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Empowering the Bottom of the Pyramid via Product Stewardship: Tetra Pak Entrepreneurial Networks in Brazil

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"A package should save more than it costs."

Ruben Rausing, founder of Tetra Pak

"We acknowledge that our operations have an impact on the environment that must be balanced with the benefits our products and services bring to society."

www.tetrapak.com

Aseptic Carton Packaging

Consumers in no fewer than 165 countries are familiar with the benefits of long-life packaging – cartons manufactured with aseptic technology which keep food fresh for at least six months without refrigeration or preservatives. The aseptic process ensures that both food and packaging materials are free from harmful bacteria at the moment the food is packaged. It allows food to retain colour, texture, taste and nutritional value.

The use of aseptic technology for packaging purposes was pioneered by Tetra Pak, a Swedish company, in the 1960s. Not only did it allow the life cycle of liquid food products to be greatly extended, it also conferred an enduring competitive advantage on the company: for more than half a century the company's uninterrupted growth has been based on this technology.

Long-life packaging is made from Tetra Brik, which consists of six layers of three different materials: long fibre duplex paper (75% by weight), low density polyethylene (20%), and aluminum (5%). The internal polyethylene layers make the packaging impermeable and prevent the food from coming into contact with the aluminum (see Exhibit 1). The aluminum layer prevents the penetration of air, light and microorganisms, ensuring the preservation of the food content.

At first glance an observer might be hard pressed to identify any problem with aseptic packaging. Technically it has never been bettered as a solution for the long-term storage of liquid food products. Commercially it enjoys high levels of consumer satisfaction. However, it is in the post-consumption phase that problems arise: the multi-layered packaging material makes total recycling very difficult, presenting a great environmental challenge.

Tetra Pak: a Very Good 'Package'

Tetra Pak was founded in 1951 by the Swedish entrepreneur Ruben Rausing. From its origins as one of the first packaging companies for liquid milk, Tetra Pak has become a global supplier of packaging systems for liquid food products worldwide. Forty years after its foundation, the company has expanded into liquid food processing equipment, plant engineering, and cheese manufacturing equipment.

Today the company not only supplies hundreds of different types of carton packaging formats but also develops processing solutions and designs, and services complete plants. It operates

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in 165 countries with over 20,000 employees, providing integrated processing, packaging and distribution lines, and plant solutions for food manufacturing.

Tetra Pak belongs to the Tetra Laval Group, which owns also the DeLaval and Sidel industrial groups and has its headquarters in Switzerland. The industrial groups' activities focus on systems for processing, packaging and distributing food and equipment for dairy production and animal husbandry. The three industrial groups are leaders within their respective areas of business (See Exhibit 2 for key figures about the company).

Tetra Pak's Commitment to Environmental Protection

Tetra Pak has long been committed to running its business in a sustainable manner, setting goals for continuous improvement in development, sourcing, manufacturing and transportation activities. As its environmental policy makes clear, the company takes a long-term, life cycle view: continual environmental performance improvements, the use of design for environment, open communication with stakeholders and regular reporting on performance.

It is company policy that all Tetra Pak packages must be suitable for recycling and in recent times it has become involved in the identification of appropriate recycling technologies. Tetra Pak supports customers in finding environmentally acceptable solutions for their packaging waste, and is committed to facilitating and promoting local collection and recycling activities for post-consumer carton packages, such as:

- supporting the development of new technologies for the recycling of used packages and the recovery of their materials;
- working closely with governments, local authorities, suppliers, recycling companies and local entrepreneurs to find stable, low-cost recycling solutions and capacity with a minimal environmental impact;
- finding ways to make recycling more cost-efficient, for example, by promoting new sorting equipment.

Tetra Pak also actively endorses efforts in the areas of human rights, labour and the environment made by organizations such as the United Nations Global Compact,¹ NetAid, a growing network of people and organisations committed to ending extreme poverty,² and the International Business Leaders Forum (IBLF),³ a not-for-profit organization established in 1990 to promote responsible business practices that benefit business and society and that contribute to sustainable development. More recently, Tetra Pak has signed an agreement with WWF on forestry management.⁴

1 www.unglobalcompact.org (All sites quoted in this article were accessible in August 2007)

2 www.netaid.org

3 www.iblf.org

4 http://www.panda.org/about_wwf/what_we_do/forests/index.cfm?uNewsID=60020

Tetra Pak Brazil: Entrepreneurial Networks

Tetra Pak Brazil started operating in 1957. By 2005 it had become the second largest operator in the Tetra Laval Group, surpassing eight billion packages in sales.⁵ There are several reasons for the company's successful growth: a broad variety of products for customers; state-of-the-art filling machines, packaging and processing equipment; a devoted workforce and a long-term market approach, which has created very close relations with customers.

Tetra Pak has two factories and seven regional offices in Brazil, and more than 200 corporate customers, among them well-known giants such as Unilever, PepsiCo, Nestlé, Italc, ELEGE, and Coca-Cola. Dairy products account for about 80% of the business, beverages for 20%.

As an extension of the mother company's Swedish culture, Tetra Pak Brazil has always adopted a 'beyond compliance' approach to corporate environmentalism. In the mid-1990s it started addressing the problem of the disposal of post-consumption aseptic cartons. The Brazilian branch has consistently invested in corporate environmentalism, spending €500,000 per year during the period 1997–2000, €1 million per year in 2001–2, and €2 million per year in 2003–5. As a result, recycling rates of aseptic cartons increased from 12% (14,000 tons) in 2000 to 25% (40,000 tons) in 2005. These figures, which exceed the worldwide average of 15%, are important not just because the overall environmental impact has been reduced, but also because the recycling networks promoted by Tetra Pak have generated new sources of wealth and alleviated poverty.

The proactive role of Tetra Pak has made it possible to develop a variety of collection systems which are unique to Brazil. In general, people working as selective waste collectors in Brazil are from the bottom of the pyramid (BoP)⁶ who make a living out of collecting saleable materials recovered from household waste. There are approximately 400,000 street collectors in the country. In São Paulo alone, a city that generates around 10,000 tons of household waste per day, there are around 20,000 collectors. According to the Brazilian Bureau of Geography and Statistics (IBGE), these people are from the "E" economic segment, with a family income that does not exceed two minimum wages – around €250 a month.

Tetra Pak Brazil's initiatives have made it the group leader in environmental innovation involving breakthroughs in both basic and advanced technologies for increasing the recycling rates of aseptic packaging. Such innovations have made Tetra Pak not only a leader in technology but also in the domain of corporate social responsibility.

5 <http://www.tetrapak.com.br/home.asp>

6 The concept of "bottom of the pyramid" (BoP) was devised by C. K. Prahalad (2004). See *Fortune at the Bottom of the Pyramid: Eradicating Poverty Through Profits*. Upper Saddle River, NJ: Wharton School Publishing.

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Selective Collection

The Problem: Low Rates of Selective Collection

Closing the cycle of aseptic packaging requires the selective collection of material. The economic viability of recycling is highly dependent on economies of scale, so the first step – the separation of household waste – is critical for the success of the overall process.

From the point of view of a privately owned company, the low recycling rate of household waste was a major challenge in Brazil. The management of post-consumption waste was the responsibility of local councils. Waste management was considered a ‘public good’, so unless private firms were paid to carry out such services there were no regulations forcing companies to be directly involved in the management of household waste.

Tetra Pak representatives were aware that most local councils tended to run very tight budgets and had little leverage to create comprehensive recycling schemes, which required education, curbside collection, and subsequent recycling. It was also aware that in local schools, financed by local municipalities or the state, educational materials were a very rare asset.

Initiative 1: Sponsorship of Environmental Education

Tetra Pak addressed this bottleneck by sponsoring environmental education. From 1997 it began supporting an educational programme on the problem of municipal solid waste and its solution. The University of Campinas (UNICAMP) developed a teaching pack to support classroom discussion about the problem of urban solid waste, the importance of selective collection, and the environmental, social and economic benefits of recycling.

Although the programme has national reach, the states of Rio Grande do Sul, Santa Catarina, Paraná, Minas Gerais, Goiás, Rio de Janeiro and São Paulo were specifically targeted because relatively more advanced schemes were already in place in these more urbanized areas. By 2006 around 5,000 primary school teachers had been trained to use the materials. The latter have been distributed to more than five million students in 40,000 schools around the country. In 2006 Tetra Pak made the programme available via videoconference.

This sort of training is seen as the primary step towards increasing the levels of waste separation in households and subsequent curbside collection. The education of new generations is the first step towards more sustainable societies, as children influence the behaviour of their parents.

Initiative 2: Technical Support for Municipalities and Street Collectors' Cooperatives

From 1997 to 2005 over 200 local councils were contacted by Tetra Pak representatives who offered their recycling expertise. Tetra Pak also spurred councils to form collectors' cooperatives. These provided a more systematic approach to the problem of collection but their formation served a much broader social purpose as their members received social assistance in the form of education and medical services, among others.

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The formation of collectors' cooperatives and the retention of their members remained a challenge, however. There was constant competition for raw materials from private recyclers, luring some individuals away from the cooperatives to work independently. Also, from a behavioural perspective, cooperative work did not suit everyone – collectors who had lived on the streets for most of their lives did not easily adapt to organisational rules and routines.

Between 1997 and 2005 Tetra Pak sent more than four million brochures to municipalities and collectors' cooperatives. In order to increase process efficiency, during that period Tetra Pak also donated 30 press machines to cooperatives in various states of Brazil. By 2005 this support meant that Tetra Pak aseptic cartons accounted for 6–10% of collectors' income.

According to research carried out by CEMPRE,⁷ 347 municipalities had selective collection programmes in 2006, representing a 200% increase in ten years. While obviously this was not a result of Tetra Pak initiatives alone, the parallel between the growth of recycling rates and the number of Tetra Pak's initiatives cannot be denied.

⁷ <http://www.cempre.org.br/>

Material Recycling

"The more they make money, the more we recycle!"

Fernando von Zuben

Once the material was being collected proper recycling could start. But until 1997 several technical and commercial hurdles limited the recycling capacity.

The Problem: Insufficient Paper Recyclers

Technically the recycling of paper present in aseptic packaging had never represented a major problem, but first the paper had to be extracted from the sandwich layers of Pe/Al via hydropulpers, a kind of large industrial blender. Even though hydropulpers are standard equipment in paper recycling plants, they had to be adapted for the separation of the Pe/Al material and the filtering of eventual residues. Such requirements made paper manufacturers reluctant to use fibre from aseptic cartons until 1997.

Initiative 3: Development of Recyclers

Tetra Pak addressed the viability of paper recycling by demonstrating the technical advantages of the fibres present in the Tetra Brik packaging: being new they are longer than fibres that have already gone through a recycling process, and therefore of better quality. Once they had understood the quality of the fibre, paper recyclers gradually started to give priority to Tetra Pak aseptic packaging. By the end of 2005 there were ten aseptic packaging paper recyclers using waste from factories and post-consumption packaging in Brazil. The range of recyclers is now very broad, varying from Klabin Embalagens,⁸ a world-class corporation specialising in the manufacturing of paper, to medium and small local producers.

Trombini, a paper manufacturer located in Canela (in the South of Brazil), offers a good example of the development of paper recyclers. In 2006, after two years of communication, Mario Cerqueira, the Environmental Engineer of Tetra Pak, managed to convince Trombini representatives to recycle Tetra Pak material. One year later Trombini was recycling 350 tons of Tetra Pak cartons per month, a volume which would double if more material were available, according to Nelson Slompo, Operations Director of Trombini Canela.

The Problem: Technical & Economic Viability of Recycling Pe/Al

Having extracted the paper from the packaging, the next challenge was to find a use for the blend of polyethylene/aluminum (Pe/Al) that remained. Until 1999 there were no applications for the discards coming either directly from the Tetra Pak factory or as post-consumption waste. A solution had to be found.

8 Klabin has been the focus of media and academic studies because of its early commitment to environmental protection. The company has received several environmental awards, including "Premio Expressão de Ecologia" (www.expressao.com.br/ecologia/) for the years 1998, 1999, 2001, 2002 and 2005. See www.klabinonline.com.br/

Initiative 4: Developing Pe/Al Material Recyclers

Tetra Pak Brazil's environmental team led the drive to find uses for the Pe/Al discards. They discovered that: (i) Pe/Al could simply be washed and dried, and used directly in the fabrication of roof tiles and boards; (ii) Pe/Al could be melted and extruded into pellets for later use in the manufacturing of plastic products.⁹

Production of Roof Tiles and Boards

The idea of using Pe/Al for roof tiles emerged in 1999 to solve the problem confronting paper mills of how to deal with this kind of material. Tetra Pak experts already knew that laminated material from factory waste could be pressed at high temperatures to produce boards, but nothing had yet been done with Pe/Al. The team conducted several trials to control moisture and particle size and, after modifications to the press, a hard board was created. The second issue was not technical but economic. Recycled board had difficulty competing with wood (a very cheap commodity in Brazil), whereas roofing tiles were more viable because they were cheaper to produce, lighter and had more mechanical resistance than fibre-cement tiles.

Basically, the process consisted of melting the Pe/Al compost under pressure, with subsequent cooling in the first phase. To reduce the size and increase the homogeneity of the material the Pe/Al went through a knife-grinding mill. The second phase consisted of putting the material into moulds, which were then pressed under temperatures of around 180° C. Finally, products were cooled – acquiring the shape of plain boards or corrugated roof tiles.

Even with very low levels of process optimisation the business could be profitable. The initial investment in equipment was about €45,000 and revenues were around €38,000 per year. Obviously profitability was dependent on various factors: location strongly influenced the cost of transport and the price of raw materials, and since profit margins were relatively low, fluctuations in the price of raw materials could have an adverse effect on the business viability.

Production of Plastic Products

Mercoplas, a company located in Valinhos in the interior of the state of São Paulo, was the key partner in the development of the process. It already had the expertise to recycle low density polyethylene (LDPE) but at that time (1998), it did not believe the extrusion of polymers contaminated with aluminum was possible.

During early trials the villain of the piece was identified: the problem was not the residual aluminum but the paper fibres that remained in the Pe/Al blend after the de-pulping process (5–10% by weight). The fibres burned inside the extruder chamber, generating carbon and water vapour, which compromised the final pellet quality, jeopardising the whole process. After a year of failed attempts, Mercoplas found a solution for the fibre contamination – a major breakthrough not only for the extrusion process but also for success of the plasma project, described below.

9 Cerqueira, Mario Henrique de (2002). "Boards and Roofs Produced with Recycled Polyethylene/Aluminium from Tetra Pak Packaging". Proceedings of the International Aluminum Conference, São Paulo, Brazil.

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The production of Pe/Al pellets was based on a well-established technology for a new type of raw material. After the Pe/Al mix was taken from the hydropulper (as residue of the paper recycling process), it was cleaned to remove dried-up fibre and then ground to increase the homogeneity of the material. The residue was then fed into an extruder which melted it down at temperatures of 200°C and extruded Pe/Al pellets.

The Pe/Al pellets were of pure plastic material (polyolefin, normally polypropylene or polyethylene) used in the manufacture of plastic products such as buckets, brushes and handles for tools. While their aluminum content contaminated the plastic material it did not compromise product performance, and so could be used as a substitute for pure plastic. Polaris, a manufacturer of brushes and brooms located in Piracicaba in the interior of São Paulo State, has used Pe/Al pellets in brushes since 2000. Pe/Al pellets are cheaper than traditional raw materials (€916 per ton as against €1,337 per ton of virgin material), and if Pe/Al pellets were more readily available, Polaris would use more.

Initiative 5: Small Scale Recycling Plants

In 2003 the environmental department of Tetra Pak Brazil also developed a small-scale recycling plant concept which could process 200kg of post-consumer aseptic cartons per hour (140 tons per month). The plant was developed to make recycling technically and economically viable in areas at a distance from paper recyclers or without an established market for recycling.

Three firms were involved in the development of the first unit, which was assembled and tested in 2003 at Mercoplas. *Sulab* developed the equipment to desegregate the paper fibres (a smaller version of the hydropulper used by paper recyclers); *Incomesp* developed the equipment to reduce the water content of the cellulose fibre rolls, and *Hidrovitae* developed the equipment to clean and recycle water (closed loop) after it had been used to extract the fibre.

This small-scale recycling plant technology has already been exported to South Africa, Costa Rica, Panama, China and Thailand. Other countries have also shown an interest in it. Investors buy a 'turn key' recycling plant from the Brazilian equipment suppliers, and Tetra Pak personnel help them with the start up procedure. More importantly, Tetra Pak helps new operators to establish and implement a clear business plan.

Closing the Loop: The Thermal Plasma Technology

Even though Tetra Pak's initiatives in Brazil had resulted in greater rates of collection and recycling of aseptic packaging, until 2004 the solution was still incomplete. Because there was no technical means of separating the layers of polyethylene from aluminum, instead of being recycled into their original application (carton packaging), the various waste elements continued to be used as raw material for very different products – brushes, brooms, boards and tiles.

It was thermal plasma technology which achieved a breakthrough in closing the cycle of aseptic cartons. The process offered a new recycling option: separating the three package components and allowing them to return to the production chain as raw materials (see

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Exhibits 3 and 4 for an overview of the process). It built on the success of the polymer extrusion innovation described earlier.

The Steps Toward Closing the Cycle

When Fernando von Zuben joined Tetra Pak in 1995 to lead the environmental department he soon realized that the Pe/Al mix would represent the greatest obstacle to closing the cycle of materials used in aseptic cartons.

Von Zuben had worked with cold plasma technology in his previous job and saw some potential in using it to solving the Pe/Al problem. In 1996 he approached Dr Roberto Szente, one of the world's top experts in plasma technology and head of the plasma research team of Instituto de Pesquisas Technologicas de São Paulo (IPT). In 1997 Szente and von Zuben initiated cooperation between IPT and Tetra Pak to try the effects of plasma technology on separating the Pe/Al mix. The first pilot tests with small (3kg) batches of aseptic packaging were developed that year.

The initial results were not very encouraging. The batches produced aluminum with high levels of carbon, due to the contamination of the mix by paper fibre. These negative results in the pilot test put the project on hold while von Zuben started looking into ways of reducing the paper fibre content in the Pe/Al mix. It was von Zuben who approached Mercoplas, who were willing to invest in the extrusion technology. As we saw earlier, within a year, Mercoplas and Tetra Pak had succeeded not only in separating the paper from the Pe/Al mix, but also in transforming the Pe/Al into pellets which could serve as raw material for plastic applications.

Having found a way of isolating the paper fibre, von Zuben and his team realised that they might have found a solution to the problem of the paper contamination of the plasma reactor. He persuaded Roberto Szente to retry the process, now with a cleaner Pe/Al mix.

The first breakthrough was reached: out of the plasma reactor came clean aluminum and methane gas. While the methane presented a problem,¹⁰ the partial solution was sufficiently encouraging to continue the trials. The second breakthrough came when, by changing the temperature of the chamber, aluminum and paraffin compost were produced instead of methane gas.

These encouraging results led Szente to ask representatives of TSL – a Brazilian company operating in the petroleum sector – whether they would be interested in investing in a pilot plant. Coincidentally, TSL had been looking into plasma technology as a solution for soil remediation, and the two parties had many common interests.

In 2001 joint tests began in a plant with the capacity to process 50kg an hour of Pe/Al. The pilot plant was, in fact, an adaptation of plant owned by Petrobras, the Brazilian state-owned petroleum company, to process soil contaminated with oil. After two years of operation the technology seemed to work without any major problems (for a description of the plasma technology, see Exhibit 4).

¹⁰ Methane is an extremely volatile gas that is notoriously difficult to transport, requiring sophisticated equipment for safety reasons. It is economically viable only if it is burned locally.

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The Joint Venture

After running the pilot plant for 24 months the quality of the plant output – paraffin wax and aluminum – was so encouraging that a proposal for a joint venture emerged. In 2004 Tetra Pak, TSL, Klabin and Alcoa, an American producer of aluminum in Brazil, constituted EET – Edging Environment Technology.

The thermal plasma plant had the capacity to process 8,000 tons of Pe/Al material per annum (equivalent to 32,000 tons of aseptic packages), representing 20% of all Tetra Pak packaging produced in Brazil (160,000 tons per year). The plant required an investment of €5 million, shared equally among the four partners. According to von Zuben, Tetra Pak did not intend to profit from the plasma technology. The patent belonged to TSL, which bought it from Dr Szente.

It was not all plain sailing. By December 2005, eight months after its inauguration in the city of Piracicaba (in the State of São Paulo, Brazil), the plant was operating at 50% of its capacity. In addition to the newness of the technology, the fibre-cleaning device did not work properly, so new equipment had to be developed.

But the investment exceeded expectations. Alcoa, the supplier of aluminum foil for aseptic packaging, bought the recycled aluminum for the production of new foil. Aluminum was sold to Alcoa at 95% of the London Metal Exchange price of around US\$2,780 per ton in May 2007. The paraffin wax was sold to the national chemical industry to be used as wax emulsion for paper at the market price of US\$620 per ton. The sales of paraffin and aluminum produced by the plant were expected to result in a payback period of only two years for the investment. Such a prospect prompted interest outside Brazil. In September 2005 a Chinese delegation visited Tetra Pak Brazil to learn about plasma technology. A second plasma plant is currently being constructed in Spain and a third is expected to be built in Belgium.

In October 2005 the Brazilian Industry Council, a government organization, awarded Tetra Pak a prestigious prize in the category of sustainable development for the plasma plant factory.

The Challenge Ahead

Even though the recycling networks created by Tetra Pak have been extremely successful so far, there are some major challenges ahead.

Ironically, the success of the recycling programme may entail its own demise. As the total recycling of aseptic packaging takes off and new businesses are created for processing Pe/Al, competition for the discards is expected to increase rapidly.

Before the plasma plant began operation, Tetra Pak representatives expected the price of post-consumer aseptic cartons to increase by 30%, resulting in more packs being collected and recycled. By 2005 paper recyclers were paying an average price of €97 per ton of aseptic cartons to collectors' cooperatives, an increase of more than 300% since 2000, when the price was €30 per ton. In August 2007 the post-consumer material reached €130 per ton.

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The price for Pe/Al discards has grown significantly in the past few years. In 2002 paper recyclers charged €38 per ton to dump the Pe/Al in landfills. By 2003 they were getting €19 per ton of recycled product, reaching a peak of €115 per ton in 2005.

If the price of the aseptic carton grows in tandem with the price for Pe/Al discards, no major disruption in the market is expected to occur. However, as the recent price history suggests, demand for Pe/Al seems to be growing faster than the demand for paper fibre. If this tendency persists, then the price for Pe/Al could rise faster than the price for the whole aseptic packaging, causing some disequilibrium in the market.

Such a scenario would certainly benefit the paper recyclers, since their costs would be smaller. On the other hand, an excessively high price for the Pe/Al mix could eventually make some businesses, such as the manufacture of roof tiles, unviable. Moreover, excessively high costs for the Pe/Al mix could even challenge the viability of the plasma plant. There is a limit to the Pe/Al cost for all technologies. Can the market set the appropriate price?

Exhibit 1:
Composition of Tetra Brick Aseptic

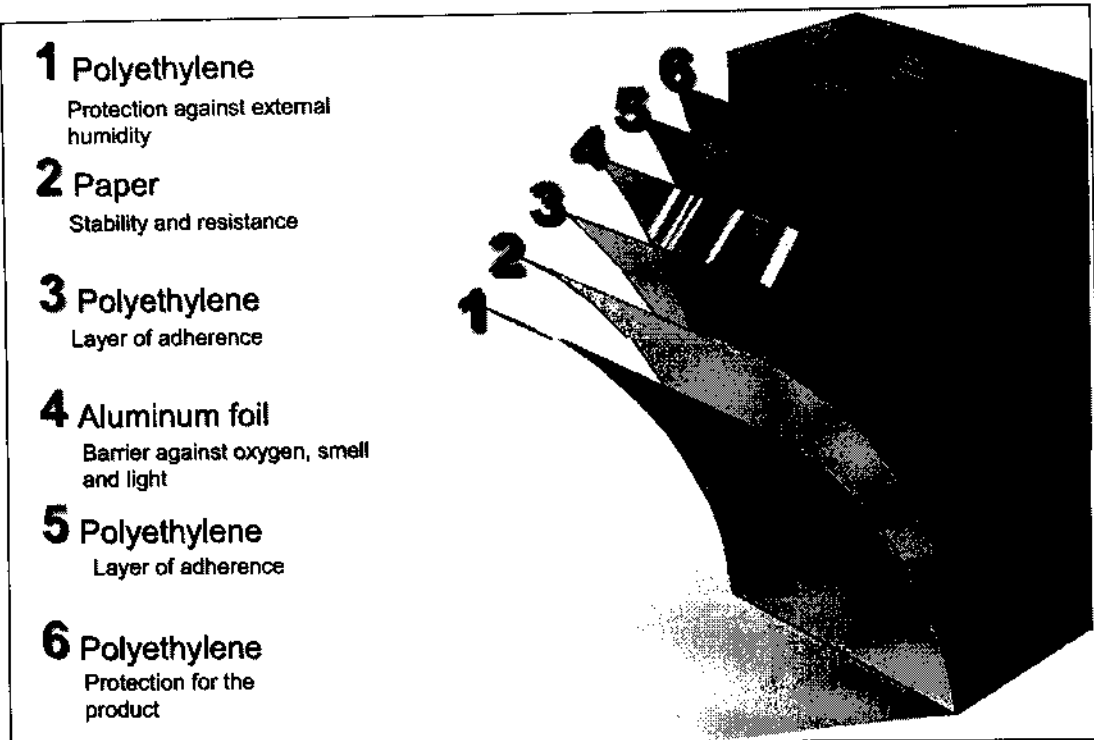


Exhibit 2:
Tetra Pak: Key Figures

Net sales in 2004 in M.EUR:	7,525
Packages delivered in 2004 (million)	110,817
Litres of products delivered in Tetra Pak packages in 2004 (million)	60,689
Employees	20,905
Machine assembly plants	16
Production plants for packaging material	53
Number of countries covered	165
Market companies	58
Sales offices	58
R&D centres	19
Service centres	59
Packaging machines in operation 2005	9,014
Packaging machines delivered in 2004	630
Processing units in operation 2005	22,546
Processing units delivered in 2004	1,816
Distribution equipment in operation 2005	12,355
Distribution equipment delivered in 2004	1,373

Figures as of January 2005

Exhibit 3:
Post-Consumption Processes for Aseptic Cartons

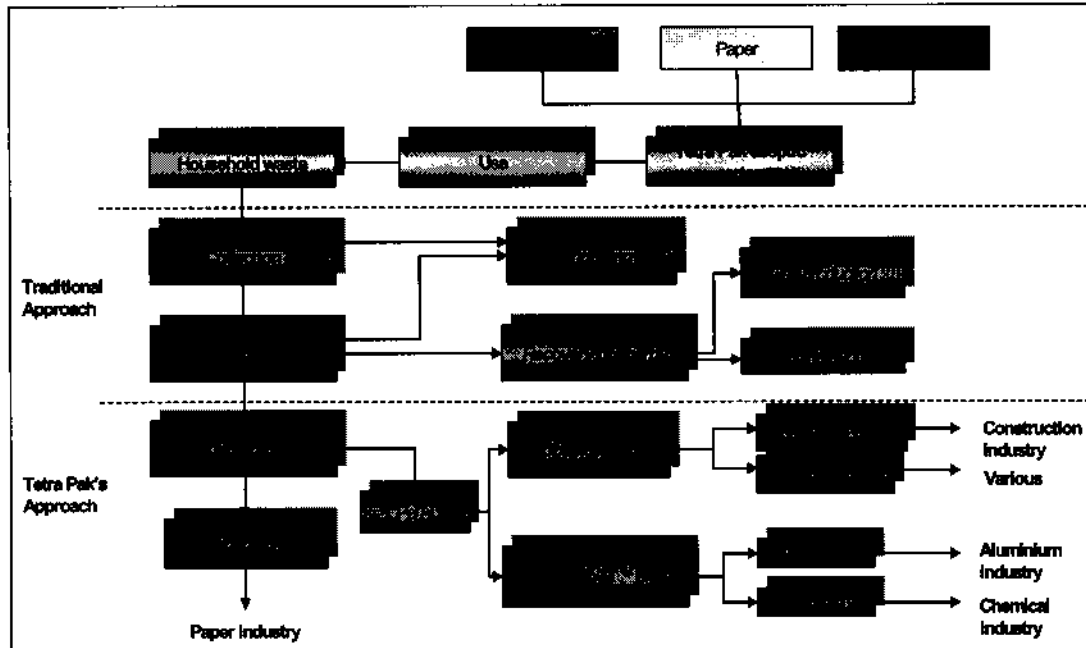


Exhibit 4:
The Plasma Technology

Basically, plasma is the fourth state of matter (beside solid, liquid and gas), which is obtained by adding energy to gas. The thermal plasma technology (TPT) uses electricity to produce a plasma torch that reaches 15,000°C. The 'plasma' is achieved by burning an inert gas (Argon) in an oxygen-free chamber, which normally operates at around 700°C. In fact, the plasma technology is not new. Metallurgical companies have traditionally used plasma technology for metal recovery. The use of plasma for the recycling of aseptic packaging is, however, novel.

In the first step of the process, the Pe/Al mix is placed into the 'plasma reactor'. Because of the absence of oxygen, the polyethylene does not burn. Rather, its carbon chain (of 25,000 carbons) breaks down into smaller molecules (chains of 18 to 30 carbons), transforming itself into paraffin. In turn, the aluminum melts down and is recovered as highly pure ingots, which can be melted down and rolled again for foil.

Plasma technology is highly efficient: 90% of energy yield is actually achieved in the process. In comparison, using the same process with natural gas would reduce efficiency to 25-30%, the aluminum would be contaminated and the plastic would burn. Besides the eco-efficiency of the process, emissions during the material's recovery are near zero because the atmosphere of the reactor has close to zero concentration of oxygen, and the raw material added to the plasma chamber is a polyolefin free of chlorine or benzene ring.¹¹

¹¹ Detailed information can be found in: Fernando von Zuben (2005), "The utilisation of thermal plasma technology to separate aluminum from plastics in laminated packages". Proceedings of the International Conference on Energy, Environment and Disasters (INCEED), June 2005: North Carolina, USA.