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Commentary

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Is the EU Green Deal channelling a transition towards a sustainable chemical industry?

1 Action Plan for the Green Transition of the Chemical Industry – Transformation for People and Planet

In our everyday life, chemicals play an important role. The renewable energy sector, the healthcare sector, the telecommunication sector, the food sector - no industrialised country could do without the supply of chemicals of a wide variance. Therefore, it is all the more important that production, use and disposal of chemicals are managed in a sustainable way.

To strengthen Europe's chemical industry, we need a policy that connects economic and industrial policies with the conservation of human health and nature. Safe and sustainable chemicals "Made in Europe" should be the new standard. This vision would contribute to the accomplishment of our climate goals and ensure that everyone is living well within our planetary boundaries. To achieve this, the EU needs a holistic policy framework. It is of key importance that all services of the European Commission (COM) effectively implement the EU Action Plan: "Towards a Zero Pollution for Air, Water and Soil" (Zero Pollution Action Plan, ZPAP) of the European Green Deal. We need this paradigm shift in order to make sure that production, use, and disposal of chemicals and the use of products containing chemicals do not harm human health nor human rights nor ecosystems. This cannot be achieved by pleas alone. Producers must take responsibility for the entire value chain of their products, from downstream users to safe end-of-life procedures. The existing legislative framework has to be complemented and strengthened. Building on the do-no-harm principle enshrined in the EU's Green Deal, we published a ten-point action plan for the Green Transition of the chemical industry (Paulus and Giegold 2020a), followed by an extensive debate with the European Commission, the European Chemical Agency ECHA, and the chemical industry (Paulus and Giegold 2020b). In the following section, I briefly present this plan, going into detail for some of the actions needed for the transition.

1. **Apply and enforce EU law rigorously.** REACH is our best legislative framework to reach the ZPAP. Nevertheless, more than 10 years of experience with REACH show, that implementation and enforcement must be improved. To successfully protect human health, including that of workers, animal health and the environment, we must refine the principle of "no data, no market" towards "no proper data, no market". Today, a much too high share of the data delivered is not adequate. For some chemicals, material safety data sheets (MSDSs) don't even exist at all. The larger part of industry invests considerable time and money in fulfilling their duties though; therefore, not acting on incompliance gives laggards a free ride and distorts the level playing field. Member States should consequently apply substantial penalties for non-compliance with chemical laws. The continued occurrence of banned phthalates in children's toys or of harmful chemicals like PFAS (per- and polyfluoroalkyl substances) in food contact materials is intolerable. Up to now, the ECHA has not been able to fulfil all its tasks in a timely manner, due to lacking sufficient and predictable funding. For example, the NGO ChemSec has compiled a SIN ("substitute it now") list (ChemSec, 2021) of hazardous chemicals, building on REACH data. Only a fraction of these substances is found on the REACH SVHC (substances of very high concern) candidate list (ECHA, 2021a) yet. The fast-

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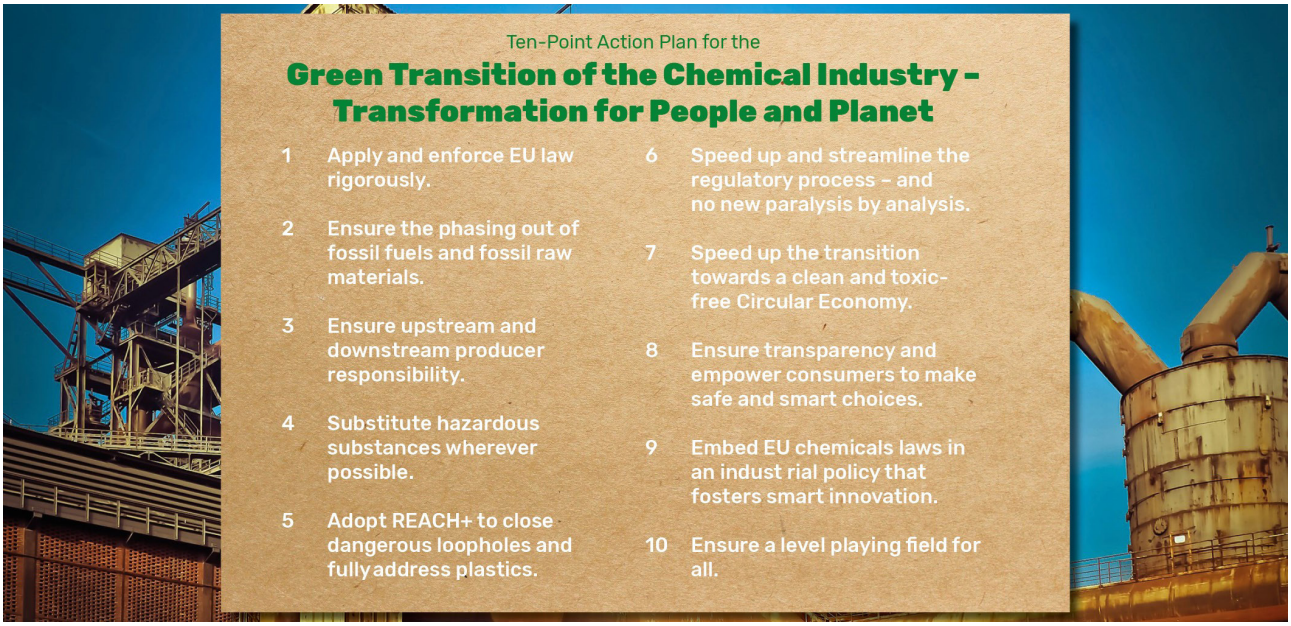

Figure 1 Ten-Point Action Plan for the Green Transition of the Chemical Industry proposed by MEPs Jutta Paulus and Sven Giegold.

track procedure for consumer use has to be extended to all SVHCs. Also, national enforcement bodies of the Member States need sufficient capacities to ensure the enforcement of EU chemicals legislation. The EU Commission as guardian of the treaties must not tolerate Member States neglecting their duties and has to open obvious cases of infringements without delay. The same is true for other environmental laws such as the *Water Framework Directive* or the *Industrial Emissions Directive*. Finally, the COM should withdraw its appeal to the judgement in case T-837/16[1] and fully apply it. The continuous use of pigments that are carcinogenic and toxic for reproduction in paintings of bridges and road marking has to stop immediately.

2. **Ensure the phasing out of fossil fuels and fossil raw materials.** The chemical industry must contribute its fair share to the EU's goal of reaching climate neutrality by 2050 at the latest. This requires enormous investment in renewable energy and electrification. Similar to the "efficiency first" principle in sectors related to energy, it is "electrification first" when it comes to replacing fossil fuels in industrial applications. Electricity from wind and solar is cost competitive today, but it is highly necessary to remove bureaucratic and fiscal barriers for its use. The guardrails for a climate neutral chemical industry have to be set today, as new production plants will run for thirty years and more. Therefore, it is crucial that no new investment into fossil infrastructure is made in the next years, and the EU and the Member States should make effective use of economic instruments to

[1]Judgement T-837/16 (General Court, 2019) was a case ended on the 7th of March 2019 in which Sweden, Denmark, Finland and the European Parliament went to court against the European Commission and the European Chemical Agency ECHA concerning the Commission Decision authorising the use of the carcinogenic and toxic for reproduction pigments lead sulfochromate yellow $Pb(Cr,S)O_4$ and of lead chromate molybdate sulfate red $Pb(Cr,Mo,S)O_4$ for some uses like the painting of bridges or road markings under Regulation (EC) No 1907/2006. The court annulled the Commission Implementing Decision C(2016) 5644 final of 7 September 2016 granting an authorisation for some uses of lead sulfochromate yellow and of lead chromate molybdate sulfate red under Regulation (EC) No 1907/2006 and also dismissed the request to maintain the effects of Regulation (EC) No 1907/2006 until the Commission is able to review the application for authorisation. On the 20th of May 2019 the European Commission appealed against the judgement and opened the new case C-389/19 P (Court, 2021) which was decided on the 25th of February 2021. The court renewed its decision to annul the Commission Implementing Decision granting an authorisation for some uses of lead sulfochromate yellow and of lead chromate molybdate sulfate red. But in the second part the Court had to approve the request to maintain the effects of Regulation (EC) No 1907/2006 until the Commission is able to review the application for authorisation. The REACH Regulation allows the continued use of authorised uses after the expiry of their authorisation until a decision has been taken on the new application for authorisation. Therefore, the annulment of the contested decision with immediate effect recalled into force the previous authorisation for the substances.

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incentivise climate-neutral and sustainable products and clean production (e.g. fees, environmental taxes). All processes, all appliances using fossil fuels have to be put to test: is electrification in principle possible? If not, what other options exist? Only for those processes where neither electrification nor the use of thermal solar or geothermal heat is possible, hydrogen - produced from renewable energy - should be chosen. The cost gap of roughly 3 €/kg between green hydrogen and grey hydrogen produced from fossil sources like gas or coal should be bridged with state-backed contracts for difference (cost for hydrogen 2020: grey hydrogen 0.59–2.11 €/kg, blue hydrogen 1.77–2.20 €/kg, green hydrogen 2.7–6,5 €/kg, (IEA, 2020)). The International Energy Agency (IEA) estimates the cost of green hydrogen in 2060 with 1,1–2.79 €/kg. Today, many stakeholders promote so-called "blue" (steam reforming methane with CO_2 capture) or "turquoise" (methane pyrolysis with solid carbon residues) hydrogen, where the cost gap would allegedly be lower. But the methane leakages during extraction and transport of fossil gas have to be taken into account. A study from 2020 showed that extraction in the Permian Basin in the U.S., which is one of the biggest oil-producing regions and contributes > 30 % to the total U.S. oil production (Zhang et al., 2020) has a leakage rate of 3.7 %. With methane being a strong greenhouse gas, 82 times as powerful as CO_2 over a period of 20 years, methane emissions must be curbed as fast as possible. The United Nations Environment Programme (UNEP, 2021) highlighted this in their Global Methane Assessment in May. In addition to mitigation measures such as leak repair and a ban on venting and flaring, the demand for fossil gas and oil must decrease substantially. Of course, the task to phase out fossil fuels in the chemical industry is huge. In 2019, the German Chemical Industry Association (VCI) published a "Roadmap towards a greenhouse gas neutral chemical industry in Germany", modelling that the electricity demand of the chemical industry would rise from 52 TWh (Internetchemie, 2017) in 2013 to 628 TWh per year in 2050 (VCI, 2019), which is higher than the total electricity demand in Germany in 2020 (UBA, 2021). Coming on top of the increase in electricity demand in other sectors like heat and transport, these numbers are alarmingly high. It is obvious that business as usual with electrification of existing processes only is not sufficient. We need new approaches in the chemical industry. A useful tool would be the development of "renewable building blocks" that can be assembled in many ways serving different purposes and fully recovered at the end of the use phase. Today, we are using tremendous amounts of energy to crack fossil feedstock, synthesize and purify compounds, then create inseparable mixtures of polymers which in their majority are not recycled but end up in the furnace (at best) or in the ocean (at worst). To put it into perspective: German chemical industry used 20.8 Mio t carbon feedstock in 2017, 13 % of which were renewable feedstock (VCI, 2017). 18.1 Mio t of fossil feedstock to be replaced in Germany alone shows the imminent danger of depleting natural resources when fossil raw materials are substituted by bio-based feedstock. Therefore, in addition to a life-cycle analysis to ensure sustainability, we need new benchmarks for efficient production to implement the best available techniques. Polymers have become more and more complex in the last decades, making recycling more difficult. Rethinking polymer production by reducing complexity and limiting additives would boost recyclability and reduce demand for virgin feedstock.

3. **Ensure upstream and downstream producer responsibility.** The EU will adopt a *European Due Diligence Law* (EPRS, 2020) to cover supply chain management within the next years. Commissioner Reynders announced this law in 2020, the European Parliament adopted an initiative report in March 2021. Along the supply chain, producers will be accountable for violations of human rights, environmental standards and labour standards. This would put an end to hazardous substances prohibited in Europe being exported to third countries or hazardous waste being exported to the Global South for "recycling" without environmental or social standards. And on the supply side, this would ensure that the resource basis for all chemicals produced and used in Europe is ecologically sound and production respects human rights. Implementing an *Extended Producer Responsibility* (EPR) to products, product groups and waste streams would strengthen waste prevention, discourage the use of hazardous substances and improve recycling.

4. **Substitute hazardous substances wherever possible.** Regarding the journey from neurotoxic substances (lead) being added to fuel and thus widely distributed in the environment or highly bio-accumulative insecticides

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applied freely all over the world (DDT), no one would claim that nothing has changed in our judgement of hazardous chemicals. But still, problematic substances are present in toys, cosmetics, textiles, leather, and food contact materials. It is paramount to establish a toxic-free hierarchy of measures that follows the principle of safe and sustainable by design. By minimising the exposure and effectively substitute hazardous chemicals with safer alternatives, including non-chemical alternatives, the safe and sustainable by design principle would avoid production and use of hazardous substances where not essential. It is often claimed that cocktail effects of chemicals can hardly be precisely assessed. But this must not serve as an excuse for inaction! Instead, these effects should be addressed by implementing a mixture allocation factor in Annex I of REACH (European Parliament and European Council, 2006). And the upcoming revision of the *EU Toy Safety Directive* (European Parliament and European Council, 2009) can ensure that children are better protected from all hazardous substances.

5. **Adopt REACH+ to close dangerous loopholes and fully address plastics.** Amending REACH to include the registration of polymers is urgently needed. Although this is bound to be difficult due to the nature of polymers as mixtures of varying molecular weight, known adverse effects on the environment show that exemption is no longer an option. But not only polymers have escaped regulatory action for too long. Far too many substances that are persistent, mobile and toxic or very persistent and very mobile are still on the market, putting people's health and environmental integrity at risk. The legacy of DDT and PCBs which can be found in the Arctic and the deep sea should guide our action on harmful substances. Taking the precautionary principle seriously would require an early warning system to protect us from emerging issues, as well as a monitoring and reporting mechanism for unwanted effects of chemicals. Finally, the addition of energy and resource efficiency to assessment criteria for chemicals used for a specific purpose would make REACH fit for the Green Deal.

6. **Speed up and streamline the regulatory process – and no new paralysis by analysis.** "One substance – one hazard assessment" can avoid duplication of work. Risks, however, must be assessed and managed depending on the respective use and exposure. Formalising the *regulatory management option analysis* (RMOA) (ECHA, 2013) would lead to "paralysis by analysis" as a complicated process would have to be completed, where each and every use of the substance would have to be assessed separately, evaluating options to mitigate the risks of the respective use, before any action could be taken. Until finalisation of the RMOA process, the substance in question would remain on the market with no restrictions at all. Therefore, the hazard assessment should be done only once, and the substance should be put on the candidate list following the result. Essential uses can then be authorised if the risks are properly addressed and mitigated. Chemicals should be grouped both for assessment and for subsequent regulatory action in order to reduce avoidable bureaucracy, to speed up the regulatory process, to avoid regrettable substitution and to reduce animal testing. As a priority, the COM should adopt an action plan for PFAS, with the goal to phase out the general use of all 4700+ PFAS "forever chemicals", allowing only essential uses. Another striking example for missing regulatory action are *endocrine-disrupting chemicals* (EDCs). For these highly effective molecules which can lead to health problems at blood levels far below thresholds for toxicity, common hazard-based criteria should be defined and adopted across all relevant pieces of legislation as a basis for effective action to minimize exposure. Of course, this must include a ban for all consumer products such as toys, cosmetics, food contact materials, and textiles. And the Classification, Labelling and Packaging regulation (CLP) needs new hazard classes for EDCs and PBT (persistent, bio-accumulative and toxic) substances which must eventually be included in the Globally Harmonised System (GHS) on the global scale.

7. **Speed up the transition towards a clean and toxic-free circular economy.** The old model of "dig out – make - use - throw away" has to be transformed to a circular economy where waste is minimised and the bigger part of material and energy are recovered. Neither our environmental nor our climate goals will be achieved if we do not re-use precious - and limited - resources. This approach has positive side effects, such as reduction of the dependency on imports, or reduction of extraction and transport cost. Of course, high recycling rates are only possible with non-toxic material cycles. Consumers are rightfully demanding the same chemical safety

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standards for products made from recycled materials as compared to virgin materials. Therefore, the COM has to develop criteria for safe and sustainable chemicals which should not be limited to (eco-) toxicological properties, but include efficiency benchmarks (e.g. for energy use and waste) for production and processing of chemical products. The overarching principle can be summarised as "safe and sustainable by design". But it will only become effective if we set targets to reduce resource consumption which can in turn to develop economic instruments to incentivise resource-efficient and circular products. Prioritising waste reduction over recycling in the waste sector only leaves the potential of benign-by-design untapped.

8. **Ensure transparency and empower consumers to make safe and smart choices.** A demand for toxic-free and low-resource chemicals can only be created if their advantages are known and communicable. An user-friendly public information system on hazardous substances present in materials and articles, e.g. via a mobile application, enables consumers to make sustainable choices. This could be based on existing information, such as the SCIP (ECHA, 2021b) database, which could be expanded to include information about recyclability as well as content of recycled materials, energy demand in production and adherence to labour standards. Transparency is also needed for scientific information. For far too long, inconvenient results of studies have ended up hidden in drawers. To prevent this, all studies performed for registration purposes should be reported to the ECHA upon commissioning. All toxicological and ecotoxicological studies that are submitted by registrants and applicants should be made publicly available by ECHA.

9. **Embed EU chemicals laws in an industrial policy that fosters smart innovation.** The Great Transition will not be possible by safeguarding the status quo. The EU should therefore act to bring forward the future champions in industry. Instead of extending the lifetime of the fossil economy, we should embrace the opportunity to boost investment in future-proof technologies. This is the only way to secure the 1.2 million jobs in the European chemical industry. Energy and resource efficiency in production is key for being a front runner tomorrow. Japan's strict energy efficiency legislation which pushed industry to develop efficient technologies is a good example of achieving innovation by regulation. But while regulation is indispensable, research and education must not be neglected. Europe is not in the lead on digitalisation today and must catch up as soon as possible. But it is home to innovative SMEs, whose potential must be strengthened to develop new business models, incentivising safe and sustainable chemicals "Made in Europe".

10. **Ensure a level playing field for all.** EU manufactured products must fulfil high chemical safety standards; therefore, the same standards must also be in force for imported products. This is not only paramount to protect EU citizens against low-standard products from other places in the world. It is also vital to keep our producers competitive who have substituted hazardous, but cheap chemicals against more sustainable alternatives. To eliminate unsafe products from the market, more tests are necessary. The EU Commission can ensure this by making use of the powers granted under the *Market Surveillance Regulation* (European Commission, 2019c). Under this regulation, minimum standards for the number of samples, frequency, and conditions of the checks performed by the national authorities can be set. Testing alone will not solve the problem, of course. Considerable fines must be imposed on the producer and/or importer, when products are found in breach of EU rules. These measures are indispensable to ensure that REACH's leading role for ambitious chemicals legislation is not subverted.

2 The European Green Deal and the chemical industry

The main focus areas of the ***European Green Deal*** can be divided in eleven different parts (Figure 2). Most of them are directly or indirectly connected to the chemical industry.

One part is the ***Sustainable Products Initiative*** (European Commission, 2020a), which will revise the existing ***Ecodesign Directive.*** The *Ecodesign Directive* itself applies only on energy-related products today. In order to channel the transition of the chemical industry towards a circular economy, an overhaul and adaptation to include environmental aspects besides energy is paramount. The COM adoption of the *Sustainable Products Initiative* is planned for Q4 2021.

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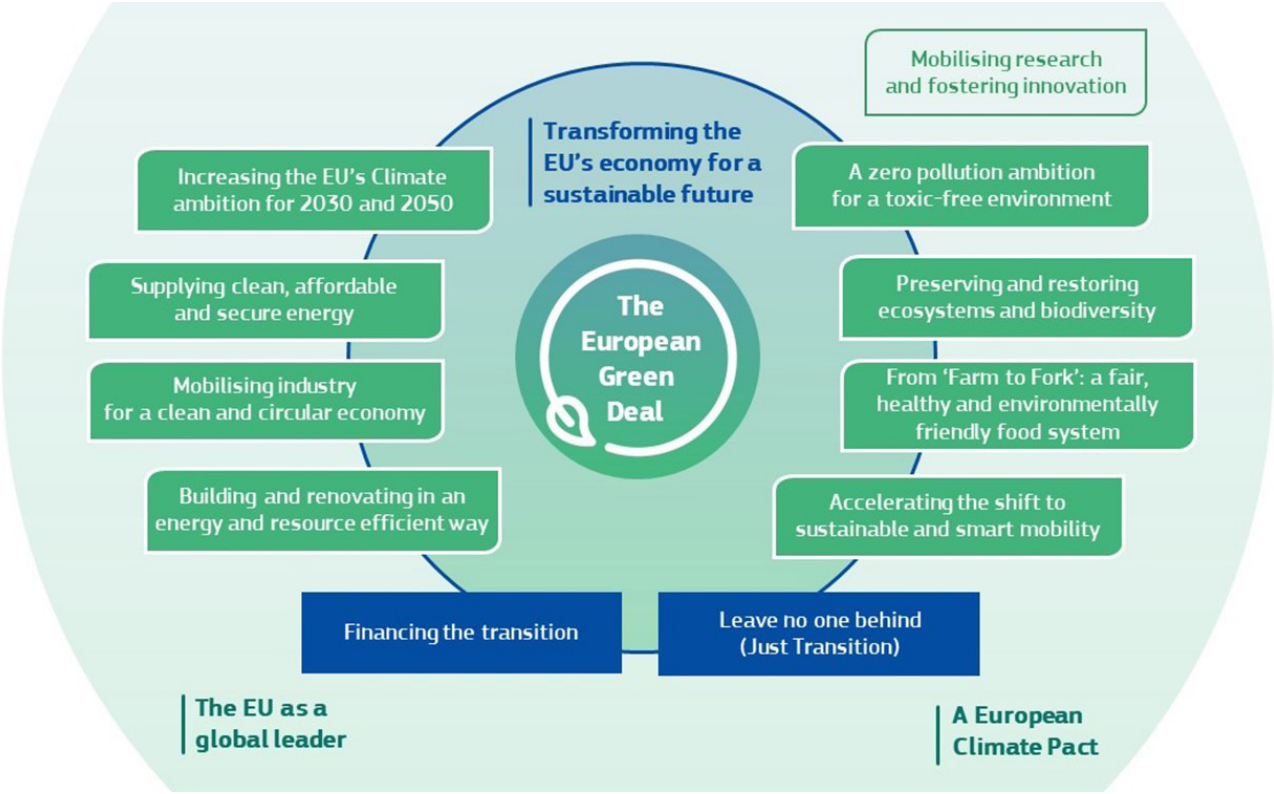

Figure 2 The European Green Deal (European Commission, 2019a).

On March 11th 2019, the COM adopted a ***Strategic Approach to Pharmaceuticals in the Environment*** (European Commission, 2019b). All phases of the lifecycle of pharmaceuticals as design, production, use and disposal are covered in this approach, unfortunately missing the opportunity to lay the main focus on the design phase. More than 20 years ago, Anastas and Warner (1998, 2021) published the "Twelve Principles of Green Chemistry" and promoted the importance of the active prevention of pollution through the innovative design of production processes and technologies instead of inefficient and extremely expensive end-of-pipe solutions. Today, even the most advanced wastewater treatment plants are not able to remove all pharmaceuticals from their effluent and most cities cannot afford to upgrade their existing plants to the so called fourth treatment stage. For production sites outside the EU, this is even more relevant. This is why we should focus on the **"benign by design" approach** (Laber-Warren, 2010) in which chemicals are designed smartly with the goal to reach the same activity with a lower impact on health and environment. Quantitative Structure-Activity Relationship (QSAR) analysis can be a great tool to design new pharmaceutically-active compounds (PhACs) or plant protection products which show better degradability leading to lower or no accumulation in the environment.

On November 25th 2020, the ***Pharmaceutical Strategy for Europe*** was adopted (European Commission, 2020b). A main goal is security of supply in the EU, but research and development for treatments for rare diseases and new antibiotics are also addressed. Sustainability of the pharmaceutical industry and the design of greener pharmaceuticals are mentioned in the strategy, but no regulatory action is announced as of today. A very effective tool to combat pollution through production of pharmaceuticals would be the inclusion of environmental standards like wastewater treatment in the principles of Good Manufacturing Practices (GMP), the minimum standard that medicines manufacturers must meet in their production processes regardless where they are taking place. These principles are monitored and audited in over 100 countries worldwide and are constantly refined by the International Council for Harmonisation of Technical Requirements for Pharmaceuticals for Human Use (ICH). Taking up environmental standards in GMP would ensure protection and a level playing field worldwide.

On May 12th 2021, the COM adopted the ***EU Action Plan: "Towards a Zero Pollution for Air, Water and Soil" (ZPAP)*** (European Commission, 2021). Part of this ambition is also

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the ***Chemical Strategy for Sustainability (CSfS)*** which was published on October 14th 2020 (European Commission, 2020c). PFAS and EDCs will be regulated in the CSfS. But the COM proposal still does not refer to a legally binding framework ensuring adherence to the polluter pays principle. One part of the ZPAP is the goal to reduce the amount of micro-plastic released into the environment by 30 % by 2030.

In total, the EU Green deal is a great toolbox to meet the climate goals, and to show the general direction for a transition towards a sustainable chemical industry. Compared to our "Action Plan for the Green Transition of the Chemical Industry" though, it lacks binding targets and mechanisms for legal enforcement.

3 Closing Remarks

The ubiquity of pollutants, from the deep sea to the Himalaya and the Antarctic ice shelves, should teach us a lesson. Neither the atmosphere nor the oceans are endless. The heritage of living hundreds of thousands of years in the ecological niche of "exploiters", gathering the resources of a landscape and moving on, strikes home on a humanity that has multiplied to staggering eight billion people and spread over the whole globe. And we have not only changed the visible countenance of the planet, loaded the atmosphere with CO_2 to a level not seen for millions of years, changed biogeochemical flows in unprecedented fashion and pushed hundreds of thousands of species to extinction. The long-term impact of manmade substances is impossible to evaluate today. The scientists compiling the concept of Planetary Boundaries (Rockström et al., 2009; Steffen et al. 2015) are not able to define a safe space for humanity concerning "novel entities", which encompass genetically modified organisms and artificial substances. From all what we know today, we leave our children and children's children a toxic legacy of reckless application of scientific knowledge and engineering competence. It may well be that archaeologists of the future will refer to our society as "the plastinizers" - if we succeed in limiting global heating and halting the sixth mass extinction at levels where civilisation as such can survive.

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