

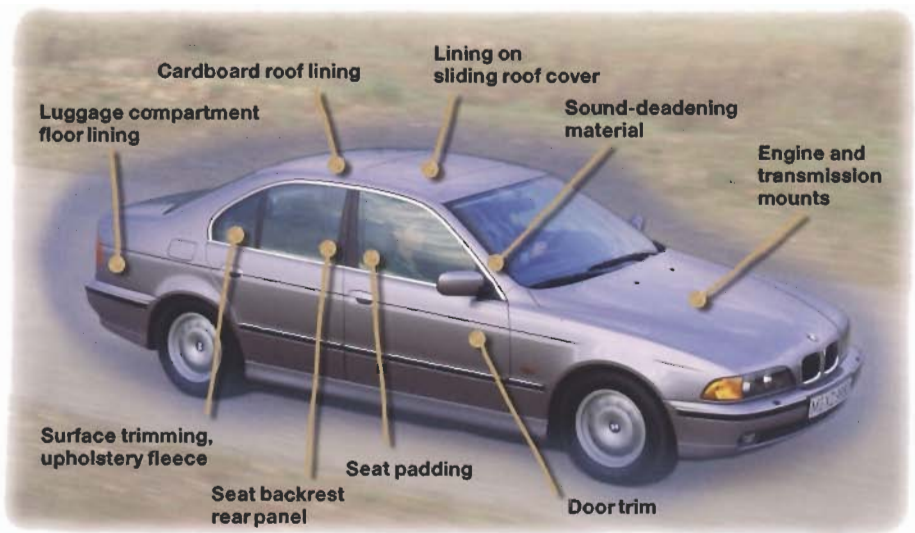
The need for automobile concepts compatible with the environment and growing awareness that our natural resources are limited have led to the re-discovery of an "old acquaintance" in car production: The use of plant fibres from re-growing raw materials in the construction of cars. Apart from significant amounts of leather and natural rubber, BMW has also been using other natural fibres for a long time and is preparing the introduction of even more natural products.



## Use of re-growing raw materials, taking the BMW 5 Series as an example

In recent decades natural fibres such as hemp, sisal, jute or flax have been replaced increasingly by synthetic fibres on account of ongoing industrial development. This was mainly attributable to the seemingly unlimited and very inexpensive supply of crude oil as a source of energy and raw materials. And there also were the technical benefits of synthetic fibres always remaining consistent in their quality and properties.

In more recent times, however, we see engineers in many areas looking at materials and combinations of various substances which might – but only at first sight – appear to be unconventional. Car makers, for example, now realise once again that flax fibres – coming from an old but almost forgotten plant – offer good technical potentials, in particular high strength and low weight. The only challenge is to put these positive mechanical properties to the right use with modern car concepts. In many areas this called for fundamental studies and the application of new perspectives, since know-how on the recovery and processing, properties as well as the use of plant fibres has been largely neglected for a number of generations and in some cases has even been forgotten. So the first step was to return once again to the traditional crafts and processes in the use and application of natural fibres. The next step is then to make such fibres and



their processing technologies compatible with the needs of modern large-volume production.

### Natural fibres in automobile fabric

First and foremost, of course, the fabric and textiles used inside the car offer good opportunities for the introduction of re-growing raw materials. Such fabric is used not only on the seats themselves, but also to a certain extent on the seat upholstery sections, the seat springs on former BMWs, for example, consisting largely of latex-processed coconut fibre, the cover itself of leather or wool. And even today the bottom of the seat upholstery is made of cotton fabric, the use of nylon flock as a synthetic fibre being limited to the top of the seats. This alone shows that BMW has been using re-growing raw materials for a long time already.

With the standards applied in modern car concepts constantly increasing, however, the demands made of fabric and textiles in terms of wear, resistance to light and colour-proofness over a long period of time have constantly become greater and more exacting.

Precisely these standards and demands make it increasingly difficult to use natural fibre in practice. And this is why natural fibres relatively sensitive to such external factors can only be used as the middle or lower layer in seats and on seat upholstery consisting of several layers. Things are different, on the other hand, when it comes to the seat padding, where now, at least in some cases, we see a certain renaissance of coconut fibre. In the interest of enhanced comfort, for example, BMW has developed foam padding with coconut fibre inserts for the seats on the 5 and 7 Series. Ensuring very good permeability and being able to absorb moisture, the natural fibre used here serves to significantly enhance seat comfort.

### Natural fibres for reinforcing specific components

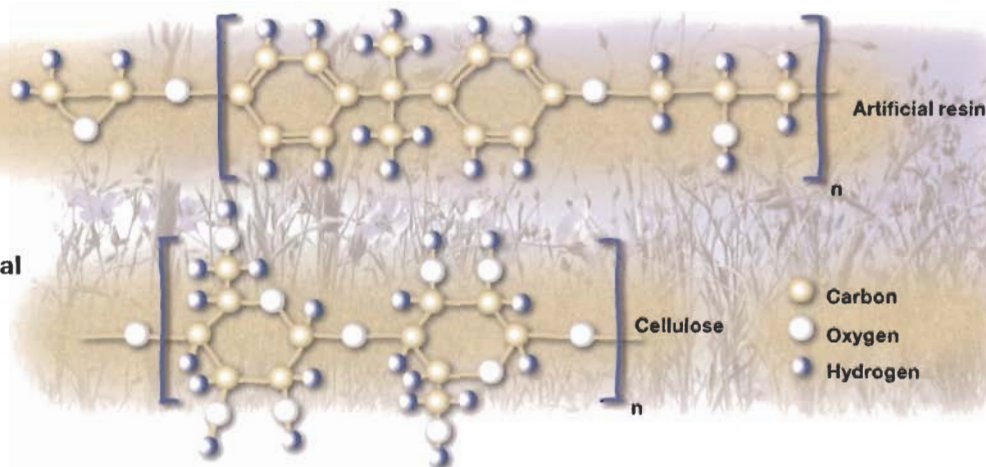
BMW was one of the first German car makers back in the early '90s to focus once again on the use of plant fibres for the purpose of strengthening or reinforcing specific materials. Conducting a pilot project together with a supplier and a manufacturer of fleece material, BMW cooperated closely also with the Bavarian Ministry of Agriculture and a flax processing specialist. The philosophy behind the project was to develop new and sensible perspectives for using agricultural areas in Bavaria that had become redundant.

BMW's membership in the non-profit-making C.A.R.M.E.N. Society must also be seen in this context. C.A.R.M.E.N. (Centrales Agrar-Rohstoff-Marketing und Entwicklungs-Netzwerk/Central Agricultural Raw Material Marketing and Development Network) has given itself the objective to promote research and development in the use of re-growing raw materials. The target, once again, is to secure the future of the farming industry by the introduction of new concepts compatible with the environment, beneficial to society, and of significant economic interest.



A blossoming field of flax

## Chemical structure of artificial resin and cellulose



## Integration of related synthetic materials

BMW's experts are convinced that the biggest potential of natural fibre these days is its use in reinforcing synthetic materials. Indeed, natural fibres and certain synthetic materials are even related to one another in terms of their organic and chemical structure. Thanks to this compatible "chemistry", and using artificial resin as a binder, it is relatively easy to establish a positive connection between such synthetic materials and natural fibres.

## Recycling and repeated use

The subject of re-growing raw materials is often raised in connection with the many debates these days on recycling old cars. Not least, this is also because "re-growing" is regarded as tantamount to "bio-degradable". In principle, however, natural fibres hardly comply with the general wish to make road vehicles recyclable to the greatest possible extent – so that the use of such materials as such does not provide a viable recycling concept. For technical reasons it is indeed essential to prevent any biological degrading (rotting) of plant fibres used in the automobile, since the various parts and components of a car must naturally remain strong and stable worldwide under all climatic conditions throughout the car's entire life-cycle. Precisely this is why new concepts use artificial resin as a binder coating the surface of the fibre and protecting it from moisture and micro-organisms. This then prevents the natural fibre from turning rotten and becoming weak.

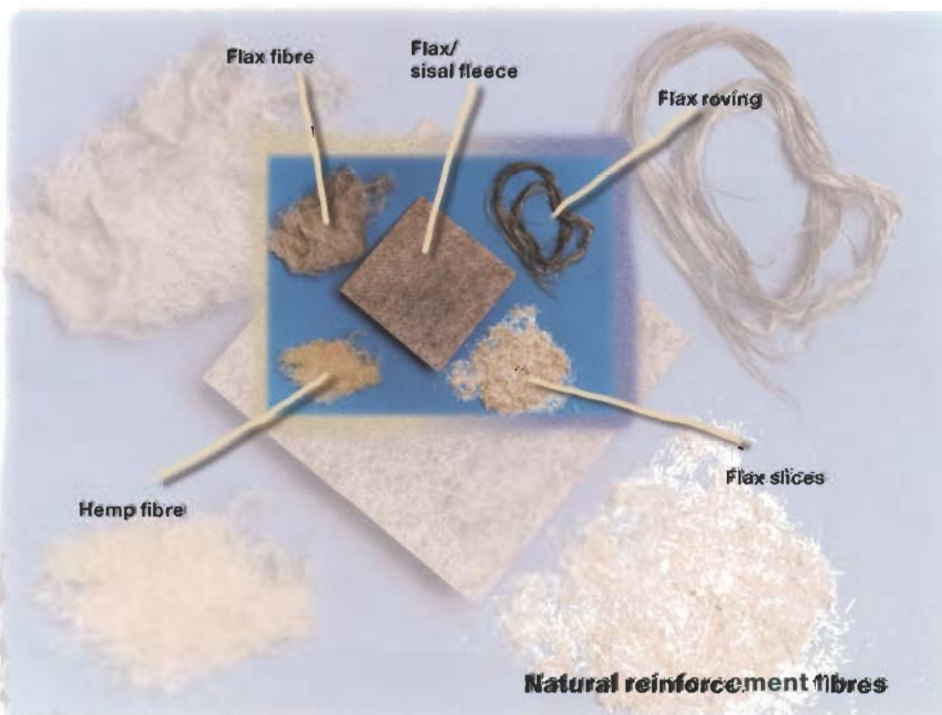
Components using re-growing raw materials – like all other components – therefore require specific recycling concepts. New methods for recycling materials, for example, grind the component in a grinding cylinder for subsequent re-use of the basic material.

Such re-use is however limited to the production of parts and components of the same nature and serving the same purpose as the original part. Another method applied for recovering natural fibres in such applications is to chemically de-compose the binders originally used. After having been used as a material, natural fibres, contrary to glass fibre, may also be used to generate energy – i.e. for combustion – with the amount of residues left over being reduced to a minimum. In this case, like with wood, the solar energy captured by the plant while growing is put to optimum use. This, in turn, helps to provide a positive CO<sub>2</sub> and energy balance and is the main reason why materials made of re-generating resources are given preference in the new German Economic Recycling Act over other materials.

## Competition of materials

Taking a very close and thorough look at re-growing raw materials at its Research and Development Centre (FIZ), BMW is a good example of the "competition of materials" now involving all materials used in the development of a new vehicle. After all, the objective in the development process is not to quite generally replace glass fibre in all cases as a material for reinforcing plastics. Rather, BMW's primary principle is to optimise each individual application from case to case.

Like all other materials, re-growing raw materials used for specific products and components must prove their benefits over other materials in terms of technical properties, ecological qualities, prices and availability. The use and consumption of ancillary materials relevant to the environment,



such as fluids sprayed on to the ground, fertilisers, and transport requirements, are of course also considered in this context, as is the origin of the materials used. It is only when the overall balance is positive, advantages outweighing possible disadvantages, that re-growing raw materials are actually considered for new applications. In this ongoing competition of materials, natural fibres nevertheless set out from a good starting point, offering the following benefits over conventional reinforcement materials such as glass fibre:

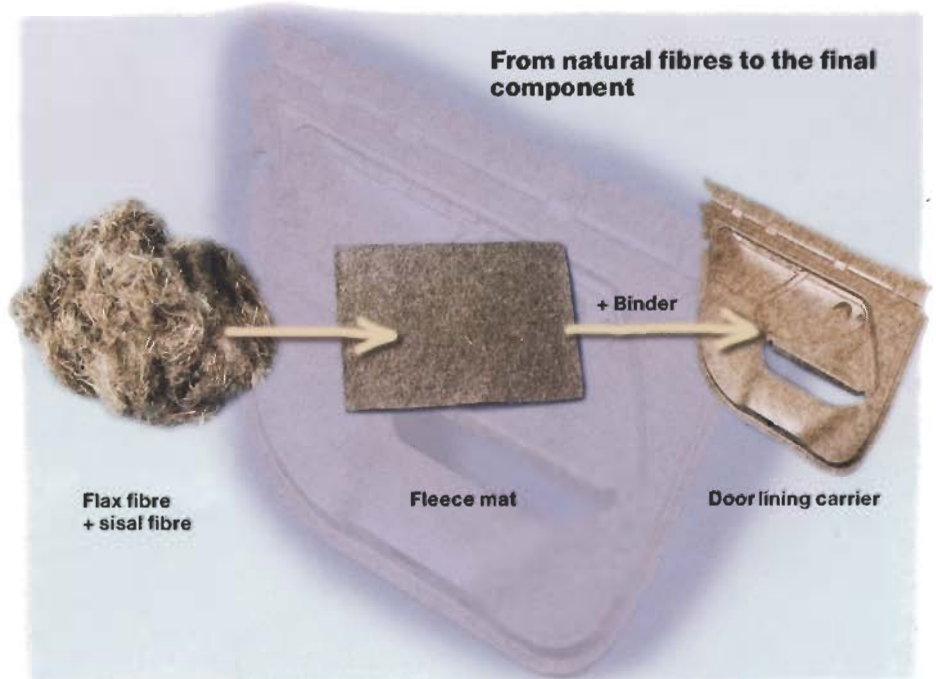
- A significant weight-saving potential thanks to their density up to 50 per cent lower, resulting in greater fuel economy.
- Better mechanical and processing properties thanks to their lower brittleness (crash behaviour) and abrasiveness (helping to preserve tools).
- A worthwhile potential for reducing costs thanks to the lower cost of raw materials under optimised harvesting conditions.
- A good opportunity to protect the environment thanks to energy saved in the recovery of fibres, the avoidance of CO<sub>2</sub>, and the preservation of raw materials.
- Good properties in terms of sound deadening.

Studies and experiments already carried out with re-growing raw materials nevertheless also indicate certain problems. One drawback is that natural fibres vary in their qualities and properties due to the effect of weather conditions. Another disadvantage is the need to store such materials for a certain period due to harvest cycles and the greater susceptibility of natural fibres to moisture and micro-organisms. In some cases the prices of fibre are still too high due to recovery methods not yet optimised with a view to BMW's specific requirements. Then there is the absence of quality standards for technical applications and the fact that the logistics required are in some cases still incomplete. And last but not least there are still problems in optimising the processing of natural fibres relatively short in length, and in building components of the right size and with the right dimensions.

Compared with synthetic fibres, it remains difficult to handle different standards of quality in the case of natural fibres, which is why BMW's development specialists seek in particular to determine and introduce standard fibre specifications and optimise their processing technology. Yet another fundamental criterion is the formation of the right fibre matrix, glass fibre being arranged in layers to provide a positive engagement of the fibre and the binder ensured by the chemical link between the glass fibre and the synthetic material. Suitable modification of the surface of natural fibres still requires further experience.

door lining of a new BMW from flax fibre, saving weight in the process.

The first step was to produce a suitable fleece material with defined technical properties from the flax fibre. One of the challenges facing the engineers was to ensure a consistent spread of fibres over the entire surface in order to obtain the mechanical properties required. Ensuring a consistent, reproducible level of fibre moisturisation with the binder (artificial resin) in the mould and obtaining the right kind of fibre needle effect were also important challenges in this context.

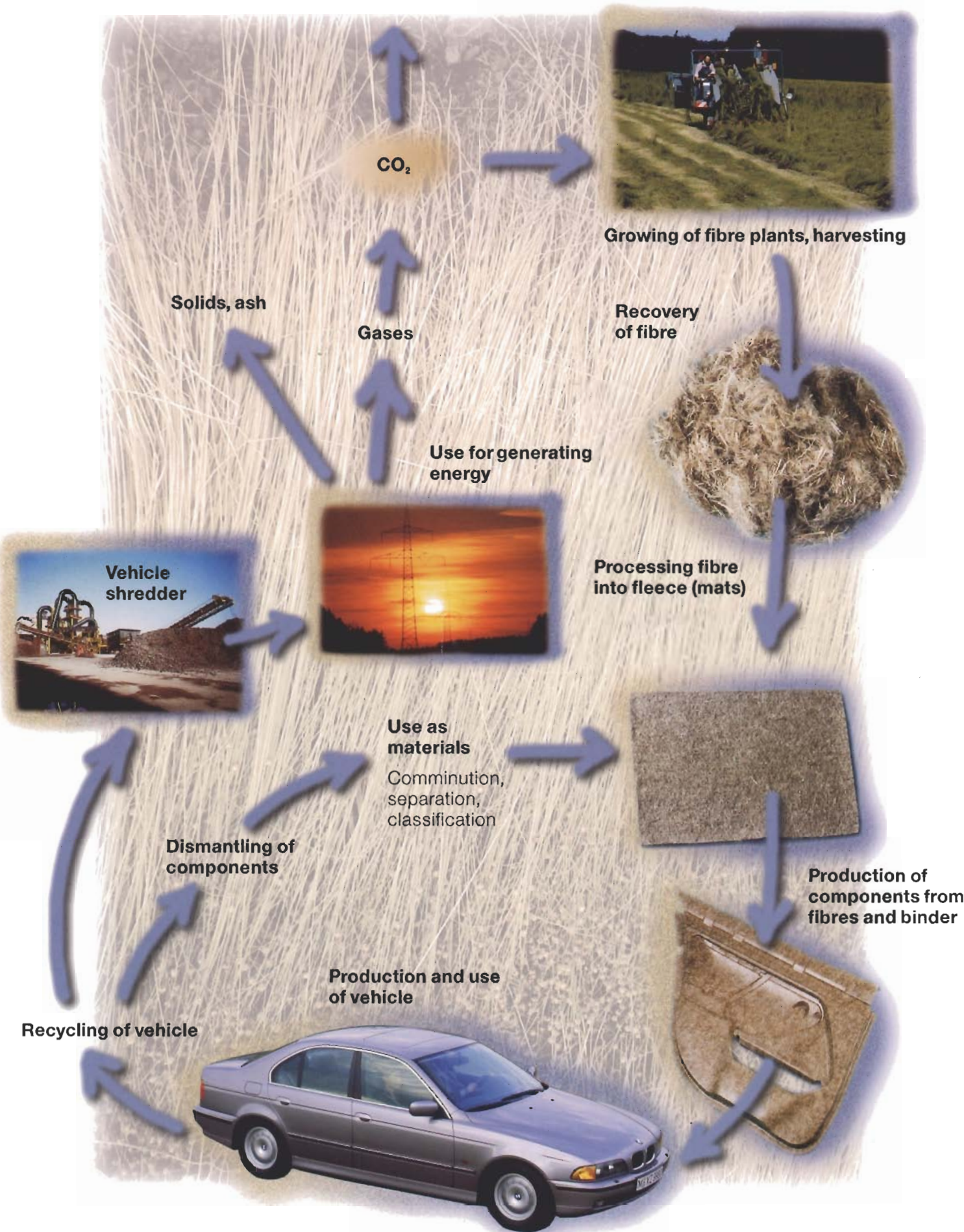


### Door trim pilot project

A three-year pilot project examining the production of the door lining shows in which areas there is still a specific need for development and what is already possible today. A number of fundamental points first had to be taken care of in this context before work could be started on the actual components as such. The specific assignment was to produce the inner

Particularly the former point – the moisturisation of the fibre – prompted the development engineers to quickly give up their original intention to use only flax, since the fine flax fibre was not able to absorb enough resin in order to produce components of suitable quality. A good solution then found, however, was to use a mixture of flax and coarser sisal fibre.

# Use of Materials Reinforced by Natural Fibres



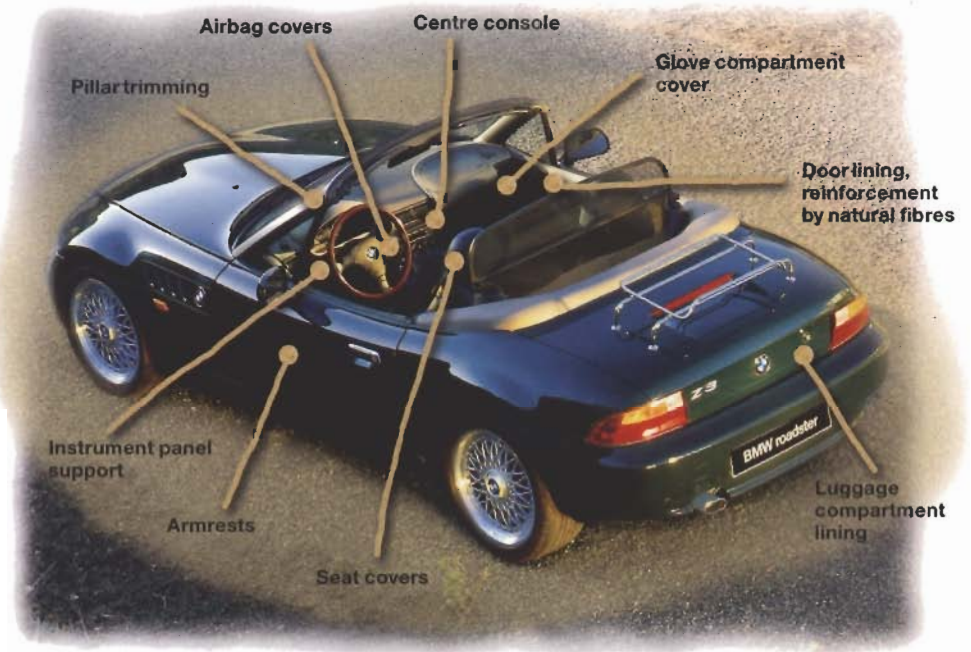
## Potentials for the production of components from re-growing raw materials

In a production concept for the inner door lining developed jointly with the manufacturer of this component, the first step is to process a mixture of flax and sisal fibres without any further additives, in the process forming a centimetre-thick layer of fleece. Mats made in this way are then sprayed with resin by a special unit developed for this purpose and moulded into the "crude" component in a high-temperature process at 160°C. Further steps serve to cover the component with trim material and to fit additional parts such as the door handles and storage boxes.

One of the most important objectives in every new development reaching standard production level for the first time in the new BMW 5 Series is to use materials with both better properties and lower weight. Taking a new approach in the processing of materials, for example, BMW's engineers were able to save approximately 150 grams per door lining, at the same time improving the splinter behaviour of the materials in the event of a crash and optimising the sound-deadening qualities. And all this was achieved at roughly the same level of costs, the extra expenditure incurred on the somewhat more expensive raw materials being set off by the lower consumption of binders, in this case resin.

The next generation of composite materials based on flax fibres is currently in the process of development and will soon reach application level. Given their thermoplastic matrix, such materials offer further benefits in terms of weldability, production methods, and recyclability.

Other types of fibre, such as hemp now also approved for growing in Germany, offer an additional potential in terms of economy, environmental compatibility, and the general performance of natural fibres when used as or in conjunction with construction materials. It is important to consider in this context that any substantial increase in the use of re-growing raw materials would require a great deal more farmland, at least when applying current standards. And at the same time the space required for growing cereals and other edible produce must of course not be restricted.



At least in the foreseeable future BMW's development specialists see pressed components inside the car as the best area for using re-growing natural resources to a greater extent. Their focus is above all on large components able to resist even substantial mechanical loads – for example lining and trim parts in the interior and luggage compartment as well as the various storage boxes and compartments. Development studies are already under way for such applications, with the objective to optimise the strength and crash behaviour, as well as the functional properties of the components concerned, such as their vibration behaviour, sound deadening, or the ratio between strength and component weight.

As a result of positive experience gained with materials developed out of re-growing natural resources, BMW has started to quite generally consider further applications of such plant fibres. One possibility is the use of thermoplastics, ie, the development of injection-cast compounds reinforced by natural fibre. Seeking to find the most suitable combination of materials for load-bearing components inside the car, BMW's development specialists are currently looking inter alia at alternatives to inorganic reinforcement materials such as glass fibre or talc used in injection-cast components.

A further project for the future is the development of alternative binders or matrix materials based on re-growing natural resources. Such "natural plastics" made of starch, sugar, cellulose or vegetable oil offer the advantage of providing an even better CO<sub>2</sub> balance. New recycling concepts would also be possible in this case due to the greater similarity of the matrix and fibre materials. And last but not least, BMW's development specialists expect these materials based entirely on natural resources to offer some entirely new properties. One day, therefore, storage compartments in the doors of a car, the roof lining, the floor panels in storage compartments as well as the compartments themselves or even complete instrument panels might be made out of re-growing raw materials, applying technologies of this kind. This is of course a long-term proposition, since development engineers, in the process of creating such new materials, production concepts and practical applications, still have lots of challenges to overcome.

Current Factbook

"Use of Re-Growing Raw Materials by BMW"

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