ENVIRONMENTALLY BENIGN PACKAGING WITH INNOVATIVE ADHESIVES

Dr. Hermann Onusseit

Henkel KGaA,
Düsseldorf

ABSTRACT

Modern packaging is an important component for the storage and distribution of all kinds of products. Next to this primary task of packaging, consumers demand more and better information about products that they buy and today packaging is responsible for marketing tasks, too. In addition to better technical solutions, a trend can be seen toward the increased importance of environmental protection in manufacturing of packaging and distributing products. As adhesives play a major role in the production of nearly all goods and especially in the production of packaging, the question of how adhesive applications influence the idea of a closed-loop economy is becoming more and more important. Adhesives are used for manufacturing as well as for finishing and closing of packaging. By the combination of different materials with selected properties an over-proportional increase in the performance can be achieved. Bonded lightweight constructions save resources and are substituting for many conventional systems today. Adhesives that are used in packaging production processes increasingly are designed so that they make a reuse of products or a recycling of materials possible. Modern packaging adhesives fulfill the idea of "Responsible Care" as well as "Sustainable Development" and help to establish a well-functioning packaging industry around the world.

INTRODUCTION

Packaging production globally is estimated at US $400 billion and of this consumer packaging is the biggest segment, accounting for some two-thirds of all consumption. The total packaging materials business is expanding gradually with regional differences consistent with GDP growth. The growth in packaging is largely driven by increased demand for consumer packaged goods. Modern packaging is an important component for the storage and distribution of all kinds of products. In addition it also serves as a preservative for food. In industrialized countries, modern food packaging has eliminated almost completely the risk of loss and damage of goods, and attack by bacterium or insects. However, in developing countries the lack of suitable packaging and logistics results in dramatic losses in goods as well as quality losses.

Next to this primary task of packaging, consumers demand more and better information about products that they buy. Content, calorie and nutrition facts, best-before date, security warning, instructions, name and address of the producer and much other information that is printed on the packaging offer a service that was unknown just two generations ago. Packaging should also simplify the handling of goods. Excellent stability of the packaging, easy opening, but also easy re-closing, transparent windows to make the contents visible, handles and other features are demanded. In addition the thought of convenience is discussed frequently today. Packaging has to be safe, too. In the packaging sector these ideas can be found, for example, in childproof stoppers on medicine bottles or on bottles containing chemicals.

Today packaging is responsible for marketing tasks, too. In modern supermarkets the goods have to sell themselves and the image of a product is decisively formed by its packaging. As surveys have shown, the average customer does not take even three seconds of time to evaluate the products. Thus packaging has to attract his attention in this short period of time and influence the purchase decision positively. Often the attractiveness of the packaging or even the "experienceability" of a package at the point of sale determines the success of a product.

Next to these wishes already considered we have to expect that in the future packaging will be even more complex. Active or intelligent packaging is discussed on a broad basis today. Active packaging is most of the times used in the food sector and influences chemically, biologically or physically parameters of the packed food by new materials. It is used e. g., to increase the keeping quality of food products. Intelligent packaging is usually defined as packaging with an external or internal indicator. This indicator can provide information about the product history and about the current product quality. There are direct indicators that provide direct information about product quality, and indirect indicators that provide information about the composition of the air contained in the packaging, or about the storage temperatures possible, which can be used for drawing conclusions about the quality of the product in the package. In addition, intelligent packaging with extended EAN-technology or RFID (radio frequency identification system) technologies are discussed, such as plastic chips made of conductive and semiconductive organic material (polymers) that can be printed like labels and bonded to the packaging. Such systems enable the collection of much information about the product, its origin and the trade route. Furthermore such systems can be incorporated into the electronic "bar code" to make possible an automatic record of the goods at checkout. Furthermore it is thought about the ways in which active packaging can "communicate" with kitchen appliances like microwave ovens or refrigerators, so that the microwave oven chooses the right temperature and cooking time and the refrigerator is informed in time about a best-before date of stored foods.

In addition to better technical solutions, a trend can be seen toward the increased importance of social responsibility and improvement of environmental protection in manufacturing of goods, especially in the production of packaging and distributing products. The thought is that our actions must be those of sustainable development that treats economical, ecological and social objectives.

These increasing demands for packaging described above plus the market penetration of discount stores and supermarkets at the end of the Sixties have lead to the development of new packaging concepts with the use of better and better materials. Traditional containers of glass, metal, and paper have been developed further or have been replaced by plastics or by flexible compounds of plastics with other plastics or with metal. However not only the quality of the materials used for packaging is constantly increasing, but also their quantity. This has to do with the fact that world population is steadily increasing [Fig. 1] and thus with the constantly increasing amount of goods that are packaged.

For the production and during the use of packaging considerable amount of natural resources are consumed. The finiteness of natural resources made it necessary to think about how to save them. Concerning saving resources there are basically two ways. One can save resources that are needed directly for the product and one can save resources needed for the production and later usage of the product. While in the first case all kinds of resources are possible, in the second case it is almost only about energy for the production of materials or the transport of the goods. The wish to save resources when manufacturing a product can be best fulfilled by avoiding particular components completely by the use of a new system solution or at least by reducing them considerably without causing problems for the function of the products. Lightweight is a buzzword that can be heard in almost every application. In recent years, packaging has been produced by intelligent solutions that required far fewer resources yet was also considerably lighter without being affected in its functions.

Next to saving material there is another ecological and economical benefit when using lightweight packaging. The reduction of weight results in a reduction of the amount of energy needed -- for production, but also for the transport of the packaging -- and thus to a saving of energy resources.

Another method to stop the impending depletion of our natural resources is reuse or recycling. By the reuse of products the consumption of resources can be delayed until the product is absolutely not usable anymore. In the recycling of products one assumes that the materials of which products are made can be reused to produce new products. This also saves resources and also usually a substantial amount of energy is saved if raw materials are recovered from the products.

TOO MUCH PACKAGING?

Consumers often think that goods are over-packaged, in part because they do not know much about the entire transport and logistics chain from filling to the end user. Packaging has fulfilled a lot of essential functions before it is in the hands of the consumer.

In principal, consumers think of unpackaged homemade food as more "natural and also more environmental-friendly" in contrary to "polluting" packed food that is prepared industrially. However often the contrary is correct. The peeling of fruits and vegetables or the preparation of poultry at home leads to losses of 10 to 60 percent. This goes directly to the rubbish bin, whereas the food industry uses these materials – sometimes up to 100 percent. The industrial solution causes less waste, on the whole, despite the packaging material needed. The importance of packaging can also be concluded from its ability to prevent the food from going bad during transport und storage. While in the industrialized countries only 5% of the food is lost by going bad during transport and storage, in the developing countries this amounts to about 60%. A look on the everyday waste of food in the industrialized world in comparison to the developing world shows that – with view to the continuously growing population on our planet – a main goal should be the development of a well-running packaging industry.

OPTIMIZATION OF PACKAGING – SUSTAINABLE DEVELOPMENT

If we look at the packaging industry, the following objectives can be defined from the environmental point of view:

- Minimization of the use of non-renewable resources
- Minimization of energy consumption
- Minimization of air pollution
- Minimization of solid waste products.

In other words: improvement of the eco balance "from the cradle to the grave" for packaging solutions. While at the beginning of the Industrial Revolution nobody much thought about the finiteness of natural resources, during the last decades of the twentieth century the call for resources-saving processes became louder and louder. The finiteness of many natural resources made it necessary to think about how to save them by developing resource-saving technologies, e. g., to recycle materials. To execute this recycling successfully, it is necessary to consider this early during the construction and production of goods, and this leads to the idea of sustainable development. Sustainable development was introduced at the environmental summit in Rio de Janeiro 1992 as a model for future action. The idea is that people living today should be able to satisfy all their needs without leaving a heritage of pollution, climate problems, and used-up resources for future generations. The solution of this task depends on the ability to use available wealth of the earth economically and ecologically efficiently. The available resources are too precious to be destroyed after single use.

SUSTAINABLE DEVELOPMENT – CLOSED-LOOP ECONOMY

Methods to stop the impending depletion of our natural resources are economical handling of resources, repeated use of sophisticated goods, and consequent recycling on the highest technical level. The concept is called waste management. To avoid waste is the highest objective -- waste must retain lasting value as far as possible. Waste does not have to be refuse, but can instead be a raw material in demand, with a lot of opportunities for usage. The part of waste that cannot be recycled will therefore be reduced to a minimum and material re-circulation will be more nearly a closed loop. Ecologically sensible programs cannot be achieved for free, but the introduction of new sorting and recycling technologies has already begun to reduce the costs of recycling noticeably and to improve the quality of secondary materials. This is a prerequisite for high-quality products that can maintain their position on the international market. For the purposes of a sustainable economy resources have to be saved for the next generation’s renewable raw material, and energy sources. This thought is pushed forward more and more by the legislature: the introduction of the Packaging Ordinance in Germany in 1991 was a decisive step in this direction. On the European level, this thought has been advanced since 1994 by the European Directive on Packaging and Packaging Waste. The aim of this directive is to continue to reduce the amount of packaging waste in Europe by 2006. Through 2001, a 50% reduction of packaging waste was planned, but at the end of 2001 55-70% was proposed as a new target for the year 2006.

Meanwhile the idea of careful treatment of resources was especially stressed in the law of waste management that was passed in Germany in 1996. Its definition of the purpose of this law makes clear the course of today’s waste policy: “The purpose of this law is the support of waste management to support the careful treatment of natural resources and the protection of an ecologically compatible disposal of waste“ (Section 1, Product Recycling and Waste Management Act, dated 7 October 1996).

ADHESIVES IN BONDING AND FINISHING OF PACKAGING

As adhesives play a major role in the production of nearly all goods and especially in the production of packaging, the question of how adhesive applications influence the idea of a closed-loop economy is becoming more and more important. Adhesives are used for manufacturing as well as for finishing and closing of packaging. By the combination of different materials with selected properties an over-proportional increase in the performance regarding temperature resistance, barrier properties, mechanical stability and optical attractiveness can be achieved. Bonded lightweight constructions save resources and are substituting for many conventional systems today. Adhesives that are used in packaging production processes increasingly are designed so that they make a reuse of products or a recycling of materials possible.

WASTE HIERARCHY

While in the past waste has either been burned or landfilled, the necessity of careful treatment of resources has lead to developing a so-called waste hierarchy. For the field of packaging technique this thought has far-reaching consequences. It would be ecologically best, of course, to avoid packaging completely, where this could be done without causing problems for products during transport and storage. Less packaging, same content. That is possible: between 1991 and 1999 the consumption of sales packaging decreased per German citizen from 95.6 kg to 82.5 kg per year, which is almost 14 % less [1]. If packaging is unavoidable, we have to consider whether a reduction in packaging material is possible, e. g., by the reduction of the thickness of the packaging material used or by new intelligent solutions.

To pick up the idea of waste management, it is also necessary to consider during the package planning stage the possibility of reuse or recycling of the used packaging materials. This includes designing all additives involved in the process in a way that they do not negatively influence the later reuse or recycling of the package materials.

If a reuse of the packaging or a material recycling, that is a regaining of the materials to reuse them, is not possible, one could imagine composting packaging based on organic material. It means closing the recycling of these raw materials by returning them to a form available for nature. There are now biodegradable materials for packaging on the market that are made especially for later disposability.

If a material reuse, that is recycling or composting, is not possible, one has to consider to what extent packaging can be designed so that it can be incinerated to utilize at least the energy contained in the packing material. In this regard one also has to consider early that the packaging additives do not lead to problems in the burning afterwards.

The last alternative, should none of the above-mentioned possibilities be available, is still landfill. But even here one must consider that packaging materials in the landfill do not lead to problems such as critical water-soluble substances getting into the ground water.

Therefore one should consider for the planning of a package the following questions:

1. Can the use of resources (materials and energy) be avoided?
2. Can the use of these resources be reduced?
3. Can the packaging be reused?
4. Can recyclable or compostable materials be used?
5. Can the used product be incinerated without problems (Energy recycling)?
6. Can this product be buried in landfill for long times without problems?

AVOIDING OF MATERIAL

The intention to save resources is of course best realized by avoiding completely the use of certain components. In the field of packaging there are a lot of examples:

Packaging-free pressure sensitive hot melt adhesives

Pressure sensitive hot melt adhesives are thermoplastic materials that are solid at room temperature and also surface-tacky. They used to be filled into siliconized packaging material (paper or PE) [Fig. 2]. The users had to take these very sticky adhesives out of this packaging and place them into the hot melt applicator, then the packaging material had to be disposed of separately.

Today PSA hot melts are packed in plastic film [Fig. 3] that is put into the hot melt applicator together with the adhesive. The packaging film becomes a part of the formulation, so no waste is created.

Renunciation of folding boxes in toothpaste packaging

When somebody bought a tube of toothpaste ten years ago, it always came in a folding box. The folding box was needed to protect the tube against damage during transport, and served as a sales package in the store. With the introduction of toothpaste dispensers the folding carton is no longer used. However, to guarantee safe transport the single dispenser must be fixed so it is not damaged during transport, and it is still important that the product is attractive and easy to handle for the customer at the point of sale.

These demands are met with adhesives. Instead of packing into single folding boxes, the dispensers are fixed in a tray with pressure sensitive adhesive [Fig. 4]. This pressure sensitive adhesive is applied very thin and serves to hold the dispensers during transport. The adhesive is formulated so that separation of the dispensers can be achieved easily in the store. For this is it especially important that the adhesion and cohesion capability of the adhesives is coordinated optimally, so that on the one hand there is sufficient tack during transport and that on the other hand the toothpaste dispenser does not get dirty because of adherent adhesive.

Substitution of stretch- and shrink-wrap by pallet stabilizing adhesives

The idea of temporary bonding can also be found in pallet stabilizing adhesives. These are used between sacks and cartons stacked on each other on pallets, so that they cannot slide or drop from the pallet [Fig. 5]. The bond must not be so strong that the sack or carton is damaged during separation in the warehouse or by the customer. Both hot melts and water-borne adhesives have been developed for this purpose. The hot melts are sticky products whose adhesion-cohesion properties are chosen in the way that they offer sufficient adhesion to prevent the goods from sliding, yet the adhesion is not so high that the surface of the packaging is destroyed during separation. Aqueous adhesives for palletizing have weak cohesion, with enough shear strength to hold against slipping, and break cohesively when packaging is separated. To achieve the desired properties it is important that the palletizing adhesives are applied very precisely. To ensure this it is necessary that the adhesives are adjusted to the application units, especially concerning their rheological properties. As the application of these adhesives is extremely thin, the remaining adhesive films do not disturb the appearance of the packaging. Because of that, pallet stabilizing adhesives can be used for sales packaging that can be displayed on store shelves.

By the use of pallet stabilizing adhesives up to 1,000 grams or more per pallet of stretchwrap or shrinkwrap can be saved, and these savings can be even bigger if packaging has to be broken down and repalletized several times. Hot melt types can provide multiple protection because they are permanently sticky, so that only one application is needed even when loads are repalletized later.

Folding-box packaging without interior pouches

Many products of daily life are packed in folding boxes today. Folding boxes are a highly versatile package form, made of different qualities of paperboard in many different sizes and printed to accommodate any number of applications. They can be produced efficiently with the help of adhesives and can be filled easily and at fast speeds. They can also be closed safely with adhesives in a tamper-evident closure. However, the critical spots in closing folding boxes are the eight corner points of the box. Depending on the style and the quality of the carton, a hundred per cent tightness of the folding box cannot be achieved all the time. It is thus common to insert an interior pouch for food and for flowable goods to avoid a trickling out of the content, or an attack of the food by insects that could enter the package through the channels formed on the corner points. As roughly half of all folding boxes are produced for the food sector, there has been an intensive search for alternative solutions to guarantee the tightness of the folding boxes, and at the same time do without the interior pouch.

Newly designed folding boxes, corresponding adhesive application units and suitable adhesives have contributed to turn this wish into reality. Folding boxes protected against insects and trickling out can be manufactured today without the interior pouch [Fig. 6]. That yields not only economic savings, but is also a progress concerning the saving of resources. By the cancellation of the interior pouch and by the smaller folding box measurements, not only is the amount of packaging reduced but also advantages in the following chain of logistics are achieved: by the cancellation of the pouch machine additional investment and production costs are reduced; and space is saved in production. The hot melt adhesives used in this process are characterized by an optimized setting behavior. They allow a fast and safe closing of folding boxes on high speed systems. Therefore it is necessary that they can be applied very precisely and show an extremely clean breaking on the application nozzles, in order to guarantee one hundred per cent bonding. The rheological properties of the ethylene vinyl acetate copolymer or polyolefin-based hot melts used for this application have therefore been adjusted especially to the application units.

REDUCTION OF THE CONSUMPTION OF RESOURCES (MATERIALS AND ENERGY)

Lightweight construction is today an important design criterion in the packaging business as well as in most other industrial fields. The possibility to reduce the absolute amount of material needed for the production of a product by clever construction is economically useful, as material costs can be saved. Furthermore it is also ecologically useful, as less resources are needed or less residuals have to be disposed. Next to saving materials there is a further economical/ecological benefit of lightweight construction. Many products must be transported over long distances and the energy needed for transportation depends above all on the mass of the goods transported. Lightweight construction leads to a reduction of energy used for transport and therefore to saving energy resources (e. g., petroleum) and to a reduction of environmental pollution by, for example, CO_2 (greenhouse effect). Due to better raw materials, improved converter technique, and more efficient design in the last two decades, considerable weight reductions have been achieved for packaging. This has often been achieved by using compound materials that can be produced with the help of adhesives.

Packaging laminates – flexible packaging

A very impressive example for this is laminated packaging film made of plastic or plastic and other materials. Different materials with selected properties are combined to achieve a disproportionate increase of temperature stability, barrier properties, mechanical strength and optical attractiveness. The range of plastic films and metal foils that are used for the compound combinations in the packaging sector comprises polyethylene, polypropylene and paper as well as rigid PVC, polyvinylidenefluoride, cellulose film, polyester, polyamide and aluminum. The plastic films can additionally be coated with aluminum to increase the protection from light and the barrier properties, or be coated with PVDC, acrylic or SiOx to increase the barrier properties.

There are special laminating adhesives for all of these different applications. The most important group of laminating adhesives are polyurethane adhesives (PUR laminating adhesives), either based on aromatic or aliphatic isocyanates. The basic chemistry is the reaction of diisocyanates or polyisocyanates with OH-terminated substances or moisture. Due to the possibility of using an excess of isocyanates reacting with moisture the application of polyurethane chemistry is the safest way of using reactive systems. The excess of isocyanate leads to the fact that the systems contain no monomers after complete curing. PUR laminating adhesives containing solvent have been used for this application for a long time and are still applied in large quantities today. The production of compounds with the help of these adhesives requires a large amount of energy involved for drying as well as larger amounts of raw material for the adhesive and the solvent added. Their environmental compatibility concerning "Sustainable Development” is insufficient, even though the production system is coupled with a solvent recovery plant. To overcome these disadvantages high solid and solvent-free PUR laminating adhesives have been developed.

The first systems of solvent-free PUR laminating adhesives were one-component moisture-curing systems. As they are NCO-terminated polyether or polyester prepolymers they are dependent on available or added moisture to cure to a polyurethane. Today these systems are preferably used for paper compounds only, such as oriented polypropylene with paper. To avoid this limitation of solvent-free moisture-curing one-component systems, two-component systems have been developed. These two-component standard systems are usually based on polyester or polyether and have a polyurethane curing agent. Both components are liquid at room temperature and can be applied cold, preferably between 25°C and 45°C. In recent years systems have been developed that can be processed at 40°C or 70°C, and this new generation of solvent-free laminating adhesives combines the advantages of the initial tack of a high solid system with the easy processability of a solvent-free liquid phase. The prepolymers are synthesized in a way that a fast curing with the curing agent is made gradually, beginning with the desired and complete reaction of the monomers.

Although adhesives are only of minor importance regarding their amount compared to the materials bonded with them in most applications, there are possibilities to save resources by using these new innovative solvent-free laminating adhesives for food laminates. From food laminates high requirements are demanded and for decades these could only be fulfilled with the help of adhesives containing solvents. To get the adhesion needed for these complicated bonds, it was common to apply 10 g/m² of a 40-percent-solids laminating adhesive: after drying, 4 g/m² of adhesive remained for the bonding. With the newly developed solvent-free laminating adhesives the same performance of the laminates can be achieved by applying 2 g/m². Next to the absolute 50 percent saving of adhesive by these new systems, resources are saved by avoiding the solvent as well as energy for drying and also for transport of the considerably less amount of adhesive.

For sterilizable aluminum/film compounds solvent-free laminating adhesives based on aliphatic isocyanates have been developed. These so-called aliphatic laminating adhesives are processed at 70°C with conventional laminating machines, dosing and mixing apparatus. Their main advantage is the lack of aromatic isocyanates, which is getting more important regarding food legal regulations.

The prerequisite for the use of all polyurethane laminating adhesives mentioned is that only after a complete curing are the full thermal and mechanical properties reached in the construction. Depending on the adhesive type, film combination, and temperature, the curing time can be a week or longer. This curing period can be shortened by increasing the temperature. The overall time needed for the production of packages including printing, cutting and so on is definitively very important. The capital lockup costs caused by long curing times influence more and more the cost situation, especially in businesses with a high competitive pressure. So it is no surprise that the customers are looking for a laminating adhesive which cures so to speak ‘on command’. One possibility to fulfill this wish is the use of radiation-curing systems. These systems have the advantage of achieving a very fast initial tack. If we compare the initial tack of laminating adhesives, we can see that solvent-free systems have a substantially lower initial tack than systems containing solvents. The reason is the considerably lower molecular weight range and the different molecular weight distribution, which makes such a low viscosity possible that the systems can be applied without thinning with solvents. With radiation-curing laminating adhesives it is possible to apply the adhesive solvent-free at low-viscosity and quickly achieve a high initial tack after radiation as well as a very fast final strength. Since the end of the nineteen nineties this systems has been developed. The different curing mechanisms of the radical and cationic polymerization allow different process steps regarding radiation and lamination [Fig. 7].

Another possibility to avoid solvents is the use of aqueous laminating adhesives, that have already been developed at the beginning of the nineteen nineties. These can be used on existing laminating machines. An additional advantage when using aqueous systems is a high initial tack and a fast curing due to the high molecular weight of the dispersed particles. Moreover no solvent residues remain in the compound.

The possibility of saving transport energy by the choice of adhesively-laminated composite material can be illustrated by coffee consumption in Germany. The annual consumption of coffee in Germany is about 160,000 tons, usually sold in 500-gram packages. If the 160,000 tons would all be packed in glass, more than 170,000 tons of glass would be needed for this. To transport these glass jars to the coffee-roasting plants about 8420 trucks would be needed. If the same amount of coffee would be sold in tins, more than 37,000 tons of sheet steel would be needed, and about 8000 trucks since empty tins take up nearly as much space as empty glass. The same amount of coffee packed in laminates would need only 5440 tons of laminates and 350 trucks. But not only the transport of the packaging material, also the transport of the packed goods is advantageous with laminates. In the transport of filled coffee containers, laminates still have the advantage because they pack more efficiently in a case and weigh less. The total number of trucks needed annually to transport all the coffee sold in Germany would be 17,390 if packed in glass, 14,550 if packed in tin, and just 6,530 if packed in laminates. This example shows that a clever choice of packaging material reduces the total amount of packaging material plus the costs and pollution caused by transport of packaging and packed goods.

High demands are made on the laminating adhesives used for the production of these coffee packages of laminates (polyethylene/aluminum/polyester). Besides safe bonding of the materials, they are expected to allow processing without problems on laminating machines running up to 400 m/min. As it is a question of packaging material for food, of course all legal food requirements have to be fulfilled.

Polyethylenetherephthalate (PET) bottles

This material was used for the first time at the end of the nineteen seventies in the USA as a replacement for glass in beverage bottles, and since then its use has spread world-wide. There are two good reasons for using PET as bottle material: considerably less weight compared to a glass bottle (less than 10%) and PET bottles are unbreakable.

This new packaging material can contribute to saving resources during the distribution of beverage bottles. If we compare 1-liter PET bottles to 0.7-liter mineral water standard glass bottles that are used in the mineral water industry, it can be seen that due to less weight of the PET bottles a considerably larger amount of filled goods can be transported. The comparison of the transport energy of the two different beverage bottles is founded on a typical distribution vehicle with a total weight of 11,900 kg and a payload of about 6,000 kg at a loading space of about 5.6 m. Such a vehicle can carry either 7 mineral water pallets with 48 crates each, or 10 Euro pallets with 40 1-liter PET reuse bottle crates each. This means that by the use of PET bottles 1,978 additional liters of mineral water can be transported per trip (in real numbers: 4,800 liters mineral water compared to 2,822 liters mineral water in glass bottles). This simple calculation shows the vast saving in transport and resources that resulted from the introduction of light plastic bottles. [2].

The introduction of this resources-saving technique has been made possible by the development of labeling adhesives that stick safely to plastic bottles and are easily removable in the bottle-washing machine. If we compare the adhesive requirements for plastic bottles with those for glass bottles, we see that the adhesion spectrum of the labeling adhesives for glass bottles is not sufficient for plastic bottles. Although PET is a relatively polar material -- 45 mN/m, thereof 15 mN/m polar share -- it is by far less polar than glass. For this reason the adhesives for PET labeling have to be based on a different formulation in order to obtain a safe final bond to PET. Hence it was necessary to develop new adhesives that also stick safely on the plastic surfaces and can be processed on fast labeling machines (of 50,000 bottles/hour or more) without problems.

PET beverage bottles for carbonated drinks are often labeled with die-cut or ticket labels. These are applied with equipment similar to that for labeling glass bottles, and from a rheological point of view similar adhesive systems are necessary. As the casein-based adhesives which used to be applied did not show enough adhesion, adhesives have been developed that provide better adhesion with the same rheological properties.

If PET bottles are dressed with wrap-around labels, hot melt adhesives are typically used, applied at high production speeds. Here the pick-up adhesives have to be designed in a way that they ensure a safe pick-up of the labels. The overlap bonds must resist high temperatures, which is a rather difficult demand since plastic bottles, contrary to glass bottles, distort at high temperatures. The resulting increase of diameter leads to high shear stress at the overlap bond. The perfect overlap adhesive is designed so that it absorbs these shear strengths elastically. The hot melts used for this are made of synthetic hydrophobic polymers and thus are not water-soluble nor alkali-soluble. Where these properties are required, as for reusable bottles or for a mono-material recycling, specially developed hot melts must be used. The rheological demands for the melt adhesive for PET labeling largely depend on the application system of the labeler. According to the construction, different labelers are used which employ either non-contact nozzle application or segment application [Fig. 8]. In both cases the adhesives have to be optimized rheologically in a way that inhibits stringing in order to avoid machine pollution and, as a consequence, interruptions of the production process.

A special challenge is labeling with plastic labels. These are becoming more and more important because they offer greater possibilities to the label designer than do paper labels. Plastic labels do not change their appearance when they get wet. Plastic labels are difficult to label with traditional water-based adhesives because the water drains only slowly from the glue line. For wraparound and labeling, hot melts are usually used and this labeling is often done directly from the roll. This can be done at very high speed. With plastic labels the so-called 'no-label look' can be created. These are labels that are transparent except for their printing, and because one sees only the print area and not the remainder of the label, the design possibilities are greatly increased. Traditional 'no-label look' labels are generally coated with pressure sensitive adhesive (PSA). Normally, these self-stick PSA labels are systems that are non-water-soluble, which is an advantage for many non-returnable applications in the cosmetic industry, like shampoo and shower gel.

REUSE OF PACKAGING

The longer a product fulfils its tasks, the smaller the demand for resources for the production of substitute products is. A life span as long as possible, and repeated use, are therefore desirable. If we want to keep our hygiene and security standards high in the industrialized countries, we have to realize that the reuse of original packaging is limited to transport packaging and to beverage packaging. These make up about 25 per cent by weight of the shopping of an average European household.

Adhesives used for labeling of returnable glass bottles must be designed in a way that they do not disturb the filling process, they guarantee an attractive package, and in the bottle cleaning machine they remove easily and without residues. Adhesives based on casein, the protein component in milk, meet all these demands. They run without problem even on very fast-running labeling machines and show excellent initial tack even on cold and wet bottles, which is often the case in the beverage industry. They also stick safely to the surface-coated returnable bottles and assure permanent labeling of the bottle while in use. In the alkaline condition of the bottle washing machine (about two volume percent sodium hydroxide at 80°C) labels which are glued with casein adhesives dissolve without residue from the bottles, thus guaranteeing excellent cleaning. One can say that they disbond on command.

Since the returnable PET soft-drink bottles and the milk and juice containers made of polycarbonate (PC) [Fig. 9] were introduced in Germany and other European countries, “reuse” is no longer limited to glass bottles. Their advantages to the beverage industry are that they are lightweight and also are unbreakable, which means no danger of injuries. However, these plastic bottles demand much higher requirements for label adhesives since, in general, they cannot be labeled with the adhesives used for glass bottles.

For the labeling of returnable bottles the applied adhesives must wash off completely in the cleansing device. This is especially valid for ticket label adhesives and for the pick-up adhesives that are in direct contact with the bottle, but also holds true for the overlap bond since it cannot be guaranteed that this adhesive does not contact the bottle also.

Newly developed synthetic adhesives - water-based and hot melts - allow the labeling of these plastic bottles and may be more safely cleaned in much milder washing conditions (1.5% by volume sodium hydroxide at approximately 60°C). These specially-developed water- or alkali-soluble adhesives are also demanded by the recyclers, as plastic bottles are usually washed before the recycling.

For returnable bottles in the beverage industry special no-label-look plastic labels have been developed, too. A synergy between the label and adhesive enables removal of the labels in the bottle washer. These ‘wash-off’ labels work because of the combination of plastic deformation from hot lye and loss of pressure sensitivity of the adhesive within a short time, without residue on the bottles and without polluting the washing lye or the bottle washer. The adhesive does not dissolve in the lye but remains on the label and sinks with it to the bottom of the washer, from where the label is removed. The adhesive is no longer sticky when it is removed from the washer [3]. Next to PSA labels no-label-look plastic labels can also be applied with the help of special water-based systems and hot melts.

RECYCLING OF MATERIALS

Even by the best product design and most careful treatment, we cannot avoid the fact that eventually a product does not fulfill its purpose and has to be replaced by a new one. In recycling we distinguish between material recycling and chemical recycling. In material recycling the material is not changed in its chemical composition and it is reused as raw material, while in chemical recycling, which is especially done with plastics, the material is decomposed into its chemical base components.

Material Recycling

Within the context of recycling, the best solution would be to recycle material as far as possible in order to reuse the used material and to save raw material. For economic reasons there has been a recycling industry for many years, long before the popularity of "green marketing". In the case of packaging these activities were limited in general to beverage containers, bottles and relatively heavy transport packaging. In recent years recycling of packaging materials has increased considerably. Due to the fact that there has been a law for approximately ten years now, a substantial amount of packaging material is recycled in Germany [Fig. 10] [2]. However, material recycling may not be seen as an isolated aim but as a means for reduction of global environmental effects. Theoretically all materials can be recycled. But irrespective of the raw material, it is sure that in practice the recyclability of materials is decreasing corresponding to weight reduction of the packaging. This applies above all for thin food packaging foils that get into contact with fat or oily food and have a typical weight of less than 1 to 10 g per package.

Due to the high temperatures that exist during the recycling process of glass and metal the adhesives on organic basis are not important, because they burn without residues at these high temperatures. On the other hand paper recycling is a field in which the influence of adhesives has been discussed intensively for years. Whereas in the beginning scarcely a paper manufacturer wanted to admit to using secondary fiber, today it is often a part of their marketing strategy and image to have a secondary fiber content as high as possible. What is more, the modern recycling process is now so highly developed that a layman usually can not tell the difference between paper from new and paper from secondary fibers. In the Nineties, paper recycling in Europe saw a remarkable increase. The amount collected and recycled annually in this period of time increased over 200%. This means also that the recycling rate (percentage of the used waste paper compared to the whole paper consumption) increased in 2001 to 52.1% compared with 38.8% in 1990. Waste paper is now one of the most important raw materials for production of paper, paperboard and carton. The objective is to achieve a reuse of at least 56% of all paper, paperboard and carton products in Europe by 2005 [Fig. 11]. Annually 10 million tons or 25% more waste paper will be recycled. The total amount of the annually collected and recycled paper will increase from 38 million tons to about 48 million tons [4]. Not only in Europe but also in many other countries the amount of wastepaper use increases steadily. World-wide, this is expected to increase from about 85 million tons in 1990 to about 188 million tons in 2005 [5].

If we look at paper and paper products more closely we realize that even the simplest papers and cardboard packaging consists not only of cellulose fibers but also additives that improve the product's usefulness. Adhesives (and adhesive tapes) play a very important role in this, so it is not surprising that paper and packaging adhesives dominate the adhesives market [Fig. 12]. As the aim of paper recycling is the recovery of cellulose fibers, it must be guaranteed that every other material contained in waste paper can be removed in a way that does not disturb the recycling process.

It is demanded from the paper recyclers: 'Non-paper components should be dimensioned and mechanically stable in such a way that they survive as large particles, without being comminuted, in the conditions of pulping and allow mechanical separation by means of punched screens, slot screens and centrifugal purifiers. Relevant examples are cover foils, staples, thick adhesive layers, various product samples. Materials applied in very small dimensions or disintegrating into very small parts are unfavorable, because they can not be removed using today's conventional sorting methods. Recovered paper components that dissolve in the process under standard conditions of deinking (pH 8 – 10) and reach the process water pose a risk of unintended spreading to all parts of the paper machine. This results in the requirement that recovered paper should contain as few components as possible which dissolve or disperse in a weakly alkaline medium and form sticky residues or cause discoloration.' [6]. Most adhesives used in the paper and packaging fields fulfill these demands. The behavior of an adhesive in the recycling process is determined not only by the adhesive but also by its geometry. Thick adhesive layers tend to be mechanically stable and can be sorted out in a paper mill without problems [7]. The thinner and smaller the adhesive application gets, the more complicated becomes the separation of adhesive from cellulose. Surveys have shown that for hot melts separation rates of 100% and for dispersion-based adhesives separation rates of more than 90% are possible [8].

Special progress has been made in plastic recycling in recent years. The sorting complications of different kinds of plastics in the waste stream had to be overcome. The more mono-material the plastic, the higher the quality of the resulting secondary raw materials. Indeed, new sorting methods have been very effective in this regard. Another possibility is to choose components compatible with each other, if the plastic packaging consists of different components. In many cases material recycling can be made more competitive by the continued development of "recycling-friendly" solutions such as PE-bottles with PE-labels, PS-yoghurt tubs with lids based on PS, etc. For such applications special adhesives have been developed that also do not disturb a later mono-material recycling of the plastic materials.

Chemical Recycling

Organic raw materials have no “immortality”: the length of the fibers of paper products decreases after several stages of recycling, and plastics get weaker after repeated recycling. For plastic material chemical recovery instead of disposal should be the ultimate option for these raw materials. Chemical recovery – the depolymerization of polymers back to their monomers -- is the established technique for clean industry waste of PMMA, PA and PET. There are some early experiences in the USA in the chemical recovery of used PET-bottles, and the techniques of gasification and cracking processes are currently being tested. When regaining monomers from plastic waste, the adhesives used usually are not very important as they can be removed by distillation from the monomer stream.

COMPOSTING OF PACKAGING

Another possibility to get back organic substances into the circulation of nature is composting them. Packaging made from natural-based raw materials such as starch derivatives can be decomposed into its original components CO_2 and water by composting. The CO_2 that is set free during this process is absorbed from the atmosphere by growing plants and thus the CO_2 circulation is closed. Adhesives used for this kind of packaging material have to be biodegradable fast, so they do not cause any problems during the composting process. Adhesives properly described as “compostable” have to pass standardized compostability tests. Two standards have so far been approved by standards committees, namely the German DIN V 54900 on “Plastics” and the harmonized European standard EN 13432, dating from 2000, which applies to “Packaging” and is nearly identical with the DIN standard.

INCINERATION (ENERGY RECYCLING)

In some cases, such as very dirty packaging or with very small and light packaging, an energy recovery of the packaging can be advantageous. Burning changes nearly all of the carbon into CO_2, and in landfill methane is formed and escapes. As methane contributes 30 times more than CO_2 to the greenhouse effect, the greenhouse effect is reduced when kitchen waste and other organic materials are burned compared to their disposal in landfill. Clean burning of solid household waste is accepted on a wide basis in countries like Sweden (50% of the entire household waste), Denmark (65%) and Switzerland (80%). Energy recovery can be very efficient. Adhesives that are used for products which are intended for incineration later on should be made of raw materials which do not make them damaging products of combustion.

LANDFILL OF PACKAGING

When none of the above-mentioned reuse or utilization options is possible, only the disposal of waste in landfills remains. When products are brought to landfill one has to make sure that a safe, long-term storage is possible and no environmental damages are caused by the storage. It is very important to avoid pollution of the ground water, which could occur if contaminants from the landfill leach out.

SUMMARY

While the Twentieth Century was marked by a steady rise in production and consumption, the Twenty-first Century will be marked by the development of new production processes intended to more efficiently use our diminishing resources. Sustainable Development – the emphasis on resource saving and the early inclusion of reuse and recycling -- will govern these new production processes. This trend is extremely obvious in the packaging industry. In this connection, adhesives as bonding technology will become more and more important. The use of adhesives for the bonding of different substrates is a very old technology that has enormously grown within the past 20 years. Mainly the use of adhesives in food packaging is a continuously developing application. The chance to connect different materials in any combination and form means that adhesives will push ever forward into the packaging field. Lightweight, resource-saving packaging systems will replace many systems used today.

But also with regard to the later recycling of packaging, bonding with adhesives plays a growing role. The kind of recycling that is ecologically and economically preferable (material, chemical, energy or compost) should be decided in any case by eco balance studies. Adhesives must not adversely influence the recycling of packaging materials. With adhesives containing an “installed switch“, parts of packaging made of different materials can be separated after use under defined conditions to allow their reuse or material recycling. The idea of sustainable development will lead to new adhesive systems and ideas from the adhesive labs will lead to new packaging solutions that fulfill the idea of sustainable development.

Adhesives that are used for production, converting, and finishing of packaging are characterized by a high “environmental standard”. Developers of new adhesives and new application techniques work steadily to optimize environmental tasks and try to develop products with less or no solvents, low monomeric contents and low content of hazardous substances.

Modern packaging adhesives fulfill the idea of "Responsible Care" as well as "Sustainable Development" and help to establish a well-functioning packaging industry around the world.

ACKNOWLEDGEMENTS

The author would like to thank Mr. Bill Leach from Henkel Adhesives, Hayward, USA for this valuable assistance.

REFERENCES

[1] DSD Webside February 2003

[2] Brauindustrie 6/2001, p. 24-25

[3] H. P. Ast The importance of outstanding product presentation 5th International Cham Paper Group Symposium 1999

[4] CEPI Europäische Erklärung zur Wiederverwertung von Papier, November 2000

[5] M. Matey Improvement of recyclability and the recycling paper industry of the future 1998, p. 23-32, Edited by A. Blanco et al

[6] INGEDE: Guide to an optimum utilisation of recovered paper 1999

[7] C. Ackermann, H. J. Putz Herkunft und Gehalt von klebenden Verunreinigungen in braunem Altpapierstoff PTS-Symposium München 2000

[8] H. Onusseit Klebstoffe für die Papier- und Verpackungsindustrie – wie beeinflussen sie das Papierrecycling? Allgemeine Papierrundschau 1999, S. 945 – 951

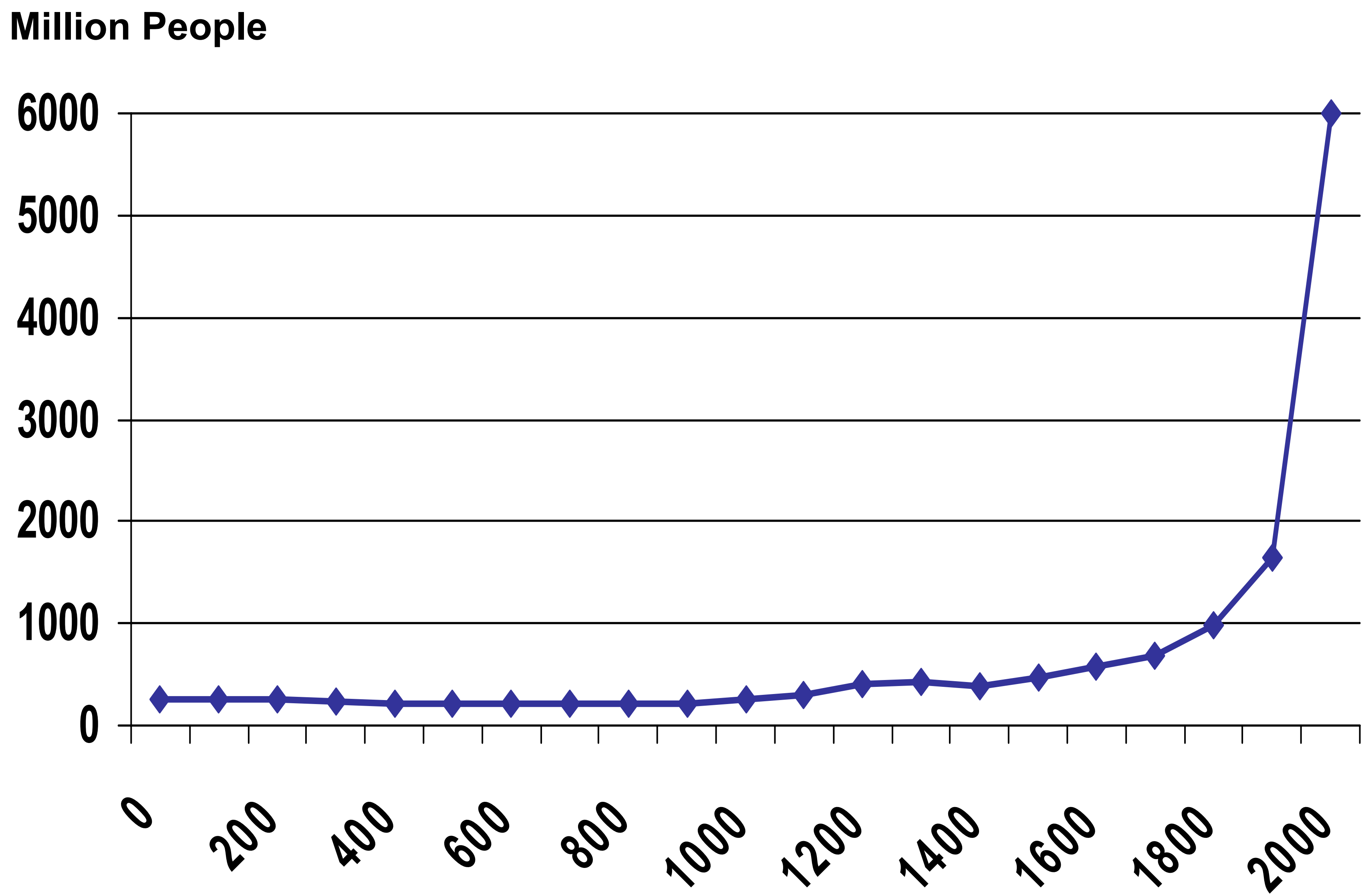

Fig. 1 World Population Growth

Fig. 2 Hot Melt in Siliconized Packaging Material

Fig. 3 Plastic Film Packed Hot Melt

Fig. 4 Toothpaste Dispenser

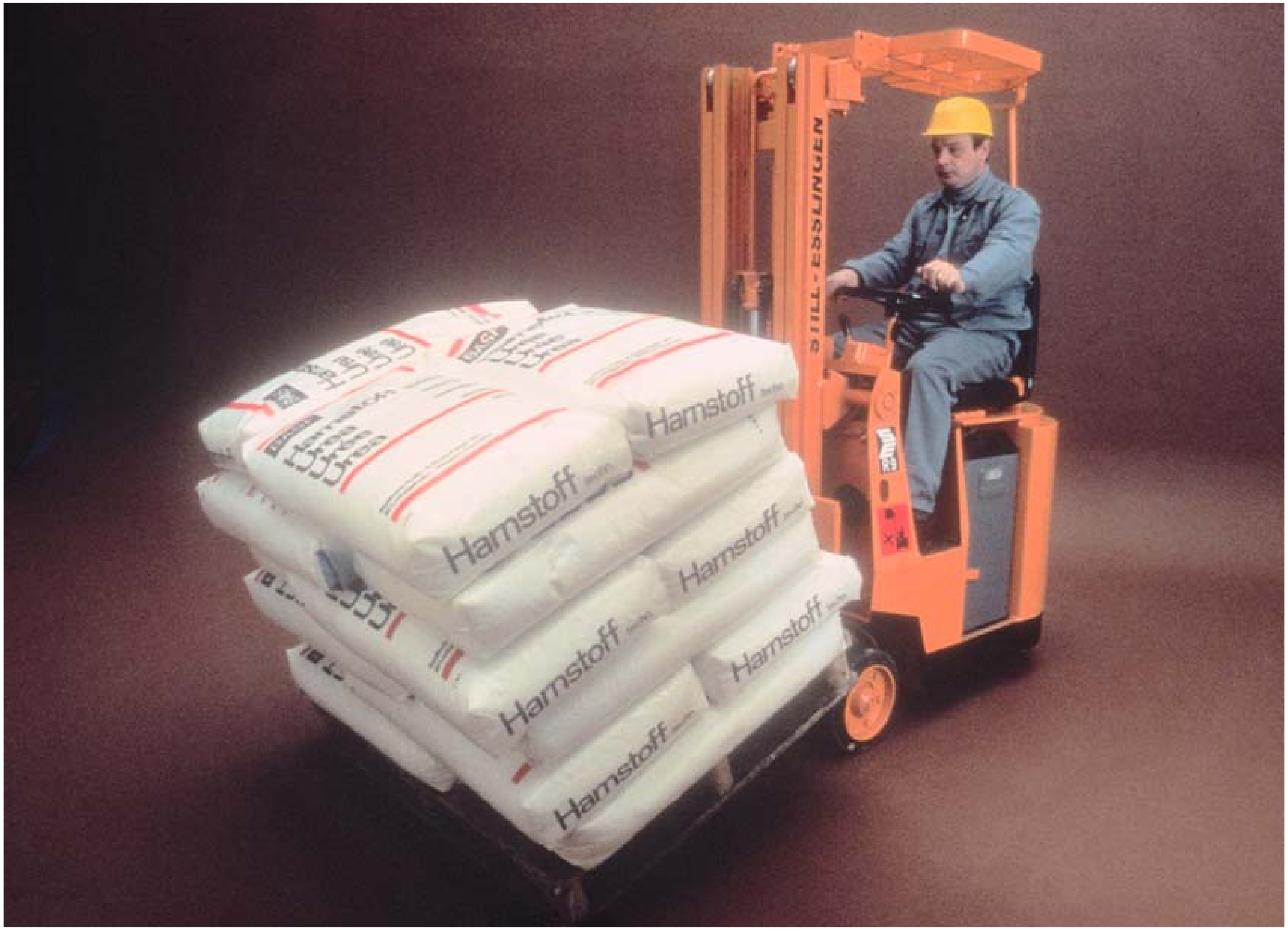

Fig. 5 Palletizing Adhesives

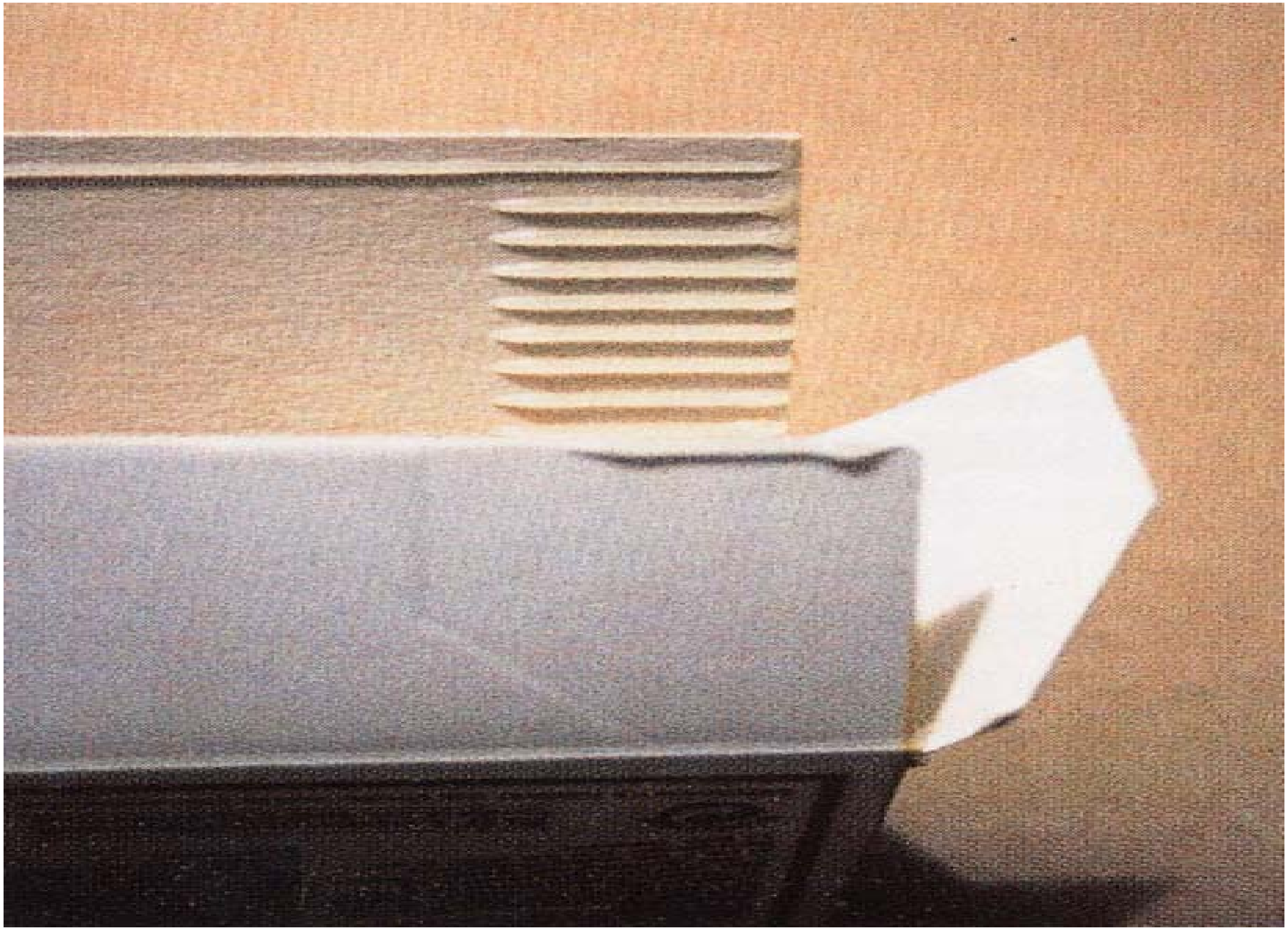

Fig. 6 Folding Box Without Interior Pouch

Curing method	Level 1	Level 2	Level 3	Level 4
Electronic beam curing	Coating	Lamination	Electronic beam radiation	Curing (very fast)
Radical UV radiation	Coating	Lamination	UV light radiation	Curing (very fast)
Radical UV radiation	Coating	UV light radiation	Lamination	Curing (> 24 hours)

Fig. 7 Radiation Curing Mechanisms

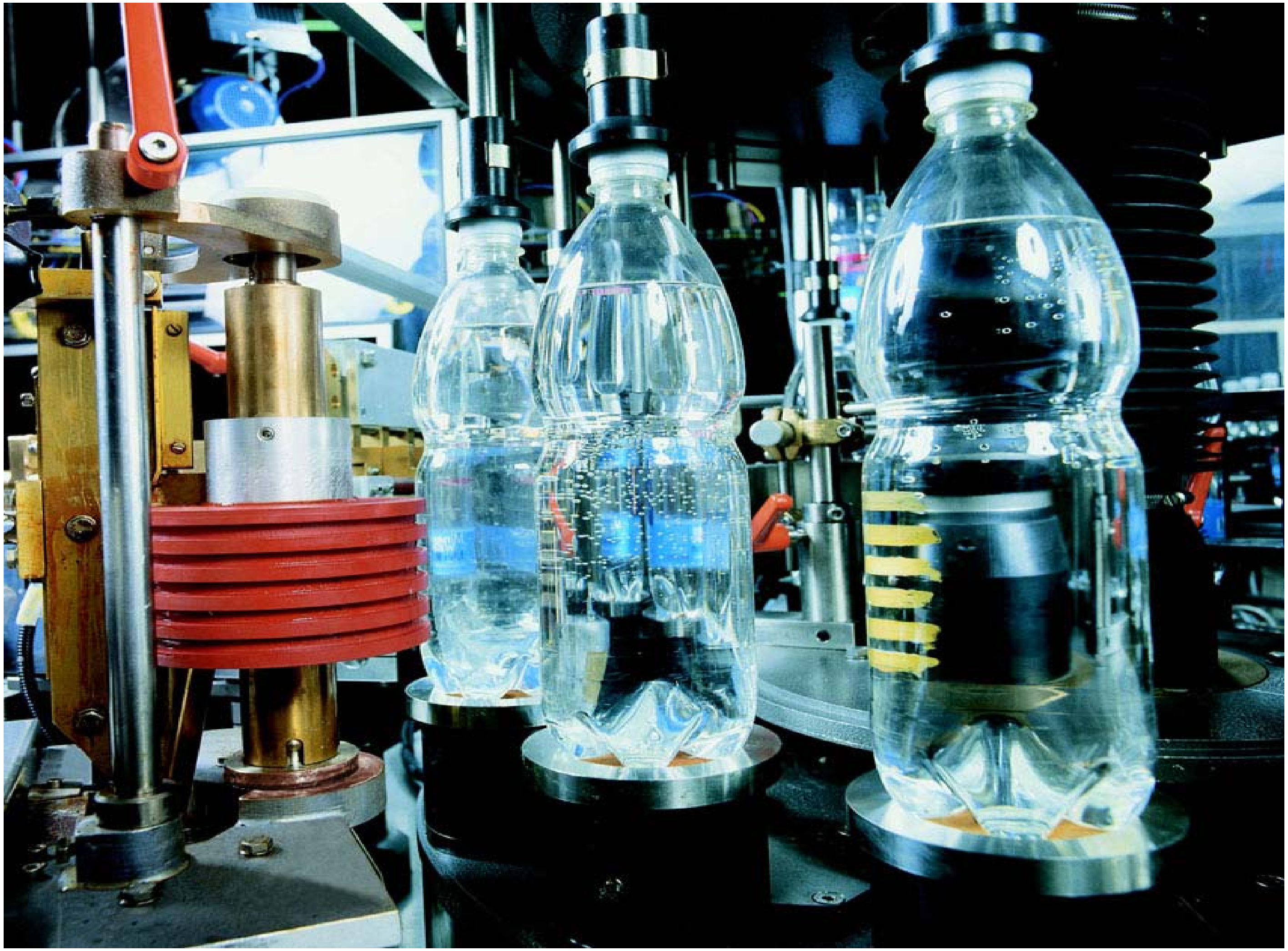

Fig. 8 Segment Application of Hot Melt

Fig. 9 Returnable Plastic Bottles

Glass	2,664,014 t
Paper, carton	1,505,956 t
Plastic	570,304 t
Composite	375,711 t
Tin plate	318,086 t
Aluminium	41,306 t
Total	5,475,377 t

Fig. 10 Packaging Recycling in Germany

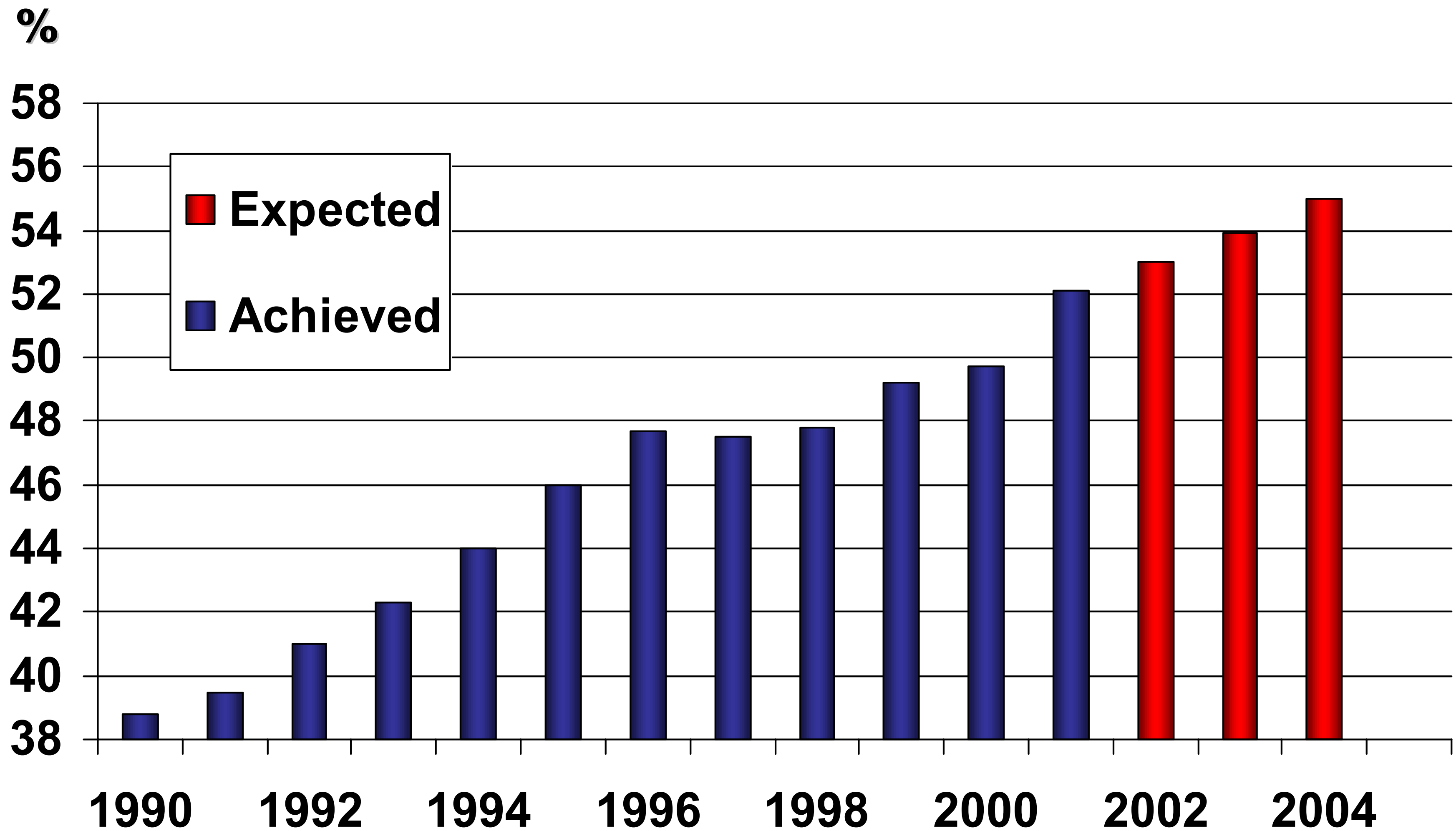

Fig. 11 Paper Recycling Rate in Western Europe

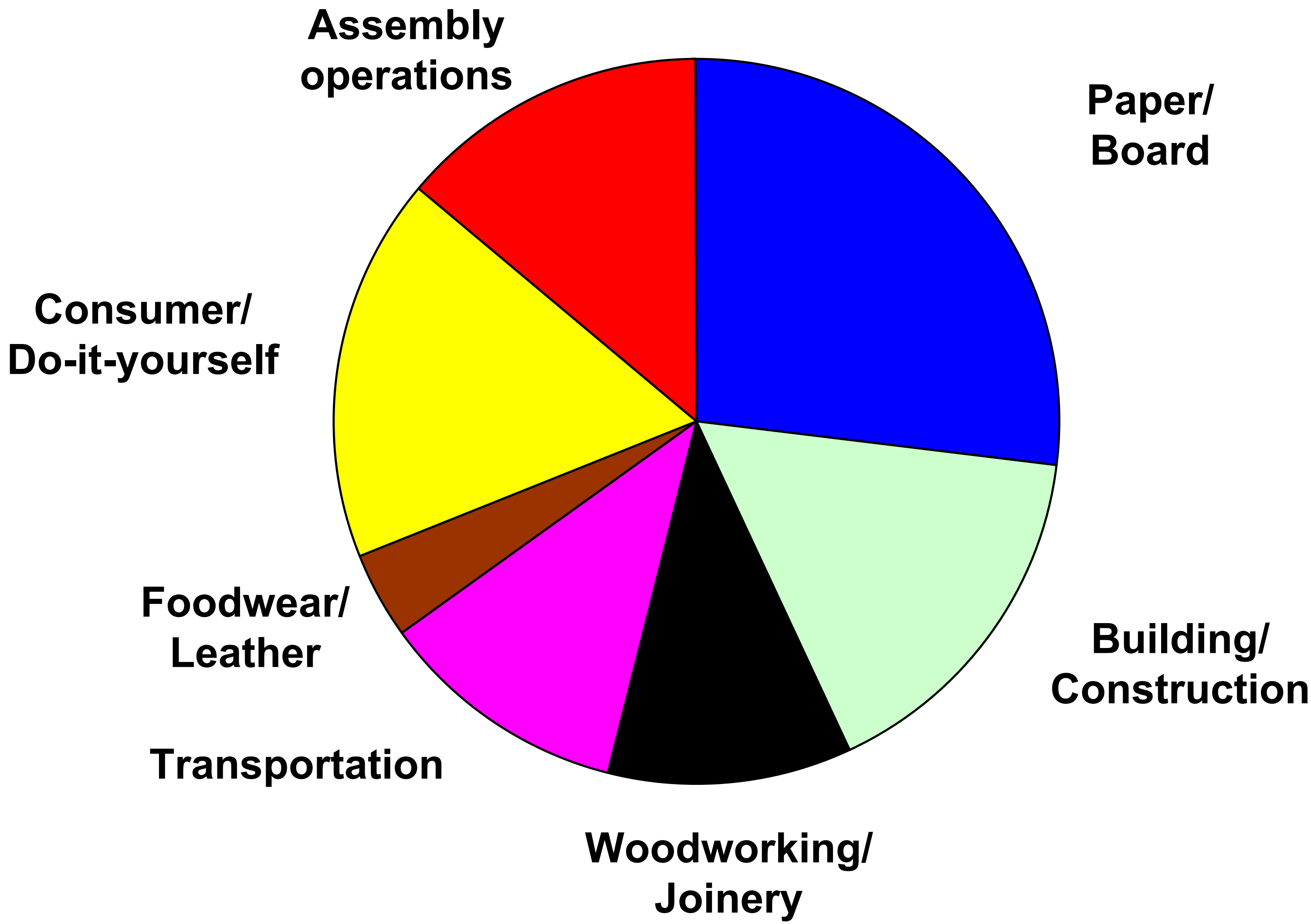

Fig. 12 Adhesives Market in Western Europe

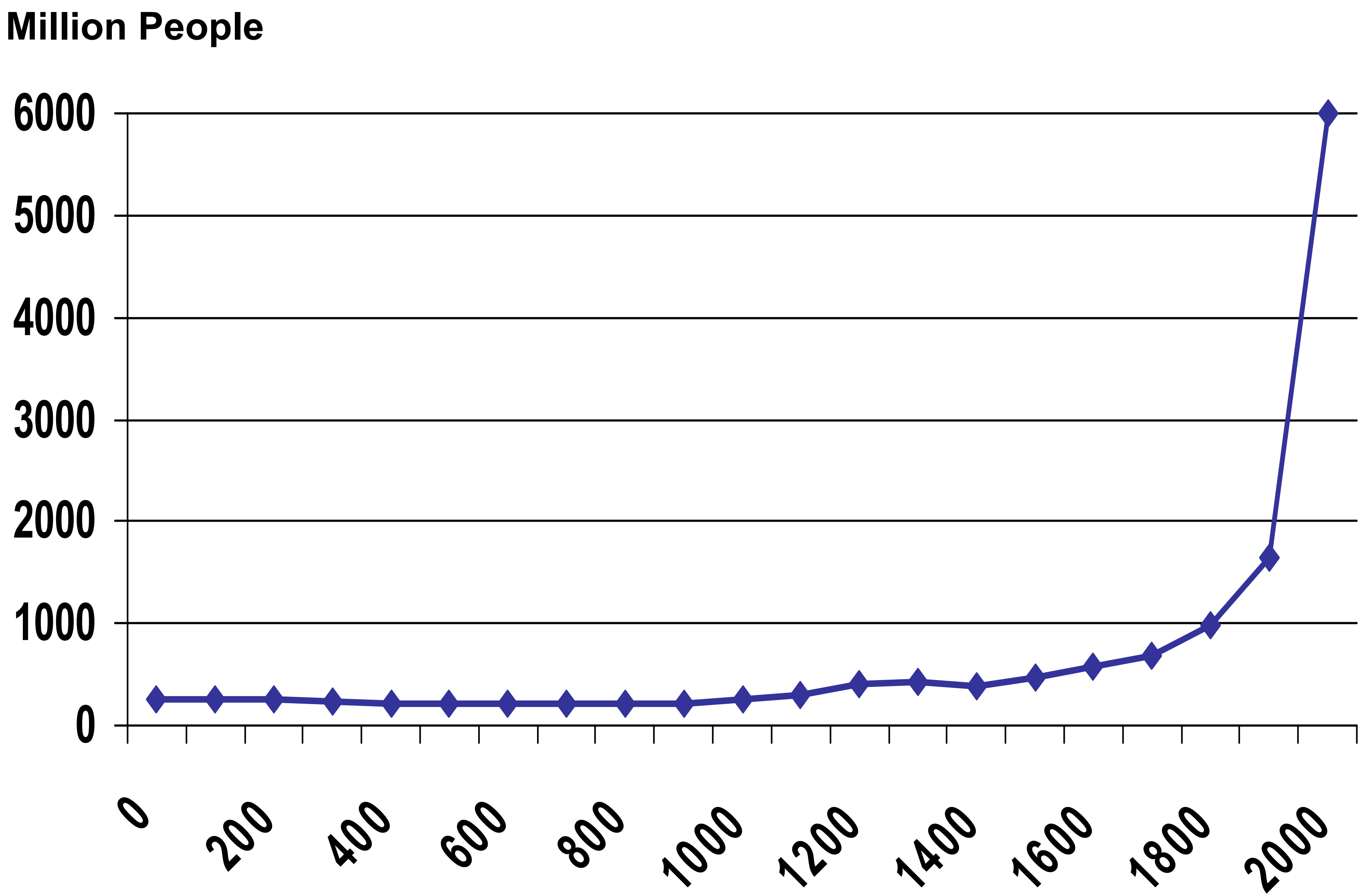

Fig. 1 World Population Growth

Fig. 2 Hot Melt in Siliconized Packaging Material

Fig. 3 Plastic Film Packed Hot Melt

Fig. 4 Toothpaste Dispenser

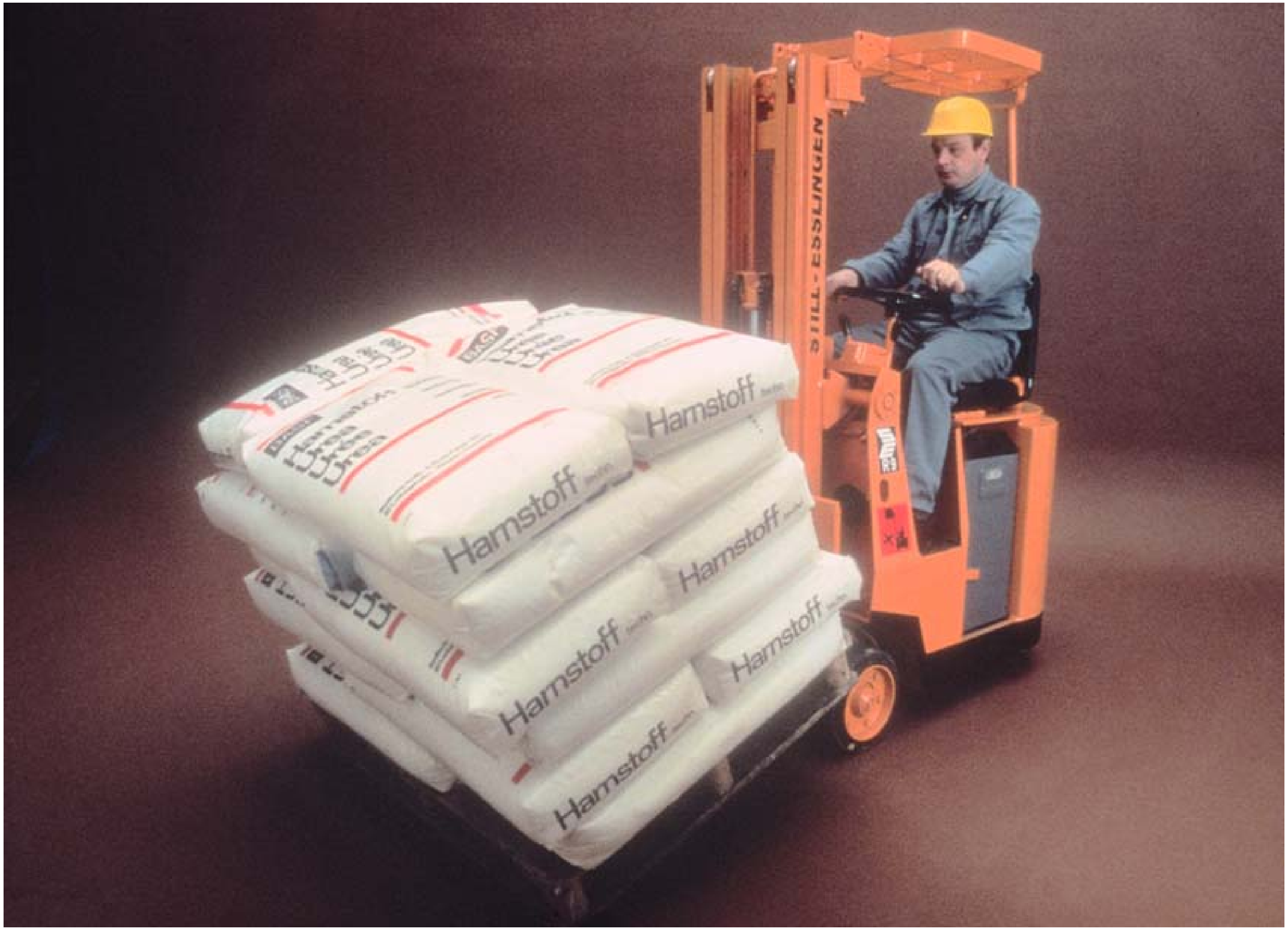

Fig. 5 Palletizing Adhesives

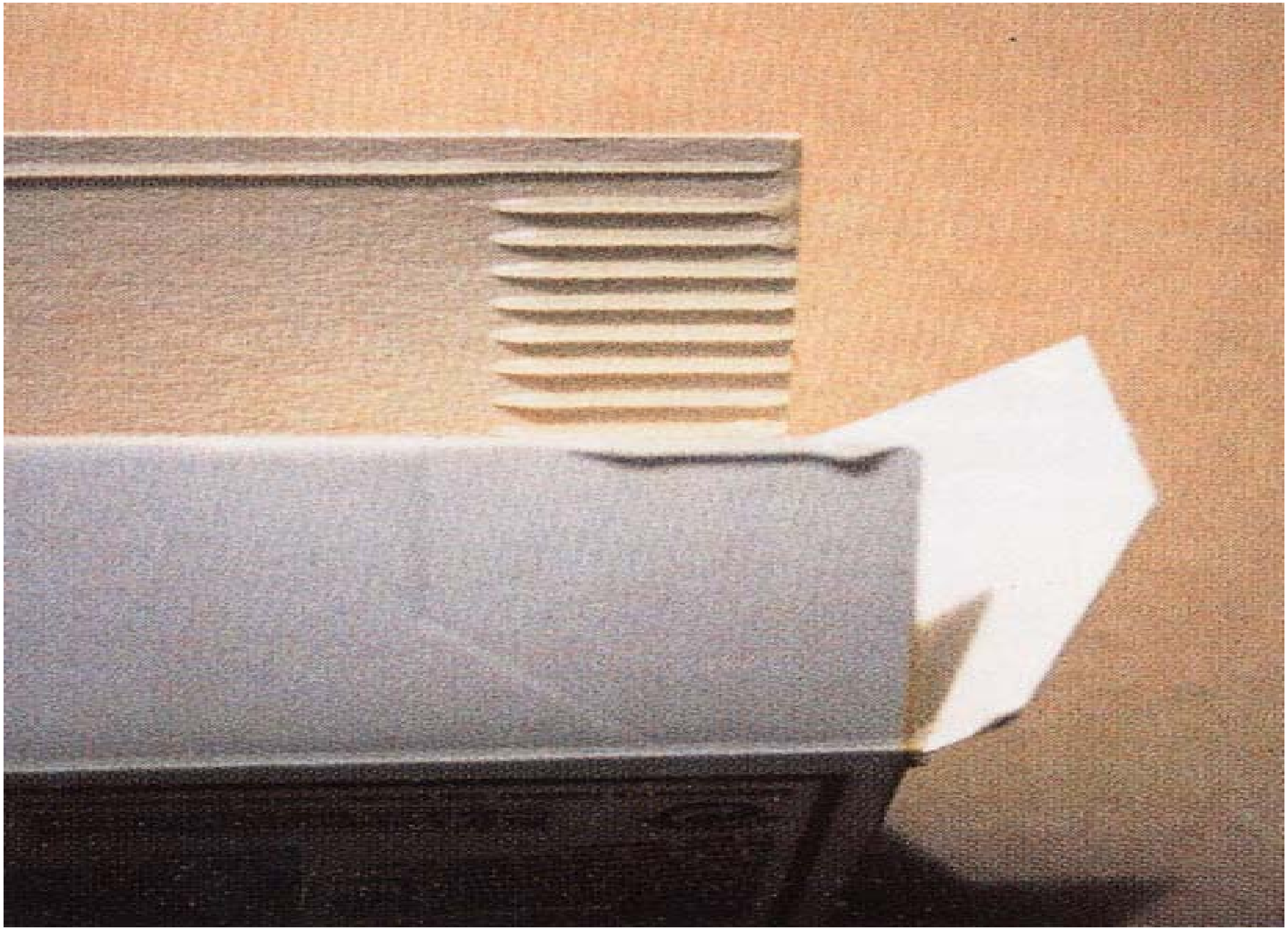

Fig. 6 Folding Box Without Interior Pouch

Curing method	Level 1	Level 2	Level 3	Level 4
Electronic beam curing	Coating	Lamination	Electronic beam radiation	Curing (very fast)
Radical UV radiation	Coating	Lamination	UV light radiation	Curing (very fast)
Radical UV radiation	Coating	UV light radiation	Lamination	Curing (> 24 hours)

Fig. 7 Radiation Curing Mechanisms

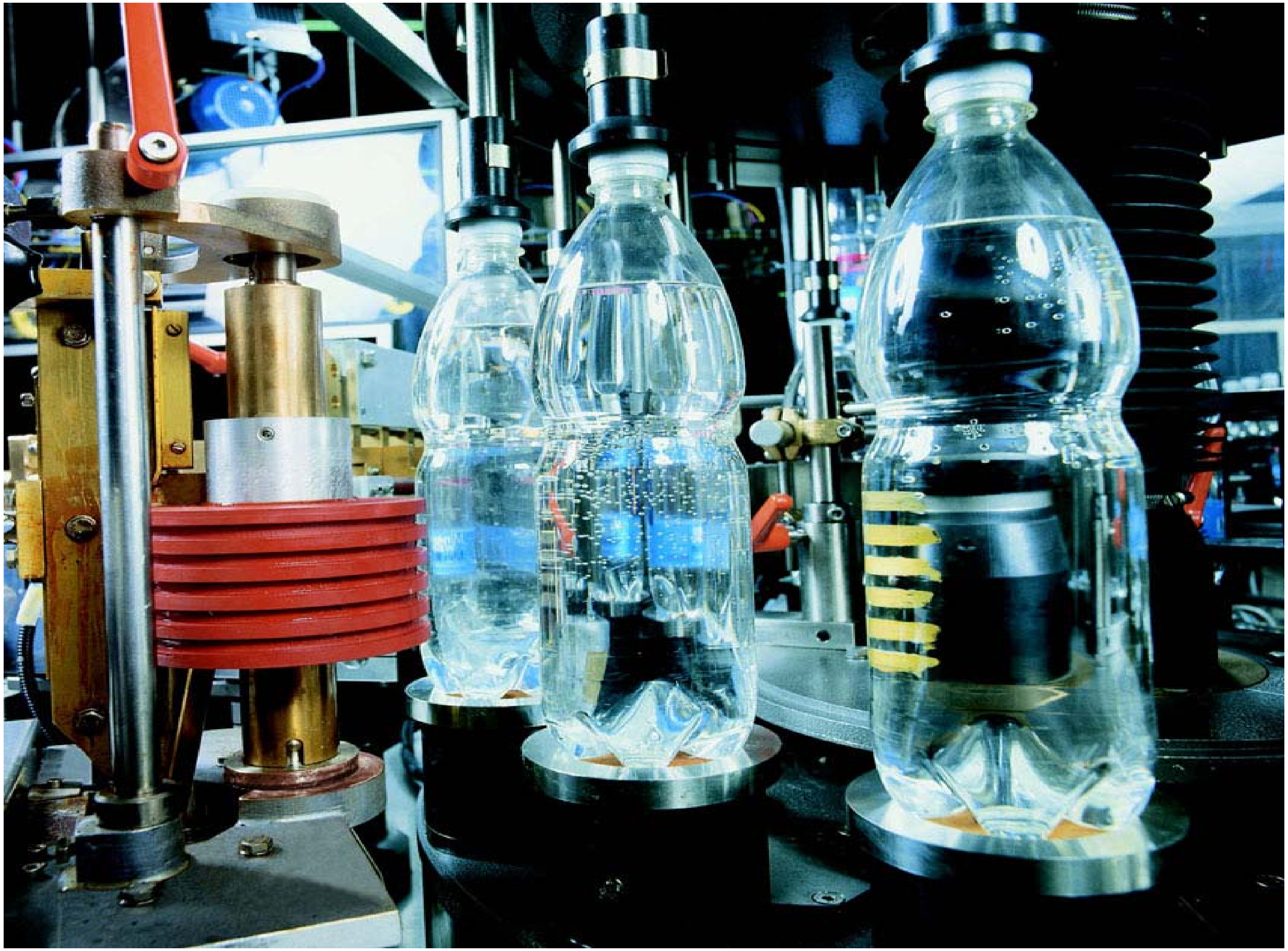

Fig. 8 Segment Application of Hot Melt

Fig. 9 Returnable Plastic Bottles

Glass	2,664,014 t
Paper, carton	1,505,956 t
Plastic	570,304 t
Composite	375,711 t
Tin plate	318,086 t
Aluminium	41,306 t
Total	5,475,377 t

Fig. 10 Packaging Recycling in Germany

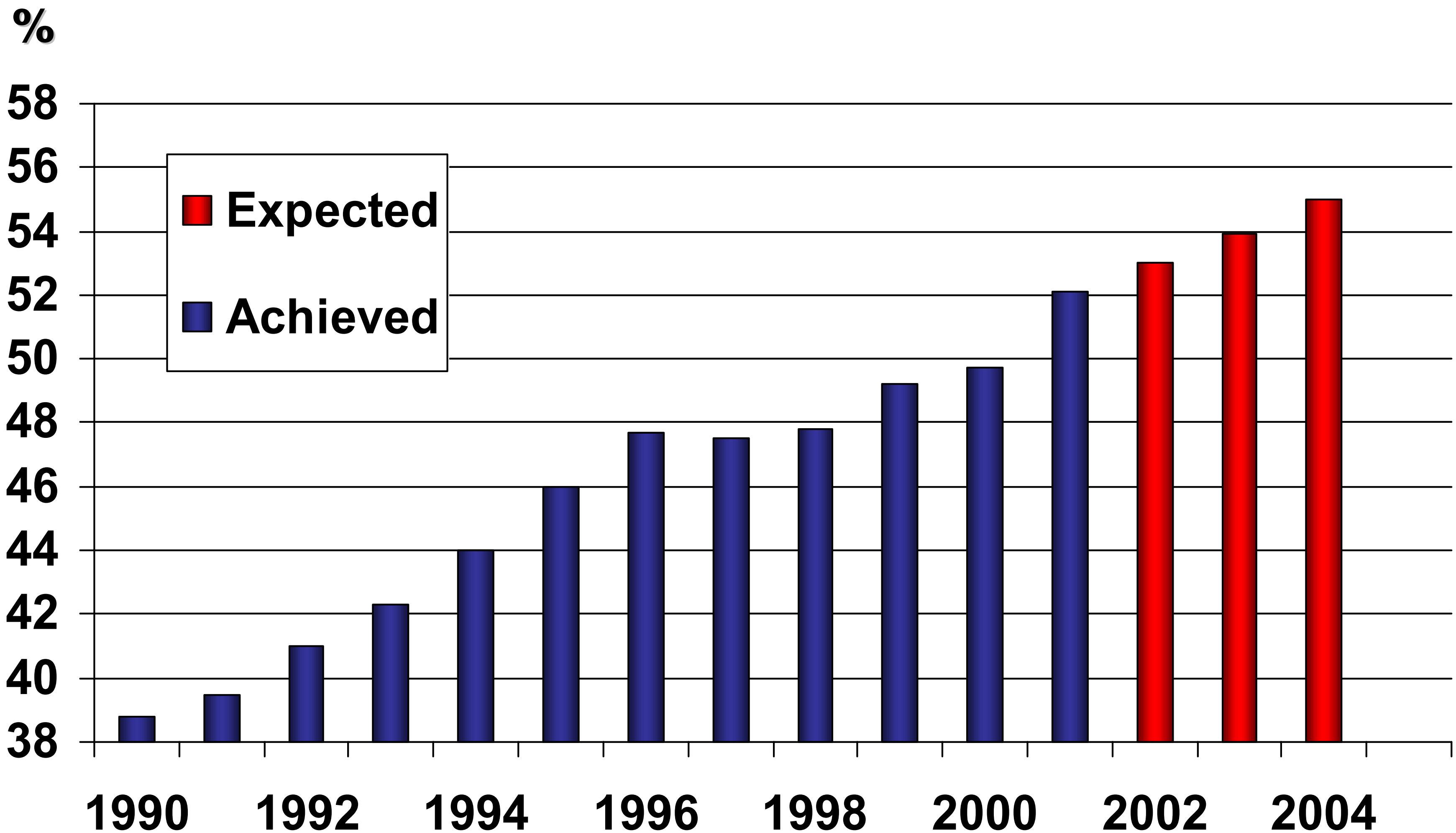

Fig. 11 Paper Recycling Rate in Western Europe

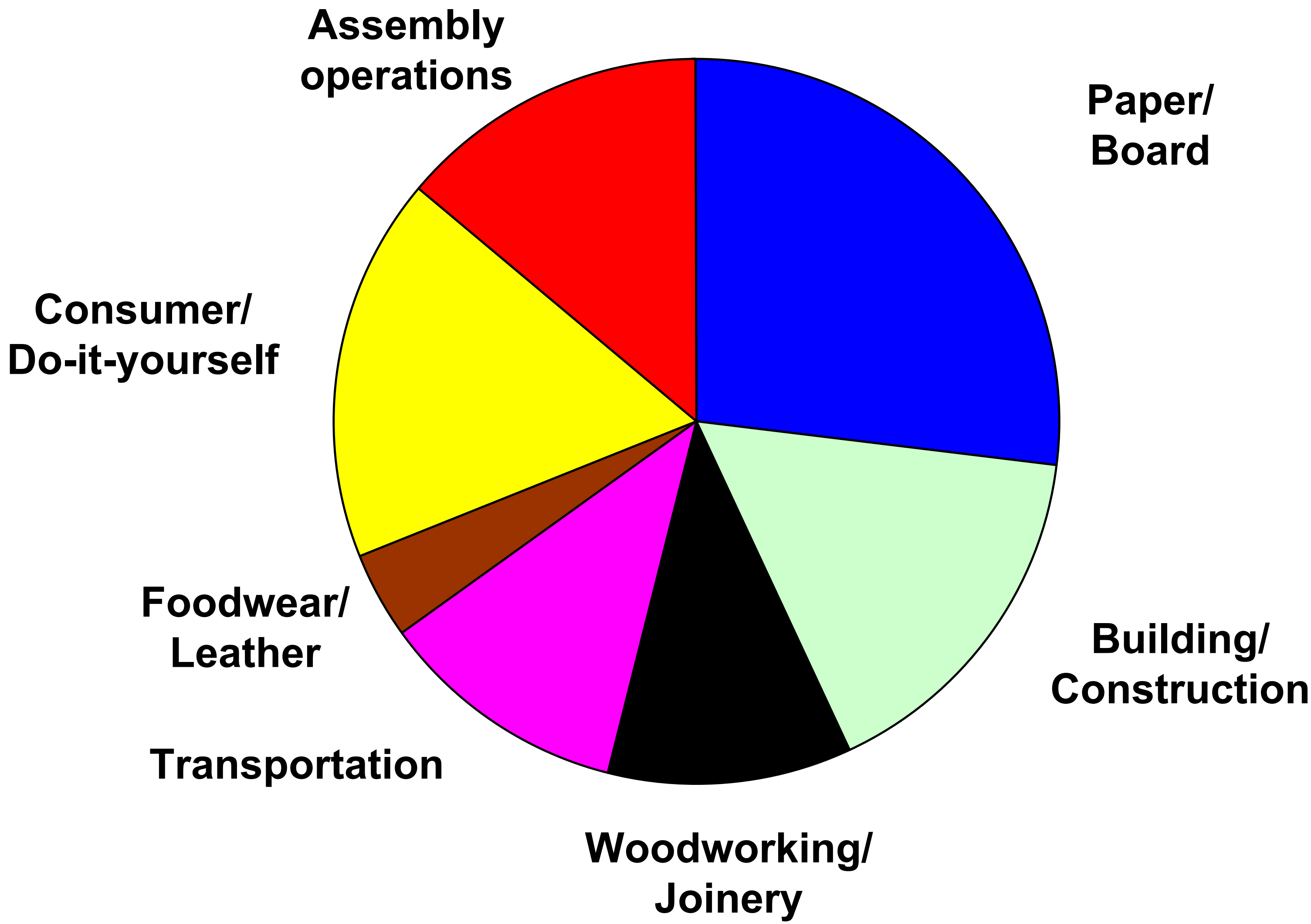

Fig. 12 Adhesives Market in Western Europe