of the survey in this narrow technology field was expected to be heavily outweighed by the additional inconvenience to the survey respondents. The decision to use a survey of this type was in line with many other sectorally focussed foresight exercises and followed the recommendations of publicly available guidance[5]. Instead of using a repeat survey in the Delphic style, a validation exercise was carried out with the original survey respondents to allow them to give a second level of input.

The primary intention of the survey was to gather qualitative information on issues and trends to extend the knowledge gained from the technology scanning and workshop activities and to establish any regional variations. This was achieved through the use of a series of open questions covering trends and issues in materials, processes and applications, as well as a SWOT analysis.

At the same time, we also attempted to capture shorter-term quantitative data on industry growth and trends in specific materials, processes and applications, wherever possible, through a series of closed questions. In the section on trends and issues, the output from the STEEP analysis was used to suggest broad topic areas where external factors that affected thermoplastic composites had already been identified.

The survey itself was conducted online through the Coronet (www.coronet.eu.com) and NetComposites (www.netcomposites.com) websites, with the survey results being held directly in a purpose-built database to allow effective breakdown and analysis of the results. The structure of the survey and the detail of the questions can be seen detailed in Annex 3.

The survey resulted in 129 sufficiently completed responses to allow constructive analysis of the answers to qualitative questions, the primary goal of the survey. Unfortunately there were insufficient answers to the quantitative questions for that data to be viewed as numerically representative of the industry.

However, as part of the survey, respondents identified their current and anticipated involvement in different technologies, materials and sectors. To minimise the time needed to complete the form, replies were limited to whether a company was involved or not, rather than indicating actual levels of activity, and this information was useful in identifying some broad trends.

A thorough analysis of the industrial survey respondents identified represented a broad cross section of suppliers, component manufacturers and end users from a range of sectors including automotive, aerospace, marine, rail, construction and sporting goods. These were coupled with researchers, designers and consultants, again in a range of sector industries, to give a comprehensive cross-section of the industry, shown in Figure 2.2 below.

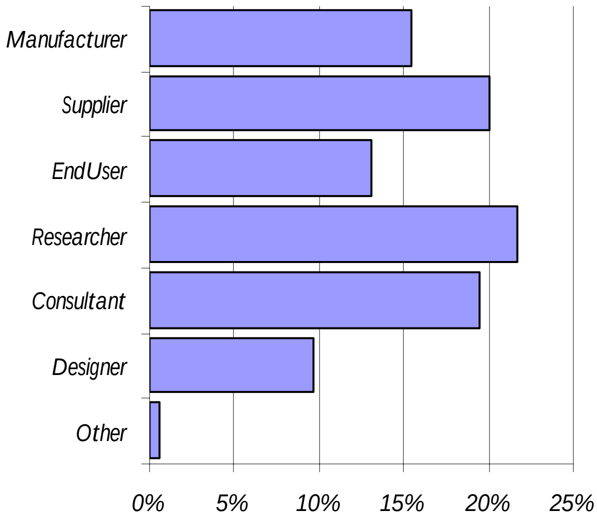


**Figure 2.2: Respondents by Activity**

Respondents to the survey were approximately balanced between European and non-European organisations, shown in Figure 2.3.

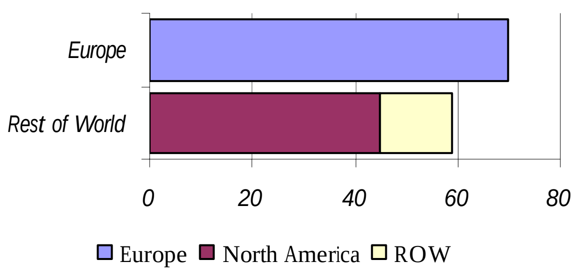


**Figure 2.3: Respondents by World Region**

In line with our investigation into the available methods (outlined above), the survey respondents were not targeted, to encourage creativity and free thinking in the range of responses that were received. However, the level of respondent was typically at Director and Manager level in SME organisations, or Project/Programme manager in larger industrial companies. For research organisations, respondents were typically at least Senior Research Scientist, but more commonly at Professor level.

An indication of the array of companies that responded is given in Annex 4.

The results of the survey were used to extend the SWOT analysis in Section 4, as well as being partial inputs into assessing the key trends in thermoplastic composites (Section 5) and Major Issues (Section 6 of this report).

## Validation

The initial findings of this series of exercises were prepared in a draft format of this report.

This draft report was then circulated to the 129 original respondents to the foresight survey, as well as to the workshop participants, inviting each to input additional comments on gaps in research and research infrastructure that had been reported. Their additional comments allowed us to amend the content of the report to better reflect their original thoughts, and also to include some areas of research and infrastructure that were thought to have been missed.

These changes have been incorporated into this second, validated report.

# 3 STEEP Analysis

The STEEP analysis is a useful technique for identifying and categorising key factors likely to influence the future competitiveness of the thermoplastic composites industry, and hence those that will influence future research and research infrastructure.

Within a STEEP analysis, external factors are grouped into 5 areas[5]:

- Sociological factors: For example, changes in consumer markets and demographic trends
- Technological factors: Anticipated advances in current technology
- Economic factors: For example, global competition and financial cycles
- Environmental factors: Factors such as the effects of global warming, waste disposal and recycling
- Political factors: Changes in local and national government, policies and legislation

In common with the majority of foresight STEEP analyses, this exercise was one of the outputs of the workshop detailed in the previous section.

This section details the broad drivers that affect the European thermoplastic composites industry, some of these particularly relevant to Europe while others are more general worldwide issues.

## Sociological Factors

The main sociological effect is due to the shift in demographics and world trade, new developing economies with lower labour costs and globalisation in products.  Linked to this is this the general decline in the popularity of engineering in Europe and the consequent lack of awareness of thermoplastic composite materials and the lack of people trained in these materials.

On the positive side, the greater degree of disposable income through all levels of the population will lead to a corresponding increase in higher value products, especially in the youth markets for sporting/leisure goods and the elderly markets for lightweight products.

## Technological Factors

Technologically, the advantage of reduced materials/parts count, the sustainability of thermoplastic composites and the consumer trend to green materials are all expected to have a significant positive impact on the uptake of thermoplastic composites.

Conversely, advances in competing materials (for example titanium, nanocomposites, foamed aluminium and ultra-high strength steel) are expected to have a negative impact on the uptake of thermoplastic composite material, although it is likely that significant opportunities exist for hybrid synergistic materials combining thermoplastic composites and competitive materials.

## Economic Factors

Economically, the major factors affecting the use of thermoplastic composites are the potential increases in productivity and the reduced costs of products over conventional materials.

Against this, compared to thermoset composites, are increased energy and tooling costs, especially at low production volumes.

## Environmental Factors

The environmental issue is probably the most critical external factor affecting thermoplastic composites.

Environmental factors offer unsurpassed opportunities for thermoplastic composites, as life-cycle thinking means that the through-life costs and environmental impacts of components are being more thoroughly considered, including VOC emissions during processing and recycling at end-of-life.

Legislation such as the End-of-life vehicle directive and directives on landfill and incineration will have a major effect on the use of thermoplastic composites. Compared to thermoset materials there are advantages, but in some cases environmental issues may suppress their use in favour of more conventional materials with established recycling routes.

## Political Factors

Political factors and policies also affect thermoplastic composites, from both National and EU government. In particular the European economic situation, the European Research Area, National research agendas and EU enlargement will all have an effect on the development and use of thermoplastic composites in Europe.

Specific areas where political decisions are expected to have a positive impact on the thermoplastic composites industry are in crashworthiness, pedestrian safety and standards.

## STEEP Output

From this STEEP analysis we are able to group the factors affecting thermoplastic composites into five main categories, each containing issues affecting the industry in a positive manner as well as those that affect it in a negative way:

- Environmental and Regulatory Issues:
  Issues encompassing the trend to green materials, sustainability, energy usage, emissions and recycling.

- Cost-Effective Manufacturing:
  Increases in productivity, lower part costs, reduced parts count, hybrids and advances in competing materials all come within this category.

- Skills, Awareness and Education
  Lack of awareness of thermoplastic composites and the lack of people trained in the materials

- Standards
  Aspects such as crashworthiness, pedestrian safety legislation and prescriptive standards

- Political Issues
  External political influences including economics, research agendas and changing political and monetary borders.

These main categories were then carried through into the survey as suggested topic areas when respondents were asked to comment on factors that affected thermoplastic composites. They are also used to structure part of the output from that survey in Section 6 of this report.

# 4 SWOT Analysis

The STEEP analysis in the previous section identifies the factors likely to influence the future position of thermoplastic composites in Europe. These factors represent both opportunities and threats to which the industry must respond, the most appropriate response being dependent on its own strengths and weaknesses[5].

This section therefore contains a SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis of issues facing the European thermoplastic composites industry.

- Strengths: Factors which place us in a positive position to exploit the trends seen in the STEEP analysis
- Weaknesses: Factors that hinder us from exploiting the trends from the STEEP analysis
- Opportunities: for exploiting the trends seen in the STEEP analysis
- Threats: Consequences of doing nothing, plus possible negative results of actions which might result from seeking to exploit the opportunities

This SWOT analysis was derived from two sources – a brainstorming session in the workshop detailed in the section 2 and the worldwide issue survey. This allowed any broader points to be included within the SWOT analysis and also gave the opportunity to see if there were any strong variations in thinking between worldwide geographic regions.

Only once the current strengths, weaknesses, opportunities and threats have been clearly identified, can we begin to think about future research and infrastructures to address the weaknesses and threats. This activity is therefore an essential building block in providing a picture of gaps in Europe's current research portfolio and research infrastructure, prior to mapping Europe's future research requirements and infrastructure.

Details of the findings are given below, with a summary in Figure 4.1.

## Strengths

From the workshop, the following factors were identified that place European thermoplastic composites in a positive position to exploit the trends identified during the STEEP analysis:

- A creative, dynamic and innovative industry
- A strong technology base at the research and supply level
- High volume production capability
- Low cost, low labour clean processing
- A wide materials choice
- Specific properties (such as toughness)
- Stable quality level compared to thermosets
- Recyclability (compared to thermosets)
- Lower stock handling costs compared to prepreg
- The fact that Europe is ahead of the USA

The wider survey of the industry almost exactly matched and reinforced these thoughts, the only addition being the fact that thermoplastics can offer improved environmental and health & safety impact compared to thermosets.

**Strengths**

- A creative, dynamic and innovative industry
- A strong research and supply base
- High volume production capability
- Low cost, low labour clean processing
- Improved environmental and health & safety impact compared to thermosets
- A wide materials choice
- Specific properties (such as toughness)
- Stable quality level compared to thermosets
- Recyclability (compared to thermosets)
- Lower stock handling costs compared to prepreg
- Europe is ahead of the USA

**Opportunities**

- Creation of databases and models
- Creation of a recycling infrastructure
- Reduced cost products, through processing advances and automation
- Meeting changes in legislation (environment, crashworthiness and recycling)
- Education of specifiers
- Applications in new markets (oil and gas, construction, decking etc)
- Alliances to create larger supply bases
- Creation of repair strategies
- New material forms (reactive materials, self-reinforced materials, bioresins)
- Enhanced fire performance with nanoclays
- New material variants
- New manufacturing routes
- A more solid supply base

**Threats**

- Alternative materials developments and costs (eg aluminium, steels, magnesium, titanium and some thermosets)
- Current materials-driven specifications
- Lack of skilled labour and researchers
- Low overseas labour cost and cheap imports
- Specific environmental legislation
- A lack of presence in some markets
- Lack of a recycling infrastructure
- Political (National and EU) research agendas
- The emergence of thermoplastic nanocomposites

**Weaknesses**

- An immature manufacturing base (infrastructure and size of companies)
- Monopolistic supply of some materials
- High and unstable materials costs
- Weak knowledge at end-user level
- High capital costs compared to thermosets
- Too wide a materials and process choice
- Lack of materials databases and models
- Limited ability to paint and finish
- Limited ability to join multi-materials systems
- A lack of materials knowledge (eg viscoelastic, creep, temperature and chemical performance)
- Low temperature and fire performance
- Low recyclability (compared to metallic materials)
- A lack of repair strategies
- Lack of a strong lobby or presence for the industry

**Figure 4.1: Summary SWOT Analysis**

## Weaknesses

The current factors that hinder the industry from exploiting the trends identified in the STEEP analysis include:

- An immature manufacturing base (infrastructure and size of companies)
- Monopolistic supply of some materials
- High and unstable materials costs
- Weak knowledge at end-user level
- High capital costs compared to thermosets
- Too wide a materials and process choice
- Lack of materials databases and models
- Limited ability to paint and finish
- Limited ability to join multi-materials systems
- A lack of materials knowledge (eg viscoelastic, creep, temperature and chemical performance)
- Low temperature and fire performance
- Low recyclability (compared to metallic materials)
- A lack of repair strategies

Again, the wider survey generally agreed with the results from the workshop, but with the inclusion of processing limitations, including cost and material viscosity. An additional, important point was also made that there is no strong lobby for the industry, especially when compared to the steel and aluminium industries.

## Opportunities

Opportunities for exploiting the trends identified in the STEEP analysis include:

- Creation of databases and models
- Creation of a recycling infrastructure
- Reduced cost products, through processing advances and automation
- Meeting changes in legislation (environment, crashworthiness and recycling)
- Education of specifiers
- Applications in new markets (oil and gas, construction, decking etc)
- Alliances to create larger supply bases
- Creation of repair strategies
- New material forms (reactive materials, self-reinforced materials, bioresins)
- Enhanced fire performance with nanoclays

Opportunities are generally seen to exist in the replacement of sheet metal components, consolidation of complex parts and lightweighting.

Additionally, the wider survey also highlights the advantages to be gained from closer direct collaboration with polymer manufacturers to create new material variants, new composite manufacturing routes and a more solid supply base.

## Threats

From the results of the workshop, the external threats to the industry are expected to come from:

- Alternative materials developments and costs (eg aluminium, steels and some thermosets)
- Current materials-driven specifications
- Lack of skilled labour and researchers
- Low overseas labour cost and cheap imports
- Specific environmental legislation
- A lack of presence in some markets
- Lack of a recycling infrastructure
- Political (National and EU) research agendas

In the broader survey, the strongest perceived threat was from the existing metal industries (aluminium, steel and newer materials such as magnesium), with material and processing developments in these materials expected to create the main challenge for composites in the future.

Threats were also seen from the existing un-reinforced thermoplastic materials supply chain. In many cases these companies are looking for new products, markets and differentiators as they struggle to operate in a mature, low margin business. Thermoplastic composites are seen by many of these companies to be a logical step in their development and they are actively looking to develop thermoplastic composite businesses. Because of the relative size of these companies compared to conventional composite moulders, these companies have the resources to be able to do this. They therefore represent a significant threat to smaller companies working in thermoplastic composites.

The emergence of thermoplastic nanocomposites was also raised as a potential threat to conventional fibre-reinforced composites.

## Relevance to Research

At its roots the thermoplastic composites industry is creative, dynamic and innovative, with a strong research and technology base. Thermoplastic composite materials themselves carry a number of inherent advantages for particular applications, such as low cost clean processing and low environmental impact. On both sides of the Atlantic, the European industry is widely regarded as being ahead of that in the USA, so the European research base is well positioned to further consolidate its technology lead.

However, the research community must address the industry's weaknesses in high materials costs and high infrastructure costs compared to more conventional thermoset materials. It must also tackle the development of virtual infrastructures for materials databases and models, creating and holding knowledge in areas such as viscoelasticity, creep, temperature performance and chemical resistance. The ability to paint, finish and join these materials must also be researched, alongside proven techniques for recycling.

Opportunities for the European research community, and hence the industry, lie in the creation of databases and models, developing cost-effective processing equipment and establishing viable recycling infrastructures. This must be achieved against the continued development of alternative materials technologies, such as aluminium, steels, magnesium, titanium and thermoset composites.

# 5 Key Trends

Key trends in thermoplastic composites were drawn from the technology scanning exercise as well as from the results of the issues survey.

The scanning activities involved systematic examination of published information from a number of sources, a comprehensive list which is shown in Annex 1.

To support this, as part of the survey (outlined in Annex 3) respondents highlighted the key trends that they saw in the three areas of materials, manufacturing and applications, the answers from the survey being combined with our the results from our own technology scanning exercise.

Although we attempted to capture some short-term qualitative data on trends in specific materials, processes and applications there were insufficient answers to the quantitative questions for that data to be viewed as numerically representative of the industry. Nevertheless, the information supplied still provided valuable supporting input on the key trends.

## Materials

Whilst it is unlikely that there are any revolutionary new fibres in the pipeline, there will still be major changes in the application and use of existing fibres in thermoplastic matrices.

From the companies that responded to the survey carried out for this study, there are significant trends in the types of fibres that are likely to be used over the next few years.

In particular, there is expected to be an increase in the use of natural fibres such as wood, jute, hemp, sisal and flax, as well as polymeric fibres such as PET, PP and PE.

This use of thermoplastic fibres within a thermoplastic matrix, usually the same polymer (such as PP), is particularly noteworthy as the materials posses a unique property profile with potentially very broad applications. This family of self-reinforced materials is also relatively new, so it is expected that significant research effort will be needed to allow their successful processing and application.

Nano-reinforcement of polymer fibres will also feature prominently, enhancing the strength and stiffness of existing polymer fibres, either to be used in self-reinforced composites or as reinforcement for a different matrix material.

A potentially large increase in the use of carbon fibre is also much anticipated. Many people are predicting double-digit growth for carbon fibre over the coming years, with its likely emergence as an affordable reinforcement due to lower prices resulting from volume growth. This will in part be enabled by increased take-up of heavy-tow carbon fibre.

The results of the survey show that the trend in fibre formats is very much as expected, with a reduction in the use of conventional woven and random nonwoven fabrics and a corresponding increase in the use of stitched (non-crimp fabric) materials. This is primarily because stitched fabrics allow higher deposition rates of material, hence faster cycle times and lower costs, although they are only currently widely used for commingled fibres.

There is also a clear trend away from short discontinuous fibres towards longer discontinuous fibres, a trend that is mirrored in the move towards LFT type processes (outlined below), but outside of Europe there is less of a change in fibre formats anticipated.

Looking at matrix materials, the primary trend seen in matrices is the diversification of materials as potential applications become larger and more demanding on existing polymer systems. This demand from the applications is fuelling the development of a range of materials new to thermoplastic composites and we can expect this trend to continue.

At the lower-performance end of the market we expect to see developments in materials such as PA, ABS, PBT, PET and TPUs. For higher performance applications then fluoropolymers, LCPs and PEKK are likely to emerge, each of these systems giving more tailored performance for cost.

It is anticipated that self-reinforced materials will see significant growth over the next 10-20 years, and that the current PP materials will being fairly quickly supplemented by other, higher performance polymers. It is also expected that there will be a significant increase in the uptake of low viscosity reactive thermoplastics such as reactive PA and PBT (Cyclics) type systems. Bio-derived materials will also see further development and growth.

As well as opening up a range of new markets, we would expect to see these new thermoplastic composite materials competing against existing thermoset composites in some applications, perhaps leading to reductions in the cost of current materials systems in all performance ranges.
It is expected that there will be a sharp increase in the use of LFTs within Europe due to their combination of cost, processability and recyclability, perhaps with a reduced use of GMT.

However, European activity and interest in GMT and LFTs is not matched outside of Europe. This most likely reflects the importance of thermoplastic GMT and LFT materials to the European automotive industry to meet through-life and end-of-life requirements, a driver which is not seen in other world regions.

Finally, the use of thermoplastic nanocomposites is expected to grow dramatically, either as stand-alone materials or synergistically with conventional fibres to harness the physical property improvements offered by nano-scale reinforcement and the mechanical property benefits offered by fibrous reinforcement. Development work in this area is however still at a very early stage.

## Manufacturing

Increases in the use of most thermoplastic composites manufacturing processes are expected over the next 10-20 years, although some reports suggest that there may be a slight reduction in the use of thermoplastic hand layup (commingled fabric processes).

A number of sources also suggest that there will be a large increase in use of thermoplastic RTM, a result that is perhaps surprising considering that the technology is still very young. The results of our survey confirmed that thermoplastic RTM is expected to feature strongly in coming years, with closed mould processes and low viscosity reactive thermoplastics such as reactive PA and PBT (Cyclics) type systems. It is also expected that more work will be carried out on other polymer systems with thermoplastic RTM, including other engineering thermoplastics and LCPs.

However, the interest in injected systems does not stop at thermoplastic RTM, and there is also strong support for new LFT injection processes. In-line compounding and LFT injection and injection-compression techniques featured strongly in our survey, suggesting a broad expansion of direct in-line compounding methods, with more rapid expansion on the injection moulding side. These newer techniques are expected to offer the ability to process more complex shapes with long fibre lengths at a competitive cost. LFT is one of the fastest-growing plastics industry sectors and automotive applications account for over 95 percent of the worldwide demand. In Europe, an annual growth rate of 10-12 percent was observed during the period 1999-2002[10].

Hybrid technologies are also expected to emerge, combining different processes and materials, such as the moulding of LFT/GMT combined with thermoforming. These techniques will allow the use of locally placed structural inserts (composite or metallic) to give the best combination of properties in the final part. For complex shapes and structures, newer techniques such as thermo-hydroforming are likely to be used to make complex shapes such as deep-drawn parts with double curvatures.

There is also expected to be a significant growth in other press processing routes, including stamping, although a key issue with this technology is the reduction of raw material wastage and a desired move towards net-shape moulding.

Thermoplastic pultrusion, diaphragm forming, filament winding, fibre placement and automated tape-laying also featured strongly in the results of our survey, with very strong growths anticipated by some respondents. Surface finishing, welding and joining were also seen as enabling technologies that will emerge more fully in the next few years.

A common theme amongst many of the survey respondents was that of automation, with development of new automated manufacturing techniques seen as key to improving the cost of thermoplastic composite parts.

This in turn could have an effect on the structure of the industry, as higher levels of automation necessitate higher levels of capital investment and make it more difficult for start-up companies with very low levels of capital to enter the industry. There is therefore an implied shift in thermoplastic composites processing towards existing larger manufacturing companies, who may already have established manufacturing operations in a number of materials, and away from traditional small specialist composites processors who will lack the resources to invest in capital-intensive technologies.

## Applications

Growth in thermoplastic composites is foreseen in almost all of the major markets, except perhaps for electronic laminates where the electrical properties of thermoset materials allow them to dominate.

In building and construction, growth is expected for example in concrete reinforcement bar (rebar), stimulated by work undertaken mainly by Dow in recent years and drawing of the formability of thermoplastic bars compared to those from thermosets. Many, smaller applications are also anticipated for other thermoplastic pultruded profiles, as well as pultrusion/extrusion of thermoplastic hybrid products.

In decking and other building products, Europe is expected to follow North America in the uptake of wood/polymer materials to replace timber. Building products is currently the largest market for these materials in North America and in 2002 accounted for more than 80% of consumption for such products as decking and railing systems, window and door profiles, and shingles. The North American market for these materials is over 5 times larger than in Western Europe[11].

Infrastructure applications are also expected to grow, with applications in relining of sewers as well as water and natural gas pipelines. This trend will also continue offshore, with specialist pipe systems, marine structures and coastline management applications where toughness is critical to the part.

In the energy sector there will be further developments on the possible use of thermoplastic composites for blade and housing applications, although it is likely that the time to application of thermoplastic composite blades will be significant.

Consumer and leisure applications will also continue to grow, especially in sporting goods. It is notable though that the sporting goods market was only identified by non-European respondents to our survey. There was a strong consensus from our survey that the industrial market would also offer some strong possibilities, for instance in process machinery and mechanical parts.

The automotive market still drives much of the thermoplastic composites industry and the sector is significant in that the primary European market drivers – recyclability and weight – are not seen in the US due to less stringent environmental legislation and lower fuel prices.

The trend is towards fewer vehicle platforms and therefore higher production volumes in common parts, necessitating greater investment in process technology for the supplier of composite components. In the high volume automotive industry (greater than 50,000 cars per annum), the main trend expected is the uptake of more structural thermoplastic composite and hybrid components.

In the US the use of reinforced thermoset composites by car manufacturers has nearly doubled in the last decade, largely because composites have increasingly been chosen by OEMs to replace steel for body panels and structural components. In Europe though the trend is towards thermoplastics, almost to the exclusion of thermosets for some OEMs, although thermoplastic composites still have to actively compete with more conventional materials that have established recycling routes.

There will also be new applications in the low to mid volume vehicle market, for niche vehicles and special editions, often seen as testbeds for future higher volume applications. In addition to the trends expected for passenger cars, non-automotive ground transportation sectors (buses, trucks and rail) are also expected to start to use thermoplastic composites, for example in panels and pressure vessels.

The use of thermoplastic composites in ship and boatbuilding is also expected to grow, mainly through the use of hand-laid commingled systems with heated vacuum consolidation processes.

Finally, in aerospace there is a very strong move towards lower cost manufacturing processes, which in turn should generate significant interest in thermoplastics. Coupled with the advent of new matrix systems such as PEKK, this should allow significant growth in both commercial aerospace and defence.

## Relevance to Research

The outcome of this trends analysis is that we are able to identify a number of key areas of research that will be needed to meet the expected trends in materials, processes and applications.

In the area of materials, the following technology areas have been identified as being key areas of research:

- Natural fibre composites, including wood fibres
- Polymeric fibres such as PET, PP and PE
- Nano-reinforced fibres
- Self-reinforced polymers
- Reactive thermoplastics
- New commodity materials (eg PA, ABS, PBT, PET & TPU)
- High performance materials (eg fluoropolymers, LCPs and PEKK)
- Bio-derived matrices
- Thermoplastic nanocomposites

As well as the development of the materials themselves, there will also be the need to research modeling techniques and performance characteristics, especially long-term performance, to enable the materials to be practically applied.

In the area of processing technologies, to match the expected trends in technologies, the areas of research needed are expected to be mainly in capital-intensive automated manufacturing techniques for high-volume manufacturing, including:

- Thermoplastic RTM
- New LFT injection processes
- Hybrid moulding processes (eg thermo-hydroforming) and structures
- Press and stamping processing routes

- Thermoplastic pultrusion and extrusion
- Diaphragm forming
- Filament winding
- Fibre placement and automated tape-laying

To support this process development research, parallel research activities will also be needed in the areas of process modelling, surface finishing, welding and joining.

Finally, an area of high importance is that of recycling, and it is expected that significant research activity will be needed in this area to enable many of the forecast applications.

# 6 Major Issues

Within the wider survey, respondents were given the opportunity to highlight the major issues that they felt will affect the uptake and use of thermoplastic composites, together with any possible actions needed by industry, government and the research community.

Previously, the STEEP analysis had identified five main groups of issues that affected thermoplastic composites:

- Environmental and Regulatory Issues:
  Issues encompassing the trend to green materials, sustainability, energy usage, emissions and recycling.

- Cost-Effective Manufacturing:
  Increases in productivity, lower part costs, reduced parts count, hybrids and advances in competing materials all come within this category.

- Skills, Awareness and Education
  Lack of awareness of thermoplastic composites and the lack of people trained in the materials

- Standards
  Aspects such as crashworthiness, pedestrian safety legislation and prescriptive standards

- Political Issues
  External political influences including economics, research agendas and changing political and monetary borders.

The comments received fell very clearly into the first four of these categories, but political issues did not feature amongst the survey responses.

This section summarises the detailed issues raised. An understanding of these issues allows us to gauge their importance and propose any necessary actions.

## Cost-effective Manufacturing

Cost reduction is seen as important mainly due to a desire to win more business from traditional materials.

To achieve this within the constraints of limited control over raw material prices and relatively high European labour costs, cost-effective manufacturing processes are seen as the primary way in which companies can reduce their costs and be more competitive. However, high materials costs are highlighted as a major issue for thermoplastic composites processors, emphasising the need for material suppliers to also improve their own manufacturing efficiencies.

The effect of this is that it currently severely limits applications of thermoplastic composites in most application sectors. It also has a direct effect on the companies within the industry as they are diluting their manufacturing effort with the constant search for more cost-effective material and processing solutions. Labour costs are also being targeted in a move towards more cost-effective automated manufacture of components.

In parallel with the desire to develop new techniques and processes for the cost-effective manufacture of high quality parts, and despite the fact that the thermoplastic composites industry is still relatively young, companies are already looking at other manufacturing efficiencies, business restructuring, outsourcing to Asia. This again accentuates the need for research into cost-effective manufacturing processes.

Further action is therefore needed in the research of manufacturing processes from industry, government and the research community. Alongside this, additional work is needed in cost modelling and in process modelling to further reduce the cost of manufactured parts.

## Environmental Issues

The environmental issue is seen both as an advantage and a disadvantage with respect to the use of thermoplastic composites. On the one hand, environmental impact legislation can open the door for thermoplastic composites in new applications with specific life-cycle costing and recycling requirements.

On the other hand the industry itself is hampered by the lack of a clear recycling route, especially compared to metallic materials. Technically, thermoplastic composite products are recyclable, but the fibre reinforcement causes many of the same concerns as with thermosets composites.

In future, companies may be obliged to take back their product at the end of its life cycle, which will cause a major environmental problem if no clear recycling infrastructure is available.

Thermoplastic composites are currently trading on the technical ability to recycle thermoplastic composites, whilst at the same time needing to develop commercially viable materials and processing routes for the practical recycling of these materials.

This is a key area of required future research and further action is needed developing robust recycling processes, methodologies and infrastructures.

## Standards and Performance

There is still great deal of work to do on long-term material performance, especially in areas such as temperature performance, impact, creep and fatigue. Modelling and stress analysis is linked to this, and public domain material data bases would also help in overcoming some of the barriers to the use of thermoplastic composites to engineers who would otherwise stick to more well-established and proven materials.

Standards are also seen as important. The lack of standards for composites restrict their uptake, whist the pre-existence of a wide range of materials-specific, rather than performance-based, standards can preclude the use of thermoplastic composites.

Research therefore needed in creating and holding realistic and accurate thermoplastic composites material data that potential customers can easily access for the own specification and design work. This applies especially to knowledge of the long-term performance of these materials.

## Awareness and Education

Variations in materials and products, together with lack of education of the end user, results in a material family that is difficult for the new user to understand, and a lack of awareness amongst potential clients is expected to have a significant impact.

Responses to the survey suggested that the thermoplastic composites industry should undertake more general awareness and promotion, transferring knowledge to schools and universities so that the next students of students are a step higher from the beginning.

There is no specific research action that can result from this, but there it is important that institutes, universities and commercial companies should take responsibility for some of this teaching in parallel with their research activities.

## Other Issues

Repair was raised as a potential issue, as major aircraft manufacturers are building thermoplastic composites structures. For example, the airline industry is set to take delivery of new aircraft with these structures and will need to establish repair procedures and outline standard materials and processes for thermoplastic composites.

One of the additional themes that was noted from the survey was that of industry maturity and fragmentation, with many small companies having been set up to exploit niche markets. As thermoplastic composites move towards higher-volume applications, parts manufacture will typically be performed by large companies, OEMs and Tier One suppliers. The implication of this is that these larger applications will be using more automated, high-capital cost equipment, an essential area of future research already identified above.

However, this also means that starting in thermoplastic composites will become far more difficult for smaller companies in very new applications, so research into cost-effective manufacturing processes is also needed for the lower-volume applications.

## Research Prioritisation

The use of a large survey to assess the factors affecting thermoplastic composites also allows us to gauge the relative importance of each of those broad issues, by calculating the relative frequency at which each of the issues was raised. In turn, this will allow the thermoplastic composites community to determine research priorities, if necessary.

Figure 6.1 below shows the percentage of survey answers that raised issues falling into each of the five categories identified by the STEEP analysis. These were:

- Environmental and Regulatory Issues
- Cost-Effective Manufacturing
- Skills, Awareness and Education
- Political Issues
- Standards and Performance

A sixth category ('Other') was used to capture issues that did not fall into any of the original five categories.

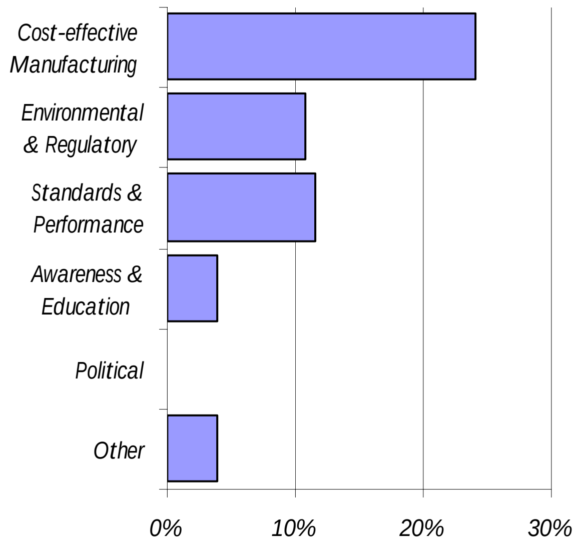


**Figure 6.1: Frequency of Issues Raised**
(Percentage of Respondents Raising Issues)

This clearly shows that cost-effective manufacturing undoubtedly emerges as the most important issue facing thermoplastic composites today. Environmental issues, standards and performance also feature prominently, and effective research can have a huge positive impact in each of these three areas.

The other main categories, awareness & education, political and other factors had a far lower rate of occurrence, although these issues are affected to a far lesser extent by research.

# 7 Future Research Activities

A number of activities have been undertaken in order to gain an overall picture of the future of thermoplastic composites, and hence the future direction of research that is needed by the industry. From this we can then identify the research infrastructures that are likely to be needed to undertake this research.

Following a thorough assessment of the possible methods that can be used in technology foresight, three main techniques were selected and implemented to gather the information needed for this exercise:

- Technology scanning
- A facilitated workshop
- A non-Delphic (issue) survey

Outputs from each of these methods were used to formulate the main sections of this report:

- STEEP Analysis
- SWOT Analysis
- Key Trends
- Major Issues

The issues raised using each of the information gathering methods have been found to be very similar, and a series of overall conclusions can be drawn by combining the outputs of each of the previous sections of this report.

**SWOT Analysis**

The SWOT analysis recognized that thermoplastic composite materials have a number of inherent advantages for particular applications, such as low cost clean processing and low environmental impact. However, it also identified that there are a number of major problems that require significant additional research in order to overcome them, including:

- High materials costs
- High infrastructure costs
- The lack of long-term data
- The ability to paint, finish and join
- The lack of proven techniques for recycling

**Trends Analysis**

The trends analysis identified a number of key areas of research that will be needed to meet the expected trends in materials, processes and applications. In the area of materials, these were:

- Natural fibre composites, including wood fibres
- Polymeric fibres such as PET, PP and PE
- Nano-reinforced fibres
- Self-reinforced polymers
- Reactive thermoplastics
- New commodity materials (eg PA, ABS, PBT, PET & TPU)
- High performance materials (eg fluoropolymers, LCPs and PEKK)
- Bio-derived matrices
- Thermoplastic nanocomposites

Modelling techniques and long-term performance characterisation of these materials are also needed. In the area of processing technologies, the areas of research needed were:

- Thermoplastic RTM
- New LFT injection processes

- Hybrid moulding processes (eg thermo-hydroforming) and structures
- Press and stamping processing routes
- Thermoplastic pultrusion and extrusion
- Diaphragm forming
- Filament winding
- Fibre placement and automated tape-laying

Research needs in recycling, process modelling, surface finishing, welding and joining were also identified.

**Major Issues**

The major issues affecting thermoplastic composites were confirmed in the survey of the wider thermoplastic composites community.

Compared to the previous STEEP analysis, political effects on the industry were not mentioned. Analysis of the survey responses showed that showed that cost-effective manufacturing is regarded as the most important issue in thermoplastic composites today, followed by environmental issues, standards and performance.

The other main categories, awareness & education, political and other factors had a far lower rate of occurrence, although these issues are affected to a lesser extent by research

Repair of thermoplastic composites was also highlighted as an issue from the survey, a factor that had not previously come out of the workshop or scanning exercises.

## Research Requirements

The research needs identified in each of the previous exercises have been summarised and assembled into a single of table, under the same heading and research categories identified in task 3.1 of the Coronet project: Competitive Benchmarking:

- Materials
- Processing
- Modelling
- Post-processing
- Testing

Under each of these heading and research categories, detailed research needs are presented, alongside the infrastructures that are likely to be required to undertake the research. This allows the key future topics to be viewed at a glance.

This table of future research activities s is shown overleaf.

Presenting the data in the same format as the results of the benchmarking exercise in Task 3.1 also allows the direct side-by-side comparison of Europe's current research activities and infrastructure (from Task 3.1) with its future requirements (from this task). This is undertaken in Task 3.3: Identification of Research Needs, which gives a picture of the gaps in Europe's current research portfolio and infrastructure.

## Materials

| Materials | Future Needs: Research | Future Needs: Infrastructure |
|---|---|---|
| Self-reinforced polymers | Higher performance polymers, nano-reinforcement | Fibre-spinning, continuous lamination lines, twin-screw extruder |
| Fluoropolymers | Processing & application in harsh environments | Pull-winding |
| LFT | In-line compounding, LFT injection, injection-compression, hybrid moulding | LFT injection and compression cells, hybrid processing cells |
| Nano-reinforced fibres | Self-reinforced polymers or other matrices, improved stiffness & temperature | Twin-screw extruders, fibre-spinning |
| Nanocomposites | Enhanced fire properties; use with/ without fibres, RTM with C nanotubes | Twin-screw extruders, analytical equipment |
| Vapour-grown carbon fibres | | |
| Bio-polymers | Bio-derived matrices for sustainability; Genetic modification | Bio-chemistry, processing & analytical equipment |
| Biocompatible polymers | Scale-up, new biocompatible, biodegradable & resorpable polymers and composites; | Fibre spinning, micro CT Bio chemistry, processing and analysis equipment |
| Recycling | Viable robust recycling, life-cycle analysis, self or nano-reinforced polymers | Pyrolysers, cryogenic grinders, shredding and separation equipment |
| Novel fibres & fillers | Polymeric fibres; weavable titanium and steel fibres | Fibre-spinning, weaving and induction heating |
| Natural fibres | Wood, jute, hemp, sisal and flax, anti-fungal systems | Harvesting, defibration, chemical treatment |

## Processing

| Processing | Future Needs: Research | Future Needs: Infrastructure |
|---|---|---|
| Thermoforming, stamping, compression moulding | Hybrid forming with local inserts, net-shape, waste reduction; advanced & rapid tooling techniques | High capacity presses, hybrid processing cells, process modelling, injection-compression; cheaper mould systems |
| Rubber & diaphragm forming | New materials, scaling up, diaphragm life, waste reduction | Diaphragm forming machines, process modelling |
| Filament winding & braiding | New fibres, process optimisation | Filament winders, braiders, software |
| Injection moulding | LFT injection | LFT injection machines |
| Pultrusion | New fibres e.g. Wood-PP, co-extruded coatings | Pultrusion-extrusion machines |
| Vacuum processing | Large-scale heated vacuum consolidation | Tool heating, process control and simulation |
| Automated tape placement | Optimisation of fibre direction, rapid placement, hybrid processing | Tape placement robots, hybrid processing cells |
| Thermoplastic RTM | Scaling-up, development of current PA & PBT systems, new engineering polymer and LCP systems | Pneumatic injection systems, chemical analysis facilities |
| Heating techniques | Microwave processing & consolidation | Smaller microwave systems |
| Rotational moulding | Parts with property gradients | |
| Hybrid processing & sandwich structures | Synergistic materials and processes, component optimisation, tape-placement, over-injection, thermo-hydro-forming | Hybrid processing cells, hydro-forming equipment |

## Modelling

| | Future Needs: Research | Future Needs: Infrastructure |
|---|---|---|
| Process modelling & formability | Part cost reduction via process and cost modelling; integrated enviro-economic modelling; flow & fibre orientation prediction; Hybrid structure analysis; friction models, draping and residual stress analysis | Process modelling & cost modelling software; LCA; enhanced FE with improved post-processing |
| Component modelling & design | Component modelling and stress analysis, access to material properties; residual life prediction | Component modelling & stress analysis software, material property databases |

## Post-processing

| | Future Needs: Research | Future Needs: Infrastructure |
|---|---|---|
| Surface finishing | Class A surfaces, in-mould painting, improved performance, durability | Surface characterisation, chemical analysis, environmental test chambers |
| Cutting techniques | Rapid, accurate, low-damage techniques | Water-jet cutting machines |
| Joining & welding | Rapid, continuous welding techniques, welding of large/complex structures, joint durability; foil welding for different materials | Induction, vibration & laser welding equipment, environmental & mechanical test rigs |
| Repair | Establishing of standard repair procedures, durability of repairs; microwave repair; self-healing composites | Welding equipment, environmental & mechanical test rigs |

## Testing

| | Future Needs: Research | Future Needs: Infrastructure |
|---|---|---|
| NDE & health monitoring | Embedded sensor fibres, improved in-situ NDE techniques | Sensor fibre placement, data measuring software, NDE equipment |
| Fire testing | Fire retardance of nano-clays | Twin-screw extruders, fire testing rigs |
| Impact & ballistics testing | Materials with high impact-resistance e.g. self-reinforced polymers | Low & high speed impact test rigs |
| Fracture testing & damage tolerance | More accurate tools for predicting initiation, interaction and evolution of damage; new failure criteria; damage tolerant materials | |
| Electrical property testing | Electrical aging | |
| Environmental, creep and high temperature testing | Enhanced knowledge of viscoelastic, creep, fatigue, temperature and chemical performance, access to material properties; residual life prediction | Environmental test facilities, material property database; combined enviro-mechanical long-term test facilities |

# Annex 1: Technology Scanning

## Publications Scanned

JEC Composites Magazine (formerly Composites)
JEC Composites SA
2000-2004

JEC Composites Weekly Newsletter (formerly Global Composites Newsletter)
JEC Composites SA
2002-2004

Journal of Thermoplastic Composites
Sage Publications
2001-2003

Composites Update
About.com
2001-2002

Reinforced Plastics
Elsevier Limited
2000-2004

Reinforced Plastics Weekly
Elsevier Limited
2003-2004

Composites Fabrication
American Composite Manufacturers Association
2002-2003

Steve Loud's Composites eNews
ISSN 1532-7248
Composites Worldwide, Inc
2002-2004

CompositesWeek
E-Composites, Inc
2002-2004

NetComposites News
NetComposites Ltd
2001-2004

Advanced Composites Bulletin
International Newsletters Ltd
1999-2004

Composites Technology
Ray Publishing, USA
2002-2004

## Bibliography of Specific Reports

Plastic Composite Materials: Industry Analysis
Marycela Carreras, Brian Forster, Christian Orta, Benjamin Yonce
Michigan Business School
Draft Report, Spring 2004

European Composite Directory and Report
Materials Technology Publications
2002

The US Composites Market: 2003 and Beyond
Composite Fabrication Magazine
January 2003

The Advanced Composites Industry:
Global Markets, Technology Trends and Applications 2002-2007
Materials Technology Publications
October 2003

Structure and Dynamics of the Composites Industry
JEC Composites
March 2004

Thermoplastic Composites: Global Technologies and Markets
Gordon Bishop, NetComposites
ThermoformNet Meeting, October 2003

Thermoplastic Composites
Klaus Gleich, Southern Research Institute
Composites 2003, Anaheim, USA

The Advanced Composites Industry:
Global Markets, Technology Trends and Applications 2002-2007
Materials Technology Publications
October 2003

# Annex 2: Workshop Participants

- Professor Chris Rudd
  Professor of Mechanical Engineering and Dean of Engineering
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  KEMA Nederland B.V, The Netherlands

- Günter Kempe
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  DLR (German Aerospace Center), Germany

- Prof. Dr.-Ing. Dr.h.c. Klaus Friedrich
  Research Director
  Materials Science Division, Institute für Verbundwerkstoffe (IVW) Germany
  *Board Member, European Society for Composite Materials*
  *Editorial Board, Journal of Thermoplastic Composite Materials (since 1988)*

- Dr António Torres Marques
  INEGI, Portugal

## Facilitator

- Gordon Bishop
  Managing Director
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  *Co-Author, UK Polymer Composites Sector: Foresight Study and Competitive Analysis*

## Observers

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  University of Nottingham, UK

- Dr Rodolfo Aoki
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  DLR (German Aerospace Center), Germany

- Dr Christoph Mayer
  Marketing Manager
  Gurit Suprem, Switzerland

# Annex 3: Issue Survey

The primary intention of the survey was to gather qualitative information on issues and trends to extend the knowledge gained from the technology scanning and workshop activities and to establish any regional variations. This was achieved through the use of a series of open questions covering trends and issues in materials, processes and applications, as well as a SWOT analysis.

At the same time, we also attempted to capture quantitative data on industry growth and trends in specific materials, processes and applications, wherever possible, through a series of closed questions.

The survey itself was conducted online through the Coronet (www.coronet.eu.com) and NetComposites (www.netcomposites.com) websites, with the survey results being held directly in a purpose-built database to allow effective breakdown and analysis of the results.

The survey resulted in 129 sufficiently completed responses to allow constructive analysis of the answers to qualitative questions, the primary goal of the survey. Unfortunately there were insufficient answers to the quantitative questions for that data to be viewed as numerically representative of the industry.

However, as part of the survey, respondents identified their current and anticipated involvement in different technologies, materials and sectors. To minimise the time needed to complete the form, replies were limited to whether a company was involved or not, rather than indicating actual levels of activity, and this information was useful in identifying some broad trends.

# Thermoplastic Composites Survey

coronet

Thermoplastic composites have enjoyed excellent growth over the last 5 years, in both Europe and North America, and against this background the Coronet partnership* was formed in 2001 to further develop the use of thermoplastic composites. We are undertaking a short study of the global thermoplastic composites market with the objective of defining the current market, predicting its growth and identifying the market needs, drivers and barriers.

The results of this work will be published as a consultation document for use by companies, researchers and government to help focus future commercial and development activities.

To ensure that our results are both accurate and useful, we would appreciate 5 minutes of your time to complete this short survey. In return we will send you a summary of our final conclusions for your own use.

**All replies will be treated in the strictest confidence**

This survey is being undertaken by NetComposites on behalf of the Coronet partnership. The Thermoplastic Composites Infrastructure Cooperation Network (CORONET) was formed in 2001 specifically to improve access to thermoplastic composites infrastructure and to encourage the sharing of knowledge and best practice. The network includes 18 research and industrial partners spanning 9 European countries and the project is funded by the European Commission.

**Progress**

**Next**

# Thermoplastic Composites Survey

coronet

## Section A. Organisation Profile

Name*

Position

Company*

Country*

Email

Telephone

Main business activity

Company type
Please tick all that apply

Manufacturer

Supplier

End User

Researcher

Consultant

Designer

Other

If 'Other', please specify

* Required Fields

**Progress**

**Next**

# Thermoplastic Composites Survey

## Section A. Organisation Profile - Business

| | | **Now** | *In 5 Years* |
|---|---|---|---|
| Percentage of company business related to thermoplastic composites<br>Please tick | 0-20% | | |
| | 21-40% | | |
| | 41-60% | | |
| | 61-80% | | |
| | 81-100% | | |

| | | **Now** | *In 5 Years* |
|---|---|---|---|
| Composites used/produced | Weight (kg) | | |
| | Value (US$/€) | | |
| Thermoplastic Composites used/produced | Weight (kg) | | |
| | Value (US$/€) | | |
| Company turnover (US$/€) | | | |

**Progress**

**Next**

# Thermoplastic Composites Survey

## Section A. Organisation Profile - Processes

coronet

What process routes do you employ?
Please tick all that apply

| | **Now** | *In 5 Years* | | **Now** | *In 5 Years* |
|---|---|---|---|---|---|
| Hand lay-up/spray up | | | Thermoplastic hand lay/vac bag (twintex) | | |
| RTM/ Cold press moulding | | | Thermoplastic RTM | | |
| Resin infusion (single side tool) | | | Diaphragm forming | | |
| Injection Moulding (thermoset) | | | Injection Moulding (thermoplastic) | | |
| Hot press moulding (SMC/DMC) | | | Press moulding (GMT/LFT) | | |
| Vacuum Bagging | | | Thermoplastic sheet stamping | | |
| Autoclave (thermoset) | | | Autoclave (thermoplastic) | | |
| Pultrusion | | | Thermoplastic pultrusion | | |
| Filament Winding | | | Thermoplastic Filament Winding | | |
| Other | | | If 'Other', please specify | | |

**Progress**

**Next**

# Thermoplastic Composites Survey

coronet

## Section A. Organisation Profile - Materials

What materials do you use?
Please tick all that apply

| | Now | In 5 Years |
|---|---|---|
| Carbon | ☐ | ☐ |
| Glass | ☐ | ☐ |
| Aramid | ☐ | ☐ |
| Other | ☐ | ☐ |

What format are these materials in?
Please tick all that apply

| | Now | In 5 Years | | Now | In 5 Years |
|---|---|---|---|---|---|
| Unidirectional | ☐ | ☐ | Continuous | ☐ | ☐ |
| Woven | ☐ | ☐ | Short discontinuous | ☐ | ☐ |
| Nonwoven (random) | ☐ | ☐ | Long discontinuous | ☐ | ☐ |
| Stitched | ☐ | ☐ | Other | ☐ | ☐ |

What matrices, precursors and compounds do you use?
Please tick all that apply

| | Now | In 5 Years | | Now | In 5 Years |
|---|---|---|---|---|---|
| Performance thermoset* | ☐ | ☐ | Performance thermoplastic* | ☐ | ☐ |
| Commodity thermoset* | ☐ | ☐ | Commodity thermoplastic* | ☐ | ☐ |
| Thermoset injection grades | ☐ | ☐ | Thermoplastic injection moulding grades | ☐ | ☐ |
| Sheet moulding compound | ☐ | ☐ | Glass mat thermoplastic | ☐ | ☐ |
| Bulk/dough moulding compound | ☐ | ☐ | LFT/Direct LFT | ☐ | ☐ |
| Prepreg | ☐ | ☐ | Pre-consolidated sheet | ☐ | ☐ |
| | | | Commingled | ☐ | ☐ |
| Other | ☐ | ☐ | If 'Other', please specify | | |

Progress

Next

* Performance materials include epoxies, BMI, PEEK, PES etc. Commodity materials include Polyester, Vinylester, PP, PET etc.

# Thermoplastic Composites Survey

## Section B. Trends and Issues

**In thermoplastic composites, what major trends do you see in the next 10-20 years in...**

If possible, please give percentage variations, expected growths/reductions etc, as this will make in easier to make a quantitative analysis of the results.

Materials?

Including imports/exports, fibre types, fabrics, resins etc

Processing technology?

Including fast processing, technology variants, processing of new materials

Markets?

Growth of new markets

Others?

**Progress**

**Next**

# Thermoplastic Composites Survey

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## Section B. Trends and Issues

**What major issues will affect the thermoplastic composites industry?**

The issues that will be affecting the industry and what we can do about those issues. These might include areas such as environmental and regulatory issues, cost-effective manufacturing, skills, awareness and education, standards or political issues.

Major Issues

% of business affected: 0-20% ☐ 21-40% ☐ 41-60% ☐ 61-80% ☐ 81-100% ☐

Time to maximum effect: 1-5 years ☐ 6-10 years ☐ 10-20 yrs ☐

Company action priority: None ☐ Low ☐ Medium ☐ High ☐

Please describe how this affects your company

Describe any relevant action already taken by you, your trade federation etc

What further action is needed by industry, government, researchers etc?

Progress

Next

# Thermoplastic Composites Survey

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## Section C: Summary

### SWOT Analysis

Please can you summarise the strengths, weaknesses, opportunities and threats associated with the growth of thermoplastic composites.

Strengths
(within the thermoplastic composites industry)

Weaknesses
(within the thermoplastic composites industry)

Opportunities
(from outside the thermoplastic composites industry)

Threats
(from outside the thermoplastic composites industry)

**Progress**

**Next**

# Thermoplastic Composites Survey

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## Section C: Summary

### Other Points

If you are not currently working with thermoplastic composites, what inhibits you?

Are there any other points that you would like to raise?

Progress

Submit

## Thermoplastic Composites Survey

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Thank you for your valuable input in completing this questionnaire, and we will send a copy of the final non-confidential report to the email address that you entered. Your survey reference number is 74c8c957-a2c0-4cc1-9e10-930b65f71916

Please be assured that we will not attribute any specific information to your company or publish any confidential data.

Please contact us at the address below with any questions about this survey

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Close Window

# Annex 4: Survey Respondents

The industrial survey respondents represented a broad cross section of suppliers, component manufacturers and end users from a range of sectors including automotive, aerospace, marine, rail, construction and sporting goods. These were coupled with researchers, designers and consultants, again in a range of sector industries, to give a comprehensive cross-section of the industry.

The level of respondent was typically at Director and Manager level in SME organisations, or Project/Programme manager in larger industrial companies. For research organisations, respondents were typically at least Senior Research Scientist, but more commonly at Professor level.

An indication of the companies that responded is as follows:

## Manufacturers

BACH Composite
AC.S
FACT GmbH
Technika Plastika
Airborne Development
DTC
COMP-LET s.r.o.
Svensk Kompositutveckling AB
Fibraplex
Adrecotech Ltd
Imhotep Ltd
Security Composites
Furmanite
Angerlehner Composites
Formitech
ZCL Composites Inc
Polywheels Mfg. Ltd.
Georgia Composites
Eleison, Inc.
Geotek, Inc.
Kemlite

## Suppliers

Saint-Gobain
Composite Process ApS
PGI/ Nordlys
BP Amoco Fabrics GmbH
Tenax Fibers GmbH
AC.S
SEAL Spa
Lankhorst
Gurit Suprem
Dow Automotive
CG Composites Pty Ltd
Indorama Synthetics India Ltd
LNP Engineering Plastics
Complastik Corp
Eastman Chemical Company
Cytec Engineered Materials
Noveon Inc
Zeon Chemicals
Owens Corning
Cyclics Corporatin
Universal Core LLC
Verdant Technologies
Phoenixx TPC, Inc.
Johns Manville

## End Users

Pilatus Aircraft Ltd
Faurecia
Fiat

Verducci Europe s.r.l.
Schelde Naval Shipbuilding
AEA Technology Rail BV
GKN Aerospace Services
Toyota Industries Corporation
Dutco Balfour Beatty LLC
NewTech Brake Mfg. (Suzhou) Co., Ltd
UTC Fuel Cells
Maxam Industries
TRW Automotive

## Researchers

K.U.Leuven MTM
Technion
Institute of Polymer Mechanics, University of Latvia
National Aerospace Laboratory NLR
Delft University of Technology
SINTEF
Universidad Politecnica de Madrid
IFP SICOMP AB
ETH Zurich
IWEP
TWI
Dept of Materials, QMUL
Oxford Brookes University
ADETE GmbH
University of Ulster
University of Newcastle
CSIRO
Japan Aerospace Exploration Agency
Erciyes University
Southern Research Institute
University of Massachusetts Lowell
National Composite Center
Michigan State University

## Consultants

PPM
L.Destouches
AC.S
DSBG
Conform
Svensk Kompositutveckling AB
Commander Consultants
Engineering Insight Ltd
Formitech
Kadis & Co.
Abaris Training Resources
Brosius Management Consulting

## Designers

Airborne Development
CETEC
Ellis Developments Ltd
ADETE GmbH
DXP
Lawrie Technology, Inc.

# Annex 5: Bibliography & References

## Bibliography on Foresight


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