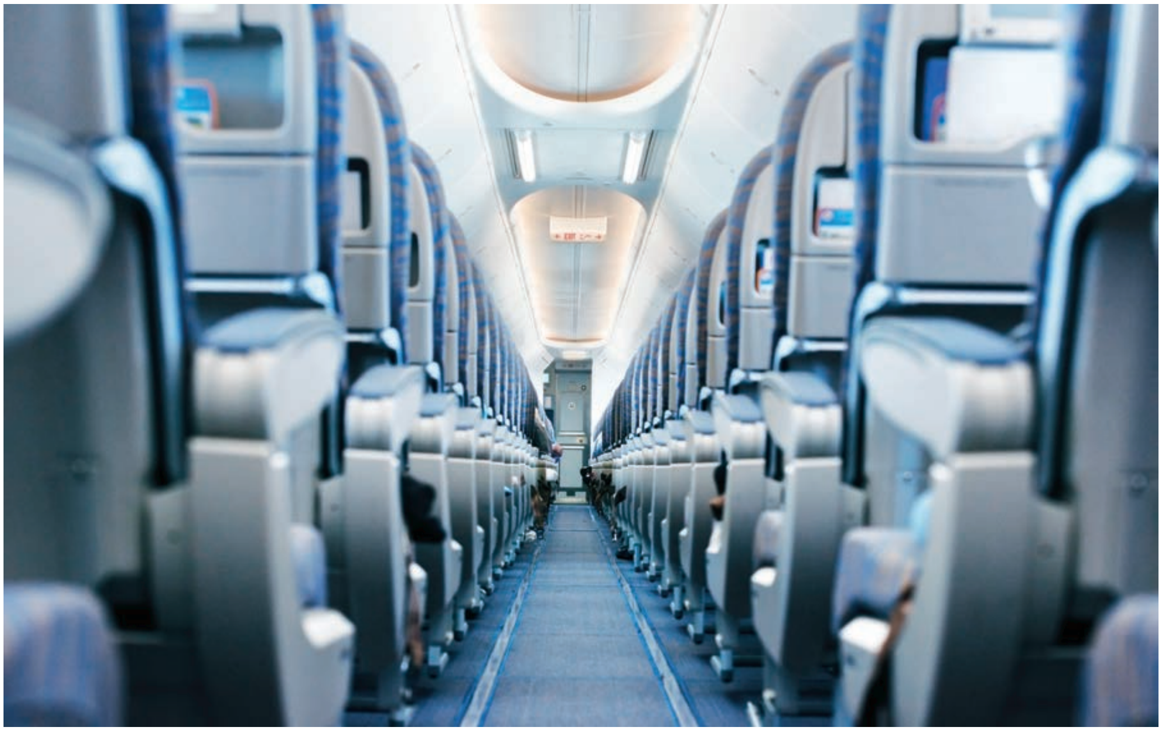
Executive Summary



Plastics are ubiquitous in our modern lives and provide benefits to people across the globe. Lightweight, durable, flexible and easy to form, their use continues to grow rapidly. Cell phones, baby car seats, blood bags, backpacks, chairs, cars, and clothing are among the many products made with plastics and reflect their beneficial properties. Yet plastic litter, gyres of plastics in the oceans, and toxic additives in plastic products are raising public awareness, consumer demand, retail pressure, and regulations for a more sustainable material.

Businesses, hospitals, and individuals are increasingly seeking plastics that are more sustainable across their life cycle—from raw material extraction to manufacturing to use to end of life. They want to know the sources of the plastic's raw materials, if a plastic contains chemicals of high concern (CoHCs)[1] to human health or the environment, the plastic's carbon footprint, its recycled content and whether it is recyclable, compostable, or biodegradable in the environment. Existing tools cover aspects of these life cycle areas of interest, however, they do not focus on the inherent hazards of

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[1] BizNGO (2008) defines "chemical of high concern" as having the following properties: 1) persistent, bioaccumulative and toxic (PBT); 2) very persistent and very bioaccumulative (vPvB); 3) very persistent and toxic (vPT); 4) very bioaccumulative and toxic (vBT); 5) carcinogenic; 6) mutagenic; 7) reproductive or developmental toxicant; 8) endocrine disruptor; or 9) neurotoxicant. Toxic, or T, includes both human toxicity and ecotoxicity.

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the chemicals used to manufacture polymers and contained within plastic products.

The Plastics Scorecard is a method for evaluating the chemical footprint of plastics and a guide for selecting safer alternatives. Version 1.0 (v1.0) addresses the progress to safer chemicals in plastics manufacturing and the chemical footprint of plastic products. Chemical footprinting is the process of assessing progress toward the use of safer chemicals and away from CoHCs. Clean Production Action defines chemical footprint as the number and mass of CoHCs used in manufacturing and supply chains, and contained in the final product.

The use of inherently safer chemicals in manufacturing will greatly reduce the costs of hazardous chemicals all along the plastics life cycle, from manufacturing to usage to end of life management.

The goals of the Plastics Scorecard are to inform the selection of safer plastics by businesses and catalyze manufacturers to reduce the number and volume of CoHCs in manufacturing processes and products. If successful the Plastics Scorecard will advance the development and use of plastics that use inherently safer chemicals in all steps of polymer production as well as in the selection of additives. The use of inherently safer chemicals in manufacturing will greatly reduce the costs of hazardous chemicals all along the plastics life cycle, from manufacturing to usage to end of life management. The Plastics Scorecard is for anyone interested in identifying and selecting plastics based on inherently less hazardous chemicals. Product designers, material specifiers, and purchasers will all find value in both the criteria for evaluating plastics as well as the assessments of individual plastics.

The Plastics Scorecard v1.0 report addresses:

- Why Plastics? The deep and impactful connections between plastics, chemicals, human health, and the environment.
- Method for Measuring the Chemical Footprint of Plastics:
  - evaluating progress to safer chemicals in polymer manufacturing and
  - evaluating the chemical footprint of plastic products.
- Key Findings
  - Benchmarking polymer progress to safer chemicals.
  - Chemical footprints of plastic intravenous (IV) bags and electronic enclosures.
- Strategies for Reducing the Chemical Footprint of Plastics

Why Plastics

Synthetic plastics are a newcomer to the family of materials manufactured and used by humans. Over the past 70 years, plastics have grown from a bit player in the material economy—with less than a million pounds produced globally in 1944—to a material behemoth, with global production at 288 million metric tons in 2012. Producing those 634 billion pounds of plastics requires a huge input of chemicals, many of which are CoHCs. The chemical inputs into plastics manufacturing are, in turn, manufactured largely from fossil fuels—millions of barrels of crude oil and cubic feet of natural gas are the raw materials for chemicals used to manufacture plastics, with plastics manufacturing and its associated energy consumption accounting for 7–8% of total oil and gas consumption globally.

Reducing the chemical footprint of plastics is a significant challenge. Starting from their feedstock base of fossil fuels, plastics rely on chemicals of high concern to human health or the environment that result from the refining of crude oil and the processing of natural gas. The plastic pathway from feedstock to polymer to final plastic is littered with CoHCs. Of the CoHCs consumed in polymer manufacturing, plastics represent approximately 244 million metric tons or 90% of the markets for those chemicals. Among those CoHCs are well known, highly hazardous chemicals, including benzene, Bisphenol A (BPA), styrene, and vinyl chloride monomer (VCM).

Exposure to a wide array and high volume of CoHCs during manufacturing, usage, and disposal poses a significant risk to the health of workers, communities, and the global environment. Reducing CoHCs in manufacturing will help to improve the health and safety of workers and communities, both by reducing the number of potentially hazardous chemicals and their overall volume. For example, recent studies find that "workers carry a body burden of plastics-related contaminants that far exceeds those documented in the general public . . . existing epidemiologic and biological evidence indicates that women in the plastics industry are developing breast cancer and experiencing reproductive problems at elevated rates as a result of these workplace exposures" (DeMatteo, et al., 2011). In addition, safer chemicals and materials can generate innovative new markets for companies, workers, and communities alike.

Current initiatives in the health care, apparel and footwear, and building products sectors highlight the drivers for incorporating safer chemistry in decisions on plastics and other materials, the attributes considered, and the methods that these sectors use to assess and select safer plastics. These practices are driven by a range of motivations, including: regulatory compliance, marketplace advantage, environmental certifications and standards, government procurement specifications, and corporate commitments to actively avoid CoHCs.

Method

The Plastics Scorecard v1.0 differentiates between chemicals used in polymer manufacturing and contained in the final plastic product, creating methods that score:

1. polymers on their progress to safer chemicals in the core steps of polymer manufacturing; and
2. plastic products on their chemical footprint.

The Progress to Safer Chemicals in Polymer Manufacturing Score assesses the hazards associated with polymer manufacturing by evaluating the core chemical inputs of the manufacturing process: primary chemicals, intermediate chemicals, and monomers. For example, in evaluating the manufacture of the polymer, polystyrene, v1.0 scores each stage of manufacturing based on the hazards of the primary input chemicals and then aggregates them into a single score that ranks polymers from 0 (most hazards) to 100 (most benign). Polystyrene, for example, was scored based on its primary chemicals of ethylene and benzene, its intermediate chemical of ethylbenzene, and its monomer of styrene.

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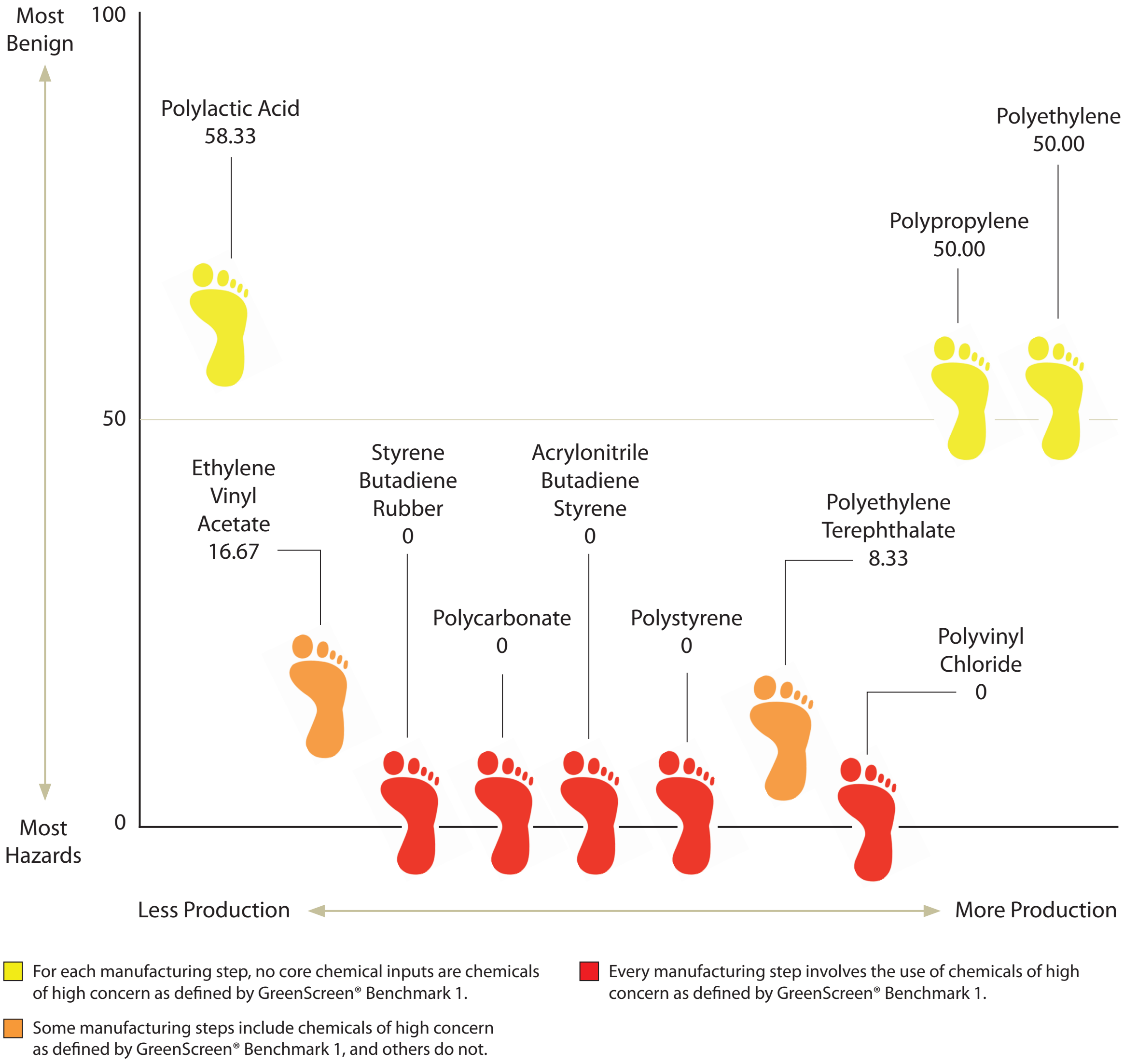
FIGURE ES-1 **Progress to Safer Chemicals in Polymer Manufacturing**



The Chemical Footprint of Plastic Products scores products on both the number and percent by weight of CoHCs in a final, plastic product.

Key Findings—Progress to Safer Chemicals in Polymer Manufacturing

Given the number of CoHCs associated with plastics, it is not surprising that five out of the ten polymers—ABS, PC, PS, PVC, SBR[2]—evaluated for their progress to safer chemicals in manufacturing scored 0 out of 100 in the Plastics Scorecard—scoring a "0" overall means that for each manufacturing stage the polymer uses a CoHC as a primary input. An ideal polymer based on low hazard chemicals would score 100. Three polymers—polyethylene, polypropylene, and polylactic acid (PLA)—scored 50 or above and are making the greatest progress to safer chemicals in manufacturing, while EVA and PET are making some progress beyond chemicals of high concern (see Figure ES-1).

It is clear that manufacturers can make significant progress towards producing polymers from

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[2] ABS=Acrylonitrile Butadiene Styrene; PC=Polycarbonate; PS=Polystyrene; PVC=Polyvinyl Chloride; and SBR=Styrene Butadiene Rubber.

inherently safer chemicals. PLA is a significant example of that. A newcomer to the commodity market of polymers, PLA had the best score in terms of progress to safer chemicals in manufacturing. Yet its score of 58 out of 100 illustrates the challenges of producing plastics from low hazard chemicals. PLA is not a green polymer by any means, but it is the greenest in terms of progress to safer chemicals in manufacturing of the ten polymers evaluated in v1.0 of the Plastics Scorecard.

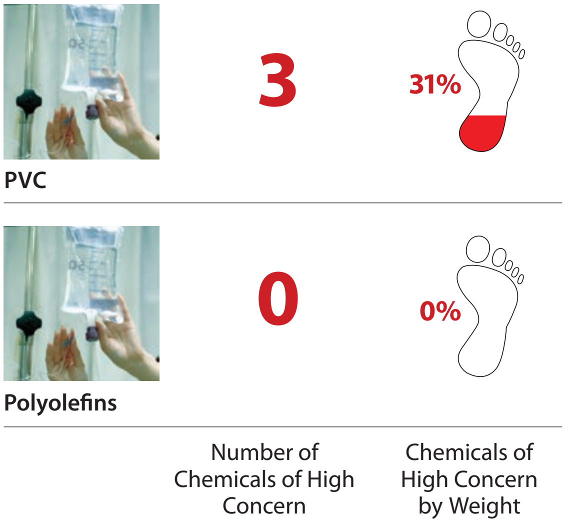
Figure ES-1 graphically illustrates the scoring of 10 polymers on their progress to safer chemicals. On the y-axis is progress to safer chemicals and on the x-axis is volume of production. Thus the polymers that are most widely produced and making the greatest progress to safer chemicals are polyethylene and polypropylene, while PLA is an emerging polymer that has made significant progress to safer chemicals but is produced in significantly smaller volumes than the other polymers.

Key Findings—Chemical Footprint of Plastic IV Bags

The chemical footprint of a plastic product measures the number and weight (or percent weight) of CoHCs in a homogeneous plastic product, be it a component such as a plastic case around a computer monitor or a plastic "rubber" duck. The homogeneous plastic product is a "compounded plastic product" because it includes both the polymer and the additives. The Plastics Scorecard v1.0 scored two plastic products for two categories of products—intravenous (IV) bags and electronic enclosures—on their chemical footprints.

Polyolefin IV bags have a much lower chemical footprint than the PVC/DEHP (di(2-ethylhexyl) phthalate) IV bags. Figure ES-2 illustrates the benefits of using polyolefins versus PVC/DEHP: they reduce the number of estimated CoHCs from three to zero and reduce the percent of estimated CoHCs by weight from 30% to 0%. PVC/DEHP IV bags contain a significant percentage of CoHCs: 30% DEHP and 0.5% BPA—in comparison to the estimated 0% for polyolefins. In addition, the polyolefin polymers (polyethylene and polypropylene) score much higher, 50.0, on the Plastics Scorecard's Progress to Safer Chemicals in Polymer Manufacturing Score than PVC, which scores 0.0 (see Figure ES-1).

FIGURE ES-2 **Estimated Chemical Footprint of IV Bags Made from PVC/DEHP and Polyolefins**



PVC = Polyvinyl chloride; DEHP = di(2-ethylhexyl) phthalate

In switching from PVC/DEHP to polyolefin-based IV bags Dignity Health reduced its chemical footprint by over 700,000 pounds over a six year period. Dignity Health eliminated the use of 673,023 pounds of DEHP (a reproductive, developmental toxicant) and 33,651 pounds of BPA (an endocrine disruptor) from 2008–2013. This example demonstrates how chemical footprinting provides a clear metric for measuring of progress to safer chemicals.

Key Findings—Chemical Footprint of Plastic Electronic Enclosures

The electronic enclosures example compared products made from High Impact Polystyrene (HIPS) flame retarded with decabromodiphenyl ether (decaBDE) to products made from Polycarbonate/Acrylonitrile Butadiene Styrene (PC/ABS) flame retarded with Resorcinol bis(diphenyl phosphate) (RDP). Figure ES-3 illustrates how PC/ABS with RDP reduces the percent weight of CoHCs in comparison to HIPS/decaBDE electronic enclosures by 15%. The key actor in the beneficial result is the elimination of the CoHC, decaBDE, and its replacement with

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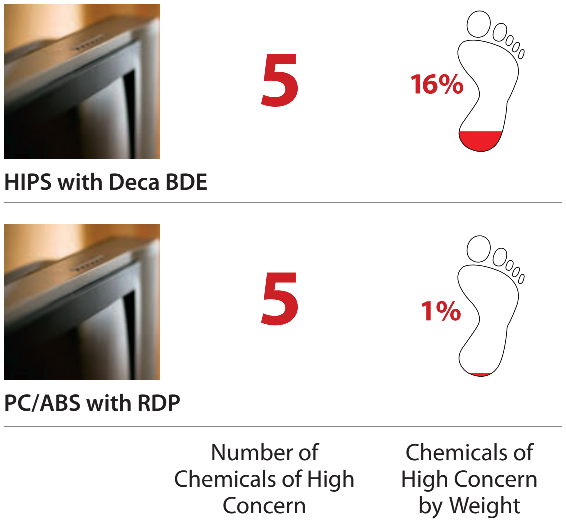
RDP. While RDP is by no means a green flame retardant, its ingredients overall are less hazardous than decaBDE. The electronic enclosures story is one where the opportunities for greening are fairly limited. Given price and performance needs, PC/ABS is the most effective solution. While the volume of CoHCs decline with RDP, the number of CoHCs in the product remains unchanged. And similarly the Progress to Safer Chemicals in Polymer Manufacturing remains grounded at 0.0 for both PC/ABS and Polystyrene (see Figure ES-1, and compare the polymers: PS, PC, and ABS).

FIGURE ES-3 **Estimated Chemical Footprint of Electronic Enclosures Made from HIPS with DecaBDE & PC/ABS with RDP**



ABS = Acrylonitrile Butadiene Styrene; DecaBDE = Decabromodiphenyl Ether; PC = Polycarbonate; RDP = Resorcinol Diphenylphosphate

Is PC/ABS with RDP a regrettable substitution? The above data indicate it is not, and at the aggregate level it results in a significant reduction in CoHCs by percent weight. Yet there are many unknowns. The science on the health effects of phosphorous-based chemistry continues to develop and to date unknown health hazards may arise with this chemistry. At the same time, the small amounts of unknown additives as well as the residual monomers (like BPA in polycarbonate) may prove to be problematic in the future. It is clear PC/ABS with RDP is a less bad solution, but it is hardly an optimal solution.

The chemical footprints of IV bags and electronic enclosures clearly demonstrate that material designers and purchasers can select alternative products based on safer chemistries and can document that progress. Yet it is important to note that knowledge gaps were an issue for both the electronic enclosures and IV bag comparisons. Gaining a comprehensive list of all additives by Chemical Abstracts Services Registry Number (CAS #), along with levels of residual monomers and catalysts, was not possible for any product. This lack of information makes it impossible to ascertain whether significant, but unknown CoHCs lurk in the plastic formulations. The knowledge gap in chemical inventories for plastic products is a barrier to accuracy with chemical footprints that will require persistence

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in terms of asking for the data from all companies in a supply chain to resolve.

Strategies for Reducing the Chemical Footprint of Plastics

The Plastics Scorecard provides value to both those that want to demonstrate the lowered chemical footprint of their polymer or product, as well as for those designers, specifiers, and purchasers who want to select products with a lesser chemical footprint. Reducing the chemical footprint of plastics is a challenging endeavor; these potential approaches provide a path forward:

- First ask, is it necessary?
- Use safer additives.
- Use safer polymers.
- Close the loop and use post-consumer recycled (PCR) content (but beware of legacy CoHCs).
- Redesign the product.

Plastics markets are shifting more quickly to safer additive packages because that is often the easiest route to reducing the chemical footprint of a plastic product. Witness the PVC industry's recent plans to eliminate the use of lead and cadmium stabilizers, certain phthalates like DEHP, and BPA. Reducing the use of CoHCs in plastics is good news, but as the Progress to Safer Chemicals in Polymer Manufacturing component of the Plastics Scorecard illustrates, safer additive packages on their own do not reduce the hazards of polymer manufacturing.

Among the challenges of effectively evaluating the hazards of additives include the absence of relevant publically available data for the various additive chemistries, as well as the total number of classes of additives utilized. This is another area ripe for research and potentially an opportunity for green chemistry solutions. As the movement to safer additive packages grows what will become increasingly significant is the small amounts of CoHCs and residual monomers and catalysts in plastic products. The knowledge gaps on chemicals in additive packages will become increasingly significant along with the necessity for full hazard assessments of the substitutes.

As companies move away from well-known CoHCs it will drive down the percentage of CoHCs in products. What will remain are questions around the hazard profiles of the alternatives as well as the small amounts of CoHCs in products, like residual BPA monomer.

Manufacturers and purchasers are making significant progress on the pathway to safer chemicals in plastics. From polymer manufacturing to final products, safer chemicals use is growing. That said, much progress is still to be achieved. The plastics economy, from cradle to grave, remains one based on CoHCs. The Plastics Scorecard v1.0 presents a novel method for evaluating the chemical footprint of plastics, selecting safer alternatives, and measuring progress away from CoHCs. Version 1.0 will support the design, production, and selection of safer plastics.

> **The Plastics Scorecard provides value to both those that want to demonstrate the lowered chemical footprint of their product, as well as for those who want to select products with a lesser chemical footprint.**

The overarching philosophy that underpins v1.0 is that the optimum route to addressing the life cycle concerns of chemicals in plastics is to use inherently safer chemicals in manufacturing and in products, thereby eliminating concerns surrounding CoHCs in manufacturing, usage, and end of life management of plastics. Hazardous chemicals in plastics create legacy issues that block closed loop systems. To effectively close the loop plastics need safer chemical inputs. Polymers are a bedrock of nature and the human economy—now the challenge is making plastics that are safer for humanity and the environment.