How can we avoid the lock-in problem in the substitution of hazardous chemicals used in consumer products?

A wide range of chemical substances is used in consumer products for various purposes, including plastic softeners, dyestuffs and colorants, flame retardants, impregnation agents, antioxidants and UV absorbers, preservation agents and biocides, and many others. Among these chemicals, there is a certain fraction of substances with hazardous properties such as persistence, bioaccumulation potential and toxicity (PBT properties) or the ability to interfere with the hormonal system (endocrine disrupting chemicals, EDCs). Large-scale screening exercises have shown that there may be several hundreds of chemicals with PBT properties among the several tens of thousands of substances on the market. There are some groups of chemicals that have raised particular concerns such as polybrominated diphenyl ethers (PBDEs) or long-chain poly and perfluorinated alkyl substances (PFASs). These substances have been regulated or are subject to voluntary phase-out programs; specifically, penta- and octabrominated BDEs are scheduled for elimination globally under the Stockholm Convention on Persistent Organic Pollutants; uses of perfluorooctane sulfonic acid (PFOS) are being restricted under the Stockholm Convention, and perfluorooctanoic acid (PFOA) and C_{11}-C_{14} perfluorocarboxylic acids are regulated in the European Union as PBT substances and vPvB (very persistent, very bioaccumulative) substances, respectively. In addition, all long-chain PFASs (substances with seven or more perfluorinated carbons) are subject of voluntary phase-out programs conducted by major producers of fluoropolymers and fluorotelomer-based products. However, it has become evident that the replacements of these substances include chemically similar substances, i.e. brominated aromatic substances in the case of PBDEs and shorter-chain PFASs in the case of long-chain PFASs. These are two examples of a substitution process that leads to an incremental rather than a fundamental change in the structure of chemicals used in consumer products. Here we discuss the conditions for incremental and fundamental changes in the substitution process of chemicals.