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Green Solutions for the 21st Century: Sustainable Development

Sustainable Packaging

Exemplified by PET

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Packaging Technology

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1. Introduction to Sustainable Development

In 1987 the World Commission on Environment and Development defined sustainable development as development that “meets the needs of the present without compromising the ability of future generations to meet their own needs”.[1] This is the most widely cited definition of sustainable development. It means that resources are used in a way that meets the human needs, not only in the present but also in the indefinite future while preserving the environment.[2]

As a resource is used, for example wood, it is replaced by growing additional amounts of the resource to make sure one will never run out of this resource. This is only possible if the resource is not finite. Oil cannot be grown, and when all the oil is extracted, there will not be any more. Current generations have to minimize their consumption to make sure that future generations can also benefit from the remaining oil. Moreover, they have to work on the development of alternative solutions since future generations are still going to need to heat their homes and fulfill many of the purposes that oil now fulfills.[3]

The term of sustainable development itself is still debated since there are major differences between the environmental concerns of rich and poor countries. There are also great differences in the needs of current generations and those of the future. Furthermore, “needs” mean different things to different people of the same generation. And some countries wish to use their resources in full capacity while others want to conserve them. Due to these reasons, the substantial debate over the meaning and practice of sustainable development still continues in the twenty-first century.[4]

Sustainable development can be limited by technology, society, or ecology. That means it includes environmental sustainability, economic sustainability, and sociopolitical sustainability.

[1] http://www.un.org/documents/ga/res/42/ares42-187.htm
[2] http://en.wikipedia.org/wiki/Sustainable_development
[3] http://www.menominee.edu/sdi/whatis.htm
[4] “An Introduction to Sustainable Development” by Jennifer A. Elliott

2. Sustainable Development in the Packaging Industry

Approximately 95 percent of today's products need to be packaged. Packaging is not an option. It is a must. The structure of society, which includes a division of labor in manufacturing and allocation, makes it essential. Avoiding packaging would lead to a great loss of produce, and this would not be compatible with ecology. Especially agricultural commodities need to be packaged to make transport and storage possible. Large urban areas depend on produce from rural areas.

At the moment packaging is based on non-sustainable methods. Decreasing fossil resources cause higher packaging prices. Especially plastics are getting more expensive due to the depletion of oil.

The approaches to sustainable packaging include cutting the amount of packaging material. That is a good start, but the fossil resources will not last forever, even if the industry minimizes the used amount radically. Regarding the future, it is not sufficient just to make packaging materials thinner or lighter. The fossil resources will still be depleted soon. And the garbage mountains will still grow higher. Non-recyclable packaging that ends in landfills or waterways is no solution for the future, whether fossil resources are used or not.

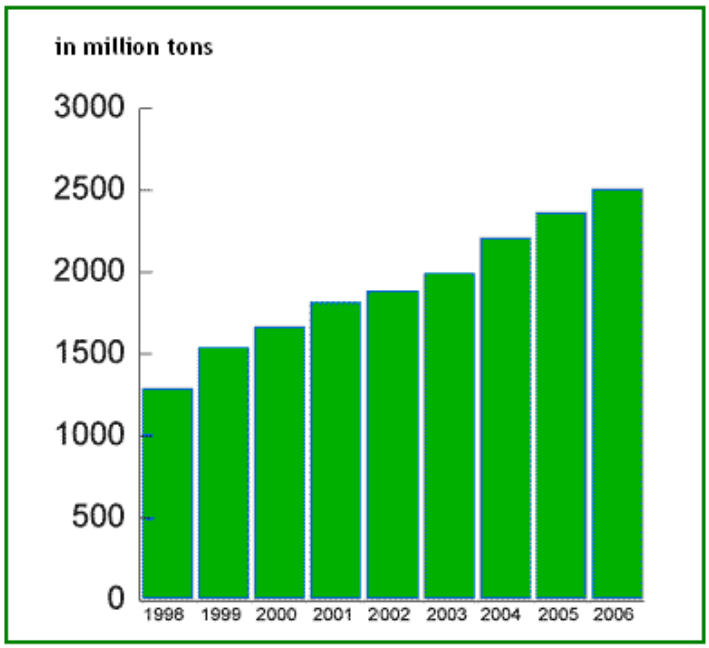
Non-recyclable packaging has to disappear and get replaced by recyclable and reusable material. Otherwise, humanity will not be able to cope with the changes ahead.

3. PET in the Packaging Industry

Polyethylene terephthalate, commonly abbreviated PET, is a thermoplastic that belongs to the polyester family. It is enjoying substantial growth as a packaging material worldwide. In a lot of cases it turns out to be a good replacement for glass, metal, and other plastics. Since 1995 the use of PET packaging duplicated, and a double-digit growth is predicted for the next years.[5] Over 50% of plastic packaging worldwide consists of PET. In 2004 ten million tons of PET packaging were produced and converted. 90% of this PET packaging were bottles.[6]

[5] http://www.cleanaway-pet.com/de/pet/pet-marktsituation.php
[6] http://www.forum-pet.de/

PET Bottle Use in Europe[7]



3.1 History

Two English chemists named Rex Whinfield and James Dickson, working at a small company called “Calico Printers’ Association”, discovered a compound that could be drawn into fibers in 1941. The fibers had a high melting point and were resistant to hydrolytic breakdown. This was the discovery of polyethylene terephthalate. “Calico Printer’s Association” sold their rights to the product to “Imperial Chemical Industries” (ICI).[8] During the Second World War the US Army was looking for an alternative material for parachutes to get over a shortage of Japanese silk and nylon. The American government founded a special committee for plastic fibers, this committee pointed to ICI and its polyester fibers. ICI agreed upon the development of their material by the American “Eastman Chemical Company”. “Eastman Chemical Company” became the first manufacturer of polyester.

The new material affected the textile industry. In the postwar era it was used for synthetic fibers with names such as “polyester”, “terylene”, and “crimplene”. Colorful, drip-dry, and easy-care clothing influenced the fifties and sixties. In the seventies PET was utilized to make crystal-clear, tasteless, and break-proof packaging. These

[7] http://www.cleanaway-pet.com/de/pet/pet-marktsituation.php
[8] http://www.bookrags.com/biography/john-r-whinfield-woc/

properties evened PET's road to success.[9] It was then further developed in the late seventies and started its career in the beverage industry. At first, only disposable bottles that were used just once and got recycled afterwards, were produced. In the late eighties the first multi-trip bottle, which could get returned, cleaned, refilled, and then reused again, was ready to conquer the market. In 1990 this bottle was introduced onto the German market. The "Genossenschaft Deutscher Brunnen" started filling reusable PET bottles with carbonated soft drinks in 1995, and with sparkling water in 1998. These bottles significantly contributed to the consolidation of the return system in Germany.[10]

Today PET is used worldwide in the most different ways. With even better qualities than before, PET is especially important in the packaging industry.

3.2 Manufacturing

PET is extracted from petroleum. 1.9 kg petroleum and 23 kWh are needed to get 1 kg PET. When PET containers were first introduced, the 2l soft drink bottle weighed over 70g. Today theses bottles weigh 52g, which helps preserving resources.[11] Condensing terephthalic acid and ethylene glycol makes PET. PET itself consists of oxygen (O), hydrogen (H), and carbon (C). Incinerated PET only releases water (H_2O), oxygen (O_2), and carbon dioxide (CO_2).[12] Manipulating the structure of the molecular chains makes it possible to affect the properties of the subsequent product. PET exists as an amorphous material that is transparent, as well as a semi-crystalline material that is opaque and white. PET gets moldable when heated and can be formed into almost any existing shape. While the plastic is cooling down it solidifies and retains the desired shape. This procedure can be repeated several times and is used for making bottles. The first step in making PET bottles consists of manufacturing the preforms, which look like test tubes with screw threads, and delivering them to the bottler to save transport costs. In a second step the preforms get reheated and inflated to obtain the desired size.[13] Every bottle has to be tested for leaks and deformations, and a verification of cleanliness is a must to make sure

[9] http://www.petrecycling.ch/index.cfm?rub=258 WertstoffPET[1].pdf
[10] http://www.forum-pet.de/
[11] http://www.packaging-gateway.com/features/feature41/
[12] http://www.petrecycling.ch/index.cfm?rub=258
[13] http://www.cleanaway-pet.com/de/pet/pet.php

that only proper bottles reach the customer. The PET bottles get filled, immediately closed, and labeled in an automated process.[14]
The molding process picked up the pace over the years. Productivity increased due to additional cavity tooling. Former PET converters operated with 16 cavities, but in less than a decade the number of cavities reached 144 while cycle times dropped. Blow molding speeds increased from 400 containers per mold per hour in the 1970s up to 1600 containers.[15]

3.3 Properties

PET is an extremely versatile material that is particularly used in the food packaging industry, especially for beverages. Due to its well-known attributes, which include high transparency, break resistance, little weight, moldability, and recyclability, PET bottles got ahead of glass bottles. PET has good barrier protection against oxygen and carbon dioxide. Therefore, PET bottles can be used for sparkling water and other carbonated drinks. PET is more impermeable than other low cost plastics, which would get attacked by acidic drinks such as fruit or vegetable juice.[16] Because PET is lightweight and future bottles get transported as preforms, it is cost-effective and does not increase traffic. It is also easy to carry for the customer. In case that the consumer drops the bottle, it does not break. This makes it safe for children. After usage PET bottles can get recycled and industry can make further use of the material. PET meets the hygienic requirements for the food industry as well as the medical area. It is impact-resistant, mostly resistant to chemicals, naturally colorless, durable for a long time, and can be extremely hard. Depending on its thickness, PET can be semi-rigid to rigid. It is the most adaptive plastic.

3.4 Application Range

PET's success story began in the textile industry. Today breathable sportswear and rainproof outdoor clothing as well as abrasion-resistant carpeting, pillow fillings for allergic persons, and flame-retardant housing textiles made out of PET fibers are

[14] http://www.multi-pet.de/de/www/info/info.htm
[15] http://www.packaging-gateway.com/features/feature41/
[16] http://www.packagingtoday.com/intro plasticexplosion.htm

common. PET is generally referred to as simply “polyester” when talking about textile applications.
The high-strength fibers are also used for manufacturing airbags (fig.1), seat belts, and audio and video tapes. PET is even strong enough to make mechanical parts out of it.
PET containers are suited for filling them with cosmetic and sanitary products or detergents because the material does not interfere with the contents’ quality.
Because of its clarity, cleanliness, and mechanical properties, PET is important for the medical and pharmaceutical sector. Besides pharmaceutical and medical packaging (fig.2) it is used for intravenous drips and surgical sewing threads.

In the packaging industry PET has already been on the rise for several years. It is extremely resilient and therefore qualified for food and liquid containers, food trays, bags, foils, films, and strapping. Especially the beverage industry tends to bottle their drinks, including soft drinks, juices, sparkling water, milk (fig.3), beer, other alcoholic beverages, and energy drinks, in PET. Almost every drink is available in PET bottles today.
PET fulfills strict legal regulations for food and beverages and is also approved for baby food.[17]

Figure 1[17]

Figure 2[17]

Figure 3[17]

[17] http://www.forum-pet.de/

3.5 Recycling

The question regarding wise recycling arises for any kind of packaging. Used PET containers are no waste material. They are collected, sorted, and processed in order to reuse the material. Sophisticated recycling concepts make the material sustainable and save resources as well as energy. Processing used PET saves energy. Compared to making new PET, it cuts the needed energy down to 60%. PET is completely recyclable and can be converted into packaging or fibers depending on the demand for the material.[18]

PET bottle recycling is rather uncomplicated compared to other plastic applications. A separate collection of PET bottles avoids commingling with other plastics, which would reduce quality. The bottles are almost exclusively made out of PET and so they provide best conditions for efficient recycling. A multi-trip bottle made out of PET circulates, that means it is returned, cleaned, and refilled, up to 25 times. For this reason, the multi-trip PET bottle was awarded the environmental label “Blue Angel”.[19] PET can be identified easily in a recycle stream. To keep the recycle stream as clean as possible, label and closure are recyclable, too.

3.5.1 Collection

To make PET recycling easier and to achieve a good quality, post-consumer PET gets collected separately in many countries. PET containers are identified by the resin identification code 1, which can be found on the side or the bottom of the containers. Depending on the country, one can find commingled collection systems, separate bins for the collection of PET, or retail deposit return sites. Deposit bottles counteract the ease to throw the bottles into non-recyclable waste bins. Consumers are the decisive factor for successful recycling of PET because they initiate the collection process.

The collected material is taken to recycling centers. To sort out materials such as metal, other plastics, and anything that is not made out of PET, processes that use the specific physical properties of the materials are employed. Optical identification can also be used. The PET itself is sorted by color. It is divided into a transparent or

[18] http://www.abvo.ch/alltaegliche_abfaelle/pet/home_pet(D).htm
[19] http://www.forum-pet.de/presse/basis04.html

uncolored section, a blue section, a green section, and a section that covers all the remaining colors. The sorted PET is crushed, pressed into bales, and sold to recycling companies. Transparent bales are the most valuable ones. [20]

3.5.2 General Procedures

PET recycling is established throughout the world. There are different methods that can be applied.

For the mechanical recycling method, the PET containers are shredded into small fragments. To remove shredded paper labels and plastic caps, the fragments are run through different separation and cleaning processes. The pure PET flakes, which are won, can be converted into a variety of new products such as fibers, strapping, sheets, and packaging. In the nineties, upgraded recycling procedures were developed worldwide. The “SuperCycle” procedure is just one example. It was introduced in 1994 and is carried out in France since 1998. The recycled PET possesses chemical and physical qualities comparable to new PET. [21]

Another method that can be employed is feedstock recycling, also known as chemical recycling. Glycolysis or methanolysis resolve PET flakes into its fundamental components, which can be purified and processed to new PET. This method is successfully used in the USA since 1991.[22]

In countries that do not have the opportunity to recycle PET, the plastic can be incinerated for energy recovery instead of going to landfills. Highly contaminated PET can also be burned as a heat carrier in power plants. This preserves other energy carriers since PET has an energy content that reaches 80% of the heating value of fuel oil.[23]

The different types of recovery make it possible to respond to ecological and economical needs and to choose the one that is most reasonable.

[20] http://en.wikipedia.org/wiki/Recycling_of_PET_Bottles
[21] http://www.multi-pet.de/de/www/info/info.htm
[22] http://www.forum-pet.de/presse/basis04.html
[23] http://www.forum-pet.de/umwelt/recycling.html

3.5.3 Bottle-To-Bottle Procedures

Recycled PET goes fast. At first, it always ended up in the non-food area to avoid food poisoning due to contaminated containers. Detergent containers and clothing, such as fleece, as well as padding for sleeping bags, were made out of the recycled material. Incorporating recycled PET into multi-layer structures for beverage bottles followed. The inner layer, which is exposed to the content, is made out of new PET. The recycled material used for these bottles accounts for 40% to 80%.[24]

Today, well-engineered process technologies exist, which make it possible to use 100% recycled PET that has been subjected to special cleaning processes for beverage bottles. Bottle-to-bottle recycling can be regarded as an eco-friendly procedure that meets the demands of a sustainable waste control.

There are EU Directives and legislation that stipulate the processes that can be used. Safety parameters, within which any recycle material in contact with food has to perform, are also defined to ensure that there is no migration of active chemicals through the plastic over the duration of the product life. In Europe the use of recycled plastics in contact with foodstuffs is subject to European Commission Directive 2002/72/EC of 6 August 2002.[25]

A careful purification of the input material is necessary to remove any pollutant the bottle might have come in contact with. The following processes have been inspected by administrations such as the Food and Drug Administration (FDA) and Institutes, for example the “Fraunhofer Institut” and the produced reclaimed PET has been approved for food packaging.[26]

3.5.3.1 URRC Technology

The patented manufacturing process developed by the United Resource Recovery Corporation (URRC), also called UnPet process, produces food grade reclaimed PET chip from post-consumer PET bottles. The Coca-Cola Company funded the research and development project, which was launched in 1996. In 2000 the FDA licensed the process.[27] The URRC process, which is a combination of mechanical and chemical

[24] http://www.forum-pet.de/presse/basis04.html
[25] email from “innocent drinks”
[26] http://www.forum-pet.de/umwelt/recycling.html
[27] http://www.urrc.net/new/pages/process.html

recycling, is utilized in Germany since 2001. It is suited for bottles from the dual system, disposable bottles, and reusable bottles pressed to bales or briquettes.[28] It is not bound to specific return or collection systems and delivery form and degree of contamination are secondary.

The process begins with a mechanical pretreatment, which starts by resolving the bales and briquettes. Coarse impurities get removed manually. After thorough washing, the PET is run through grinders to receive uniform flakes. Then it proceeds to a separation and cleaning process, which removes adhesive labels. A float and sink process sorts out the caps, and air separation takes charge of plastic labels.[29] Spraying the flakes with sodium hydroxide and warming them in a rotary furnace cause a peeling of the upper layer.[30] Thus inherent contaminations are removed, and the PET will be applicable to food products again. After subjecting the PET flakes to further process steps they arrive at the mechanical drying station. The process closes with a quality control.[31] The processed PET can be used for making PET preforms, which are converted to PET drinking bottles.[32]

3.5.3.2 VACUREMA Technology

The FDA and the „Fraunhofer Institut“ have approved the VACUREMA process for food packaging in 2000.[33] The company Erema developed the technology, which processes bottle flakes, new pellets, grounded trimming waste, and scrap web waste to food-contact grade PET.[34]

The washed PET flakes are inserted in a patented vacuum reactor that is combined with an extruder system. The high vacuum and a high temperature in the reactor remove volatile contaminations from the flakes and eliminate moisture. In the extruder the PET is plastified and homogenized. A fine filter removes very small solid contaminations from the PET melt, resulting in food grade, finest filtrated PET pellets. Filtering is inevitable for high-quality feedstock.[35]

[28] http://www.plastverarbeiter.de/news/80a77194b8d.html
[29] http://www.cleanaway-pet.com/de/urrc/urrc-verfahren.php
[30] http://www.plastverarbeiter.de/news/80a77194b8d.html
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[34] http://www.erema.at/assets/pdf/folder_vacu_d.pdf
[35] http://www.erema.at/de/42/

For a bottle-to-bottle recycling, a process has to be inserted before the basic VACUREMA process. A crystallization dryer increases the intrinsic viscosity (IV), which depends on the length of the polymer chain. The higher the intrinsic viscosity, the stiffer is the PET. For making bottles an IV between 0.76 and 0.84 is needed.[36] The crystallization dryer can increase the intrinsic viscosity by 2% to 6%, depending on the input material. It conduces to an additional predrying and decontamination of the PET flakes. Subsequent to this process the basic VACUREMA technology can be employed.[37]

3.5.4 Processing Issues

The intrinsic viscosity of the input PET has to be optimized to make sure that it provides its best possible performance at the converting site. The processing speeds are affected by the intrinsic viscosity and can therefore influence the production costs.

Another issue concerns the use of additives and barrier material. New beverage segments are conquered by PET and give rise to special barrier properties. The challenge is to develop bottles, incorporating additives, color, or barrier materials, which do not affect the recycle stream significantly. The additives have to show thermal stability to avoid emitting fumes or smells, and, of course, they have to comply with food contact regulations.[38] Even with the highest grade of clear PET, discoloration is an issue. Due to the reprocessing a yellowing of the plastic, other color deviations, and haze emerge. The next grade down usually contains a lot of tinted bottles in the selection; especially blue ones from the water bottle industry. The color of the reprocessed bottles can therefore be blue, gray, or green or the bottles will have a slight tint. So-called „black specks“ can further affect the bottle appearance. They are common in recycled PET that has not been selected to a high enough grade, but can be avoided or at least be minimized by modern processing technologies.[39] Additives must not compound any of the unwanted effects. Their

[36] http://en.wikipedia.org/wiki/Polyethylene_terephthalate
[37] http://www.erema.at/assets/pdf/folder_vacu_d.pdf
[38] http://www.petrecycling.cz/Guidelines.pdf
[39] email from “innocent drinks”

application is limited by the processability and the properties specifications of the new bottle.[40]

4. Conclusion

Today, more than ever, people are concerned about sustainable packaging. PET is so versatile that it is irreplaceable in many industries and just as important, it is an excellent example of a closed loop recycling management. The modern recycling procedures make bottles made out of 100% recycled PET possible. This was unimaginable a few years ago.

However, using more refillable bottles should be considered for sustainability reasons. A combination of multi-trip bottles and bottle-to-bottle recycling might be an excellent option. Skipping the recycling process until the circulation limit of the reusable PET bottle is reached, and substituting it with a cleaning process only, is much more ecological. Even though the cleaning process requires sensory devices to ensure that only clean bottles get circulated, more reusable bottles can raise the sustainability level. Bottles, which are contaminated by substances that should not be in contact with food, can still be recycled and hereby the PET can be used again. Gaining an increased return for the original processing input benefits the environment and conserves resources.

Despite the outstanding processes that were developed in recent years, advance should never stop. This is particularly important when the improvements are related to sustainability

[40] http://www.petrecycling.cz/Guidelines.pdf

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