coming clean

TRANSFORMING THE CHEMICAL INDUSTRY:

Safer Substitutes and Solutions for a Non-Toxic Economy

POLICY PAPER # 3
for the LOUISVILLE CHARTER

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Clean Production Action

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SUMMARY

The urgent transformation of the chemical sector is closely linked to a transition to a fossil fuel free, renewable energy future. We need to set carbon and chemical footprint reduction goals together in all regulatory, company and financial policies. Just as we are at 'code red' for climate change mitigation, we are at 'code red' for halting the ongoing toxic assault on all life from plastic proliferation and hazardous chemicals released from production through disposal. The use of toxic chemicals has now crossed the point at which human-made changes to the Earth push it outside the stable environment of the last 10,000 years.

Eliminating hazardous petrochemicals and plastics and replacing them with demonstrably safer alternatives requires:

- immediately eliminating toxic emissions to workers and communities from current chemical and plastics manufacturing and prohibiting the planned expansion of the petrochemicals and plastics sectors;
- redesigning chemical products and systems to reduce both carbon and chemical footprints;
- altering production processes and substituting with safer alternatives;
- eliminating non-essential uses of chemicals and using chemicals that are shown to be safe throughout their lifecycle; and
- rewarding innovation that benefits local communities and is safe and sustainable for future generations.

All twelve Principles of Green Chemistry and Green Engineering Principles (see Appendix 1 and 2) need to shape innovation in a transformed chemical sector that transitions from fossil-fuel based chemical feedstock production to biobased, and other alternative forms of material synthesis, with low hazard platform chemicals. Key characteristics of green chemistry continue to be developed that emphasize precaution and reduced consumption. Reducing the complexity and overall production of chemicals is key. New chemical synthesis designed with the above principles and key criteria will fundamentally change the chemical sector and allow innovation in locally sourced and new chemicals with lower hazards and less resource consumption. Achieving a non-toxic economy requires political will and a shift in power that puts the health of people and the planet above the profits of industry.

The petrochemical sector's reliance on fossil-fuel feedstocks and manufacturing processes that have evolved little in a hundred years is a massive barrier for change – but the Louisville Charter for Safer Chemicals is a clear roadmap for this necessary transformation. The 10 planks of the Louisville Charter provide a roadmap for the innovation that is required to reverse the ongoing assault from hazardous chemicals and their use.

This paper outlines one important piece of the roadmap– the need for safer substitutes and solutions focusing on the chemical sector - beginning with the seven basic building block chemicals that are used to produce the vast majority of chemicals on the market today. It summarizes the extent of the global problem and offers policy recommendations to help detoxify our future, reduce resource consumption, and reward innovation in safer chemical production.

> **"Achieving a non-toxic economy requires political will and a shift in power that puts the health of people and the planet above the profits of industry."**

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1. FOUR FUNDAMENTAL PROBLEMS WITH THE PRODUCTION AND USE OF CHEMICALS TODAY

This section summarizes four reasons why the chemical sector needs urgent transformation if innovation for safer chemicals is to succeed. This section is for companies, regulators, climate change solution providers, circular economy proponents, investors, students and the general public to understand the severity of the chemical pollution crisis.

Four major problems are:

1. The chemical industry, and those who incorporate toxic chemicals into products, are not held to account for the hazardous chemical impacts to communities, workers, wildlife and planetary ecosystems;

2. Chemicals proliferate on the market with little to no health data and few regulatory requirements for chemical producers or downstream users of chemicals to fill much needed data gaps and/or demonstrate safety prior to market.

3. The number of chemicals in circulation is more than three times what has been assumed. The projected increase in chemical production will generate even more unidentified chemical substances and associated exposures. No sustainability criteria is given to justify this planned expansion.

4. The planned expansion of chemicals and plastics production will increase greenhouse gas emissions, hazardous chemicals, plastic waste and safety risks to communities.

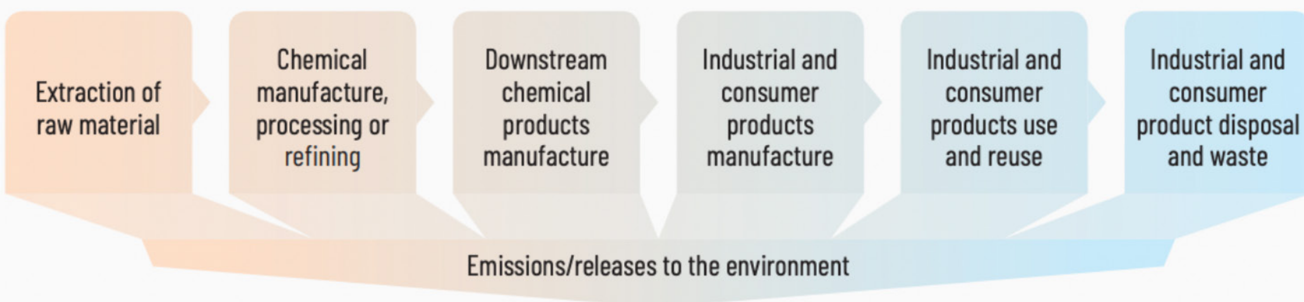
1.1 The chemical industry, and those who incorporate toxic chemicals into products, are not held to account for the hazardous chemical impacts to communities, workers, wildlife and planetary ecosystems.

The projected expansion of the petrochemical sector in the United States and globally will intensify health impacts from toxic chemicals in tandem with the climate crisis.

The 2019 United Nations Global Chemicals Outlook confirmed[1] that:

- an enormous volume of chemicals is released to the environment every year, most of which is unregulated and much of which is toxic and hazardous (see Figure 1);
- hazardous chemicals are ubiquitous in all media, in all regions of the planet and in all human bodies;
- for people living in fenceline communities this is an Environmental Justice issue; and
- in high consumer purchasing economies, products may be the largest source of hazardous chemical exposures for some populations.

Figure 1: The value chain of the chemical industry, with emissions/releases to the environment



Credit: UN Global Chemicals Outlook Report II, 2019.

Although the global chemical industry is one of the world's largest manufacturing industries, representing US$4 trillion of sales in 2019, it is: slow to innovate; requires massive economies of scale to be profitable; has burdensome capital investment; and has rigid production systems that are vulnerable to economic and supply chain disruptions. It mostly relies on fossil-fuel feedstocks and is the third largest industrial source of greenhouse gasses with many of today's top chemical corporations being the very same companies that produce oil and gas such as ExxonMobil, Chevron, and Shell, among others.[2]

A 2022 scientific study concludes that chemical pollution has crossed a "planetary boundary," the point at which human-made changes to the Earth push it outside the stable environment of the last 10,000 years, which now threatens Earth's systems by damaging the biological and physical processes that underpin all life. The study's researchers advocate for a future fixed cap on chemical production and release, in the same way carbon targets aim to end greenhouse gas emissions.[3]

The petrochemical sector externalizes its costs to human and planetary health. Proximity to chemical production sites, waste dumps and high pesticide use[4] results in acute and chronic health impacts and disease. A 2022 report from the Human Rights Council of the United Nations highlights the 'unconscionable environmental injustices around sacrifice zones' such as Mossville, St. Gabriel, St. James Parish and St. John the Baptist Parish, located in Louisiana's Cancer Alley where cancer rates are far higher than the United States average. These predominantly Black communities are home to more than 150 refineries and petrochemical plants, including the world's largest producer of polystyrene.[5]

The proliferation of the petrochemical industry in the United States has resulted in almost 12,500 high-risk chemical facilities putting 39% of the US population (124 million people) who live within three miles of these facilities at constant risk of chemical disaster.[6] Workers in these facilities face ongoing injury and death from chemical accidents.[7]

Health costs from hazardous chemicals use are extensive, yet producer responsibility for remediation and health impacts is absent. A recent analysis of health impacts from per- and polyfluoroalkyl substances (PFAS) in Europe identified annual direct healthcare expenditures at 52–84 billion euros. Equivalent health-related costs for the United States, accounting for population size and exchange rate differences, would be $37–59 billion annually. As the authors note, "These costs are not paid by the polluter; they are borne by ordinary people, health care providers, and taxpayers."[8] Exposures to hazardous chemicals result in immediate costs that extend throughout the lifetime of impacted communities. For example, the costs present themselves as children with asthma (missed school days/not feeling well in school) and/or learning disabilities that can drastically affect educational attainment, reducing future earning ability, in addition to the more immediate costs to parents who have to leave work to take care of children who are ill.

Though settlements have been won in recent lawsuits against a few chemical producers, the amounts are dwarfed by the profitability of these companies. For example, in January 2021, DuPont, Chemours and Corteva announced a cost-sharing agreement worth $4 billion to settle lawsuits involving the historic use of PFAS chemicals[9] and Bayer agreed in June 2020[10] to pay more than $10 billion to settle tens of thousands of claims for damages caused by the glyphosate herbicide, RoundUp, manufactured by Monsanto whom they acquired two years previously. Legal settlements do not, however, result in a ban on these targeted chemicals, or an end to ongoing exposure from the use of the chemical.

In the case of glyphosate, despite the findings by the International Agency for Research on Cancer 2015 that glyphosate is a probable human carcinogen, the U.S. Environmental Protection Agency maintains that glyphosate is not likely to be carcinogenic to humans, thereby allowing Roundup and other glyphosate-based herbicides to be easily purchased throughout the country, unless a municipality has banned its use on city owned property. Furthermore, Bayer's announcement in 2021 that it will stop selling Roundup in the United States Lawn & Garden residential market beginning in 2023, will not reduce exposure from its wider use in industrial agriculture.[11]

American workers in multiple industry sectors use tens of thousands of chemicals every day but only a small number are regulated in the workplace. As a result, workers suffer more than 190,000 illnesses and 50,000 deaths annually related to chemical exposures.[12] Workplace chemical exposures have been linked to cancers, and lung, kidney, skin, heart, stomach, brain, nerve, and reproductive diseases. In the agricultural sector, the pesticide poisoning incidence rate among U.S. farmworkers is 39 times higher than the incidence rate of pesticide poisoning found in all other industries combined.[13]

Biodiversity is highly impacted by hazardous chemical and fertilizer use and releases to the environment. Recently, researchers raised the alarm that 40 percent of all insect species are in decline and could die out in the coming decades.[14] They conclude that "a rethinking of current agricultural practices, in particular a serious reduction in pesticide usage and its substitution with more sustainable, ecologically-based practices, is urgently needed to slow or reverse current trends, allow the recovery of declining insect populations and safeguard the vital ecosystem services they provide."

Pesticides and fertilizers are an integral part of chemical production and use. Each year, an estimated one billion pounds of pesticides are applied to U.S. farms, forests, lawns and golf courses. More than 17,000 pesticide products are currently on the market — with many of them approved through "conditional registration," a regulatory loophole that allows products on the market quickly without thorough review.[15] Many of the most commonly used pesticides are linked to a range of health impacts, including increased risk of cancer, Parkinson's disease and neurodevelopmental effects such as autism and ADHD.[16]

1.2 Chemicals proliferate on the market with little to no health data, and few regulatory requirements for chemical producers or downstream users of chemicals to fill much needed data gaps and/or demonstrate safety prior to market.

Chemicals of High Concern, are defined by international bodies as those that are Persistent, Bioaccumulative and Toxic (PBTs); Carcinogens, Mutagens and Reprotoxic (CMR)s, Endocrine Disruptors, Neurotoxins, and Persistent and Mobile (PM). Other chemicals of concern include those with high flammability and explosive potential.

Although the criteria for highly hazardous chemicals are clear, the quantity of chemicals that meet this criteria is far from clear. The vast majority of chemicals in consumer products and packaging, pesticides, and manufacturing have no or only incomplete chemical hazard information.

A lack of chemical hazard data means scientists are unable to estimate the true toxic impacts to health and biodiversity. In the US, it has been estimated that 85,000 chemicals have been used in industrial, commercial and consumer product applications. But the global inventory analysis reveals that about one-quarter of the CAS-numbered chemicals are not included in the North American and European inventories commonly used to evaluate chemical exposure and impact. Researchers note that countries are making, using, or importing some 60,000 chemicals that are not well understood and regulated.[17]

The PFAS class of chemicals underscores how we are flying blind with unknown and untested chemical use. PFAS have been produced and used since the 1960s. PFAS are highly persistent and will remain in the environment for thousands of years making these "forever chemicals" an urgent priority for class based restriction in the US and globally. Biomonitoring studies by the federal Centers for Disease Control and Prevention show that the blood of nearly all Americans is contaminated with PFAS. Additionally, water supplies for about 110 million Americans are contaminated with PFAS – though this may be an underestimate.[18] PFAS is used in common household products for stain and grease resistance in food packaging, cookware, carpets and furniture; for water repellency in clothing, in cosmetics and other products -- but there is no consumer labeling and few regulatory restrictions - nor was the necessity of these chemicals ever discussed. They have been used for decades in firefighting foam resulting in widespread water pollution and impact to firefighters' health. A legal battle to uncover data DuPont hid for decades,[19] along with independent scientific data, reveals PFAS is linked to cancer, developmental impacts in children and a range of other diseases. Recently PFAS has been correlated with a reduction in the effectiveness of vaccines[20] but, production of this chemical class is allowed to continue with little or no toxicity information for most of the approximate 5,000 chemicals in this class and few, if any, restrictions. The result is ongoing pollution which is perfectly legal, plus a growing legacy of costly cleanup efforts in farmers' fields,[21] drinking water supplies and toxic waste dumps[22].

Cancer and other disease prevention efforts will fail unless chemical ingredient and hazard information is disclosed for all products and industrial sectors. For example, many chemicals of high concern are known to be carcinogens and cancer is now the largest cause of death from disease in American children. In 2019, more than 16,000 children in the United States were diagnosed with cancer, including leukemia, brain cancer, kidney cancer, and bone cancer, with the number of new cases of cancer per 100,000 children increasing. From 1975 to 2017, leukemia incidence rates in children increased by roughly 34%, and incidence rates of brain and other central nervous system cancers increased 40%-- and the science is clear that harmful environmental exposures contribute significantly to these trends. However, because we lack a comprehensive list of chemicals that may cause cancer in children, "we are essentially flying blind with no instruments," observed Dr Philip J. Landrigan, Professor Emeritus of Pediatrics and Preventive Medicine, Icahn School of Medicine at Mount Sinai Hospital.[23]

Confidential business information and lack of chemical information throughout the supply chain remain barriers to innovation and obstacles in protecting community and global population health. Chemical ingredient information for polymers is next to impossible to obtain. Researchers tested 34 products made from seven plastics with the biggest market and detected more than 1,000 chemicals in these plastics, 80 percent of which were unknown.[24]

This lack of chemical hazard information is tied directly to lax regulatory requirements that have not substantially changed. The growth of the petrochemical sector, particularly since the 1940s, allowed the production and use of chemicals with no requirement for data on toxicological impact to human health and the environment. In the United States the Toxic Substances Control Act (TSCA) passed in 1976, resulted in 62,000 industrial chemicals remaining in commercial use, and deemed to be safe unless the Environmental Protection Agency (EPA) could demonstrate unreasonable risk of harm. However, because the burden was on regulators to demonstrate harm, rather than on the producer to demonstrate safety, only 5 chemicals were restricted prior to 2016. A revised Toxic Substances Control Act in 2016 entrenched EPA's requirement to demonstrate unreasonable risk, and although several more substances have been added to the restriction list, the Act failed to require chemical producers to demonstrate safety prior to market. This has resulted in a predicted "regulatory paralysis, especially in the face of a well-framed opposition and critical courts."[25] In 2020 the EPA was sued by a coalition of health and environmental justice organizations for failing to inform the public upon receipt of an application to manufacture a new chemical and disclose all non-confidential information, particularly information about the health effects of and exposures to the new chemical.[26]

Chemical regulation in the European Union (EU) requires comparatively more hazard data from producers under the Regulation on the Registration, Authorisation, Evaluation and Restriction of Chemicals (REACH) but since the regulation was passed fifteen years ago, less than 100 substances have been restricted.[27] Recognizing the need for quicker assessment of chemical hazards and restrictions of chemicals of high concern, the EU published its Chemical Strategy for Sustainability in 2020 with the objective of better protecting citizens and the environment and boosting innovation for safe and sustainable chemicals.[28] On April 26, 2022 it adopted a roadmap that could see up to 7,000 chemicals restricted by 2030.[29] This may hopefully set the template for other countries to follow - however this will depend on the reality of political decision making in other parts of the world.

1.3 The number of chemicals in circulation is more than three times what has been assumed. The projected increase in chemical production will generate even more unidentified chemical substances and associated exposures.

A recent global inventory lists more than 350,000 chemicals and mixtures of chemicals registered for commercial production and use worldwide, which is more than three times as many as is commonly estimated.[30] In spite of this, global chemical production continues to increase in terms of quantity, turnover and diversity.[31] In recent decades, production has roughly doubled every twelve years with a corresponding further increase predicted. But this increase in chemical production lacks any justification for necessity or integration of any sustainability criteria. There is no acknowledgment of producer responsibility for the life cycle impacts of these chemicals, little or no integration of green chemistry and green engineering principles into molecular design, and no description or any discussion as to whether these chemicals are necessary.

1.4 The planned expansion of chemicals and plastics production will increase greenhouse gas emissions, hazardous chemicals, safety risks to community, and plastic waste.

The role of petrochemicals is one of the key "blind spots" in the global energy debate, according to the International Energy Agency (IEA).[32] The chemical industry's contribution to climate change is detailed in the Plank 1 policy paper of the Louisville Charter for Safer Chemicals.

Petrochemicals which now account for 14 percent of oil use, are expected to drive half of global oil demand growth between now and 2050, according to the IEA. Much of this projected increase is based on a doubling of plastic production in the next 20 years with the U.S. seen as a growth area enabled by cheap fracked gas.

Since 2010, companies have invested more than $200 billion in 333 plastic and other chemical projects in the U.S. and many of these facilities are in the permitting process.[33] Drivers of this growth are the natural gas liquids produced from US fracking sites and subsidies to the fossil fuel sector, along with corporate marketing that natural gas is a bridging fuel to a renewable energy future. Exxon promotes natural gas as a cleaner fuel than coal, stating that it will emit 'significantly fewer pollutants such as NOx, SOx, particulates, mercury, and up to 60 percent fewer GHGs.[34] However methane, the primary component of natural gas, is a stronger greenhouse gas than carbon dioxide and on a weight basis has 21 times the global warming potential of carbon dioxide. Methane leaks are common around fracking sites and satellite data reveals the fracking heartland of the US is leaking 3.7 percent of that gas into the atmosphere.[35] This is worse for climate change than coal.[36] Planned plastics production will generate greenhouse gas emissions (GHG) over and above the U.S. Nationally Determined Contributions commitments to decrease GHG emissions by 50 to 52 percent by 2030.[37]

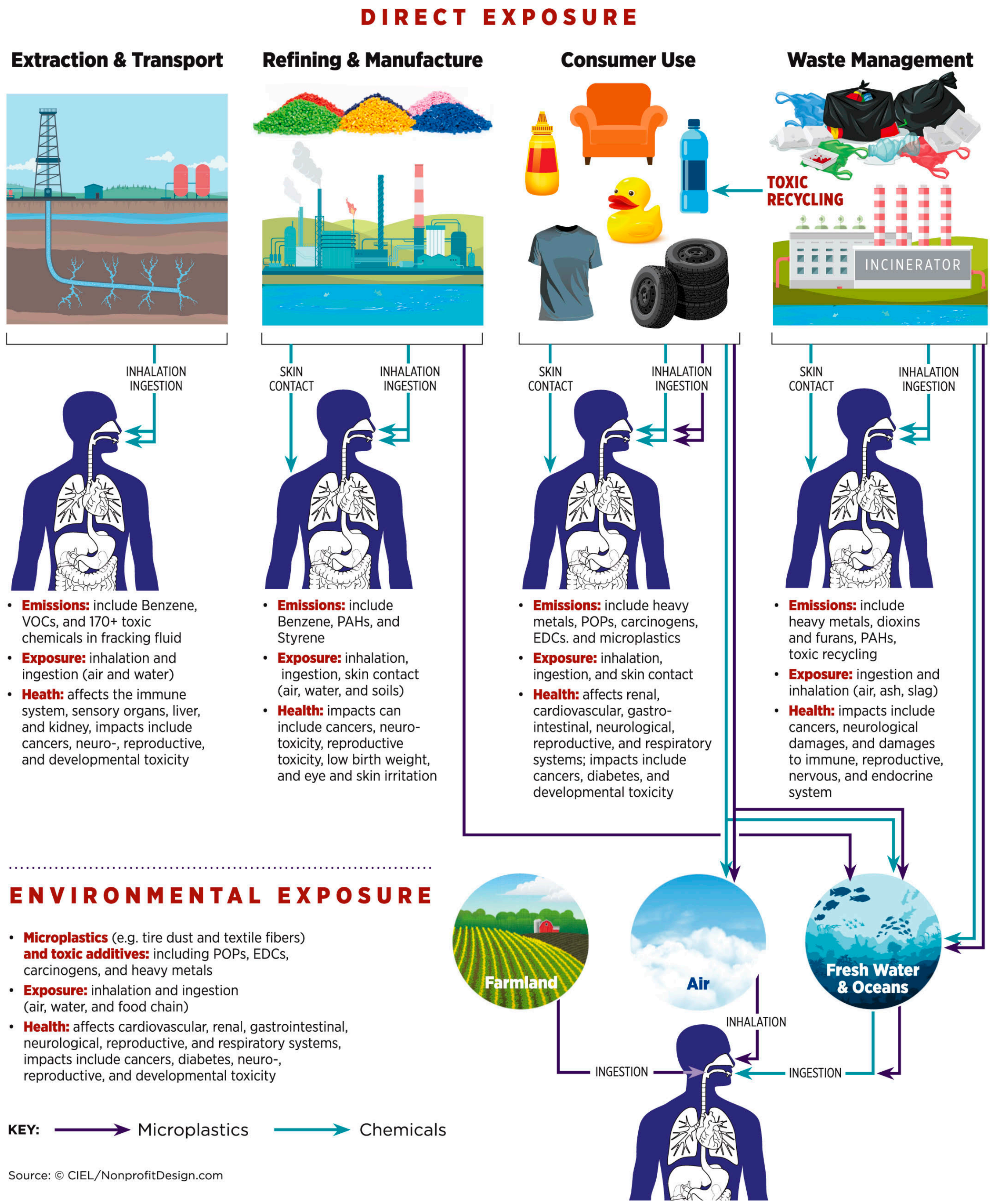
Increased chemical and plastic production will directly impact fenceline communities who are already exposed to hazardous chemical releases and face disproportionate risk from climate change. Extreme weather events exacerbated by climate change already demonstrate what is in store. After the landfall of Hurricane Harvey in Houston, Texas, in 2017, oil refineries and chemical plants across the Texas Gulf Coast released more than 1 million pounds of dangerous air pollutants in the week following. Floating rooftops sank on oil storage tanks, chemical storage tanks overflowed with rainwater, and broken valves and shutdown procedures triggered flaring at refineries. This resulted in large releases of highly hazardous chemicals including benzene, 1,3-butadiene, hexane, hydrogen sulfide, sulfur dioxide, toluene and xylene a week after the hurricane struck.[38] Communities are left with very few options in the event of an explosion or major leak. Transportation to evacuate is non-existent for some, sheltering in place is not fully understood and may not even be an option and the purchase of masks and other equipment that could save lives is unattainable for many.

Expansion of plastics production will generate even more single use plastic and waste, and as plastic degrades into microplastics and nanoplastics it releases these particles and their chemical additives - many of which are endocrine disrupting chemicals - into water, soils, air, wildlife and humans, including human placenta.[39] The entire lifecycle of plastics releases hazardous chemicals as shown in Figure 2. Plastic additives, such as phthalates, bisphenol A and other endocrine active additives, are now reported amongst the most commonly found anthropogenic substances in environmental samples.[40] In 2016, the United States generated the largest amount of plastic waste of any country in the world.[41] Currently over 40% of plastics production is used in single use packaging – a growing focus of restrictions. But although reducing the use of single use plastic packaging and passing plastic bag bans are necessary it will not be sufficient in itself to solve the global problem created by expanded plastics production and the increased use, and release, of highly hazardous chemicals. On March 2, 2022 heads of state, ministers of environment and other representatives from 175 nations endorsed an historic resolution at the UN Environment Assembly in Nairobi to address the full lifecycle of plastic, including its production, design and disposal with a goal to achieve an international legally binding agreement by 2024.[42] However implementation of a concrete plan is still to be agreed and will be years in the making. That is why an immediate ban on planned expansion of this sector is so urgent.

FIGURE 2

Plastic & Health: The Hidden Costs of a Plastic Planet

Humans are exposed to a large variety of toxic chemicals and microplastics through inhalation, ingestion, and direct skin contact, all along the plastic lifecycle.



Credit: CIEL, Earthworks, GAIA, Healthy Babies Bright Futures, IPEN, Texas Environmental Justice Advocacy Services (t.e.j.a.s.), University of Exeter, and UPSTREAM. Plastic & Health: The Hidden Costs of a Plastic Planet. Feb 2019.

SECTION 2: CHEMICAL SECTOR TRANSFORMATION

A transition to a more sustainable chemicals sector must begin now and will require:

- immediately eliminating emissions to workers and communities from current chemical and plastics manufacturing and prohibiting the planned expansion of the petrochemicals and plastics sectors;
- redesigning chemical products and systems to reduce both carbon and chemical footprints;
- altering production processes and substituting with safer, low hazard alternatives;
- eliminating non-essential uses of chemicals and using chemicals that are shown to be safe throughout their lifecycle; and
- rewarding innovation that benefits local communities and is safe and sustainable for future generations and our environment.

All twelve Principles of Green Chemistry and Green Engineering Principles (see Appendix 1 and 2) need to shape innovation in a revamped chemical sector that transitions from petroleum based chemical feedstock production to biobased, and other alternative forms of material synthesis, with low hazard platform chemicals. Key characteristics of green chemistry continue to be developed that emphasize precaution and sufficiency. Reducing the complexity and overall production of chemicals is key. New chemical synthesis must not put workers, local communities or environments at risk and must be designed with the full lifecycle in mind. To this end, the Louisville Charter for Safer Chemicals sets out ten planks to ensure any proposed roadmap to chemical sector reform will not put disproportionate exposure and hazards on environmental justice communities.

Section 2 presents ten recommendations for safer substitutes and solutions. Each subsection 1-10 outlines challenges and opportunities for implementing these recommendations:

1. Replace the current seven hazardous petrochemical building block chemicals with safer alternatives.

2. Redesign products and systems to reduce both carbon and chemical footprints.

3. Prioritize a "hazard-first" approach to reduce risk in chemicals management and set chemical footprint reduction goals while transitioning to inherently safer substitutes with lower hazards.

4. Require full material disclosure across supply chains.

5. Bend the curve down for all chemical use and especially toxic chemicals through functional substitutions, class based restrictions, and safer substitutions with a lifecycle perspective.

6. Prioritize hazard reduction, full material disclosure, and reduced consumption in the circular economy.

7. Reward innovation in safer chemicals production by financially penalizing petrochemicals through removing subsidies on fossil fuel developments, taxing the use of hazardous chemicals and integrating chemical footprint reduction goals and investment in safer chemicals into all Environment Social and Governance reporting.

8. Scale benefits to local communities through smaller-scale, decentralized, and modular chemical and material manufacturing facilities. Halt all new facilities from being built in or near communities.

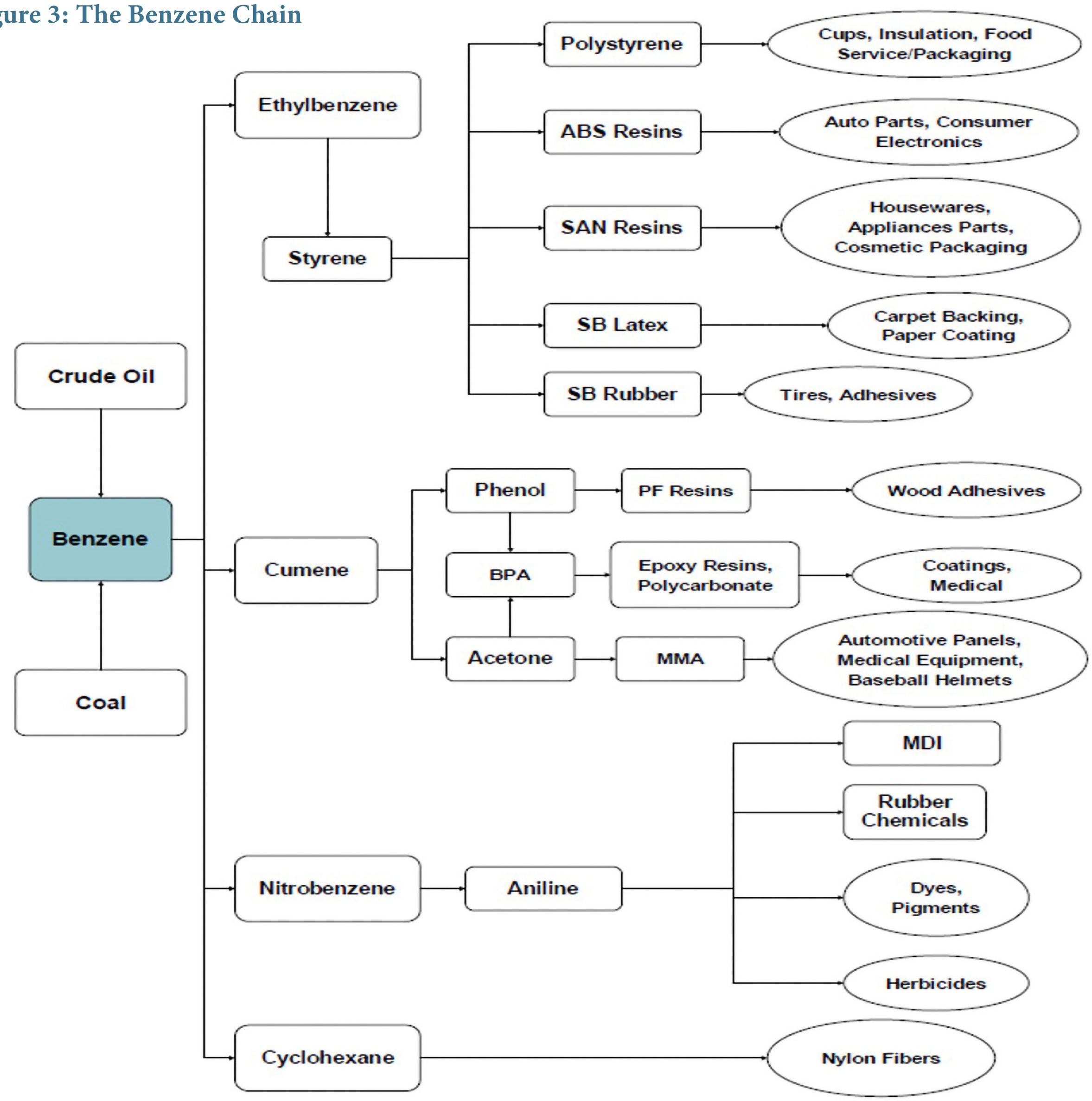
9. Produce food without petrochemicals.

10. Train the next generation in chemical hazard literacy, green chemistry and green engineering principles and policies that advance a non-toxic future.

2.1 A reformed chemical sector will require replacing the current seven high hazard petrochemical building block chemicals with safer alternatives.

Currently, just seven petrochemicals are the building blocks for more than 90% of downstream organic chemical production, including tens of thousands of chemical products.[43] Called "platform chemicals," these seven chemicals are: methanol; olefins—ethylene, propylene, and butadiene; and aromatics—benzene, toluene, and xylene. Most of these platform chemicals have high intrinsic hazards and perpetuate these hazards throughout the value chain. For example, the benzene chain is demonstrated in Figure 3 below.

Figure 3: The Benzene Chain



Credit: American Chemistry Council Guide to the Business of Chemistry. 2020. p.8.

Chemical sector reform is urgent – beginning with a transition from high hazard platform chemicals to low hazard alternatives that are designed using the 12 Principles of Green Chemistry and Green Engineering Principles. Currently, many of the green chemistries on the market are made from fossil fuel-based building block chemicals with high or relatively high hazards. New platform chemicals with lower intrinsic hazard are needed and research shows these can be made from sugars, biobased feedstocks, synthetic biology techniques or other material design options.

> **"Currently, just seven petrochemicals are the building blocks for more than 90% of downstream organic chemical production, including tens of thousands of chemical products... Most of these platform chemicals have high intrinsic hazards."**

To illustrate the inherent hazards of these seven petrochemical building block chemicals, GreenScreen chemical hazard assessments were done for the primary chemicals, intermediate chemicals and monomers used in nine common plastics (Figure 4).[44] GreenScreen® for Safer Chemicals[45] is a globally recognized and widely used chemical hazard assessment method that groups chemicals into four Benchmarks ranging from Benchmark-1 'chemical of high concern' to Benchmark-4 'preferred chemical' as shown in Figure 4.

Figure 4

GREENSCREEN FOR SAFER CHEMICALS BENCHMARK DESCRIPTIONS

BENCHMARK 1	AVOID- CHEMICAL OF HIGH CONCERN
BENCHMARK 2	USE BUT SEARCH FOR SAFER SUBSTITUTES
BENCHMARK 3	USE BUT STILL OPPORTUNITY FOR IMPROVEMENT
BENCHMARK 4	PREFER- SAFER CHEMICAL

Credit: Coming Clean, Adapted from Clean Production Action.

The Benchmark criteria were developed to reflect hazard concerns that have been established by governments nationally and internationally. An important value of GreenScreen is that Benchmark-1, "Avoid - Chemical of High Concern", clearly defines the criteria for chemicals of high concern to human health and the environment consistent with global regulations like the European Union's REACH regulation. Benchmark-1 chemicals include: carcinogens, reproductive, developmental and neurodevelopmental toxicants, mutagens, persistent, bioaccumulative and toxic chemicals (PBTs), very persistent and very bioaccumulative chemicals (vPvBs), and endocrine disruptors.[46]

Figure 5:

Polymers and Hazard Rankings of their Primary Chemicals, Intermediate Chemicals, and Monomers

Polymer	Primary Chemicals (CAS #)	Intermediates (CAS #)	Monomer(s) (CAS #)
Acrylonitrile Butadiene Styrene (ABS)	Propylene* (115-07-1)	Ammonia (7664-41-7)	Acrylonitrile (107-13-1) 1,3-Butadiene (106-99-0)
	Ethylene(74-85-1) Benzene(71-43-2)	Ethylbenzene (100-41-4)	Styrene (100-42-5)
Ethylene Vinyl Acetate (EVA)	Ethylene (74-85-1) Methanol (67-56-1)	Acetic Acid* (64-19-7)	Ethylene (74-85-1) Vinyl Acetate (108-05-4)
Polycarbonate (PC)	Benzene (71-43-2)	Cumene (98-82-8) Sulfuric Acid (7664-93-9)	Bisphenol A (80-05-7)
	Propylene (115-07-1)	Phosgene (75-44-5)	
	Chlorine (7782-50-5)	Acetone (67-64-1) Phenol (108-95-2)	p-tert-butylphenol (98-54-4)
Polyethylene (PE)	Ethylene(74-85-1)	Ethylene(74-85-1)	Ethylene(74-85-1)
Polyethylene Terephthalate (PET)—Terephthalic Acid (TPA) Route	para-Xylene (106-42-3)	Ethylene Glycol* (107-21-1)	Bis-(2-hydroxyethyl)-terephthalate* (BHET) (959-26-2)
	Methanol (67-56-1)	Acetic Acid* (64-19-7) Terephthalic Acid* (TPA) (100-21-0)	
Polylactic Acid (PLA)	Glucose* (50-99-7)	Lactic Acid* (50-21-5)	Lactide* (L-lactide - 4511-42-6; DL-lactide - 615-95-2)
Polypropylene (PP)	Propylene* (115-07-1)	Propylene* (115-07-1)	Propylene* (115-07-1)
Polystyrene (PS)	Ethylene (74-85-1) Benzene(71-43-2)	Ethylbenzene (100-41-4)	Styrene (100-42-5)
Polyvinyl Chloride (PVC)	Ethylene (74-85-1) Chlorine (7782-50-5)	Ethylene Dichloride (EDC) (107-06-2)	Vinyl Chloride Monomer (75-01-4)
Styrene Butadiene Rubber (SBR)	Ethylene (74-85-1) Benzene (71-43-2)	Ethylbenzene (100-41-4)	1,3-Butadiene (106-99-0) Styrene (100-42-5)

GreenScreen® Benchmark List Translator 1 or GreenScreen® Benchmark Possible 1

GreenScreen® Benchmark 2; or no data that defines the chemical as a GreenScreen® Benchmark List Translator 1 or GreenScreen® Benchmark Possible 1.

Verified GreenScreen® Benchmark 3

Actual GreenScreen® assessment with determination of GreenScreen® Benchmark Score of U - unspecified.

* = verified GreenScreen® assessment

Credit: Clean Production Action.

As seen in Figure 5, methanol, benzene, and xylene are all classified as GreenScreen Benchmark 1 chemicals –"Chemical of High Concern." Toluene and 1,3, butadiene have also been assessed as GreenScreen Benchmark-1 chemicals.[47] These chemicals are not just building blocks for thousands of substances but can also be found in consumer products including gasoline, detergents, air fresheners, toys, playground equipment, polystyrene, polyester textiles and other common products. For example, independent testing has found hundreds of popular personal care items in the US to be contaminated with benzene, prompting several big brands to voluntarily recall dozens of products.[48] Ethylene and propylene, two of the seven platform chemicals, were assessed as GreenScreen Benchmark-2, "Use but search for safer substitutes."

Substituting these building block chemicals with lower hazard alternatives requires new molecular design that is based on environmental and human health, as well as needed function. The 12 Principles of Green Chemistry and associated 12 Green Engineering Principles ensure sustainability criteria are built throughout the lifecycle of chemicals, including design, manufacture, use, and ultimate disposal (Appendix 1 and 2).
Green chemistry is the design of chemical products and processes that reduce or eliminate the use or generation of hazardous substances.[49] Green chemistry focuses on designing inherently safer chemicals and products that are fully effective yet have little or no toxicity. The principles emphasize the need for chemicals and products to break down to innocuous substances after use so that they do not accumulate in the environment and minimize the potential for accidents including explosions, fires, and releases to the environment. Using renewable feedstocks is one of the twelve principles (see Appendix 1).

These principles are informing new developments such as safer substitutes for phthalates and halogenated flame retardants.[50] However these greener chemicals on the market are probably often sourced from the seven petrochemical building block chemicals discussed above with their high or relatively high hazards. To truly encompass green chemistry principles, platform chemicals, as well as chemical synthesis downstream, must be designed with renewable feedstocks and low hazards. This is fundamental to chemical sector reform. Researchers note that designing new feedstocks with low intrinsic hazard can be facilitated by new computing tools, data from molecular reference libraries and lessons learned from medicinal chemistry where human safety is paramount. Green chemistry and engineering inspired research provide opportunities to create new building block chemicals and novel chemistries with less energy-intensive syntheses, higher efficiency, and lower toxicity and persistence in the environment.[51] Financial incentives and supportive regulations must now reward front runners in safer chemical synthesis that are based on low hazard platform chemicals.

The Principles of Green Engineering[52] are an important complement to the Principles of Green Chemistry because they apply to the process stage of chemical production. These principles emphasize that all materials and energy inputs and outputs are as inherently non-hazardous as possible; that waste prevention is better than treatment; materials are designed for reuse and recycling; and all materials and energy should be renewable rather than depleting (see Appendix 2).

Another set of green engineering principles - The Sandestin principles of Green Engineering[53] - were developed by chemists and engineers from industry, academia, and government and also include important social dimensions. Principle 9 of these principles, "actively engage communities and stakeholders in development of engineering solutions," is particularly important when considering the siting of new chemical production facilities. Local communities need to be at the table from the beginning of any proposal for new chemical production facilities. Community participation could address criteria about the ownership of the facility; benefits to the local economy; impacts to health and the environment; the design and necessity of these new chemicals; possible trade offs; and more.

The Sandestin Declaration: 9 Principles of Green Engineering

- Engineer processes and products holistically, use systems analysis, and integrate environmental impact assessment tools.
- Conserve and improve natural ecosystems while protecting human health and well-being.
- Use life-cycle thinking in all engineering activities.
- Ensure that all material and energy inputs and outputs are as inherently safe and benign as possible.
- Minimize depletion of natural resources.
- Strive to prevent waste.
- Develop and apply engineering solutions, while being cognizant of local geography, aspirations, and cultures.
- Create engineering solutions beyond current or dominant technologies; improve, innovate, and invent (technologies) to achieve sustainability.
- Actively engage communities and stakeholders in development of engineering solutions.

Green chemistry and green engineering principles together with a goal of decreased consumption need to be central to any new material design, including nanotechnology and synthetic biology, so that innovation is by design and not by accident. But such criteria needs to be implemented before widespread commercial application of new materials - if we are to learn anything from past mistakes.[54]

2.2 Redesigning products and systems requires a reduction in both carbon and chemical footprints. A transition to biobased or other building block chemicals with no consideration of hazard will only perpetuate hazardous chemical production and use throughout the supply chain.

Carbon footprint reduction is a large focus in current sustainability metrics. A carbon footprint can be defined as the total greenhouse gas emissions caused directly and indirectly by a person, organization, event or product.[55] Various forms of non fossil-based carbon exist as alternative renewable feedstocks for chemical production to reduce the carbon footprint of facilities and thereby meet Green Chemistry Principle #7. Current research into non arable biomass, lignocellulose, algae, chitin and biocrude from sewage and food waste is being explored.[56] Other research is investigating the use of renewable energy to convert water and CO2 from the air into fuels and other molecules, with no need for oil.[57]

However, reducing carbon footprints while neglecting to reduce chemical footprints will perpetuate the toxic chemical economy. Green chemistry principles of low inherent hazard and renewable feedstocks are equally needed to achieve true innovation in the design of safer products and a revamped chemical sector.
A chemical footprint is a hazard based metric that identifies and measures the amount of chemicals of high concern used by an event, organization, service, building, or product. For example the chemical footprint of an organization would include the total mass of chemicals of high concern in products sold by a company; used in its manufacturing operations, facilities, and by its suppliers; and contained in packaging.

> **“Simply replacing fossil fuel based carbon with biobased carbon to produce hazardous chemicals and materials is a false solution. It is essential that the goals of low chemical hazard and renewable feedstocks are equally prioritized when designing safer solutions.”**

Various platform chemicals can and are being produced in biorefineries and several value-added chemical products and polymers produced in a biorefinery have been commercialized.[58] In 2020, the International Energy Agency assessed the revenue from biobased products that included platform chemicals, solvents, polymers for plastics, paints, coatings, inks and dyes, surfactants, cosmetics and personal care products, adhesives, lubricants, plasticisers and fibers. They estimated that the production of biobased chemicals could generate over US$10 billion of revenue for the global chemical industry.[59]

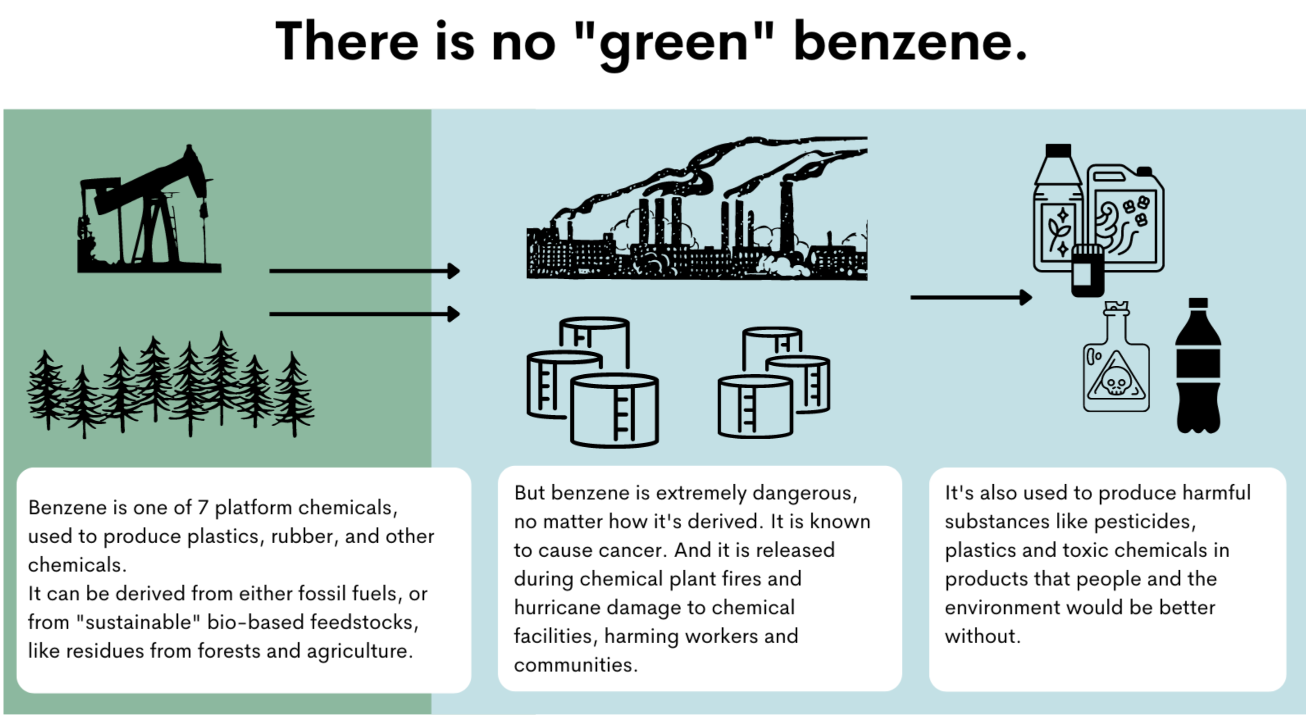
Biobased chemistries can be significantly less hazardous than fossil fuel chemicals, but the hazard assessment needs to show this is indeed the case. For example, the assessment of polylactic acid (PLA) in Figure 4 shows that the building block of this polymer is glucose, which is assessed as a GreenScreen Benchmark-3 chemical - “Use - but still opportunity for Improvement.” Products made from platform chemicals with lower hazards and that use additives with lower hazards are being commercialized. For example, food service ware made from PLA by Natureworks has achieved a GreenScreen Certified platinum designation for achieving Benchmark-3 assessments for all ingredients in the product.[60]

Ensuring all ingredients in a biobased product are made with lower hazard chemicals is unfortunately far from mainstream; and producers and certifications often focus solely on reducing carbon footprints. Two examples that neglect chemical hazard reduction in the pursuit of biobased feedstocks are given below.

SPOTTING FALSE SOLUTIONS

False Solution: Benzene, toluene and xylene made from biobased carbon sourced from forest residues, agricultural residues and perennial crops. Chemical engineers have found a framework that determines the most profitable processes to produce benzene, toluene, and/or xylenes from biomass via methanol."[61] However these biobased chemicals will still exert the same hazardous properties as their fossil-based counterparts throughout their lifecycle. As Figure 6 illustrates, there is no such thing as "green benzene."

Figure 6:

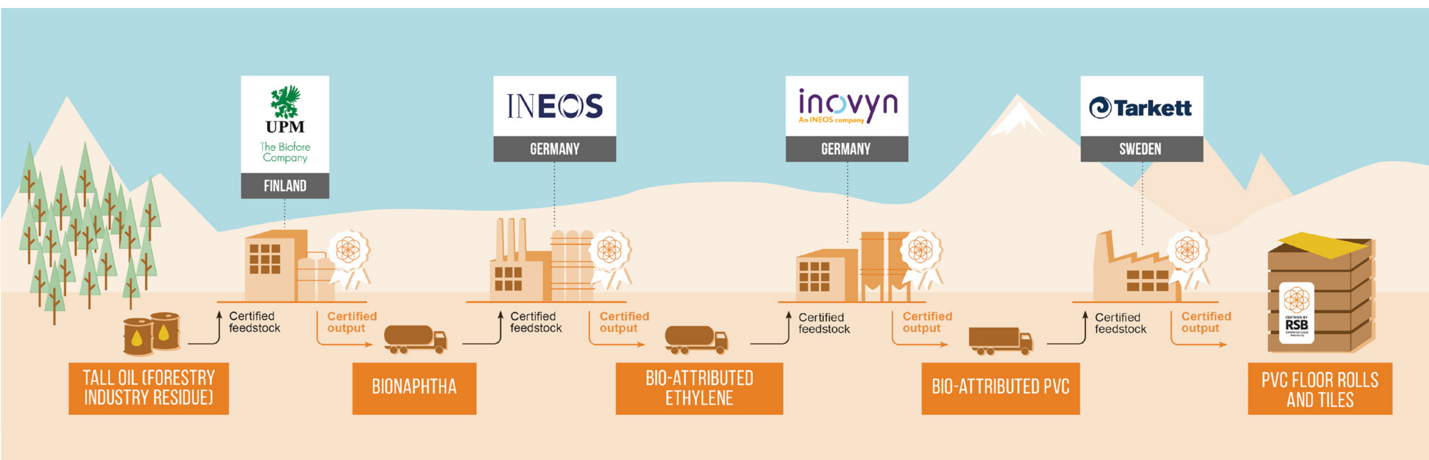


Credit: Coming Clean, 2022.

False Solution: Biobased feedstock used to produce polyvinyl chloride polymer (PVC) with inherently high hazards. Ineos, one of the largest producers of PVC polymers, has sourced biobased carbon as their stated contribution to a circular and sustainable economy.[62] As shown in Figure 5, the company Inovyn uses renewable residue of wood pulp processing to produce bio-attributed PVC 'Biovyn'. The Roundtable on Sustainable Biomaterials (RSB) has certified each step in the process, starting from UPM Biofuels converting the wood-based residue (crude tall oil) into hydrocarbons, through to the final polymer. Bio-naphtha is mixed with virgin fossil naphtha from UPM when it enters the INEOS supply chain in Germany. Inovyn produces the chlorinated chemicals (VCM) that go into PVC. Tarkett then produces PVC floor rolls and tiles which carry the RSB certification.

The certification is promoted as a sustainable contribution to the circular economy but unfortunately, omits any consideration of the inherent hazards in the final product or the high chemical hazards perpetuated throughout the value chain. PVC production involves the use of vinyl chloride monomer and other chemicals of high concern (Figure 4), the use of hazardous chemical additives and the generation of toxic emissions throughout the entire product lifecycle, including at the disposal stage.[63]

Figure 6: Biobased feedstock is used to produce polyvinyl chloride polymer (PVC) with inherently high hazards



Credit: Roundtable on Sustainable Biomaterials (RSB) www.rsb.org.

In summary, false solutions include using biobased carbon sources (e.g., forest residues, agricultural residues or perennial crops) to make toxic chemicals (e.g., benzene, toluene, and xylene) and materials (e.g., PVC).

2.3 During this transition to chemical sector reform, chemical producers must prioritize a "hazard-first" approach to reduce risk in chemical management and set chemical footprint reduction goals while transitioning to inherently safer substitutes with lower hazards. Retailers and brands, further down the supply chain, can reduce their chemical footprints even more quickly.

As green chemistry innovations are rolled out by some chemical producers and formulators in the supply chain, the chemical footprint of the alternatives should be transparent. Chemical footprinting is the process of benchmarking progress away from hazardous chemicals and towards safer alternatives. Measuring a chemical footprint allows a company to quantify their use of chemicals of high concern, and set goals to reduce their chemical footprint over time.

Chemical hazard assessment tools and databases now exist to help companies identify chemicals of high concern and choose safer alternatives with lower intrinsic hazards.[64] The GreenScreen® for Safer Chemicals benchmarking tool and other chemical hazard assessment methods are used by leading corporations, governments and standard setting bodies to make informed decisions about their chemical choice. Identifying chemicals of high concern based on their intrinsic hazards and choosing substitutes with lower hazards fulfills many green chemistry principles. Hewlett Packard, an early adopter of the GreenScreen method, emphasized in 2013 why a hazard-first approach is best:

> "A basic premise of Green Chemistry is that chemical risk is most effectively managed by reducing hazards because exposure controls can and do fail, products are used in unintended ways and end of life management of obsolete equipment is often problematic. Therefore, a dedicated hazard screening step in the alternatives assessment process to identify lower hazard options is consistent with the principles of Green Chemistry."[65]

One attempt to measure the chemical footprint of chemical producers is ChemScore, which ranks the world's top 50 chemical producers on their production of hazardous chemicals. It was developed in order to provide investors with better information to assess which companies have strong chemicals management strategies, and which do not.[66] Each company's total production of hazardous chemicals in the European Union and the USA, is set in relation to the company's total revenue. The scope of hazardous chemicals includes substances on Chemsec's SIN List, the EU's REACH candidate list and authorization list, a list of persistent chemicals, the Stockholm Convention Persistent Organic Pollutant List, the Rotterdam Convention's Prior Informed Consent List anda list of Highly Hazardous Pesticides.[67]

Each company is scored based on their product portfolio, development of safer chemicals, management and transparency, and lack of controversies.

ChemScore is a useful resource to contextualize the progress made by chemical producers on green chemistry research and adoption. For example, the listing of three green chemistry achievements by Dow Inc for non-epoxy can linings, safer surfactants and non solvent binders[68] is an important achievement, but this is juxtaposed by the ChemScore ranking of a D+ grade for Dow Inc in ChemScore's 2021 report. In this case, it would be helpful for the corporation to outline its overall plan and timeline to reduce the production of chemicals of high concern with safer substitutes based on green chemistry and green engineering principles. Such information will increasingly be scrutinized by investors in the near future.

For retailers and brands downstream from chemical producers, a reduction of their chemical footprint can be done even quicker, notwithstanding the challenge of getting full ingredient disclosure from their suppliers. Third party certifications for formulated products and products in other sectors such as US Safer Choice, GreenScreen Certified™ or Cradle to Cradle Certified® allow purchasers to know a chemical hazard screen has been applied. But such certifications cover only a minority of products being produced. That is why some retailers and brands are calculating their chemical footprint for certain product categories and setting chemical footprint reduction goals.

The Chemical Footprint Project (CFP) offers a way for companies to both calculate chemical footprints and set up a best in class chemicals management system to do so. The CFP defines a chemical of high concern as a GreenScreen Benchmark-1 chemical ("Avoid - chemical of high concern") which is consistent with international precedent such as the European Union's definition of substances of very high concern. The CFP provides an open source list of over 2,000 Chemicals of High Concern based on GreenScreen Benchmark-1 criteria to enable companies to get started in identifying known chemicals of high concern and pursue comprehensive chemical hazard information from their suppliers. Company front runners in the CFP disclose their chemical footprint reduction goals and their progress in eliminating chemicals of high concern.[69] For example, GOJO was the first company to announce in 2015 the goal to reduce their chemical footprint by 50% by the end of 2020. The company exceeded that goal, reducing it by 64%.[70] By 2022, Walmart aims to reduce its consumables chemical footprint for applicable products in Walmart stores and Sam's Clubs in the U.S. by 10 percent.[71]

It is imperative that dollar stores set chemical footprint reduction goals for the products and food they sell because consumers in these communities face cumulative impacts from hazardous chemicals.. Almont one-half (about 13,000) of the almost 27,000 dollar stores owned by the largest US chains are located within three miles of a hazardous facility. Residents in such communities can also experience lower rates of food access and higher rates for cancer and risk of non-cancer respiratory disease, as compared to the rest of the country.[72]

2.4 Informed substitution requires full material disclosure throughout supply chains.

The intention of informed substitution is to reduce or eliminate chemicals of high concern with a functional match that is safer for humans and the environment. This is accomplished via one-to-one chemical replacement, a change in product design, or change in manufacturing process. An evaluation of chemical function is the starting point for informed substitution. In a given application, it is the function of the chemical that is important, not the chemical itself.[73] For example, the use of toxic flame retardant chemicals in electronics can sometimes be replaced by product redesign, rather than using alternative flame retardant chemicals with lower hazards.

For brands and retailers downstream in the supply chain, choosing safer chemicals in products and manufacturing processes is essential to reduce business risk, avoid regrettable substitutes, and protect human and environmental health. A regrettable substitution is the replacement of a known toxic chemical with another that proves to be equally or more harmful to human health or the environment, such as the replacement of BPA in plastics and cash receipts with BPS - which has equal hazards.[74] Regrettable substitutions often disproportionately affect vulnerable populations that are harmed first by the original toxic chemical and then by its substitute.

A fundamental barrier to choosing safer substitutes is lack of chemical ingredient information through the supply chain. The BizNGO Principles for Safer Chemicals[75] underscore the need for manufacturers to disclose chemical constituents in their products, particularly chemicals of high concern. Companies are endorsing The Principles for Chemical Ingredient Disclosure to better promote transparency.[76] State legislation requiring disclosure of chemical ingredients is increasing[77] while purchasers are demanding full material disclosure from suppliers to reduce their business risk. It is essential that regulatory agencies remove barriers to full chemical ingredient disclosure.

2.5 Functional Substitution can reduce chemical consumption. A class based restriction for many hazardous chemicals will lower consumption of chemicals and speed adoption of safer substitutes. Safer substitutes take a lifecycle perspective, including what platform chemicals were used at the source of production. Informed substitution does not shift hazards to other communities.

Functional substitution can reduce chemical consumption. The "service" provided by a chemical could be functionally substituted by a less hazardous chemical or through product, process, or systems-level changes. Functional substitution also questions if the chemical is actually necessary. For example, to meet GreenScreen certification for PFAS-free textiles, a leading textile design firm discovered that 'often a finish is not needed at all and that textiles without a finish, or with a PFAS-free finish, clean just as well (and sometimes better) than those with a PFAS-based finish. Years ago it was assumed that the more layers of chemical finishing, the better, but this thinking is outdated and we know more about the environmental impact of these chemicals now.'[78] A recent study of 35 international apparel manufacturers found that 22 had already phased out PFAS or were planning to do so by 2030.[79]

A class-based approach to hazardous chemical restrictions will speed innovation in necessary and safer substitutes. In October 2020, the European Union declared a goal to phase out all uses of PFAS unless a specific use could be shown to be essential.[80] This concept of "essentiality" questions the need for the production and use of toxic chemicals and the idea that such chemicals have benefits for society.[81] Chemicals are assessed as either Non-essential; Substitutable, or Essential – with the latter requiring research and development for eventual safer substitution. A non-essential use is defined as uses that are not necessary 'for the betterment of society in terms of health, safety and functioning', such as PFAS in dental floss, cookware coatings or ski waxes. In these cases the use of PFAS may be "nice to have" (e.g. non-stick frying pans) but it is not essential. In many cases the "nice to have" function can be fulfilled through substitution with fluorine-free alternatives. As researchers point out, even where there are no alternatives to PFAS for providing the "nice to have" function, the use can be banned or phased out because it is not essential. However if the chemical's function can be shown to be beneficial in some cases, then the Substitution Principle[82] is used to find safer alternatives within a specified time frame.

Defining the "essential uses" of hazardous chemicals will be contentious but researchers point out that there is an established policy precedent for applying this type of framework to phase out harmful substances –the elimination of ozone depleting substances within the international Montreal Protocol. How decisions will be made about the essential use concept is yet to be clarified. But equally important will be the process to identify functional substitutes for any current 'essential' use of a hazardous chemical and a rapid timeline to implement these safer solutions.

The Montreal Protocol's goal to remove chemicals with ozone depleting potential dealt with the immediate threat to the ozone layer. However a comprehensive understanding of a chemical's hazard and its breakdown products is needed, if we are to avoid unintended consequences and prevent exposure to toxic emissions from production sites. For example, the community in Louisville, Kentucky is experiencing the direct impacts of the production of hydrochlorofluorocarbon-22 (HCFC-22) - which, although banned under the Montreal Protocol as an ozone depletion chemical, received a permit for ongoing production because it is used as a feedstock chemical in other uses. In addition to the hazardous releases from the production facility, an unwanted byproduct of HCFC-22 is hydrofluorocarbon-23 (HFC-23), a potent greenhouse gas. The Chemours Louisville Works facility is the largest emitter of HFC-23 in the United States.[83] The local community continues to be impacted by toxic emissions from the plant including chlorine, hydrogen chloride, chloroform and hydrogen fluoride.[84]

In addition to PFAS, the class based approach for elimination should be applied as a priority to organohalogens, bisphenols, phthalates, heavy metals, and antimicrobials.[85] The announcement by the European Commision on April 26, 2022 that it has adopted a roadmap to eliminate whole chemical classes by 2030 is an important and proactive step forward.[86] In the United States, many states are now taking action on PFAS disclosure and elimination.[87]

The purpose of informed substitution is to prevent the use of a "regrettable substitute" or an alternative with equal or higher hazards. This requires full chemical ingredient disclosure and chemical hazard information. But such transparency should also extend to how the chemical was sourced. Safer substitutes should ultimately be made from lower hazard platform chemicals in order to be truly considered 'safer'. To date, there is no requirement to disclose what platform chemicals were used in the design of chemicals on the market . Yet, transparency about the hazards of the building block chemicals used in the creation of chemicals on the market is essential for a non-toxic future that is rooted in environmental justice, human rights and protection of biodiversity.

2.6 The promotion of a Circular Economy must prioritize hazard reduction and full material disclosure together with a decrease in consumption. Chemical recycling of plastics for fuel will perpetuate toxic emissions and does not address the need to reduce plastic production.

The promotion of a circular economy aims to move away from the linear “take-make-use-dispose” model and transition to a regenerative growth model in order to keep resource consumption within planetary boundaries. In a circular economy, the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste is minimized.[88]

However, reducing waste- but not addressing hazards of chemicals and materials- will only perpetuate toxic emissions along the product chain, putting workers, communities near recycling plants and consumers of recycled products at risk.

Researchers examined 540 small plastic consumer products including children’s toys, purchased in 18 countries between 2015 and 2019. Almost ten percent of the total, mainly those made of black-colored plastic, contained hazardous phased-out and banned polybrominated diphenyl ether (PBDE) flame retardant chemicals which probably originated from electronic waste.[89] Studies conducted by the International Pollutants Elimination Network found that toxic chemicals that have been banned under international chemicals conventions, such as PBDEs, are being recycled from old waste into new consumer products, such as restricted brominated flame retardant chemicals found in recycled plastic products from China, Indonesia and Russia.[90]

Company leaders who promote the circular economy and who recognize the need for chemical hazard information are advocating for stricter chemical regulations. H&M Group and Inter IKEA Group have committed to only use 100 percent renewable, recycled or other sustainably sourced materials by 2030. They and other brands conducted a collaborative study to examine chemicals in recycled textiles in order to identify which chemicals might be found in waste streams containing cotton, wool and polyester. Although the majority of recovered textiles by weight did not have hazardous substances above regulatory requirements, at least ten percent of textile waste did contain substances of high concern. The companies concluded that chemicals hampering recycling and material recovery should be restricted as a class to avoid regrettable substitutions and avoid legacy waste problems.[91] A focus on fast-fashion and the need to cut consumption in the apparel sector overall is a necessary corollary to reducing the sector’s use of hazardous chemicals.

Substituting single-use plastics with reusable alternatives helps to reduce plastics use and is an urgent priority in procurement specifications and legislation. The National Reuse Network is a movement of activists and innovators creating a world without toxic, single-use food and beverage packaging. The network supports leaders working across the U.S. to catalyze and pass policies that promote reuse and reduce single-use food and beverage packaging and ensure that reducing toxic chemicals in packaging is integrated in the policy work.[92]

The disproportionate impact on environmental justice communities living at the fenceline of plastic and chemical production is well documented but needs much higher awareness and action. The Environmental Justice Health Alliance for Chemical Policy Reform is a national network of grassroots Environmental and Economic Justice organizations and advocates in communities that are disproportionately impacted by toxic chemicals from legacy contamination, ongoing exposure to polluting facilities and health-harming chemicals in household products.[93] Their submitted comment letter to the White House Office of Science and Technology Policy on June 8, 2022, emphasized the need to inclusively engage and address the harms faced by communities disproportionately affected by current practices of chemical use, production and disposal as the federal government develops a consensus definition of "sustainable chemistry."[94] The comment also calls for a "focus on equity and justice at all stages of the chemical lifecycle," particularly during oil and gas extraction, chemical production, product manufacturing and use, and disposal and end of life.

Replacing fossil fuel feedstocks with chemical recycling of plastics is contentious. Chemical recycling technologies use heat, chemical reactions, or both, to break down used plastics into raw materials for new plastic, fuel, or other chemicals. The US Government Accountability Office is researching chemical recycling as one way to reduce the amount of plastic that ends up in landfills and is asking policymakers what steps could be taken to further incentivize chemical recycling rather than disposal.[95] However this does not address the inherent toxicity of plastics throughout the lifecycle of these materials and it perpetuates the use of fossil fuel feedstocks. It is also an unproven technology and could release hazardous emissions into communities already exposed to disproportionate and cumulative emissions. While the viability and impacts of plastic repolymerization remain highly uncertain, industry uses the term "chemical recycling" to greenwash plastic-to-fuel technologies, seeking public approval for the continued use and disposal of plastic.[96]

According to the NGO Chemsec, a leading advocate for strong European chemical policy, chemical recycling could have a role to play in reducing resources, if certain conditions are met[97] and the content of the material poised for recycling is known and safe. This is a subject under intense scrutiny and needs to be positioned within the larger criteria of essentiality, low hazard chemicals and materials and functional substitution to reduce consumption. To date this has not happened. In the meantime the planned expansion of increased plastic production will increase hazardous chemical use, toxic releases and waste into communities and the global environment.

2.7 Reward and incentivize innovation in safer chemicals production through financial incentives including removing subsidies on fossil fuel developments, taxing the use of hazardous chemicals and integrating chemical footprint reduction goals and investment in safer chemicals into all Environment Social and Governance reporting.

Our society wants healthy products and food. Regulators need to support research and development that will advance low hazard chemicals and materials. This requires ending perverse subsidies and tax breaks for oil and gas production.[98] Current government subsidies to the oil and gas sector —upward of $20 billion/year in the United States—should be reallocated to support renewable energy and green chemistry development - with a focus on local community supported enterprises. Doing so would raise the price of fossil fuels, making sustainable feedstocks more competitive, and provide the market signals that would drive new private-sector investments.[99]

New chemical manufacturing can involve a diversity of smaller-scale producers employing a range of feedstocks and production processes. It is anticipated that a more networked and collaborative chemical industry and matching supply chains will be more agile and better prepared for faster adoption of innovations and reaction to disruptions, changing market conditions, and new knowledge of unintended negative impacts.[100]

A widely cited 2004 U.S. Department of Energy study, summarizes the opportunity of biomass-derived basic chemicals – some of which are already in use.[101] But this study, almost twenty years old, needs updating to reflect the opportunities in new biobased and molecular opportunities that are sustainable with low hazards throughout their lifecycle.

Regulations should not stifle innovation in safer substitutes but hazardous materials and plastics are often cheaper than lower hazard substitutes. Without parallel fiscal incentives, companies may try to avoid substitution for as long as possible. An assessment of fiscal policies that could help companies adopt safer chemicals includes a tax on hazardous chemical use, subsidies and grants to cover part of the increased investment and operational costs associated with the switch to alternatives. Researchers found that giving companies economic incentives for moving away from hazardous chemicals can unlock a multi-billion market for safer alternatives.[102]

The financial sector will have an essential role in transforming the chemical sector but it must set roadmaps that advance a non-toxic future. A report entitled, The Invisible Wave - Getting to Zero Chemical Pollution in the Ocean, published by Economist Impact[103] summarizes the various ways that investors could take action.

Three recommendations from this report are given below - with modifications to further advance overall chemical sector reform:

1. To date most of the reporting on Environment, Social and Governance (ESG) measures under ESG reporting has focused on persuading companies to reduce their climate emissions—hence the global wave of corporate pledges to reach a net zero carbon impact. While the focus on climate will remain, momentum is also growing for investments that are net zero, nature-positive and socially just. For example, Shareholder activist group ShareAction launched a campaign in September 2021 targeting the chemicals industry over its carbon emissions from the seven building block chemicals (referred to in 2.1). ShareAction argued that phasing out these seven platform chemicals would provide the sector with a credible decarbonisation pathway.[104] This example offers creative opportunities to put the focus on both the chemical footprint and carbon footprint of these chemicals, and together plan a fundamental shift to renewable platform chemicals with low chemical hazards.

2. The report recommends that reporting to clear principles is needed. For example the Ocean Business Action Platform has developed a set of Sustainable Ocean Principles. Major investment funds are working with the UN Global Compact to support companies using the principles as a reporting mechanism. In this case, the Louisville Charter for Safer Chemicals could be used to define clear principles for investors and financial bodies who are keen to support protection of biodiversity and environmental justice.

3. The report's roadmap for investor-led action on marine chemical pollution could be modified for wider chemical sector reform as summarized below. For example the roadmap could:

- Develop improved ESG guidance, particularly around emerging nature-related frameworks such as the new Taskforce on Nature Related Financial Disclosures to include social justice and chemical footprint audits. Aligning to a widely agreed list of chemicals of high concern such as GreenScreen Benchmark-1 chemicals and chemical classes such as PFAS, will help measure chemical footprints and support the ESG community in driving corporations to reduce their use of toxic chemicals.
- Publish more and better data, that is free, accessible and open access, particularly around companies' chemical hazard impacts and plans to reduce their chemical footprint while investing in research and development of green chemistry innovations.
- Provide a template for setting out the risks that investors may face during the transition to a more sustainable and socially just chemical sector.
- Provide collaborative ways for industry and investors to work together to uncover opportunities for transition financing and align the supply of, and demand for, large-scale deals.
- Outline how private equity and Mergers & Acquisitions activity can help drive innovation in the burgeoning green chemistry startup scene.
- Outline a just transition plan for impacted workers and communities during the transition.
- Establish a clear mechanism for early and active participation by impacted communities in any financial or investment planning.

2.8. New innovations in chemical processes could benefit local communities through smaller-scale decentralized, or modular facilities - but regardless of the type of manufacturing facility, appropriate zoning laws should apply and prohibit construction in close proximity to homes or schools. Community participation in decision making will be key.

Designing safer chemicals and materials will involve a variety of new technologies such as bioprocessing, electrochemistry, and new synthetic molecular processes. It will also involve a complete change in infrastructure and scale of production. According to researchers, the potential for these forms of production to benefit local communities through smaller-scale decentralized, or modular facilities could enable regional manufacturing and differentiation in chemical production based on local feedstocks and help protect against the impacts of global supply chain disruptions.[105]

The environmental justice considerations and impact on communities from the location of biorefineries and the chemicals and products being produced needs to be prioritized. The IEA notes that: "Biorefinery development … requires a social contract from the communities and countries in which they plan to operate. This can include issues of direct and indirect employment, new skills development, health, noise and nuisance factors, ownership and consultative decision-making."

As new forms of production are proposed, it is important that local communities who will be most impacted by innovations are participants in decision making with full information disclosure from the beginning to the end. The history of petrochemical expansion has resulted in the unjust and disproportionate exposure to fenceline communities. The planned expansion of chemical and plastic production facilities will further increase this toxic assault on communities. That is why innovation in the production of safer chemicals must prioritize community engagement. Community residents, not just local businesses, must be consulted at the beginning of any proposal - and not as an add on once decisions are made. The expertise of community members is based on actual lived experience - which is often not understood by companies and regulators. Leaders working at the intersection of environmental justice and chemical policy recommend[106] that regulators and companies engage vulnerable populations to participate in deliberations and decisions about:

- the uses and exposures at each lifecycle phase of proposed alternatives to avoid shifting the burden of hazardous exposure to another community;
- trade-offs in decision making;
- the social, economic and job implications of switching to an alternative;
- how to regularly evaluate progress and implement further changes as needed.

As renewable feedstocks are increasingly promoted, information about the health and environmental impact from the sourcing of feedstocks will also be important. Are chemicals of high concern used in the production of these feedstocks? What are the environmental justice impacts from the sourcing of these feedstocks? What are the health impacts to workers, communities and the environment? These considerations need to be foundational in the transition to a biobased chemical economy. Otherwise we will simply replicate the mistakes created by the petrochemical sector, as set out in Section 1.

2.9 Promoting what is known to be safer - food and fiber production without petrochemicals.

Crucial to reversing the climate crisis along with the loss of biodiversity, food insecurity and water crisis is an overhaul of food and fiber production. Chemical hazard reduction is a key reason to transition from intensive industrial agriculture to sustainable and more local food production. There is limited justification or need for petrochemical use in agriculture and farmers have shown non toxic alternatives are effective. The simplest and most direct indicator that synthetic pesticides and fertilizers are unnecessary for economically viable production of virtually every crop in the U.S. market is the continuing positive growth of the certified organic industry that disallows use of virtually all petroleum-derived synthetic pesticides and all fertilizers. The organic sector has relied primarily on market forces alone to grow and thrive. In order to realize the full health, environmental and economic benefits of organic farming systems, we need to ramp up governmental support for organic-specific technical assistance and research programs. Farmers and ranchers would also benefit from incentive programs that help offset the risk of adopting new practices during the three year organic transition process. The 2019 USDA Organic Survey showed that sales of certified organic crops increased by 31% from the previous survey in 2016. The number of operations producing certified organic commodities was up 17%, and land used for certified organic production was up 9%. This represents 16,585 farms, 5.5 million acres, and $9.9 billion in sales.[107] However financial support for organic farming needs to be reflected in a reduced price for organic food sold in stores. The cost of organic produce is too costly for most people, which further increases cumulative impacts to communities already highly impacted by toxic chemical exposure. Lowering the cost of organic food will expand the market and bring multiple health benefits from a reduction in pesticide exposure to farmworkers and consumers.

Certified organic farming can be considered a first step in a transition to a safer, more agroecological food system.[108] Agroecology is a scientific discipline, a set of practices and a social movement. As a set of practices, it seeks sustainable farming systems that optimize and stabilize yields. An agroecological transition can be proposed at several levels, usually starting with resource use efficiency, followed by the substitution of conventional inputs. The ultimate goal is not only to promote substitutions that reduce the reliance on external synthetic inputs, but also a redesign of the system to one that embraces complexity in order to enhance diversification and recycling, gain nutritional quality and promote farmer and community autonomy. As with green chemistry innovation, fiscal and regulatory policies are urgently needed to scale sustainable food production.

2.10 Train the next generation in chemical hazard literacy, green chemistry and green engineering principles and policies that advance a non- toxic future

Understanding the human and environmental health impacts from hazardous chemicals – and the opportunities for safer solutions – should be integrated into a wide range of educational curricula, including medical, biology, economic, and engineering departments. Few doctors understand the link between chemical exposure and impacts to human health. For most people, the word 'chemicals' sounds complicated and overwhelming. Most science, engineering or business degrees do not integrate an understanding of hazardous chemicals impact into biology, chemistry, engineering or business administration curricula.

To teach the next generation, we need to increase literacy about chemical impacts across the entire education system, and as an immediate measure prohibit the use of harmful chemicals in schools. Some efforts are now being made. For example, Beyond Benign provides educators with the tools, training and support to make green chemistry an integral part of chemistry education. Set to launch in 2023, the Green Chemistry Teaching and Learning Community (GCTLC) is a new online community resource sharing and network co-developed by Beyond Benign and the ACS Green Chemistry Institute.[109] Incentives and rewards are needed at collegiate level to encourage students to pursue a future in safer chemical design. This is a start, but we need to also massively scale awareness about the tools, databases and networks that are available to help companies, regulators and the public promote a non-toxic future.

POLICY RECOMMENDATIONS FOR PLANK 3

1. A transition to a more sustainable chemicals sector must begin by prohibiting the planned expansion of both petrochemicals and plastics production and engaging in mandatory emissions reductions of toxic output from this sector. This involves:

- A halt to permitting process for new petrochemical and plastics production facilities.
- No decades-long 'transition' fuels such as natural gas as a bridging technology.
- Immediate removal of all fossil fuel subsidies, financial support, tax relief, and grants for current petrochemical production.
- Urgent, mandatory chemical emissions reduction that are real, permanent and verifiable by impacted communities. This must be accompanied by the adoption of policies and practices that remedy the disproportionate chemical hazards and exposures faced by environmental justice communities - communities of color, Tribes and Native/Indigenous communities, and low-income communities. See Louisville Charter Plank 2: Prevent Disproportionate Exposures and Hazards, and Reduce Cumulative Impacts on Environmental Justice Communities.
- Transition planning for workers.

2. A transition to a more sustainable chemicals sector prioritizes a 'hazard first' approach to risk reduction guided by all 12 Green Chemistry Principles and green engineering principles. Priority is given to a clear implementation plan to transition away from current petrochemical building block chemicals to renewable feedstocks and platform chemicals with lower hazards.

3. New chemical production facilities produce materials with clearly stated functionality, and created from lower hazard platform chemicals and renewable feedstocks. Producers supply full disclosure of chemical ingredients and an assessment of their chemical hazards. Communities are fully informed and participate as priority stakeholders in decisions concerning the permitting and ownership of new chemical production plants.

4. During this transition phase, current chemical producers adopt a 'hazard-first' approach for risk reduction in their chemical portfolio and set chemical footprint reduction goals. Chemical classes with high hazards are a priority for elimination with a clear timeline. Functional substitutes are prioritized for research and development and an implementation plan.

5. Regulations require full material disclosure from chemical producers and reverse the onus of proof onto producers to transparently demonstrate safety of chemical products and assume the otherwise externalized costs on society.

6. Promoters of a circular economy prioritize chemical hazard reduction and full material disclosure into all circular economy implementation plans. Chemical recycling of plastics is prohibited for polymers containing chemicals of high concern. Full disclosure of chemical constituents and their hazard assessments is mandated for all polymers. Chemical recycling under the guise of 'plastic waste to fuel' otherwise known as incineration, is prohibited.

7. A comprehensive plan for financial support and investor strategy for green chemistry startups that benefits local communities and involves community participation is established. Policy rewards and incentivizes innovation in safer chemicals production and use throughout the supply chain. Incentives for purchasing low hazard products are created that are comparable to financial incentives for low energy use, such as Energy Star. Financial and regulatory support for organic food production and agroecology is prioritized. Financial incentives include, but are not limited to, removing subsidies on fossil fuel developments, taxing the use of hazardous chemicals and integrating chemical footprint reduction goals and investment support for safer chemicals innovation into all Environment Social and Governance reporting.

8. Chemical impact literacy is integrated across the education system at all levels. Knowledge of human health impacts from hazardous chemicals is integrated into biology, chemistry, engineering and business administration curricula. Course curricula for sustainable design in any application integrate green chemistry and green engineering principles.

Appendix 1: The 12 Principles of Green Chemistry

1. **Prevent waste:** Design chemical syntheses to prevent waste. Leave no waste to treat or clean up.

2. **Maximize atom economy:** Design syntheses so that the final product contains the maximum proportion of the starting materials. Waste few or no atoms.

3. **Design less hazardous chemical syntheses**: Design syntheses to use and generate substances with little or no toxicity to either humans or the environment.

4. **Design safer chemicals and products:** Design chemical products that are fully effective yet have little or no toxicity.

5. **Use safer solvents and reaction conditions:** Avoid using solvents, separation agents, or other auxiliary chemicals. If you must use these chemicals, use safer ones.

6. **Increase energy efficiency:** Run chemical reactions at room temperature and pressure whenever possible.

7. **Use renewable feedstocks:** Use starting materials (also known as feedstocks) that are renewable rather than depletable.

8. **Avoid chemical derivatives:** Avoid using blocking or protecting groups or any temporary modifications if possible. Derivatives use additional reagents and generate waste.

9. **Use catalysts, not stoichiometric reagents:** Minimize waste by using catalytic reactions.

10. **Design chemicals and products to degrade after use:** Design chemical products to break down to innocuous substances after use so that they do not accumulate in the environment.

11. **Analyze in real time to prevent pollution:** Include in-process, real-time monitoring and control during syntheses to minimize or eliminate the formation of byproducts.

12. **Minimize the potential for accidents:** Design chemicals and their physical forms (solid, liquid, or gas) to minimize the potential for chemical accidents including explosions, fires, and releases to the environment.

Appendix 2: Principles of Green Engineering

1. Designers need to strive to ensure that all materials and energy inputs and outputs are as inherently non-hazardous as possible.
2. Prevention Instead of Treatment. It is better to prevent waste than to treat or clean up waste after it is formed.
3. Design for Separation. Separation and purification operations should be designed to minimize energy consumption and materials use.
4. Maximize Efficiency. Products, processes and systems should be designed to maximize mass, energy, space, and time efficiency. Simplicity is key.
5. Products, processes, and systems should be "output pulled" rather than "input pushed" through the use of energy and materials.
6. Conserve Complexity when making design choices on recycle, reuse, or beneficial disposition.
7. Targeted durability, not immortality, should be a design goal.
8. Meet Need, Minimize Excess. Designing for unnecessary use or "one size fits all" solutions should be considered a design flaw.
9. Minimize Material Diversity to promote disassembly and value retention.
10. Integrate Material and Energy Flows in the design of products, processes, and systems with available energy and materials flows.
11. Design for Commercial "Afterlife."
12. Material and energy inputs should be renewable rather than depleting.

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