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Paradigm Shift in Polyester Recycling

From Second Grade Replacements
To Green Labels and Virgin Products Cost Cutting

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1. The Polyester Recycling Industry
~ Some about the past, current situation and near future

As the PET bottle appeared in the market which was about end of the 70th of the last century nearly nobody was aware of the huge potential which was hidden behind this kind of new packaging.

Some pioneers started in the 70th of the last century the first steps towards of new plastic recycling processes. One of them was DSM which entered in 1976 in plastic recycling and started with the company RECO BV the first 1500 t/a PET bottle recycling plant.

During the early 90th Johnson Controls stepped in the polyester recycling business in a larger scale and also Goodyear achieved the FDA approval for its PET reclaiming process. After the frontier companies in recycling process development and engineering like for instance DSM, Re-Tech, Sorema and Goodyear prepared the ground during the 80th new recycling processes and companies sprung up like mushrooms during the 90th.

The biggest hurdle of recycling at that time was the bottle by itself because of the two piece design containing the bottle body made of PET and the bottom made of HDPE. The invention of pentaloid bottom was a break through. Another big jump was the stepwise ban of PVC as packaging material.

The triumphal procession of the PET bottle started during the 90th of the last century and we have not jet reached the stage of saturation. Table 1 is showing the market development of the bottle resin between 2004 and 2010.

Table 1: Bottle PET resin production 2004 - 2010

PET Resin Capacity [kt/a]	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
North America	3.685	3.745	3.923	4.595	4.595	4.595	5.000
South America	513	500	500	725	950	950	1.200
Europe	2.411	2.894	3.515	3.766	4.005	4.005	4.205
Africa, Middle East	308	338	499	604	843	843	843
Asia (ex China)	4.107	4.411	4.636	4.636	4.636	4.636	4.636
China	1.469	2.490	3.217	3.255	3.255	3.255	3.255
Total WORLD	**12.493**	**14.378**	**16.290**	**17.581**	**18.284**	**18.284**	**19.139**

The huge potential of PET bottle recycling is becoming obvious by comparing data of resin and flake production in Table 1 and 2. Provided the estimated production amount of 5 Mio t in 2010 is realistic the rate of recycling achieved world wide is a little more than 25% only

Table 2: Bottle PET recycling market development estimation

R-PET Capacity all in [kt/a]	**1999**	**2002**	**2003**	**2004**	**2006**	**2010**
North America	470	480	500	550	600	800
Europe	211	350	430	680	800	1200
ME, Asia, South America, Others	218	370	470	670	1 700	3 000
World R-PET Bottle Flakes	899	1200	1400	1 900	3 100	**5 000 ↑ ??**
World PET-resin	7 100	9 900	11 800	12 500	16 300	19 200
Recycling potential	**6 201**	**8 700**	**10 400**	**10 600**	**13 200**	**14 200**

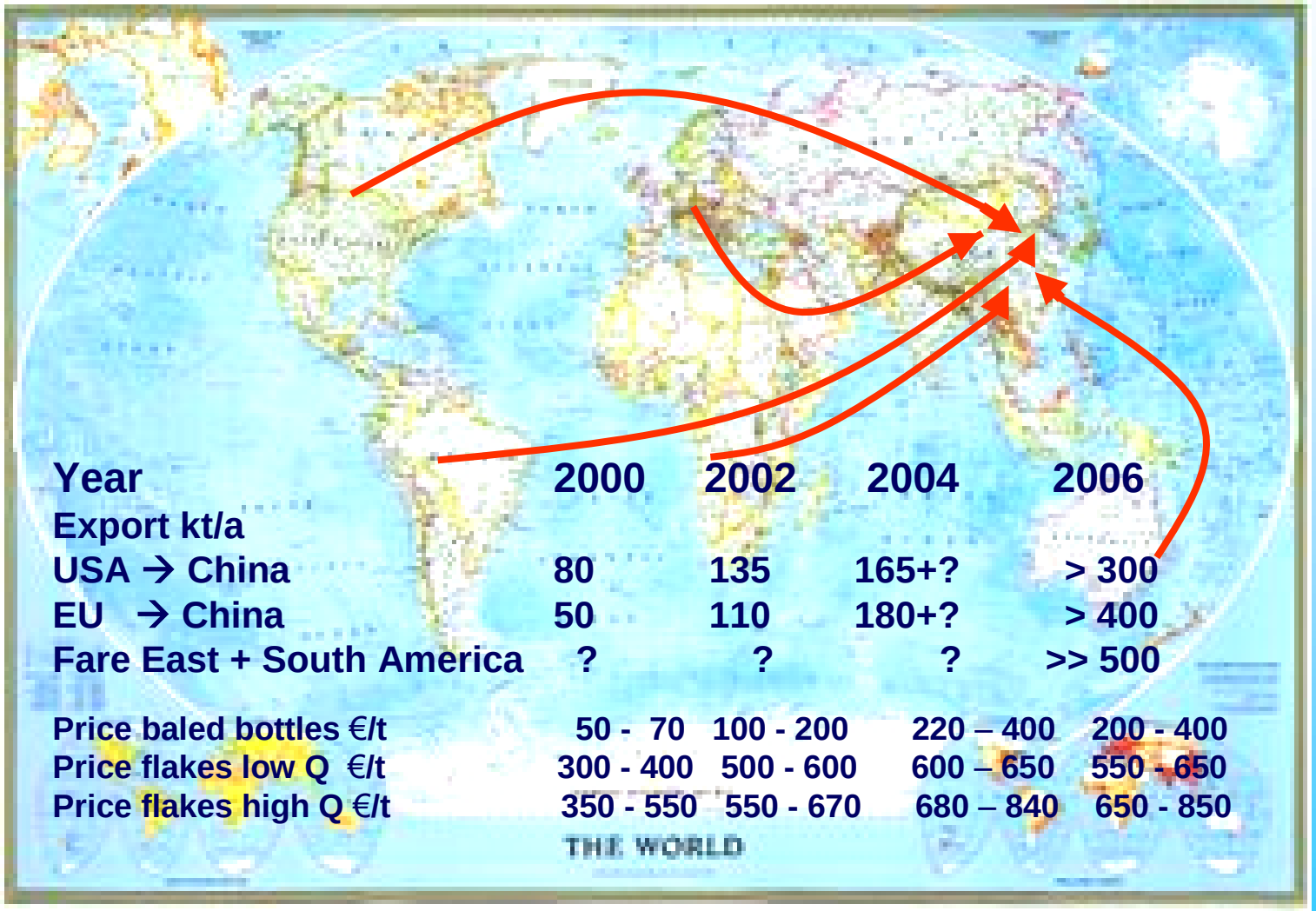
2. Focus to Bottle Flakes
~ Significant Global Differences in Collection and Emergence

Differently to all other industries the growth rate of PET bottle recycling is unfortunately **NOT** a matter of investing money only. Growth is dominated by societal conditions within the different World regions. Quaint enough that countries with highest living standard and highest environment pollution like USA have the lowest collection rate (~23% in 2005) with stagnant or even slightly dropping tendency.
To gain higher collection rates especially in highly developed countries the existing governmental collection structure should be supported by private initiatives in the future

~ How China is Influencing Global PET Recycling Development

The next figure is teaching us that the current situation is dominated by the huge export of all kind of polyester wastes to China. Unfortunately from China are no serious data regarding flake production and collection rates available. But the fact, that China converted in 2006 about 2 Mio t of bottle flakes to mainly polyester fiber underlines that all export data are to use with severe caution. Result of this huge product hunger of China and the connected price increase is unfortunately a declining of PET bottle flake processing activities in USA and Europe.
Reason is declining profit margins when the baled bottle price is step by step cannibalizing the profit margins of bottle flakes processed in USA and Europe.

Figure 1: Polyester flakes are going to China, and prices are going up



Year	2000	2002	2004	2006
Export kt/a				
USA → China	80	135	165+?	> 300
EU → China	50	110	180+?	> 400
Fare East + South America	?	?	?	>> 500
Price baled bottles €/t	50 - 70	100 - 200	220 – 400	200 - 400
Price flakes low Q €/t	300 - 400	500 - 600	600 – 650	550 - 650
Price flakes high Q €/t	350 - 550	550 - 670	680 – 840	650 - 850

3. Ways of Conversion

~ Chemical recycling very rare in industrial scale till now

Especially Japanese companies like Teijin pushed the chemical recycling based on glycolysis to produce BEHT ,methanolysis to produce DMT and the hydrolysis of the DMT to produce PTA.

Problem No.1 is the meanwhile very high price of the feed material “baled bottles” or “bottle flakes” which resulted in shut down of such facilities

Problem No.2 is the stable feed of large scale chemical recycling plants (> 50 kt/a) at such high price levels. As a result the continuous availability of sufficient amounts of bottle waste becomes insecure.

Conclusion: Chemical recycling is possible and executed in exceptional cases only within large and integrated polyester producers.

~ Quality gap virgin PET to Re-PET is narrowing

The steady increase of PET bottle flake quality was and is till now eminently driven by the “Bottle-to-Bottle” technology. No other polyester recycling process is caring in such a consequence for the reduction of impurities – especially in cases when the re-PET chips are processed at 100% to soft drink bottles again.

Once developed the necessarily high-tech sorting, cleaning and decontamination processes and facilities are penetrating step by step the whole polyester recycling industry.

The driving force for this development is clearly the price gap between low grade bottle flakes of about 550 – 650 €/t and the high grade bottle flakes or re-granulates which are touching sometimes nearly the price of virgin PET.

~ Wide variety of processing paths and processes available and in operation

With the exception of China, where till now more than 90% of the recycled PET bottles are converted to a wide variety of fibers and filaments especially in North America and Europe PET bottle flakes are converted to nearly all kind of polyester products.

Exceptions are micro denier filaments, high grade biaxial oriented film, optical film and other specialties. Those products which need even special grades of virgin PET are till now fare apart from bottle flakes as raw material.

Product selection made of bottle flakes:

~ Staple fiber, vide variety of denier
~ Non woven based on recycled SF
~ Dope dyed black fiber
~ POY filaments, coarse denier preferred
~ Bottle grade resin
~ Spunbond
~ Foam PET
~ Cast-film, thermoforming film, A-PET film
~ High tenacity packaging stripes
~ Technical filaments
~ Monofilaments
~ Bulked carpet fiber – BCF
~ Engineering plastic
~ Masterbatch

Partially used to produce of special polymers like melt glue, PUR-precursor, alkyd-resins, biodegradable polyesters

The most common applications in **BOLT**.

4. Making Profit in Polyester Recycling

Observing development and life time cycle of industrial processes one can find in general similar pattern. After a certain ignition and development phase which was in polyester recycling industry during the years 1980 – 2000 the phase of substantial growth is following. During this phase – which we are living in now – most of the technologies are developed and known and mainly **cost reduction** is coming to the fore.

~ Concentration and vertical integration

Comparable to other industries the vertical integration and the capacity growth of single production units becomes important. As more steps of the recycling process are done at one processing site as higher the profit margins. Another advantage of vertical integration is that flake production and flake processing are possible to be concerted to each other. This limits the flake cleaning efforts to the necessary optimum related to the flake conversion process at site.

Sufficient production capacity of vertical integration starts at about 10 000 t/a.

~ High tech replaces handicraft – sorting and purification are keys

For the time being cheep man power for hand sorting is still available in China and Fareast – still.

But disadvantage of hand sorting is the high failure rate. The human eye is not able to distinguish the large number of polymers which are contaminating the collected bottles. As in all industries – the main quality problems and failures are caused by humans.

And – like in all fast developing industry nations – the cheap workforce will be step by step reduced which is to observe even now in at the highly developed centers of Chinese East-Cost-Areas (labor cost is increasing steadily)

To ensure a high and consistent final flake quality the introduction of automatically working high sophisticated sorting systems – for bottles as well as for the final flakes (see the contribution of Se-So-Tec) are becoming mandatory**.**

Similar important but by fare not as detailed described are cleaning technology and there mainly the water circuit management. Water supply, water heating and water cleaning and recycling are main cost factors of bottle recycling but also similar important for the final flake quality like sorting. Here sufficient "**recycling know how**" of PET recycling engineering from market leaders like for instance Buhler, Sorema, Amut, Erema, Krones, Starlinger or Herbold are available and useful.

~ High tech replaces handicraft – sorting and purification are keys

The hand knitted and home made, cheap engineered and low capacity recycling plants are

~generating more environmental problems

~wasting valuable raw materials and

~organizing finally more losses than profits for the entrepreneur and the society!

~ Exploit current environmental discussion

A great challenge for all recyclers is the currently strongly heated up discussion about climate change and its human impact.

Each ton of recycled polyester products reduces the CO2 emission and the consumption of fossil resources significantly as one can see in table 3.

Table 3

Net indicator results for variant scenarios "PET end-of-life options" (Figure 4-14 to 4-15)

Impact Category	Unit	PET (base)	PET (mechanical recycling)	
Fossil Resource Consumption	kg crude oil equ.	17,04	10,56	**38%**
Global Warming	kg CO_2 equ.	92,9	52,6	**43%**
Summer Smog (POCP)	g ethene equ.	69,50	35,38	**49%**
Acidification	g SO_2 equ.	287	158	**45%**
Terrestrial Eutrophication	g PO_4 equ.	20,8	11,7	**44%**
Carcinogenic Risk	mg As equ.	24,90	12,75	**49%**
Human Toxicity (PM10)	g PM10-equ.	266	147	**45%**
Aquatic Eutrophication	g PO_4 equ.	0,63	0,50	**20%**
CED renewable	kJ.	5904	9397	
CED (non-renewable)	kJ	1222106	769178	
CED (total)	kJ	1228010	778575	

See also „Life Cycle Assessment of POLYLACTIDE (PLA)"
A comparison of food packaging made from NatureWorks® PLA and alternative materials
Final Report
IFEU Heidelberg
July 2006

Exploiting this strong current trend needs intensive investment in marketing and labeling

~ Green or eco labels

Textiles are regarding their ecology of high direct impact to the consumer. This trend is rapid increasing in Europe and USA today.

For other products like engineering plastics, stripes or films the producers even today likes more to hide the presence of recycling PET in the product to avoid a low grade quality image. But this might also change step by step.

What is the target of green or eco labels?

To demonstrate the environmentally friendly status of the product including its productions processes

What are the advantages of eco labeling:

- → The producer has an official ecological approval for his product
- → The approval procedure is assuring and increasing the product quality
- → The consistency of eco-quality is granted
- → The consumer trust in the eco product will be increased
- → The label is an excellent marketing tool
- → The selling of the product is supported
- → The product awareness level is increased
- → The pricing or competitiveness are of advantage compared to non label products

Examples of eco label institutions and organizations

Meanwhile a number of organizations and institutions are present which are providing the approval for different eco-labels. The labels are not limited to the textile industry.

Interesting for fiber producer are the material composition labels which are approving the textile source as ecologically proven.

Some examples of labeling organizations:

www.oecotex.com - Switzerland

Provides eco-tex-standards
100, 1000. 1000 plus

Ecotex approved meanwhile more than 700 companies in China in different areas of textile production.

The Europaen environmental label
www.europa.eu.int/ecolabel

The Terratex label
www.terratex.com
specialized in PET recycling fiber products

The green Council label Hong Kong
http://www.greencouncil.org/eng/
greenlabel/res.asp

Cost Cutting

When we talk about cost cutting during polyester production the proportionate replacement of PTA and MEG during polyester polycondensation is meant. Meanwhile bottle flakes are added in a side stream in different stages of the polyester process – form feeding directly to the esterification reactor till melt blending prior the spinning beam.

But all those recycling additions are limited till now regarding the recyclate purity. Addition rate of 10 – 30 % are common today. Largest hurdle is the danger of downgrading high purity virgin material by the recycling addition.

To reduce the risk of downgrading the addition of recyclates shall be as late as possible in the process to minimize thermal degradation – especially the degradation of the still existent organic impurities.

Conclusions:

~ The polyester recycling industry is becoming rapidly a large scale industry comparable to virgin polymers like PBT or polyamides

~ Further healthy growth rates needs besides governmental rules and laws the private initiative to enlarge collection rates – especially in Europe and USA

~ In 2010 not much less 10% of the total polyester production of the world is expected to be recycled material – mainly from collected bottles

~ Vertical integration from collection / baled bottles to the final products and substantial plant capacity > 10 000 t/a is providing significant profitability, at the same time introduction of high tech and matured recycling technology improves flake and R-PET quality significantly

~ A wide range of processing technologies and processing experience to produce polyester intermediates from bottle flakes are available meanwhile

~ Exploiting the ecological advantage of PET recycling and organizing eco labeling approvals improves competitiveness and profit margins

~ High purity flakes only reduce processing risk in raw material replacement during polyester production processes