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VALUING PLASTICS – THE BENEFITS OF PLASTIC PACKAGING COMPARED TO SUBSTITUTES FROM A LIFE CYCLE PROSPECTIVE

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Introduction

In the context of the EU's commitment to reduce greenhouse gas (GHG) emissions by at least 40 % by 2030 as part of its 2030 climate and energy framework[1] and its commitments under the Paris Agreement[2], and in the interests of long-term sustainable development, it is clear that the environmental impact of materials needs to be taken into account when selecting materials.

A wide variety of material types play a role in meeting the needs of modern society and sensible product stewardship is necessary for all products.

Plastics offer many social benefits: plastic packaging keeps food fresh and safe for human consumption and prevents food waste, and plastics help save lives through a wide range of medical applications such as packaging for pharmaceuticals and in the manufacture of healthcare equipment. There is also large potential for future applications in renewable energy generation and in improving transportation[3]. In addition, the plastics industry makes an important contribution to employment: in 2019, the European plastics industry employed more than 1.6 million people and earned revenues of € 360 billion, according to Plastics Europe[4].

Plastic products account for the use of just 6 % of the consumption of non-renewable fossil fuels[5] and a literature review showed that, contrary to popular belief, reducing the use of plastics would actually have the opposite effect, by increasing the overall consumption of non-renewable fossil fuels, increasing GHG emissions, increasing the severity of other impacts like acidification and eutrophication potential, smog formation and ozone depletion as well as substantially increasing the overall costs to society. For example, recent scientific studies by Franklin Associates (2014)[6] and (2019)[7], Denkstatt (2011)[8], and Trucost (2016)[9], which modelled the substitution of plastics by alternative materials such as paper, paperboard, steel, aluminum and glass, indicate that a move away from plastics may come at an even higher net environmental cost in all regions of the world.

This is clearly a completely theoretical scenario as the benefits and convenience that plastic materials provide to society are such that complete substitution would be an impractical proposition. Furthermore, plastics have established themselves so extensively within the spectrum of modern materials that there are some applications (approximately 16 %) designed with plastics, which cannot feasibly be substituted without changing the design significantly, because their function is to offer a certain service such as is the case with packaging, transporting food aid over long distances, transparent films for food, hygiene control, water bottles for use during sport events, etc. The resultant negative impacts of substituting plastics with other materials have been reported in various scientific studies.

All the studies were carried out by universities or independent research institutes. They followed the principles of life cycle assessment (LCA) methodology covering the three main phases of a product's lifespan (production, use phase and waste management) and were peer reviewed by different universities or research institutes in Europe. Calculations were derived from very reliable datasets, such as the World Bank[10], PlasticsEurope[11], Eurostat[12], US EPA [13] and Ecoinvent[14].

Due to the very broad scope considered in such studies, such as the regions covered, the sector, the application, the technologies etc., a number of extrapolations and assumptions have had to be made when calculating the impact of both alternative materials and plastics. Nevertheless, the general conclusions are considered valid by the scientific community.

Summary of results

The results of the different substitution analyses available in the literature show plastic packaging to be an efficient packaging choice in terms of energy consumption, global warming, and several other environmental impacts as well as from the perspective of reducing the cost to society.

Energy consumption and global warming potential impact

The Denkstatt study[8] showed that if all plastic packaging were to be substituted by other materials (such as paper, paperboard, steel, aluminum, and glass) in Europe (EU27+2) only, the result would be as follows:

- The respective packaging mass would increase on average by a factor of 3.6.
- The life-cycle energy demand would increase by a factor of 2.2 or by 1,240 million GJ a year, which is equivalent 27 million metric tons of crude oil in 106 VLCC tankers or comparable to
- 20 million heated homes.
- GHG emissions would increase by a factor of 2.7 or by 61 million tons of CO_2 equivalents per year, comparable to 21 million cars on the road or equivalent to the total CO_2 emissions of Finland (2018)[15].

The main reason for this result is that plastic packaging usually provides the same function with significantly less material mass per functional unit. In most cases this leads to the use of less energy for the production and lower GHG emissions per functional unit than for the mix of alternative materials. Moreover, the benefits during the use phase (preventing food loss, less energy for transportation, etc.) are greater in the case of plastic packaging than when alternative materials, like paper or paperboard, are used[8]

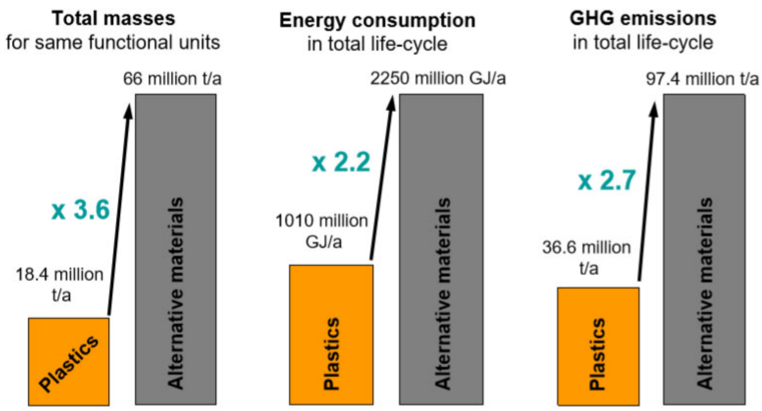

Figure 1: Effect of substitution of plastic packaging on masses, energy demand and GHG emissions in Europe[8].

Other important findings are:

- The GHG benefit of preventing food loss is (on average) at least five times higher than the impact due to the production of the packaging even when only 10 % less packaged food goes to waste.
- Recycling and recovery of plastic packaging helps conserve energy resources; recovery processes with high efficiency also enable reductions in GHG emissions to be made.
- Biodegradable plastic packaging is not per definition better than conventional plastic packaging. Such a comparison strongly depends on the mass ratio of the products, the specific materials used and the waste management conditions pertaining in each country.

Similar substitution studies[6,7] conducted on plastic packaging applications in the United States and Canada showed the following:

- On a US national level, the use of plastics for packaging applications instead of the main alternatives that provide the same functions results in:
  - materials savings of more than 64 million metric tons
  - greenhouse gas emissions that are 67.1 million metric tons of CO_2 eq. a year lower than with other materials. Using the equivalency factors derived from the US EPA Greenhouse Gas Equivalencies Calculator[16] the savings are equivalent to the annual GHG emissions from over 14 million passenger vehicles or 889 thousand tanker trucks of gasoline the US.
  - a cumulative energy demand benefit of 1,196 billion MJ a year.
- On a Canadian national level, the savings would be in the order of:
  - more than 5.5 million metric tons of material
  - a cumulative energy demand benefit of 121 billion MJ a year
  - greenhouse gas emissions that are 8.66 million metric tons of CO_2 eq. a year lower than with other materials – equivalent to the GHG emissions from 1.9 million passenger vehicles a year[16].

Other environmental impacts

In addition to the global warming potential impact, the same scientific studies[6-8] have also showed that substitutes for plastic packaging would result in significantly higher impacts for all the results categories evaluated: water consumption, solid waste by weight and by volume, acidification potential, eutrophication potential, smog formation, and ozone depletion.

Specifically:

- *Water consumption*

  Overall, the substitutes that would replace US plastic packaging would consume almost six times as much water, and Canadian substitutes would consume almost four times as much water. The savings in water consumption would be sufficient to fill 460,000 Olympic-size swimming pools for the US plastic packaging and about 55,000 Olympic pools for the Canadian packaging[17].
  Production of plastic resins and plastic converting processes consume less water per kg than production of substitute packaging such as paper and paperboard (on average 190 liters water/kg PET compared to 350 liters water/kg virgin paper if water is not reused[14]), leading to significant savings in water consumption with plastic packaging.

- *Solid waste*

  The overall solid waste weight benefits ratio for plastic packaging compared to substitute packaging is 4.9 for the US and 3.9 for Canada. The savings in weight of solid waste expressed as the equivalent number of 747 aircraft[18] are 290,000 747s for US plastic packaging and about 22,000 747s for Canadian packaging.
  There tends to be significantly more solid waste with substitute packaging (e.g. paper, metals, glass, etc.) because the substitute packaging required to perform the same function as the plastic packaging generally weighs more. Moreover, process solid wastes for plastics tend to be lower than solid wastes for materials like paper, paperboard, and metals, whose production creates sludges, mining residues, and slags.

- *Acidification potential*

  Acidification means that substances with a low pH are emitted and enter waters and the soil to such a degree that they do not have any chance of becoming neutralized naturally. Acidification impacts are typically dominated by emissions associated with fuel combustion, particularly SO_x and NO_x. These acidifying chemicals have a wide variety of adverse impacts on the soil, organisms, ecosystems and materials (buildings). The higher the acidification potential, the greater the risk of acid rain and the associated environmental damage.

  The overall acidification benefits ratio for plastic packaging compared to substitute packaging is 3.3 for the US and 4.3 for Canada. Acidification potential is normally high when forestry-based packaging systems are involved, mainly due to the emissions from the paper manufacturing process as well as due to ammonia emissions from the black liquor melt dissolver, the causticizing process, white liquor preparation and the bark boilers. Upstream production of chemicals as well as transport are also important contributors to the acidification potential in the production of paper packaging.

  The reduction in acidification can be expressed in terms of the emissions from the combustion of the equivalent number of railcars full of coal. Acidification savings for US plastic packaging compared to substitutes are equivalent to the acidification from burning over 290,000 railcars of coal, and the corresponding Canadian savings are equivalent to 29,000 railcars of coal[16].

- *Eutrophication potential*

  Eutrophication potential is based on releases of nutrients (phosphorus, nitrogen, etc.) into the aquatic and the terrestrial environment, which can cause a decrease in the oxygen content. This in turn can lead to ecosystem disturbances such as algal blooms and fish kills. Emissions from the combustion of fossil fuel account for the largest share of eutrophication with plastic packaging systems. In addition to the fuel-related emissions contribution to eutrophication for substitute packaging, some significant process related emissions, such as biological and chemical oxygen demand from paper and paperboard manufacturing processes, have a large eutrophication impact. As a result, the total eutrophication due to plastic packaging is only 2 % of that for substitute packaging, and the overall eutrophication ratio for substitutes compared to plastic packaging is very high: 54 times higher for US packaging, and 66 times higher for Canadian packaging if all plastic packaging were to be replaced with alternative materials.

- *Smog formation potential*

  Smog formation potential reflects the photochemical creation of reactive substances (mainly ozone) in the lower atmosphere which affect human health and ecosystems. This ground-level ozone is formed in the atmosphere by nitrogen oxides (NO_x) and volatile organic compounds (VOCs) in the presence of sunlight.

  Overall, using substitutes to replace plastic packaging in the US would result in three times more smog formation, and in Canada the figure would be almost four times higher. The impact of smog formation is generally dominated by emissions associated with fuel combustion, so it is higher for life cycle stages and components that have higher process fuel and transportation fuel requirements, like in the case of the substitution of packaging with plastic packaging.

- *Ozone depletion potential*
  Depletion of stratospheric ozone increases exposure to radiation, which can lead to increased frequency of human health issues such as skin cancers and cataracts as well as detrimental effects on crops, other plants, and marine life.
  Overall, the substitutes that would replace plastic packaging would result in almost four times more ozone depletion, in both the US and Canada. For paper and paperboard packaging, the emissions released by the combustion of wood fuel in boilers at paper mills explain the differences in the reported ozone depletion results.

A summary of the savings for plastic packaging compared to substitute packaging in the US and Canada for the various results categories is shown in Table 1.

Table 1: Savings for plastic packaging compared to substitutes in the US and Canada (adapted from Franklin Associates[7]).

Results Category	Results Category Units	US Savings	Canadian Savings
Total Energy Demand	billion MJ	1196	121
Water Consumption	billion cubic meters	1106	130
Solid Waste by Weight	thousand metric tons	52887	4044
Global Warming Potential	million metric tons CO_2 eq.	67.1	8.66
Acidification Potential	thousand metric tons SO_2 eq.	526	52.3
Eutrophication Potential	thousand metric tons N eq.	340	37.4
Smog Formation Potential	thousand metric tons O_3 eq.	6549	666
Ozone Depletion Potential	metric tons CFC-11 eq.	1.15	0.13

Costs to society

Previous studies, such as “Valuing Plastics” (2014) by Trucost[19] and “The New Plastics Economy: Rethinking the Future of Plastics” (2016) by the World Economic Forum[20], examined the environmental costs of using plastics.

Trucost’s latest study[9], “Plastics and Sustainability: A Valuation of Environmental Benefits, Costs, and Opportunities for Continuous Improvement,” builds on the earlier research by comparing the environmental costs of using plastics with those for alternative materials.

The study is based on natural capital accounting methods, which measure and express in monetary terms the environmental impacts – such as the consumption of natural water and emissions to the air, land and water as well as environmental services such as food and climate regulating services – which are not typically factored into traditional financial accounting. For example, the social cost of the environmental damage caused by plastics and other materials littering the ocean comprises the physical, chemical, and biological impacts in monetary terms of this litter on wildlife, fisheries, aquaculture, and tourism.

Put simply, it puts a price on pollution and use of resources to enable an easier comparison to be made between the impacts of the materials. This impact valuation methodology has been developed by universities and research institutes lately as well as by sustainability experts within larger corporations in order to create a global impact measurement and valuation standard for monetizing and disclosing impacts of activities[21,22,23,24].

The scientific results obtained by Trucost dispel a common misperception regarding plastics: substituting the majority of plastics used in the consumer goods sector with a mix of alternative materials that provide the same function would not decrease environmental costs – it would increase them by a factor of almost four, to over US$ 533 billion a year, as illustrated in Figure 2[9].

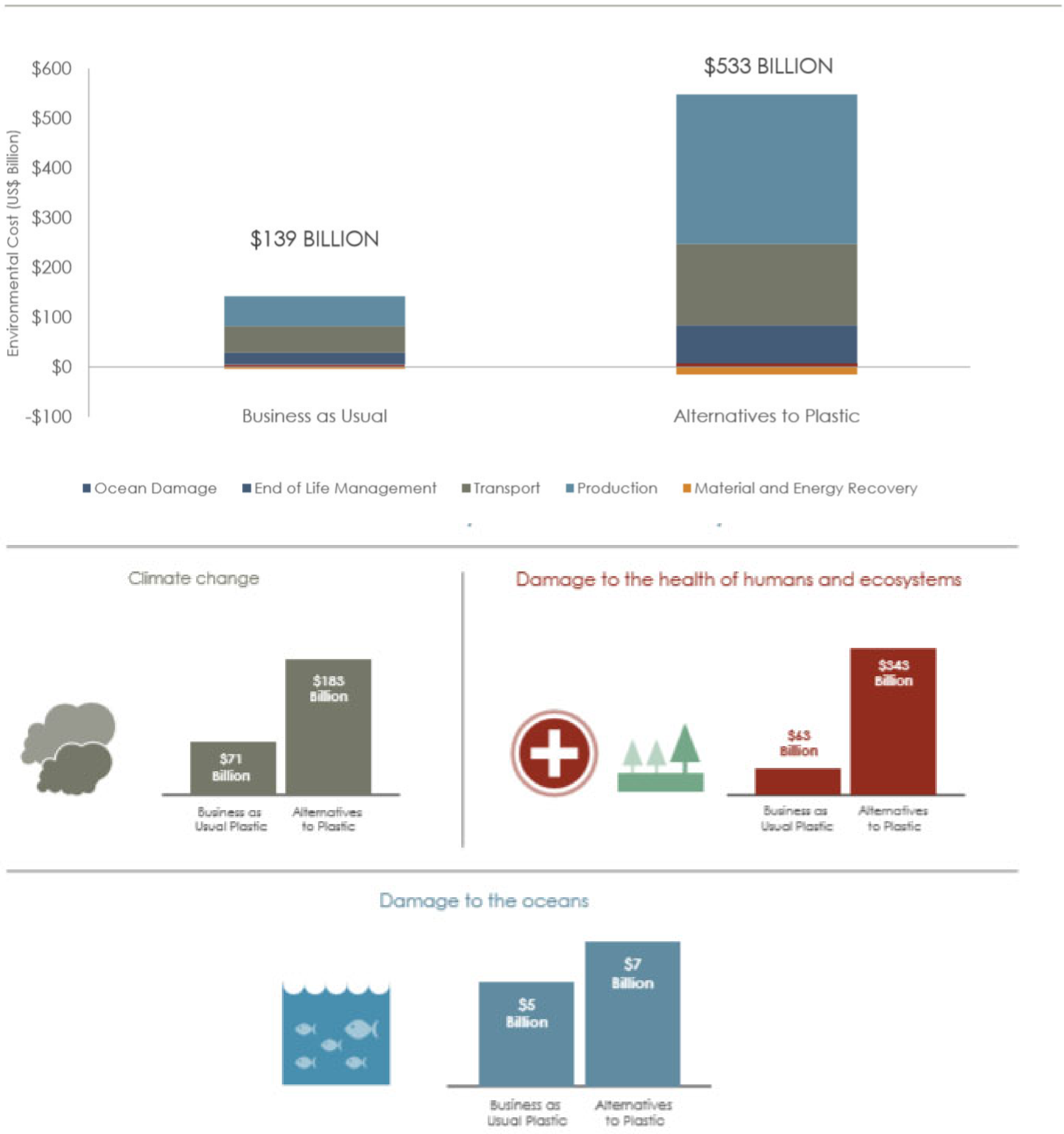

Figure 2: Environmental Costs of Plastics vs Alternatives in the Consumer Goods Sector ($US Billion)[9].

Specifically, Trucost estimates the cost of marine debris caused by plastics from the consumer goods sector in the business-as-usual scenario to be US$ 4.7 billion a year. Replacing plastics with alternatives would increase the amount of marine debris due to the consumer goods sector by 3.4 times compared to the business-as-usual situation: 8.6 million metric tons a year at a cost of US$ 7.3 billion (1.5 times higher than the figure for the business-as-usual case).

Moreover, the cost of land and water pollutants per metric ton of plastics is lower on average than that for alternative materials: US$ 362 and US$ 626 per metric ton, respectively.

The reason for this is that plastics do more with less material, and that provides environmental benefits throughout the lifecycle of plastic products and packaging. To be precise, four metric tons of alternative materials are required on average to achieve the same function as one metric ton of plastics. The largest share of environmental costs is associated with aluminum (39 %), paper (23 %), glass (17 %) and steel and tin plate (12 %), with negligible contributions from the other alternative materials studied, due to the energy and water intensive nature of the production processes for these materials.

Figure 3 presents the distribution of environmental costs for the business-as-usual case (continuing to use plastics) and the scenarios for the alternatives to plastics in the six regions covered by the Trucost study: Europe, North America, Asia, Oceania, Latin America and the Caribbean, and the Middle East and Africa. Each region's environmental impacts were estimated based on its share of the market in each consumer goods sub-sector, and its share of global plastics production. Environmental impacts were valued based on region-specific environmental valuation coefficients that take account of local conditions such as water scarcity, population density and the mix of natural ecosystems.

Europe and Asia shoulder the largest share of environmental costs associated with the use of plastics and alternatives in the consumer goods sector. Europe is a major consumer goods sector market, managing a large proportion of end-of-life consumer goods products, and is a major producer of plastics globally. China has a smaller share of the global consumer goods sector, but shoulders disproportionately high environmental costs due to poor waste management systems in comparison to North America and Europe.

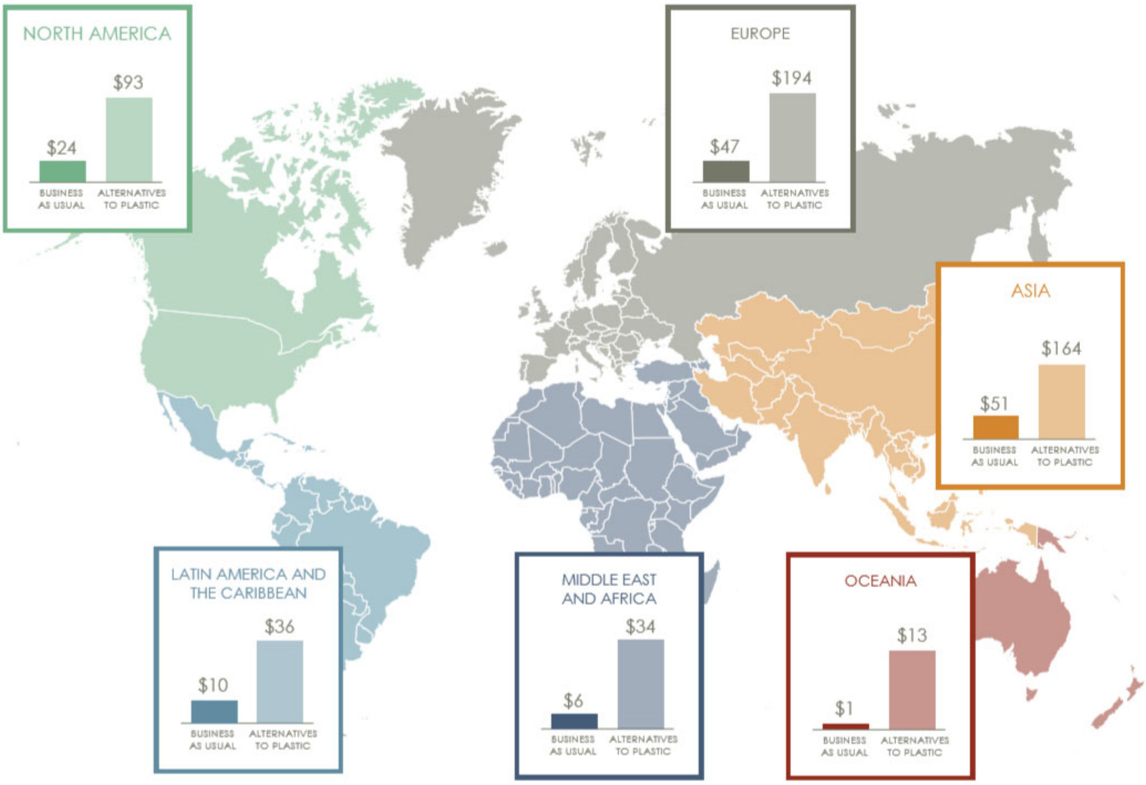

Figure 3: Environmental Costs by Region – Business as Usual (plastics) vs Alternatives to Plastic ($US Billion)[9].

Conclusions

Several scientific studies using life cycle assessment methodology challenge common misperceptions regarding plastics and show that plastics have a lower environmental impact and lower costs to society than alternative packaging materials for the same function in all regions of the world.

These studies use several extrapolations and assumptions for both plastics and the alternative materials. Nevertheless, the following important conclusions can be drawn:

- Replacing plastics with alternative materials in common consumer goods applications using current technology does not reduce environmental costs at the sector level – it increases them.
- The higher environmental impacts and costs of alternatives to plastics are driven by the poorer material efficiency of these materials when used in common consumer goods applications – on average, replacing one metric ton of plastics requires 4.1 metric tons of alternatives materials across the sector. Although the impacts per kg of plastic packaging may in some cases be higher than the impacts per kg of substitute packaging, significantly greater amounts of substitute packaging are required to perform the same function and therefore substitution would pose an added burden on the environment and society.
- The cost of marine debris due to plastics arising from the consumer goods sector is over US$ 4.7 billion a year, and despite the greater biodegradability of many alternative materials[25,26], like paper and paperboard, the ocean-related cost of the alternatives is estimated to be 150 % greater than this due to the quantity of alternative materials needed to replace plastics. The

greatest opportunities to reduce the ocean-related cost of plastics may lie in investments in waste collection systems in Asia.

- Plastics can offer significant environmental advantages over alternatives during the use phase, including the use of innovative packaging formats to minimize food waste.

ABOUT PACCOR

At PACCOR we create innovative and sustainable packaging solutions for the consumer, food and foodservice market. Our overall goal is to protect what is worth being protected: our planet, our partners' products and our employees. We have high expertise in developing and providing valuable rigid plastic packaging products. Our solutions meet current market trends by constantly thinking outside the box. With more than 3,000 dedicated employees in 15 countries, PACCOR is a global player in the packaging industry. Everything we do contributes to the protection and hygienic safety of valuable products. PACCOR leads the transition towards a circular economy. Because we believe this is the best way to achieve real change in the industry and to create shared value for all our stakeholders and society. More: https://www.paccor.com/

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