Circular EconomyPLUS:

Recommendations for action for a German Circular Economy Strategy

A contribution to the discussion on a circular economy for plastics

Moderated by [PlasticsEurope Deutschland e.V.]

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Preliminary remarks

The present paper has been created on the basis of intensive consultation between the group of experts listed below during the course of workshops that took place in the first half of 2022. Here, leading scientists and experts describe, on an interdisciplinary basis, a target picture for a circular economy with plastics up to 2045, and derive from this recommendations for action. At the heart of the discussions was the question about ways to significantly drive the circular economy with plastics forward through innovations and suitable framework conditions. The aim of this paper is to derive recommendations for action on a technical-scientific basis. It also aims to make a contribution to the discussion of the German Circular Economy Strategy targeted in the coalition agreement[1] – with the focus on the greatest possible sustainability in the circular economy of plastics. Other materials are not explicitly looked at.[2] In the coalition agreement, a bundling of raw material strategies as part of the national circular economy strategy is planned. Measures for a circular economy of plastics should therefore be summarised in a plastics strategy of its own.

The dialogue process was initiated and moderated by PlasticsEurope Deutschland e.V. Contributions to the recommendations for action were made by:

- **Prof. Dr. André Bardow**, Professor Energy and Process Systems Engineering at the Department of Mechanical and Process Engineering ETH Zurich, Switzerland.
- **Prof. Dr.-Ing. Christian Bonten**, Head of the Institut für Kunststofftechnik at the University of Stuttgart, Germany.
- **Dipl.-Phys. Michael Carus**, CEO nova-Institute for political and ecologic innovation GmbH, Hürth, Germany.
- **Prof. Dr.-Ing. Christian Hopmann**, Head of the Institute for Plastics Processing (IKV), RWTH Aachen University, Germany.
- **Prof. Dr.mont. Reinhold W. Lang**, Head of the Institute of Polymeric Materials and Testing, Johannes Kepler University Linz, Austria.
- **Dr. Markus Schopf**, Public Affairs Advisor.
- **Prof. Dr.-Ing. Dieter Stapf**, Head of the Institute for Technical Chemistry (ITC), Karlsruhe Institute of Technology (KIT), Germany.
- **Dr. Henning Wilts**, Director Division Circular Economy, Wuppertal Institut für Klima, Umwelt, Energie GmbH, Germany.

The process was moderated by:

- **Ingemar Bühler**, Managing Director PlasticsEurope Deutschland e.V. (PED).
- **Carolina Hupfer** M.Sc., Head of Economics, PED.
- **Dr. Alexander Kronimus**, Head of Climate Protection and Circular Economy, PED.

[1] Coalition agreement (bundesregierung.de)
[2] With composite materials, e.g. fibre composite plastics, links exist to other material cycles.

Summary

To effectively keep plastics – and thus carbon – in a cycle, virtually all the necessary technologies already existed in 2022. The value chain set about making a contribution to a climate-neutral circular economy by the year 2045. Nevertheless, we are at present still a long way away from this target and, as before, are coming up against a predominantly linear value chain.

The concept of a **Circular EconomyPLUS** described below aims for a holistic and sustainable system change. The distinguishing characteristic of a Circular EconomyPLUS compared with a conventional circular economy is the **input** into the material cycle **of non-fossil carbon on a production basis that is open to all types of technology**. Such an input of carbon dioxide (CO_2) and biomass can balance out unavoidable material losses from the cycle that need to be minimised, and in this way can enable a **completely closed** circular economy. The main aim of the Circular EconomyPLUS for plastics is to get by completely without the use of raw materials and energy from fossil sources – in other words, **complete defossilisation**.

The expert discussions have shown that the Circular EconomyPLUS model can address five urgent challenges of our time. It can: **1. Achieve effective climate protection through closure of the carbon cycle, 2. Contribute to sustainable development and the UN Sustainability Development Goals (SDGs), 3. Dispense with fossil resources and reduce dependence on imports of raw materials and reusable materials, 4. Offer better protection of the environment and the seas by curbing the plastic litter problem, 5. Provide additional innovation stimuli and increase the competitiveness of sustainable technologies for the use of plastics.**

For this it is decisive that we forget the approach of individual measures for certain products or applications and instead, with the help of the described technologies, bring about a holistic system change that addresses both the production and the usage patterns of plastics in the sense of effective waste prevention. This system change enables the carbon contained in the plastic system to move in the cycle and, as a result, to spare the climate and the environment, and to decouple value added from fossil resources. This is because the closed-loop circulation of carbon as a key component of plastics is decisive, on the one hand in the target vision, to stop its release as CO_2[3] into the atmosphere, and, on the other, to bring to an end the use of fossil raw materials as the source of carbon.

For this, we give the following **recommendations**:

1. With a Circular EconomyPLUS, carbon cycles are closed, a climate-neutral industrial production is achieved and the impact on the environment and the oceans is reduced. In order to achieve this effect in the next two decades, the recycling of – if at all possible – all plastic waste must be maximised and optimised in a way that is open to all types of technology. For this, products must be optimised with regard to their recyclability by so-called “Design for Recycling“.

2. Basically, it is important to avoid waste wherever possible, to reuse products and, at the end of their useful life, to recycle them mechanically or chemically. Simply incinerating plastic waste **without** separating and using the CO_2 emissions by CCU (Carbon Capture

[3] With the conventional incineration of plastic waste, the carbon contained in plastic is released into the atmosphere as CO_2.

and Utilisation) must be avoided. Nor can the dumping of plastic waste on a landfill site be reconcilable with the climate and sustainability targets.

3. The key technologies are **mechanical and chemical recycling**, supplemented by the use of **biomass** for biobased plastics and utilisation for thermal energy, essentially **coupled with CCU**[4]. The technology mix must be constantly optimised according to sustainability criteria such as ecological and economic efficiency criteria[5].

4. The short-term further development and scaling of all previously mentioned technologies must be priority fields of action. In the medium term, ‘Design for Recycling‘ will also provide further potential for long-life plastic products (e.g. plastics in the construction sector). Accompanying this, the carbon cycle must be completely closed through the **use of CO_2 with hydrogen** and increased utilisation **as sustainably certified biomass**.

5. In order for the described fundamental transformation of the economic operation to be successful, it is necessary to have an improved linking-up of the value chains, further development and scaling of the technologies described here, stimulation of circular business models through investment-friendly boundary conditions and initial lighthouse projects, as well as improved coordination of environmental, economic, industrial and research policy, with the aim of achieving a climate-neutral circulation of plastics.

6. A critical revision of political and legal boundary conditions is needed in order for a Circular EconomyPLUS to be successful. There are decisive influencing factors, such as target values for recycling, the availability of plastic waste, boundary conditions for key technologies such as innovative mechanical and chemical recycling processes, carbon capture and utilisation (CCU), and the use of biomass. In addition to this, the expansion of renewable energies and the setting up of a hydrogen economy is essential. Some of the aforementioned technologies are subject to innovation-hindering rules and regulations or are politically discriminated on principle (e.g. chemical recycling, which has to date not been fully recognised in the regulations), although they can make an important contribution to the climate-neutral circular economy. In addition to this, there is a need for new effective incentive and tracking systems, such as sustainability certificates and digital product passes. A national circular economy strategy will now aim to provide a holistic view of these influencing factors and key technologies.

[4] i.e. incineration of plastic waste coupled with electricity generation and the offtake of useful heat as well as the separation and utilisation of the CO_2 produced during the incineration by means of Carbon Capture and Utilisation (CCU).
[5] Taking account of the aspects: Planet, People, Profit.

I. Why do we need a circular economy?

With the Green Deal[6], the European Commission presented a concept in 2019 for the transition to a modern, resource-efficient and competitive economy, with which Europe was to become the first climate-neutral continent by the year 2050.[7] Without a circular economy, this target cannot be reached. Current studies point to the considerable greenhouse gas savings potential from recycling plastics – right the way through to potential negative emissions.[8]

At the same time, there is a **global plastic waste problem** because of the large volumes of plastic litter in the environment and especially also in the seas. The United Nations environment programme has therefore resolved to draw up a global and binding agreement against contamination of the environment with plastic litter.[9] The fact is that reusable materials such as plastic waste that is recycled as **secondary raw material** does not get into the environment. For this reason, a circular economy for plastics makes a contribution to solving the plastic litter problem. The recirculation of plastics and the plastic litter problem are also addressed by the European circular economy strategy and the plastics strategy.

Carbon is an essential component for life on Earth and for many products in daily use, such as pharmaceuticals and plastics. Even more, products made of plastics are needed to implement the transformation to greenhouse gas neutrality, for example as insulation materials for buildings and for building photovoltaic and wind energy plants, for protecting and preserving foodstuffs and for lightweight construction components in the transport sector. But there is also a downside: Firstly, for the production of plastics, fossil raw materials still account for the vast majority of materials being used as the source of carbon and hydrogen. Secondly, more than half the plastic waste produced in Germany is today still being incinerated, so that the carbon contained in the plastics is released into the atmosphere in the form of carbon dioxide (CO_2), where it acts as greenhouse gas. **The initially resulting contradiction between the necessary avoidance of fossil raw materials and CO_2 emissions on the one hand, and the necessary need for carbon as a raw material basis on the other can be resolved by a climate-neutral recycling of plastics and CO_2.** As a result, the **carbon contained in the plastic waste is, as far as is technically possible, recycled** and used for the manufacture of new products. The recycling of plastics is thus aimed **not** at **decarbonisation** (i.e. avoiding the use of carbon), **but** at **defossilisation**, i.e. avoiding and possibly ending for ever the use of fossil raw materials. This will assist not only climate protection but will also reduce the dependence on raw material imports and conserve primary resources.

A circular economy that is focused exclusively on material recycling is, however, **not enough to meet the climate targets.** Further requirements need to be met over and above recycling in order to allow long-term independence from fossil resources. The concept described below of a **Circular EconomyPLUS** targets a correspondingly holistic and sustainable approach.

II. Target vision: Circular EconomyPLUS

To achieve a Circular EconomyPLUS, the recycling of – if at all possible – all plastic waste must be maximised in such a way that it is **open to all types of technology** and optimised

[6] Climate protection measures by the EU and the European Green Deal (europa.eu)
[7] The Federal Climate Protection Act provides for net greenhouse gas neutrality for Germany by 2045.
[8] SYSTEMIQ-ReShapingPlastics-April2022.pdf (plasticseurope.org).
[9] Historic day in the campaign to beat plastic pollution: Nations commit to develop a legally binding agreement (unep.org)

according to eco-efficiency criteria. For this, 1) the amount of waste must be reduced), 2) products must be reused, and, at the end of their useful life, 3) must be mechanically or chemically recycled. Simply incinerating plastic waste **without** separation and utilisation of the CO_2 emissions via CCU[10] **must be avoided**. Instead, products must be optimised with regard to their recyclability through so-called "**Design for Recycling"**. The dumping of plastic waste on a landfill is not compatible with the climate and sustainability targets. A major distinguishing characteristic from the conventional circular economy is the **feeding into** the material cycle **of non-fossil carbon on an open-technology production basis**, which balances out unavoidable material losses from the cycle and thus enables a **completely closed** circular economy. Material losses can come about, for example, through secondary reactions in the production process, but also through errors in the distribution or disposal logistics, and must be minimised at the relevant process stage. Furthermore, the demand for plastics in Germany regularly exceeds the quantity of waste available because the service life of the plastic applications varies significantly. [11] To be able to close the gap between supply and demand in a climate-neutral and non-fossil way, the following raw material principles must be considered – in addition to the measures relating to waste avoidance and reuse:

1) renewable raw materials certified as sustainable[12] and
2) the use of CO_2 by means of CCU from fossil, biogenic and other (e.g. cement production, waste incineration) point sources and from the atmosphere, together with hydrogen produced in a climate-neutral way.

The functional principle of a Circular EconomyPLUS is shown in Figure 1.[13]

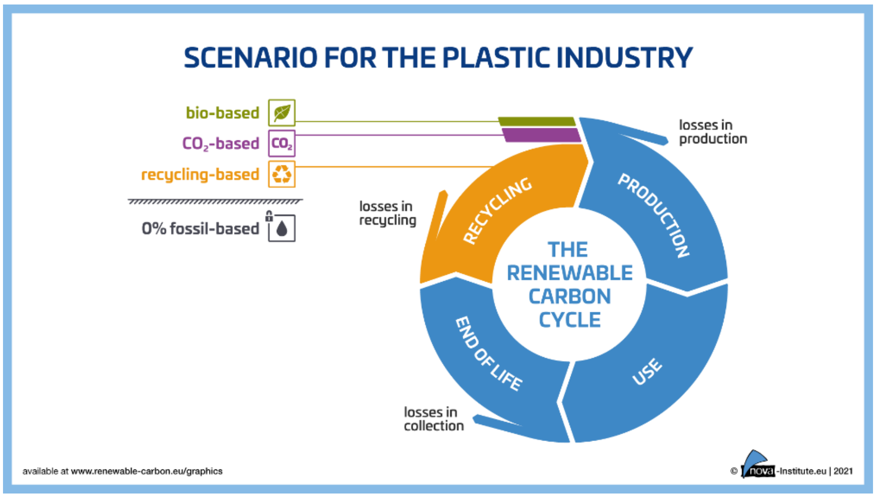

Fig. 1. Schematic representation of a Circular EconomyPLUS.[13] "RECYCLING" denotes the mix of technologies in the Circular EconomyPLUS.

[10] Waste incineration by means of Carbon Capture and Utilisation (CCU) enables the separation of CO_2 from the incinerator's exhaust gas and its circulation.
[11] The typical service life or useful life for e.g. packaging is a few days or weeks. For building materials it is several decades.
[12] e.g. according to ISCC-/ISCC-Plus certification, ISCC System (iscc-system.org).
[13] Modified according to nova-Institute for political and ecologic innovation GmbH, Download.

Fig. 2 illustrates the interlocking of non-fossil raw material principles, closed-loop circulation, and Design for Recycling in the Circular EconomyPLUS.[14]

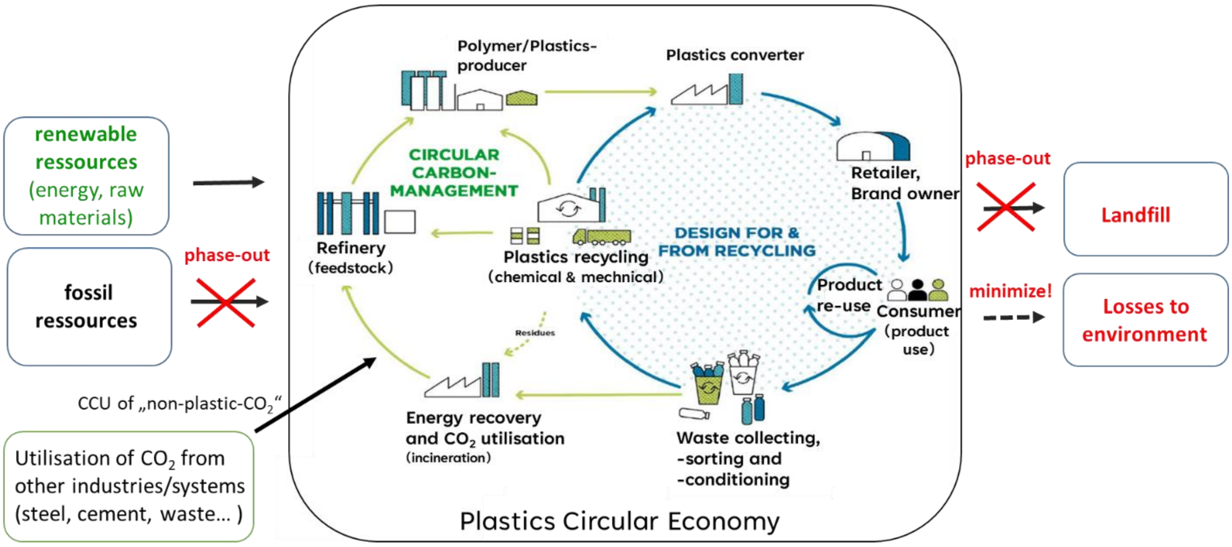

Fig. 2. Mechanisms of the Circular EconomyPLUS.[14]

In the target vision of the Circular EconomyPLUS, combinations of the raw material basis (Recyclate from mechanical/chemical recycling, renewable raw materials, CO_2) will also play a role in the production of plastics. This flexibility is necessary in order to obtain optimum solutions in line with the sustainability criteria; for this, instruments such as **flexible mass balances** are needed for recording and documentation.

The required energy supply into the cycle can come from the energy content of part of the materials that are present in the cycle. Over and above that, any necessary energy is, in accordance with the target vision of the Circular EconomyPLUS, produced **exclusively from renewable sources**.

Two necessary **key technologies are the processes of mechanical recycling and chemical recycling**, **which supplement each other. The technology mix and the prioritisation of the technologies must adhere to sustainability criteria.** For this, life cycle assessments (LCA) and product environmental footprints (PEF) must be used. **Mechanical recycling** generally requires the least amount of energy and financial resources, but, with mixed waste flows such as mixed residential waste, building and electrical/electronic waste, composites and lightweight shredder fractions from car production, it is now **nearing its limits**. Also plastics without thermoplastic properties[15] can so far not – or only to a limited extent – be recycled by mechanical recycling methods. Furthermore, the polymer chains of the plastics become shorter after several successive mechanical recycling cycles (polymer chain degradation), which leads to deterioration of the properties. Such recyclate material is then no longer suitable for all purposes: With numerous recycling cycles, “downcycling“ occurs. One

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[14] According to Lang R. W., Fischer J., Institute of Polymeric Materials and Testing, Johannes Kepler University Linz, Austria (2020), adapted by Lang, R. W., Schopf, M. (2022).
[15] So-called thermosets: e.g. polyurethane foams (used among other things for insulation material and mattresses), epoxy resins (e.g. insulation material for electronic components).

possible consequence is a supply bottleneck for higher-grade recyclate. **Chemical recycling** on the other hand produces recyclate in **virgin quality**[16] at higher financial cost and consumption of resources. Through the complementary use of mechanical and chemical recycling and thermal-energy technologies, coupled with CCU, synergies can be generated because of the different technology-specific advantages.

The main **characteristics of the target vision of Circular EconomyPLUS** are finally, in addition to the purely material recycling: (1) maintaining and even increasing the innovative capability of plastic products with tailor-made performance, (2) a significant improvement in the eco-balance and eco-efficiency of plastic products across all fields of application, (3) the wide-ranging use of renewable energy technologies at all process stages, (4) the defossilisation of the raw material basis, and (5) further contributions to sustainability such as the closing of technologically necessary water circuits. The innovation impulses come on the one hand from the constantly more complex social demands made on the sustainability and recyclability of materials, and, on the other, on the products made from them. Further innovation potential comes from the extensive possibilities to tailor the material properties of plastics to specific multifunctional requirement profiles. This applies especially to plastics that will in future be increasingly produced by renewable methods (i.e. non-fossil), but also to mechanical recyclate.

III. Status quo of the circular economy for plastics in Germany

In 2019, 6.28 million tonnes of plastic waste were produced in the Federal Republic of Germany. Of this, 3.31 million t (52.8%) was used for energy recovery, i.e. incinerated to extract the energy from the waste or as a substitute fuel (especially in cement plants), 2.93 million t (46.6%) was mechanically recycled. Chemical recycling methods were unimportant in 2019.[17] The dumping of plastics on landfills, with 0.04 million t (0.6%), no longer plays a role in Germany. In total, 1.95 million t[18] of plastic recyclate was incorporated in 14.23 million t of virgin plastic material. This represents a recyclate use of approx. 13.7%.[19]

Regulatory targets have been introduced to increase the use of recyclates. According to the requirements of the current European Packaging Directive, a mandatory packaging-related recycling quota of 55 mass percent applies for 2030. New recycling targets are expected as part of upcoming European legislative initiatives. Furthermore, the EU Single-use Plastics Directive targets a 30% recyclate content in PET bottles for 2030. This has been implemented accordingly in the German Packaging Act. Furthermore, the EU Commission has set itself the target of ten million tonnes of recycled plastic being used in new products by 2025. As of January 1, 2022, the German Packaging Act obligates the Dual Systems to recycle at least 90% of the plastic packaging involved in the system and to recycle 70% of this material mechanically. Recyclates generated by chemical processes are not eligible at this point due to the excessively narrow definition of "mechanical recycling" in the packaging sector. The

[16] Plastics produced from biomass and CO_2 also exhibit virgin material quality.
[17] In the EU, on the other hand, approx. 25% of the plastic waste is still being landfilled, 43% used for heat generation and 32% recycled: Plastic waste and recycling in the EU: Facts and figures.
[18] Of the 2.93 million t of plastic waste intended for material recycling, 0.58 million t was exported for recycling abroad (export surplus); in addition, there were 0.30 million t of losses in the recycling process that were used for thermal purposes and 0.09 million t export surplus of recyclate.
[19] Plastics flow analysis for Germany 2019.

definition of recycling in the circular economy legislation, on the other hand, does not exclude chemical recycling processes.

Chemical recycling is still in its infancy in Germany and Europe. Nevertheless, some plants are already in operation and a large number have since been announced. In Germany, a plant for the pyrolysis of used tires is currently in operation at the Pyrum company in Dillingen, which, among other things, supplies its cooperation partner BASF with pyrolysis oil as a raw material. In addition, a pyrolysis plant for plastic waste is being operated by CARBOLIQ in Ennigerloh. Covestro operates a pilot plant for the solvolysis of polyurethane foams in Leverkusen. In Spain, Plastic Energy operates plants in Almeria and Seville for the production of pyrolysis oil from polyolefin plastics and supplies customers in the chemical industry throughout Europe. In Geleen/NL, a first 10kt/y solvolysis plant for PET was started up by Ionica. OMV and Borealis operate a pilot pyrolysis plant in Schwechat, Austria. Further investments are also planned in Europe. For example, Dow and Valoregen have announced the start-up of a hybrid plant for mechanical and chemical recycling of plastic waste in Damazan, France, with an expected start-up date at the end of the first quarter of 2023.

IV. On the way to the target vision

Further development and scaling up of the necessary technologies

The main goal of the Circular EconomyPLUS for plastics is to completely eliminate the need for raw materials and energy from fossil sources - in other words, to achieve complete defossilisation.

The transformation of **today's still predominantly linear economy** into a Circular EconomyPLUS requires a **roadmap with intermediate targets** to achieve a 100% Circular EconomyPLUS by 2045 at the latest, i.e. complete defossilisation of the plastics cycle. A roadmap must maintain the competitiveness of the plastics industry, which is indispensable for the transformation to a climate-neutral economy, and consequently also offer **long-term and competitive career prospects** for those employed in the plastics industry and in the recycling sector, as well as for the next generation, in order to build up and pool the expertise required to achieve the goal.

Life cycle analyses (LCA, PEF) form the basis for the detailed technology and raw material mix. Achieving the target necessitates the following developments:

1) Mechanical and chemical recycling are **key technologies**. Waste that cannot be recycled mechanically or cannot be recycled to a high quality can be returned to the cycle through chemical recycling processes. This combination results in the highest recycling rates. Together with **Design for Recycling**, the further development and scaling of these technologies must be **priority fields of action**, also to stem the competition for use of the scarce resource of renewable electricity. This is because complementary mechanical and chemical recycling is significantly less electricity-intensive than the use of the alternative raw material sources, CO_2 and climate-neutral hydrogen. Unnecessary plastic applications should be avoided (reduce) and reusable applications should be promoted (reuse). The long-life plastics currently in use (e.g. in the construction industry) are in most cases not optimised for recycling. Design optimisation also of these long-lasting plastic products must tap further potential in the medium term.

2) The biomass content of 13% now used in the raw material mix of German organic chemistry should be further increased - depending on the availability of certified "sustainable" renewable raw materials.

3) At the same time, the carbon cycle is closed completely by **using CO_2 with green hydrogen**. The perspective necessary use of CO_2 together with hydrogen produced in a climate-neutral way, initially with CO_2 from point sources (also from the reuse of waste for heat and energy) and later additionally by Direct Air Capture (DAC) from the atmosphere, shows a very high consumption of renewable electricity. Therefore, the expansion of renewable energy must be advanced. The measures required for these technologies must also be immediately included in a roadmap for the purpose of accelerating the need for implementation and scaling. Plastic waste and solids remaining from the pyrolysis of recyclable materials can be returned to the cycle by heat/energy waste recycling with the decoupling of useful energy and the retention and use of the CO_2 produced during incineration by means of CCU.

Biodegradable and compostable plastics can also contribute to a solution. However, the respective life cycle analysis must demonstrate sustainability advantages compared to the use of non-biodegradable plastics when viewed from an overall systemic perspective.

Comprehensive life cycle analyses (LCA) as a guiding principle

Appropriate tailoring of the technology mix and raw material mix should be based on life cycle analyses (LCA, PEF). This is intended to measure the environmental consumption of a product or activity (e.g. a service) for production and disposal (or recycling), also including the entire useful life. It is crucial that it is not just the CO_2 footprint of a product that is taken into account, but an **absolute environmental footprint that is as comprehensive as possible**, which, for example, takes account of water and land consumption, soil erosion, influences on air quality, etc. Conventional LCAs often only allow relative assessments. Absolute analyses can be achieved perspectively by means of **Absolute Environmental Sustainability Assessments** (AESA), which are derived from the **concept of planetary boundaries**.[20] The technology and raw material mix for the Circular EconomyPLUS must accordingly be tailored so as to be optimised as far as possible, both ecologically and economically, to **holistic life cycle analyses**. Currently, the usage patterns for plastics and other materials are still far from this target picture.

V. Targets and investment incentives for an adequate supply of recyclate

The transformation to a defossilised economy must be accompanied by **mass balances** that prove the reduced use of fossil feedstocks. In addition, circular economy targets are needed. Targets for recycling must be open to all technologies. Specifically, the German “special path” in Section 16 (2) of the Packaging Act with regard to the target for mechanical recycling of packaging must be opened up to chemical recycling, i.e. designed to be open to new technologies. Furthermore, it is necessary to establish **output-based targets**, i.e. targets for the product-related use of recyclates, instead of input variables aimed at the recycling of certain minimum waste masses to be achieved. This can be implemented by means of dynamic and time-limited product-related minimum recyclate use rates. The ultimate goal is a complete circular economy based on renewable raw materials. This is because input-based targets take

[20] Bjørn et al. (2020), Steffen et al. (2015), Tulus et al. (2021).

into account non-recycled sorting residues and thus systematically overestimate the effectiveness of the circular economy. Targets for product-related recyclate use, on the other hand, can incite a sufficiently high recyclate quality. This creates a safeguard for the sale of recyclates based on innovative recycling technologies (i.e. complementary mechanical and chemical recycling). This in turn creates investment security and investment incentives. Accompanying this, incentives and targets for minimising waste (reduce) must be created and maintained. Once the complementary recycling technologies have been scaled up through investment, care must be taken, by looking at the spatial effect of the production plants, to ensure that no overcapacities are created in Germany and Europe.

For establishing circular business models, the **initiation of priority lighthouse projects** for the scaling up of new recycling and raw material technologies is required. This calls for **regulatory sandboxes, shortened and simplified approval procedures** and the **efficient link-up of different authority competencies**. In practice, the diversified authority responsibilities act as obstacles to project implementation - even if all parties involved are in agreement. Regulatory sandboxes allow regulatory relief for pilot projects in order to avoid regulatory barriers. In addition, a **framework for mass balances** is needed to record, document and present the recycled content in plastic products in a standardised way. A **flexible balance sheet allocation of recyclates** in products is necessary to advance the circular economy.

An adequate supply of recyclates necessitates accessibility to recyclable waste. This requires **digital product passes** and technologies such as watermarking to enable the traceability of plastic waste. This encourages optimum ecological recycling. In the context of the targeted technology mix to be optimised, this involves the best possible return of products for recycling (reuse) as well as the optimised allocation of waste or a waste stream to recycling or recovery processes (recycle).

VI. Targeted steering instruments

Levies, such as a plastics tax for financing the EU's own resources, can create targeted steering effects. However, this only applies if there are **no misplaced incentives for ecologically disadvantageous material substitution** of plastics, for example the replacement of plastic packaging by paper composite packs, which are normally less recyclable and heavier and thus causes more packaging waste and more CO_2 emissions during transport. In addition, wrong incentives to switch to materials with poorer packaging performance that can lead to increased food waste, for example, must also be avoided. A levy charged on the basis of putting materials into circulation, e.g. within the framework of the EU's own plastic funds, must therefore be collected across all materials in order to create a **level playing field for all materials**. Furthermore, the proceeds should be reinvested in the **setting up and expansion of a Circular EconomyPLUS**.

Extended producer responsibility for distributors of plastic products promotes effective waste collection. The effectiveness can be additionally increased by suitable incentives, e.g. by reducing license fees for waste collection systems in the event of significant recyclate use, and a bonus/malus modulation system depending on the recyclability of the plastic products ("eco-modulation" of fees, levies). This in turn requires generally applicable assessment criteria, for example for the recyclate content of products.

Furthermore, **innovative deposit and return systems** are conceivable in order to replace disposable packaging made of materials with a high environmental footprint with more efficient reusable packaging. The return systems should be organised on a nationwide basis, and prospectively on an EU-wide basis. To create transparency for consumers and encourage conscious purchasing decisions, a **digital recycling label** that is open to all technologies is needed for product identification. New business models can also have desirable steering effects: Innovative approaches such as **product leasing and return models** can help reduce post-consumer waste. To this end, regulatory obstacles to any business models, e.g. in the field of taxation, must be removed. Transferring **municipal waste incineration to the European Emissions Trading Scheme** would improve the relative economic viability of chemical recycling compared to purely thermal waste utilisation, thus stimulating an expansion of recycling.

VII. Market for secondary raw materials, carbon leakage protection

With the transition to an increasingly global Circular EconomyPLUS, every country can become a raw material supplier for climate-neutral hydrocarbons, since essential fundamentals (renewable energy, CO_2) are basically ubiquitous, albeit to varying degrees regionally. However, because of Germany's export-oriented industry, but at the same time limited supply of wind and solar radiation, and also the limited land area, a significant import demand of green (i.e. non-fossil-based) feedstocks and energy sources such as hydrogen, methanol, methane, ammonia, naphtha, and kerosene can be assumed for Germany. Maximising recycling can reduce this demand as an alternative source of raw material. Nevertheless, the remaining need for imports may result in a possible shift of value-added stages of basic chemistry to regions of the world with higher renewable energy conversion potential. To address these effects, a **national industry strategy** is needed **to accompany the transformation of the raw materials industry** that is necessary for a Circular EconomyPLUS. After all, **securing jobs and working locations** are also part of a sustainable circular economy. In addition, Germany as a technology location offers potential for **value creation through new business models** in the field of innovative circular economy technologies (e.g. chemical recycling, use of non-fossil raw material bases).

Globally, circular plastics compete with fossil-based products. There is thus a risk of **production being relocated to another site as long as globally comparable climate protection targets are not binding**. This effect, known as carbon leakage (hereafter referred to as " C_fL ", with the sub-f standing for fossil to emphasise the competitive situation between non-fossil circular and fossil-based plastics), is generally recognised and is addressed in European law, for example, by the free allocation of emission trading certificates under the European Emissions Trading Scheme.

One increasingly discussed model to counter C_fL is the formation of **climate clubs**. This could extend the framework conditions of the EU internal market, for example, to markets of the G20 group. However, the C_fL problem persists at the external borders of the extended market region. For this reason, **C_fL protection measures will continue to be necessary**. Any market mergers allow, over and above the C_fL protection, potential for **high market transparency for waste streams** (i.e., secondary raw materials) and recyclates, as well as uniform specifications and certifications. This, in turn, can lead to **economies of scale** in the hitherto rather small-scale waste management sector, can secure waste streams and sales markets, and can thus create **certainty for business models and investments**. **An efficient circular economy requires a large transparent internal market as well as foreign trade with waste**

as a raw material. However, foreign trade must be limited to **countries that have a sufficiently well-developed circular economy infrastructure** to prevent raw materials from escaping the cycle and to avoid incineration (without CCU), landfilling, and plastic in the environment. If these conditions are shown to be met, trade in plastic waste also contributes to a situation in which the waste is sent for recycling rather than purely for energy recovery within the country.

VIII. Summary: What needs to be done?

The expert discussions have shown that the Circular EconomyPLUS model can address five pressing challenges of our time: 1. Effective climate protection by closing the carbon cycle, 2. Contribute to sustainable development and the UN Sustainable Development Goals (SDGs), 3. Dispense with fossil resources and reduce dependence on imports of raw materials and recyclables, 4. Provide better protection of the environment and oceans by curbing the plastic waste problem, 5. Create additional innovation stimulus and increase the competitiveness of sustainable technologies for the use of plastics.

To achieve this, it is crucial that we abandon the approach of individual measures for specific products or applications and, with the help of the technologies and concepts described here, bring about a system change that addresses both the production and the use patterns of plastics in terms of efficient waste prevention. This will enable the carbon contained in the plastics system to be recycled, thus protecting the climate and decoupling value creation from fossil resources. To this end, we make the following recommendations:

1. With a complete circular economy in accordance with Circular EconomyPLUS, carbon cycles are closed, climate-neutral industrial production is realised, and the impact on the environment and the oceans is reduced. In order to achieve this effect in the next two decades, the recycling of, if possible, all plastic waste must be maximised and optimised in a way that is open to all types of technology (recycle). To this end, products must be optimised with regard to their recyclability by means of so-called "Design for recycling".

2. In general, the aim is to avoid waste as far as possible (reduce), to reuse products (reuse) and, at the end of their useful life, to recycle them mechanically or chemically. Simply incinerating plastic waste without separation and utilisation of CO_2 emissions by means of CCU is to be avoided. Similarly, landfilling of plastic waste is not compatible with the climate and sustainability goals.

3. The key technologies are **mechanical and chemical recycling**, supplemented by the use of **biomass** for bio-based plastics and thermal-energy utilization, definitely **coupled with CCU**. The technology mix has to be continuously optimised according to sustainability criteria[21], such as ecological and economic efficiency criteria.

4. The short-term further development and scaling up of all the above-mentioned technologies must be priority areas of action. In the medium term, "Design for recycling" will also open up further potential for durable plastic products (e.g. construction plastics). In addition, the carbon cycle must be completely closed by **using CO_2 with hydrogen** and by increasing utilisation **as sustainably certified biomass**.

[21] Taking account of the aspects: Planet, People, Profit.

5. In order for the fundamental transformation of the economy outlined above to succeed, there is a need for improved linking together of the value chains, further development and scaling up of the technologies described here, a stimulation of circular business models through investment-friendly framework conditions and initial lighthouse projects, as well as improved coordination of environmental protection, economic, industrial and research policy, with the aim of achieving the climate-neutral recycling of plastics.

6. A critical revision of political and legal framework conditions is necessary for the success of a Circular EconomyPLUS. There are crucial influencing factors, such as recycling targets, the availability of plastic waste, framework conditions for key technologies, such as innovative mechanical and chemical recycling processes, CO_2 capture and utilisation (CCU), and the use of biomass. In addition, the expansion of renewable energy and the establishment of a hydrogen economy are essential. Some of the technologies mentioned are subject to regulations that hinder innovation or are politically discriminated against on principle (e.g. the lack of full recognition of chemical recycling by the regulations), although they can make a significant contribution to a climate-neutral circular economy. In addition, new effective incentive and tracking systems such as sustainability certificates and digital product passes are needed. A national circular economy strategy should now provide a holistic view of these influencing factors and key technologies.

PlasticsEurope Deutschland e.V. is the association of plastics manufacturers in Germany. We are a trade association of the German Chemical Industry Association (VCI) and part of the Plastics Europe network with representatives in Brussels and in the European economic centres and capitals. Currently, more than 1.5 million people work in the plastics industry in about 55,000 companies throughout the Europe.

As a material, plastic is essential for sustainable living and for achieving climate protection goals. Whether wind turbines, energy-saving houses or e-mobility, high-performance plastics make it possible to save resources and CO_2. The plastics industry is undergoing a comprehensive transformation to the circular economy. The aim of the circular economy is to use plastics as efficiently and for as long as possible and then to recover and reuse them. For this reason, the entire life cycle of a plastic is taken into account from the outset: from raw material extraction through production, processing and use to recycling. The transformation to a circular economy requires determination, interdisciplinary thinking and action, and new ideas. To achieve this, it is important to have good interaction between different stakeholders in business, politics and a wide range of social groups.

To promote this interaction, Plastics Europe provides relevant expertise and innovative approaches to solutions. We want to present these transparently, discuss them and introduce them into political and social decision-making processes. Our aim is to understand challenges, ideas and criticism, and to be available to answer the questions of anyone who is interested.

Our association is in regular contact with representatives of politics and the media, and we engage in public discussions. All our activities are guided by openness, transparency and integrity. Our commitment is based on communicating and discussing fact-based information and arguments. At Plastics Europe, we are committed to this transformation and want to ensure a sustainable future for our member companies, partners and society at large. Our entire commitment is governed by our Code of Conduct for Responsible Lobbying.