Plastics Packaging in a Closed Loop

Potentials, Conditions, Challenges

acatech/Circular Economy Initiative Deutschland/SYSTEMIQ (Eds.)

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Summary

Between October 2019 and December 2020, the packaging working group of the *Circular Economy Initiative Deutschland* created a roadmap with the aim of achieving a Circular Economy for plastics packaging. **The members of the working group are representatives of academic institutions, leading German businesses and civil society organisations. They have proven experience in the packaging sector and cover the entire value chain** from design via production and use to reuse/recycling infrastructure. As a result, the working group, whose central findings are presented in this report, were able to take a maximally integrated approach to the subject. The report includes a discussion of the potential, barriers and possible trade-offs involved in a Circular Economy for plastics packaging, drafts a vision for 2030 and 2050 and outlines the development of policy recommendations for the central stakeholders. The members are thus creating the foundations for an enduring Circular Economy in Germany and beyond.

Background – significance of a circular packaging industry

Packaging performs important functions and modern life is inconceivable without it. However, higher levels of packaging consumption are also accompanied by an increase in waste volumes. **Plastics packaging,** in particular, has become a **highly charged social, political and environmental issue** since increasing volumes of plastics waste are ending up in the environment.[1, 2] Germany has effective collection, sorting and recycling structures in place and, as a result, such packaging waste does not get directly into the environment. However, the consumption of resources and resultant volumes of packaging waste are still on the rise, a new maximum being recorded in 2018. Plastics packaging in particular presents huge challenges. Over the last twenty years, the quantity of plastics packaging in Germany has doubled from 1.6 million tonnes (1998) to 3.2 million tonnes (2018).[3] On the other hand, even **in Germany with its reputation for efficient recycling,** the **mechanical recycling rates** for plastics packaging are comparatively low at "just" 47 per cent. Over half (approximately 53 per cent) of the recorded volume is thermally recovered, i.e. burnt in incinerators or waste-to-energy plants, or is sent for co-combustion, for example in cement production. **Only 10.9 per cent of the volumes of plastics processed in the packaging industry are recycled materials.**[4]

Given that Germany generates large volumes of packaging and waste and these volumes are set to rise further, **Circular Economy approaches have the potential to reduce environmental impact**. There are, however, no one-size-fits-all solutions because evaluating the sustainability of packaging solutions is complex, in particular due to the packaging's interactions with its contents. **Social and political debates** have set many positive things in motion but have also encouraged **activism** and offered opportunities to **raise political profiles** in ways which are not always helpful to the environment. There is accordingly an urgent need **to create an objective and well-founded basis for the debate** so that truly effective measures can be prioritised and the path to a Circular Economy for packaging in Germany smoothed – a Circular Economy which does not conflict with other sustainability goals such as climate protection.

Key results from the working group

Challenges identified

A lack of transparency and inadequate compatibility mean that the challenges in implementing Circular Economy approaches in the packaging industry are not only **within individual steps in the value chain** but also **across the entire value chain**. Examples of challenges in individual steps in the value chain are unsuitable packaging design which makes it impossible to reuse or recycle the packaging, the conflict between better sorting quality on the one hand and a faster and less costly sorting process on the other and, not least, high misplacement rates during collection. Examples of challenges spanning all steps in the value chain are the wide variety of packaging designs which are not tailored to the existing recycling landscape, a market mismatch between guaranteed demand for recycled material[5] and available

1 | See Jambeck et al. 2015.
2 | See Geyer et al. 2017.
3 | See Federal Environmental Agency 2019.
4 | See Conversio 2020.
5 | Recovered material which has been reprocessed into a finished product or a component for incorporation into a product. For the purposes of this report, recycled materials are taken to mean post-consumer materials. These are materials which have been produced by households or by commercial, industrial and institutional organisations in their role as end-users of a product and which can no longer be used for their intended purpose. Focusing on post-consumer recycled material is justified by the fact that the aim of closing resource loops in a Circular Economy is to ensure circulation between post-consumer and manufacturing.

quantities of the appropriate qualities as well as transnational differences between national regulatory objectives.

Vision for a circular packaging industry

Against the background of the stated challenges, by 2050 the packaging industry will have created closed resource loops and helped to increase material productivity (see section 3.3 on the vision for a Circular Economy) by making use of defossilised materials.[6] Packaging will no longer be considered disposable in a climate-neutral Circular Economy. **Potential solutions will be evaluated holistically** and will accordingly be subordinate to the Circular Economy hierarchy of the following **major principles**:

- **Avoiding packaging is the top priority**, providing the overall environmental footprint does not increase as a result (e.g. due to greater food waste if less/other packaging is used).
- All unavoidable packaging will be based on efficient and effective resource management to ensure that it is **usable, reusable and recyclable to a high quality for the longest possible period.**
- Material and product design will consistently **eliminate toxic effects** along the value chain and will ensure safe subsequent use.
- Where reasonable and feasible, **secondary materials or alternatives to a fossil-based primary material** will be used.
- All Circular Economy measures will have their **environmental footprint evaluated** in a life cycle assessment (LCA).

Modelling has revealed that **greenhouse gas emissions can be cut considerably in the medium and long term** if greater use is made both of mechanically and chemically recycled plastics waste and of reusable packaging. In comparison with a business-as-usual scenario, an increase in the use of mechanically recycled material **to 40 per cent by 2050 could save on average approximately 1.9 million tonnes of CO_2 equivalents (CO_2e) annually, while a proportion of 20 per cent from chemical recycling would save 1.2 million tonnes. Increased use of reusable packaging systems could save around one million tonnes of CO_2e emissions.** At the same time, however, the same modelling shows that, in the absence of additional measures, even in 2050 there would still be a substantial shortfall in achieving both climate neutrality and closed-loop management.

Examination of two specific case studies

Two case studies were examined in greater detail to validate and put flesh on the bones of the findings:

- high-density polyethylene (HDPE) detergent bottle;
- polyethylene terephthalate (PET) tray as cheese packaging.

In addition to their significance in volume terms, the two examples illustrate different circumstances in the current situation since they differ in terms both of packaging content (foodstuff versus cleaning agent) and their current recycling route (mainly mechanical recycling versus incineration). Bottles made from high-density polyethylene are among the types of packaging which, right across Europe, have longest been systematically collected, sorted and recycled. The bottle design has furthermore already very largely been optimised for easy sortability and recyclability. However, most of the resultant recycled materials are removed from the packaging market, used in other applications, for example in waste water pipes, and so lost to further lifecycles. The stringent food technology requirements applicable to cheese packaging complicate the recyclability of polyethylene terephthalate (PET) trays. Unlike HDPE bottles, almost no cheese packaging has yet been designed to be recyclable, since in particular the trade-off between food shelf life and a recyclable packaging design presents a major challenge.

The case studies also reveal that **considerable work on packaging recyclability** has been done in recent years but there is still potential for further optimisation in many areas. In addition, **packaging makes relatively little use of recycled material** because the necessary quantities of the material grades required for this purpose are not available. One reason for this are insufficient high-quality sorting and recycling capacities. The **investment required is unattractive to recyclers** since the mixed price they obtain for high-grade and lower grade recycled materials plus the compliance fee under Germany's dual system recycling scheme is insufficient to fund it. Such investment is moreover considered to be high-risk since the price for virgin material as an alternative to recycled material is too low and the voluntary pledges made by the consumer goods industry to use more recycled material in their packaging are an insufficient guarantee. Another reason for low levels of recycled material usage is that the only recycled material approved for food contact by the European Food Safety Authority (EFSA) is currently polyethylene terephthalate (PET) obtained from the deposit scheme for

6 | The term "defossilised material" is used in this report as an umbrella term for bio-based virgin and recycled material. These include all material alternatives to fossil-based virgin material. Despite the energy inputs involved in conversion, for which fossil energy sources are currently used, this term was selected in the light of the electricity mix being 100 per cent generated from renewables in 2050.

single-use plastic bottles. Further Circular Economy approaches are available for **individual products,** for example **zero-packaging sale or sale in multi-use packaging**. For instance, solid, highly concentrated detergents and personal hygiene products are available which use little or no packaging. Projects requiring a systemic approach and support by a critical mass, such as deposit return schemes for foodstuffs, are currently at best at the design stage.[7, 8]

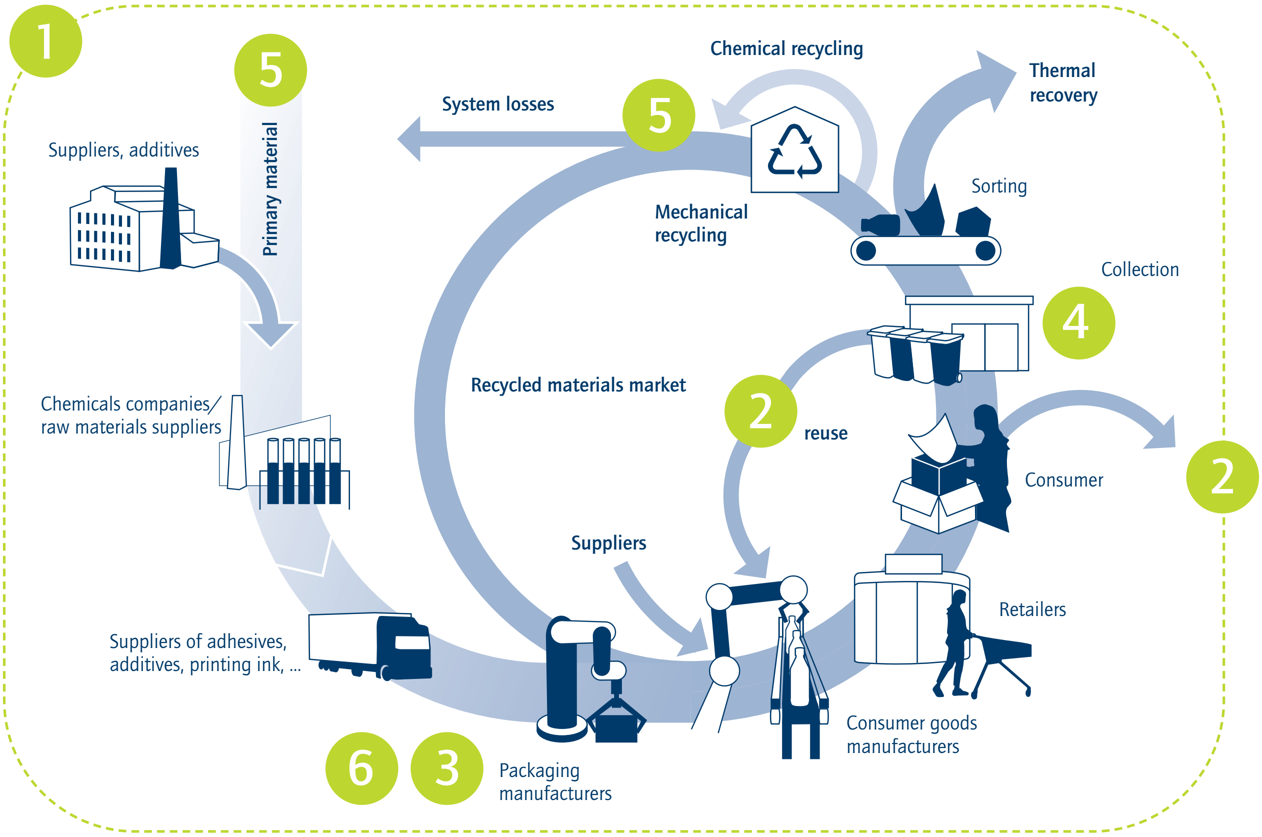
Policy recommendations

Transforming the packaging industry into a system based on circular value creation means implementing measures which take effect along the entire value chain. The working group has identified six lines of approach (see figure 1):

1. Creating comparability with a **generally accepted decision-making aid for packaging alternatives;**
2. Setting specific and binding **targets for avoiding packaging and packaging waste;**
3. Implementing **design for circularity and sustainability** by EU-wide packaging material harmonisation and accompanying economic incentives;
4. Harmonising **collection and sorting infrastructure** with separation by material and using new digital solutions;
5. Expanding **sources of defossilised materials** by modernising existing recycling infrastructure and further developing recycling technologies;
6. Boosting **demand for defossilised material** by expanding applications for recycled material approved by the European Food Safety Authority, setting standards for recycling and recycled materials and creating appropriate economic incentives.

The packaging working group of the *Circular Economy Initiative Deutschland* (CEID) is in agreement that a **circular packaging industry is a European task.** The policy recommendations set out in detail below are therefore not restricted to Germany, but also indicate how Germany as a central player in the debate should show the way forward for Europe.

7 | See Circolution n.d.
8 | See pacoon n.d.



1 Creating decision-making aid for packaging alternatives
2 Avoiding packaging and packaging waste
3 Implementing design for circularity and sustainability
4 Enabling better and harmonised collection and sorting
5 Increasing the supply of defossilised materials
6 Increasing the demand for defossilised material

Figure 1: Approaches to Circular Economy measures along the entire packaging value chain (Source: own presentation)

1. Creating a generally accepted decision-making aid for packaging alternatives

Given the **trade-offs between different sustainability goals** and different packaging alternatives, there is no universal way to determine which alternative is the "most sustainable". As a result, the decision as to which is the best packaging alternative for a product always has to be made on a **case-by-case basis** because the answer depends on many different product, process and market factors (e.g. on the requirements of the package contents, modes of transport, the number of possible reuses or the recycling infrastructure accessible under real-world conditions). However, **case-by-case evaluations are impractical** when it comes to helping companies decide which is the best packaging for their product. First of all, a life cycle assessment would have to be carried out for all potential types of packaging (and their potential infrastructure). Secondly, a case-by-case evaluation can only model the environmental potential of systemic changes to a very limited extent. **Research funding is therefore necessary to develop a holistic decision-making aid which is usable under real-world conditions**.

2. Avoiding packaging and packaging waste

In the past, gains in efficiency in packaging design have no longer been able to offset the constantly growing volume of plastics packaging waste. The primary objective of the Packaging Act (see § 1 Waste management objectives) of **avoiding packaging and packaging waste** has therefore not been achieved for years and will in future have to be prioritised. This entails a plan with **specific targets, measures, economic incentive systems and a defined timeline**. Such a plan could also include **independent**

monitoring bodies. Another step for avoiding packaging waste is to expand options for making further use of packaging. There is a need to further develop and test **reuse concepts suitable for large-scale application** which are environmentally advantageous and economically viable. Policy makers should provide appropriate assistance here, for example by **offering discussion platforms** and providing greater **startup support**.

3. Implementing design for circularity and sustainability

One major obstacle to closing the loop for packaging is that too little attention is still paid to packaging recyclability. Section **21 of the Packaging Act**[9] has introduced an important lever in this respect: **compliance fees** are intended to reward both recyclability and the use of defossilised alternatives to plastics. If this economic incentive is actually to be effective, however, there is a need for **specific minimum requirements** as to the impact such a bonus would have to have on the compliance fees. Such bonus incentives should additionally also include meaningful approaches to avoidance, such as reuse systems. Moreover, some issues regarding funding remain unresolved; one option might be **to set up a fund backed by private and public stakeholders**. Overall, there is a need to reduce the large number of packaging materials and material combinations on the market. **Minimum standards for EU-wide harmonisation of packaging materials and their components** should be defined in order to achieve this. Implementing minimum requirements for packaging in order to harmonise material streams could likewise be controlled by means of the compliance fees. Overall, the evaluation criteria for establishing **surcharges and discounts on licences** must be transparent. A **systematic approach must be developed** for this purpose which can be adapted as required while still safeguarding previously agreed fees. It is important for measures to remain technology-neutral; excessively rigid harmonisation must not, for example, rule out the use of innovative plastics material.

4. Enabling better and harmonised collection and sorting

Despite greater efforts having been made to make the dual system better known and more comprehensible, **the misplacement rate of post-consumer packaging waste is high**. On the one hand, this **reduces the quality of the recycled material** and, on the other hand, **considerable volumes of material**, which might potentially be recyclable, **fail to reach** the dual system and are instead incinerated by being disposed of with residual waste. Household sorting in Germany should in future proceed entirely **on the basis of the materials involved** rather than the level of funding of disposal. **Modern sorting technologies**, for example marker-based technologies or technologies based on artificial intelligence, should be further developed and put to greater use. Progress here is currently hesitant due to low levels of return. More use should be made of policy instruments, such as greater embedding of Circular Economy principles in **training,** while **mandatory labelling requirements for consumer information** or the **extension of mandatory deposits** to further product groups should be evaluated and, where appropriate, implemented.

5. Increasing the supply of defossilised materials

Significant **investment in recycling technology and infrastructure** is required to **modernise and upgrade existing plants** and **create the necessary increased capacity.** Further research is also required into which materials are particularly suitable for closed-loop management and how **the number of mechanical recycling cycles** can be increased. There is nevertheless a need in a closed Circular Economy model to offset material and quality losses in mechanical recycling with **virgin-grade defossilised plastics**. **Chemical recycling and bio-based plastics** may be the answer here if they offer a more environmentally sensible solution than fossil-based virgin material. Ensuring that this is the case means drawing up energy balances, investigating emissions, analysing health risks and determining the environmental footprint on an industrial scale. Given that the chemicals industry has a future feedstock problem to solve and recognising that huge international effort is being put into scalable chemical recycling processes, **Germany should be more than simply an observer.** Germany could instead forge ahead innovatively and point the **way forward to climate-neutral chemical recycling**. Gaining a better understanding of the purposes for which and volumes in which chemically recycled and bio-based virgin materials are required entails investigating what an **environmentally optimised and technically meaningful defossilised material mix** might look like. To enable applicational research into these issues and for example allow integrated sustainability analyses

9 | Packaging distributors are subject to mandatory licensing in a dual system. Licensing fees have previously in particular been defined by material type and weight. Section 21 of the Packaging Act now specifies that environmental aspects should also define the level of the licensing fees. The intention is accordingly to create incentives for recyclable packaging design and the use of recycled and renewable materials.

to be carried out, pure research funding could be complemented by also setting up a **real-world laboratory.**[10]

6. Increasing the demand for defossilised material

Defossilised material is in price competition with virgin material. As a result, especially in times of low oil prices, **economic incentives are necessary** in order to increase the use of defossilised material and create stable demand. The cost of fossil-based virgin material can be increased in a controlled manner by a general, ambitious **carbon levy,** while the cost of defossilised alternatives can be reduced by an appropriate **compliance fee bonus system** (see excursus "Thought experiment"). Defined **minimum proportions of post-consumer recycled material** would also help to stabilise demand for recycled materials and so create investment certainty for recyclers. Such a quota will have to be introduced progressively and be coordinated with available volumes of recycled materials of the appropriate grades. There are also regulatory obstacles to the use of recycled materials in a large proportion of primary packaging. **European Food Safety Authority (EFSA)** requirements currently specify that only recycled material from the deposit bottle material stream achieves food grade quality. However, there is a need to prevent any future drift of secondary material away from a functioning cycle into packaging for which there are currently no recycling options. In addition, mechanisms and strategies for having **further recycled materials approved as secondary raw materials for food contact** should be devised in future. **Safety requirements and standards for recycled materials** which are applicable across the EU should also be defined to simplify the use of these materials. Such common standards should ensure that recycled materials are always used in a specific quality for a particular product group and are produced accordingly. Clearly defined standards would moreover help to make demand more plannable and so ensure sufficient availability of recycled material of the particular grade.

The members of the packaging working group of the *Circular Economy Initiative Deutschland* hope that this report is a useful contribution to the dialogue in favour of a Circular Economy for packaging. The transformation is still at its outset and is dependent on further collaborative exchange. It is now up to all the various stakeholders from politics, business, academia and civil society to make a concerted effort to put the proposed policy recommendations into practice.

10 | Real-world laboratories are time-limited test beds for trialling innovations under real-world conditions. They are necessary because some technologies and business models are not entirely compatible with the existing legal and regulatory framework and, as a result, some latitude must be allowed. In addition to trialling sustainable technologies and business models, this approach also enables early regulatory learning in terms of test methods and approvals and the associated norms and standards. Not only the necessary regulatory adjustments but also approval procedures can be accelerated as a result, so enabling prompt introduction of new technologies and business models by breaking down market barriers. Such a test bed can also encourage a productive interchange between academia, business and civil society, for example to resolve issues of acceptance.

Project

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1 Introduction: Significance of the Circular Economy to packaging

Packaging performs important functions and modern life is inconceivable without it. It ensures hygiene and safety, extends product storage life, protects its contents from external influences and enables safe transport and use of the products. Packaging also provides space for necessary consumer information and performs a marketing function.[11] Packaging can therefore play a positive part in achieving the United Nations Sustainable Development Goals[12]. For example, it extends the storage life of foods and can so contribute to Goal 2: "Zero Hunger". By protecting its contents from contamination, packaging can, moreover, also contribute to Goal 3: "Good Health and Well-being". On the downside, however, improper handling of packaging can also jeopardise these very same goals, for example Goal 14 "Life Below Water".

Figure 2: Significance of packaging to the United Nations Sustainable Development Goals (Source: own presentation)

11 | See Gesellschaft für Verpackungsmarktforschung mbH/Denkstatt 2018.

12 | The 17 Sustainable Development Goals are policy goals of the United Nations which are intended to ensure global sustainable development in economic, social and environmental terms. They came into force on 1 January 2016 and are to be achieved by 2030.

The meteoric increase in packaging consumption and the consequent waste volumes are a problem. Thanks to the major advantages it offers, packaging is used on a large scale for foods and consumer goods. The consumption of packaging is rising continuously not only in Germany but also across Europe and worldwide.[13, 14, 15, 16] In Germany, this rise is primarily the result of general economic growth, but booming online sales, the trend towards smaller households, and more ready meals and takeaway foods are also playing a part.[17, 18, 19] Most packaging is designed for single use with a very short service life which means that packaging material very quickly becomes waste.

Plastics packaging in particular has become a highly charged social, political and environmental issue since, in addition to the rising quantities, greater inputs into the environment are being recorded. One prominent example of accumulations of plastics in nature are the constantly growing "plastic islands" in the world's oceans.[20, 21] Calculations suggest that in 2010 between 4.8 and 12.7 million tonnes of plastics waste entered the oceans, with a large proportion being packaging waste.[22]

A lack of collecting, sorting and recycling structures is a major cause of waste inputs into the environment. According to United Nations Environment Programme estimates, some three billion people have no access to controlled waste disposal facilities.[23] Human behaviour, however, also plays a significant role; even when available, facilities are not always used. Open landfill sites close to the coast, illegal disposal of waste into rivers leading into the sea and the wind all result in municipal waste getting into the oceans. The most visible impacts have so far been the negative effects on living conditions for marine animals and economic losses in the tourism and fishing industries.[24, 25]

Moreover, there has to date been little scientific knowledge of the toxicological risks and consequent long-term impact on ecosystems and human health. In line with the precautionary principle, however, the negative effects which are already known and relevant hypotheses justify taking comprehensive measures.[26, 27]

Germany has effective collection, sorting and recycling structures in place and, as a result, packaging waste does not generally get directly into the environment. Nevertheless, German packaging can still end up in the sea via a circuitous route, with the main cause, apart from inadequate or improper use of the systems, being waste export to countries without functioning recycling structures and with low environmental standards.[28] The new requirements of the Basel Convention will shut off this route from 2021 when a EU-wide export ban on plastics waste which is unsorted, uncleaned and mixed with other types of waste will come into force.[29] Packaging waste placed on the market in Germany should then stop adding to the littering of the world's oceans. Germany can, however, make a further contribution by becoming a role model and pioneer of properly functioning closed-loop management of packaging. This offers German industry the opportunity to open up new markets as a systems supplier for Circular Economy solutions. However, there is potential for optimisation within Germany too.

In Germany, the problem primarily resides in the large volume of packaging waste and the associated consumption of resources. Generating 227.5 kilograms of packaging waste per capita (in 2018)[30], Germany is Europe's number one waste producer. In addition, Germany's packaging consumption has been rising continuously from 14 million tonnes of packaging waste in 1998 to 18.9 million tonnes 20 years later.[31] Nevertheless, thanks to its high **recycling rates in comparison with other European countries, Germany is a showpiece** for packaging management.

Mechanical recycling rates for plastics packaging are comparatively low even in Germany with its reputation for efficient recycling. While the mechanical recycling rates for paper, cardboard, glass and metal are comparatively high (at over 85 per cent) due to their high sorting accuracy and high value

13 | See United Nations Environment Programme 2015.
14 | See Eurostat 2020.
15 | See Schüler 2020.
16 | See Lau et al. 2020.
17 | See Schüler 2020.
18 | See Hoornweg et al. 2013.
19 | See United Nations Environment Programme 2015.
20 | See Jambeck et al. 2015.
21 | See Geyer et al. 2017.
22 | See Jambeck et al. 2015.
23 | See United Nations Environment Programme 2015.
24 | See Newman et al. 2015.
25 | See World Wide Fund For Nature 2019.
26 | See Bertling et al. 2018.
27 | See Science Advice for Policy by European Academies 2019.
28 | See Bishop et al. 2020.
29 | See Federal Ministry for the Environment, Nature Conservation and Nuclear Safety 2019.
30 | The largest proportion, at 98.5 kilograms per capita, was paper. Plastics packaging waste came to 38.5 kilograms per capita.
31 | See Schüler 2020.

(especially metals), the material recycling rate for plastics packaging is 47 per cent in Germany (globally, the rate is below 10 per cent). Only 10.9 per cent of recycled material on average was processed to produce new packaging in 2019.[32] Against the background of elevated and still increasing packaging and waste generation in Germany, closed-loop management approaches involving new applications for plastics have the potential to reduce raw material consumption and negative environmental effects.

Evaluating the sustainability of packaging solutions is complex and there are no one-size-fits-all solutions. The low recycling rate for plastics also results in plastics being considered in themselves to be a particularly environmentally harmful material. However, an examination of life cycle assessments for various packaging concepts often reveals this sweeping judgement to be incorrect.[33, 34] Packaging cannot be divided into environmentally compatible and environmentally harmful solely on the basis of the material from which it is made. Instead, numerous sometimes conflicting criteria throughout the entire life cycle have to be borne in mind when it comes to evaluating sustainability. Accordingly, improvements in terms of conserving resources may have negative effects on other criteria, for instance by increasing energy input and consequently causing more emissions with a climate impact.

One guiding principle when selecting which packaging solution is environmentally preferable is the "Reduce – Reuse – Recycle" waste hierarchy. As section 3 explains in greater detail, this hierarchy is even today still too infrequently applied. But even this broad-brush prioritisation has to be reexamined in each specific context. This is because one particular aspect of applying the waste hierarchy to packaging is the interaction of the packaging with its contents. The packaging and its contents must in this respect be considered together and this system optimised as a unit. If omitting packaging results in greater food waste, for example, the overall environmental balance-sheet is negative.[35] If reuse systems are organised in such a way that heavy containers have to be transported over long distances, the life cycle analysis may even turn out in favour of single-use packaging.[36] Accordingly, in addition to the design of the packaging, further factors, for example maintaining functional requirements, transport and the actual post-use phase, must also be included in the consideration to enable a decision about which solution is the most suitable.

32 | See Conversio 2020.
33 | See Haupt et al. 2018.
34 | See Fehringer 2019.
35 | See Gesellschaft für Verpackungsmarktforschung mbH/Denkstatt 2018.
36 | See Coelho et al. 2020.

2 The packaging working group of the Circular Economy Initiative Deutschland

About the *Circular Economy Initiative Deutschland*

The *Circular Economy Initiative Deutschland* (CEID), funded by the Federal Ministry of Education and Research (BMBF), aims to initiate a dialogue about how the economic system can be turned around from a linear to a circular model.
The objective of the initiative is to develop a roadmap showing how the change towards a Circular Economy in Germany can be shaped so as to achieve long-term objectives of increasing raw material productivity. In addition, accompanying guidance in the form of policy recommendations will also be devised for all relevant stakeholders.
Driven by members from business, academia, politics and civil society, the *Circular Economy Initiative Deutschland* is a broad-based stakeholder dialogue (see Appendix D). The intention is to take a systemic approach to devise specific policy recommendations for circularity and solutions for the prevailing barriers.
The work of the *Circular Economy Initiative Deutschland* is divided between three working groups: while one addresses the potential for circular business models and digital technologies as drivers of innovation in general terms, the other two working groups focus on the specific functional systems[37] of traction batteries and packaging.
These two functional systems can be used as examples for outlining the transformation to a Circular Economy. While traction batteries exemplify a product with high-value materials and an extended service life, packaging (in particular primary packaging in the consumer goods industry) are examples of lower value, short-lived goods. These two functional systems therefore cover the range of differing challenges to the implementation of circularity and can act as models of the necessary changes across different economic sectors.

Germany has to strike a balance here: on the one hand, it is viewed internationally as a pioneer of technical solutions and serves as a role model for progressive political acceptance of circularity, on the other its consumption of packaging is very high and is continuing to grow. Against this background, the packaging working group is formulating a position on the role and contribution of all stakeholders in developing a Circular Economy for packaging in Germany.

2.1 Presentation of the working group

The work of the group benefits from the extensive participation of top-class participants from academia, business, politics and civil society. The packaging working group takes a cross-value chain approach and combines the specific outlooks of raw material suppliers, branded goods companies, retailers, recycling companies and system service providers, while scientists and representatives of civil society complement the working group with their specialist expertise.

37 | See Weber, T./Stuchtey, M. 2019: The idea of using functional systems as the level for considering the implementation of Circular Economy measures in value networks arose from the preliminary study carried out by acatech and SYSTEMIQ. In contrast with approaches focusing on materials, sectors or life cycles, making "functional units" the focus of consideration is beneficial and makes it possible to go beyond product optimisation and for example also consider alternative business models.

This open multi-stakeholder dialogue in particular is how the *Circular Economy Initiative Deutschland* packaging working group adds value. This inclusive approach makes it possible to shed light on incentives and benefits of closed-loop management of packaging materials between relevant stakeholders and so identify policy options along the entire value chain. In addition, systemic interactions between different circularity approaches can be revealed and mutually consistent policy recommendations formulated or measures derived for accelerating a Circular Economy for packaging in Germany and beyond.

Figure 3: Participants in the packaging working group (Source: own presentation)

2.2 Philosophy and objectives of the packaging working group

The packaging working group aims to contribute to the already broad public debate on the circularity of packaging. Specific challenges for the German packaging industry on the way to a Circular Economy are identified and solutions indicated by an in-depth analysis of two specific use cases.

The working group does not see the transition to a Circular Economy as an end in itself but instead as a way to achieve overarching sustainability goals. In order to avoid conflicts with these goals, for example with climate protection targets, the aim is to ensure maximally closed loops without additional anthropogenic greenhouse gas emissions: a climate-neutral Circular Economy, an industry with net zero greenhouse gas emissions.[38]

The working group's results include a vision for a circular packaging industry which discusses various circularity levers and identifies the need for action by all relevant stakeholders in order to achieve the objective of a climate-neutral Circular Economy by 2050 (see section 3). On the other hand, two representative case studies are used as the basis for a detailed examination of the current situation and the obstacles to the closed-loop management of packaging. The case studies, high-density polyethylene (HDPE) bottles for liquid detergents and polyethylene terephthalate (PET) trays for foodstuffs, pose different challenges which are discussed in greater detail in section 4.

This work thus complements other projects funded within the framework of the *Resource-efficient closed-loop economy (ReziProK)* funding initiative initiated by the Federal Ministry of Education and Research.[39]

2.3 Scope of the packaging working group

The working group's frame of reference encompasses the entire life cycle of packaging, starting from the raw material and the design phase through production and use to the collection and recycling of the packaging. All circularity strategies known to the working group will also be taken into account. Since the individual areas of activity are interdependent, a holistic view is important in order to be able to use and coordinate all possibilities for optimisation.

The focus of the packaging working group's work is on **primary packaging**. There are several reasons for this. Firstly, direct contact with the package contents in primary packaging places stringent requirements on functionality, both technical and regulatory. Since primary packaging also performs, for example, an information and marketing function for end customers, numerous secondary requirements must also be met.

The focus of the analysis is on Germany but measures and policy recommendations in the European context are also taken into account.

The working group primarily describes the challenges in transforming the value chain into a circular scenario and remains material-neutral when it comes to formulating the vision. The working group's aim is not to compare the suitability of different packaging materials and rank them accordingly. This is because questions about material substitution can only be considered in relation to the particular application, for example in the context of a life cycle analysis, in order to take overall account of packaging, transport and hygiene requirements.

In the in-depth work on specific applications in the closed-loop management of packaging, the focus in terms of starting material is on **plastics packaging** but the scope for solutions is material-neutral. This is attributable, on the one hand, to the low mechanical recycling rates already mentioned above combined with a simultaneous increase in the volume of plastics processed in the packaging industry.[40] On the other hand, in many applications plastics are inexpensive in comparison with alternative materials which are capable of meeting the same requirements.

38 | A systemically conceived and sustainable Circular Economy will make a comprehensive contribution to the EU target of net zero greenhouse gas emissions by 2050, allowing economic growth to be completely decoupled from resource consumption. It will ensure planetary limits are respected and sustainability goals achieved and help to increase quality of life and ensure equitable prosperity through collaborative, inter-company value creation and innovation.

39 | See Federal Ministry of Education and Research 2020.

40 | See Schüler 2020.

In particular, current low petroleum prices[41] exacerbate the challenges of keeping plastics packaging in a circular system because high-quality closed-loop management is often more expensive than virgin material.

Plastics are high-performance materials whose chemical and mechanical properties make them adaptable to a huge variety of requirements. In particular, given a suitable framework, they can be an advantage in terms of packaging sustainability.[42] The low weight of plastics packaging in comparison with other types of packaging means there is, for example, significant potential for energy savings during transport. Plastics packaging can also extend food storage life and so reduce food waste. It is thus highly probable that plastics will continue to play an important role in packaging systems in the future. In a complex environment of many and varied policy options, opportunities and threats, it now important to identify needs for action from a systemic perspective and to address them with suitable measures.

41 | As a result of the COVID-19 pandemic, petroleum prices fell considerably and, briefly, even into negative territory. The excursus, "The impact of the COVID-19 crisis on the packaging industry", in Appendix G provides a detailed examination of the consequences on the closed-loop management of plastics.

42 | See Haupt et al. 2018.

3 A climate-neutral Circular Economy for packaging in Germany

The working group has developed a vision for a climate-neutral Circular Economy for packaging by 2050. Starting from the current situation, existing system losses and limits are examined (see section 3.1) and existing obstacles addressed and categorised (see section 3.2). In order to state in concrete terms how a climate-neutral Circular Economy for packaging can be achieved, section 3.3 describes circularity strategies and models their potential for greenhouse gas emission savings in a circularity scenario for 2030 and 2050. The framework which would be required for achieving the circularity scenario is then discussed. The policy recommendations derived in section 5 are geared towards achieving the presented vision.

3.1 The current situation – where do we stand?

3.1.1 Material flows

In 2019, Germany processed 14.2 million tonnes of plastics, 24 per cent of which in the packaging industry.[43] Over the last 20 years, the quantities of plastics used in packaging have doubled from 1.6 million tonnes in 1998 to 3.2 million tonnes in 2018. Approximately two thirds of this volume was accounted for by product packaging which ended up in households and one third by transport and outer packaging.[44]

The following figure shows that Germany primarily processed polyethylene (both low-density (LDPE) and high-density (HDPE)), polypropylene (PP) and polyethylene terephthalate (PET), these polymers accounting for some eighty per cent of the total quantity. PET in particular is used almost exclusively in packaging.

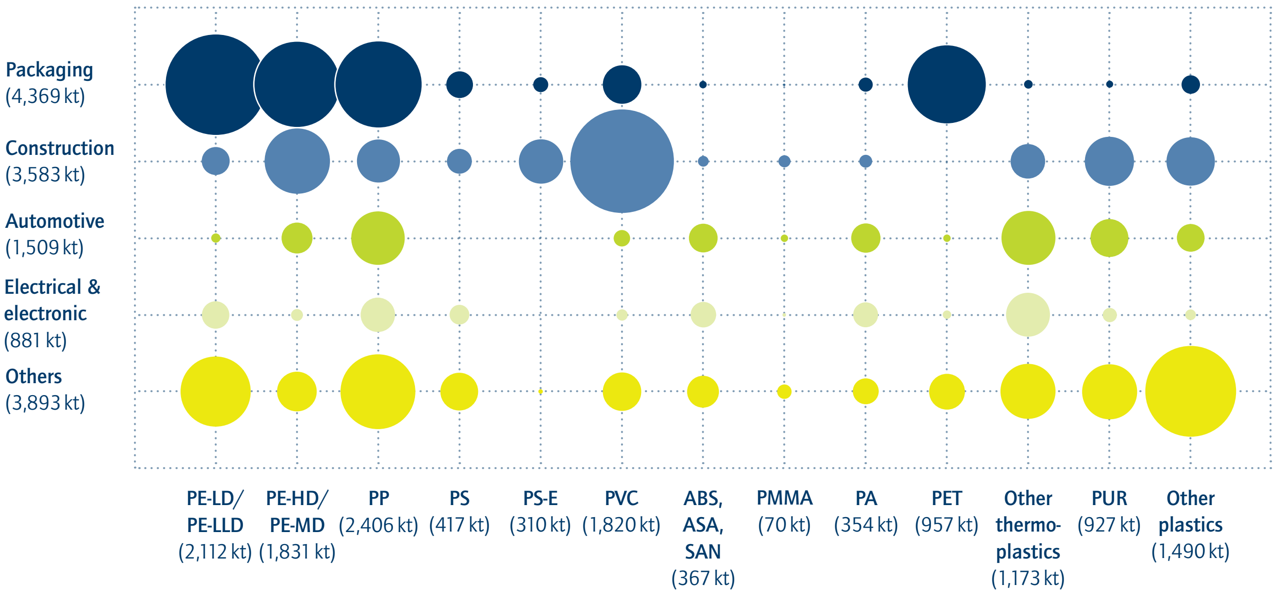


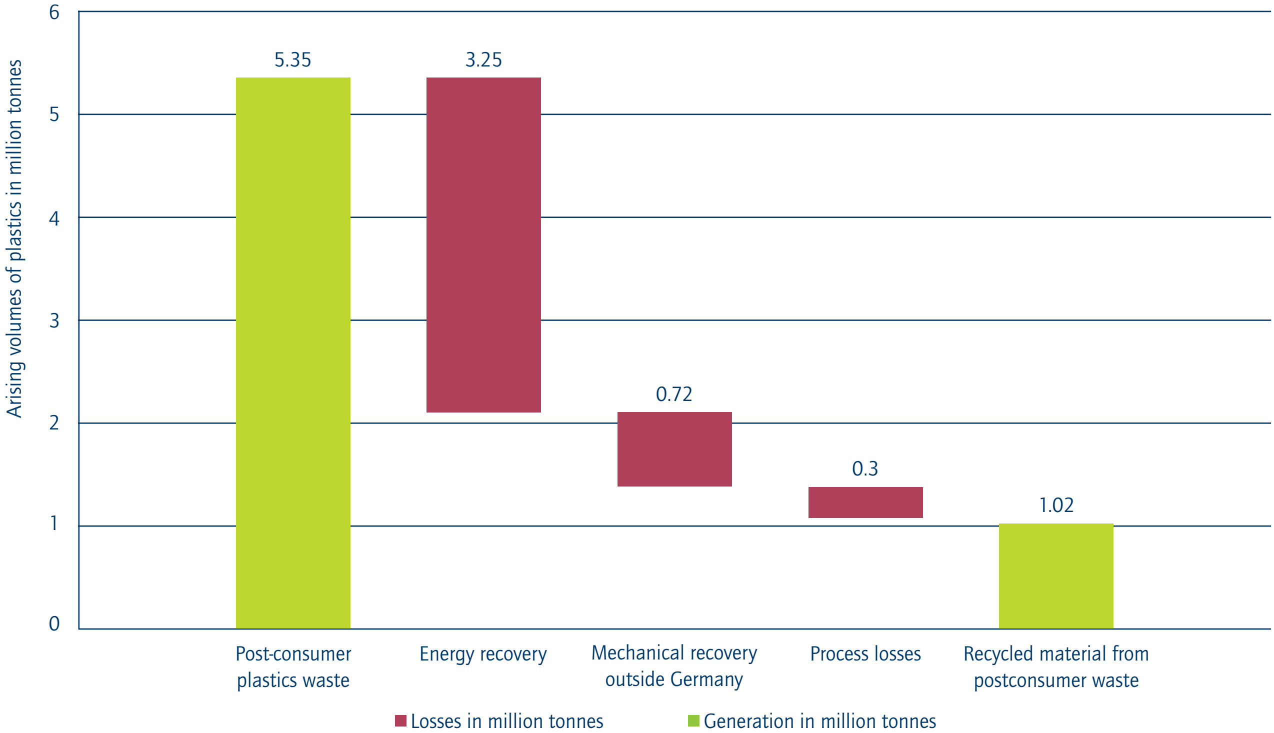
Figure 4: Type and proportions of plastics in various sectors (Source: Conversio 2020)

43 | See Conversio 2020.
44 | See Schüler 2020.

Of the quantities of plastics processed in the packaging industry in 2019, only some 474,000 tonnes or 10.9 per cent were recycled materials, so almost 90 per cent virgin material was used.[45]

When it comes to packaging system circularity, it is important to distinguish between the various options at the end of life. Germany generates approximately 6.3 million tonnes of plastics waste each year, some 5.35 million tonnes of which in household waste. In solely per capita terms, Eurostat data indicate that Germany's plastics packaging waste figure of 38.5 kilograms per capita is distinctly above the European Union (EU) average.[46] The major difference between the volumes placed on the market and those arising as waste may be explained, among other things, by the long service life of plastics in the construction sector, where deposits for the "urban mining"[47] of plastics are continuously building up.

Even when compared internationally, Germany has a very high recycling rate of over 99 per cent; Germany is one of the few countries in the world which has banned untreated landfilling. However, over half (approximately 53 per cent) of the recorded volume is thermally recovered, i.e. burnt in incinerators or waste-to-energy plants or sent for cocombustion, for example in cement works. Somewhat less than half (around 47 per cent) is mechanically recycled. If only post-consumer plastics waste is considered, the amount recycled in Germany is halved due to exports and processing losses. Ultimately, a quantity of just over one million tonnes of post-consumer recycled



* Due to the small volumes involved, the graph does not show losses due to landfilling (~0.03 million tonnes), feedstock recycling (~0.01 million tonnes) and export surplus (~0.01 million tonnes)

Figure 5: Losses in recycling post-consumer plastics waste in 2019 (Source: own presentation, data from Conversio 2020)

45 | See Conversio 2020.

46 | See Eurostat 2018.

47 | Urban mining refers to the recovery of materials from durable items such as buildings or infrastructure when they come to the end of their useful life.

material[48] is available, which amounts to just 7.2 per cent of the initial quantity of plastics processed in Germany of around 14.24 million tonnes. In addition, a large proportion of this originates from single-use PET containers recycled under deposit schemes. A further 6.7 per cent of the initial quantity is accounted for by recycling industrial plastics waste. The following figure illustrates the losses at the various stages of the recycling process.[49]

3.1.2 Policy framework

These developments are offset by a number of measures which have already been set in motion by policy makers (in Germany and at European level) in order to pave the way for a Circular Economy. This legislative framework alongside voluntary pledges from industry define the trajectory along which the entire plastics and packaging industry is currently developing its strategic market position. The following paragraphs provide an overview of the current situation, which simultaneously defines the field of action and provides a tailwind for the transformation.

At the **European level,** on the basis of the Circular Economy Action Plan published by the European Commission in 2015, the European Union (EU) adopted the Plastics Strategy in 2018.[50] The EU Plastics Strategy comprises numerous measures and objectives which are intended to enable circular management of plastics and packaging.

Specifically, by 2030, all plastics packaging placed on the EU market should be reusable or recyclable. With the adoption of the EU Packaging and Packaging Waste Directive 2018/852,[51] new material-specific recycling quotas have been set. By 2025, 50 per cent of plastics packaging and 65 per cent of packaging waste are to be recycled. By 2030, the quotas will increase to 55 per cent and 70 per cent respectively. In addition, from 2020, stricter rules for calculating the fulfilment of targets are set to ensure that country-specific progress is transparent and comparable.

As part of the EU's Ecodesign Work Plan 2020 to 2024, the Ecodesign Directive 2009/125/EC is to be harmonised with Energy Labelling Regulation (EU) 2017/1369.[52] In addition, consideration is being given to ecodesign requirements which are intended to promote the recyclability of plastics.

The EU Single-use Plastics Directive stipulates that polyethylene terephthalate (PET) bottles should consist of at least 25 per cent recycled material by 2025 and of at least 30 per cent recycled material by 2030. Moreover, trade in various single-use products such as plastic plates and plastic drinking straws will be banned from 2021. Furthermore, 77 weight per cent of the waste from single-use plastic items is to be collected separately by 2025 and plastics manufacturers are to be made responsible for collection and cleaning.[53]

The EU Directives are being transposed into corresponding legislation at the **federal level** in Germany. The new Circular Economy Act (KrWG) transposes the EU Waste Framework Directive into German law and comprehensively modernises existing German waste legislation. The purpose of the Act is to promote a Circular Economy in order to conserve natural resources and to ensure that waste is managed in an environmentally compatible manner. The central principle of the Act is the waste hierarchy.

In addition, the Packaging Act, which supersedes the Packaging Ordinance,[54] came into force in Germany in 2019. The Packaging Ordinance was a statutory ordinance which had been issued on the basis of section 24 of the KrWG. The Packaging Act, on the other hand, is now on an equal legal footing with the KrWG, i.e. at the same hierarchical level. The Packaging Act specifies a recycling rate for plastics of 58.5 per cent. From 2022, the rate will rise to 63 per cent. These rates are well above EU regulations and are an ambitious target, in particular with regard to the changeover in the method of calculation. At present, recycling rates in Germany are calculated on an input basis.[55] Changing the calculation method to an output basis would reduce Germany's plastics recycling rates by approximately 4.5 to

48 | According to DIN ISO 14021: 2016-07, post-consumer recycled material is the material which is generated by households or by commercial, industrial and institutional organisations as end-users of a product and which can no longer be used for its intended purpose. This also includes material returned from the supply chain.

49 | See Conversio 2020.

50 | See European Commission 2018b.

51 | See European Union 2018.

52 | See European Commission 2019b.

53 | See European Union 2019.

54 | See Bundesanzeiger 2017.

55 | The input calculation method measures the amount sent for recycling from a sorting plant. Amounts which cannot be materially recycled but are instead incinerated are not deducted from the reported rate. According to the amendment of the European Waste Framework Directive, this calculation will in future be made on an output basis throughout Europe. Work is currently under way on the specifics of this output-based approach.

12 per cent.[56] This changeover could reduce Germany's plastics recycling rate targets (63 per cent from 2022), which are calculated on an input basis, to below the EU targets (55 per cent from 2025) since the latter are calculated on an output basis.[57]

Furthermore, the Packaging Act obliges initial distributors, manufacturers and importers to guarantee nationwide take-back and recycling of packaging waste and to join a dual system. Germany's newly created Central Agency Packaging Register ensures that all packaging is licensed. The compliance fees paid to the dual systems by packaging distributors for recycling their packaging are additionally linked to the recyclability of the packaging. This obligation to structure compliance fees on an environmental basis is a new instrument in waste legislation which is thought to have considerable potential for steering packaging solutions in a more sustainable direction. The practical form this obligation will take is, however, still at the planning stage.

Section 33 of the KrWG furthermore provides a waste prevention programme which aims to decouple economic growth from waste generation.[58] This is updated every six years. The main criticism of this programme, however, is that it does not contain binding targets. In order to implement the product responsibility set out in section 23 KrWG, the Packaging Act also aims to achieve a proportion of at least seventy per cent multi-use beverage packaging for all bottled beverages.[59]

The **industry** itself is pushing ahead with further activities, often at the urging of representatives of **civil society**. For example, 175 organisations from industry and academia together with government representatives are participating in the EU-wide *Circular Plastics Alliance* voluntary pledge campaign. The intention is to implement the target enshrined in the EU Plastics Strategy of processing ten million tonnes of recycled plastics by 2025.[60]

As part of the *New Plastics Economy Global Commitment* initiative by the Ellen MacArthur Foundation, 450 organisations which produce 20 per cent of the world's plastic packaging have committed to reducing plastics consumption and promoting its circularity.[61] In line with this, cross-sectoral, national Plastics Pacts in the United Kingdom, France, the Netherlands, Poland and Portugal are formulating specific goals and measures to adjust the use of plastics and packaging in the interests of a Circular Economy. There is also a *European Plastics Pact,* in which Germany is also involved.[62] Legislation has furthermore been passed for example in France, Portugal and Denmark which, among other things, taxes the use of single-use plastic bags.

3.2 Existing challenges in the current situation

As described in section 3.1, system losses can be observed at various steps of the value chain. The causes can be divided into two categories:

1. Lack of transparency and inadequate compatibility in the overall value chain and
2. Gaps within individual steps in the value chain.

Addressing the first category involves orchestrating all the links in a Circular Economy in such a way that as much material or resources as possible can be kept in the cycle. Addressing the second category involves strengthening individual links in the chain. These two categories are explained below in greater detail.

3.2.1 Lack of transparency and inadequate compatibility in the overall value chain

Successful cooperation between all stakeholders along the value chain requires a **common objective** from which a common approach is derived. Today's system has no such common objective, each step in the value chain and each stakeholder instead pursuing their own rationale for optimisation.

Packaging is today usually designed and produced individually for each application. This means that packaging manufacturers must take account of specific functionalities defined by the requirements of the package contents while at the same time keeping an eye on manufacturing and filling costs in a highly diverse processing industry; it is the machinery manufacturers here who determine the potential for differentiation. The external design of a package, the material selected and how it is

56 | See Schüler 2013.
57 | See Obermeier/Lehmann 2019.
58 | See Federal Ministry for the Environment, Nature Conservation and Nuclear Safety 2013.
59 | See Bundesanzeiger 2017.
60 | See Circular Plastics Alliance 2019.
61 | See New Plastics Economy 2019.
62 | See European Plastics Pact 2020.

shaped and printed moreover play a major role in product marketing.

This market dynamic in what is a hugely fragmented, margin-driven industry results in **many different types of packaging** being placed onto the market. This results in a great variety of materials and consequent problems in separating material composites and sorting the materials. Sorting into numerous pure fractions cannot be done economically. This variety of materials also means that consumers have problems in assigning the varied packaging waste to the correct disposal channels, which are in turn differently configured within the catchment areas of the individual dual systems. The diversity of materials means that the secondary raw materials from mechanical recycling are predominantly of indefinable quality. As a result, their "second" use is reduced to a few applications which can cope with fluctuating quality and low technical requirements. Because the packaging placed on the market is the result of optimisation steps in terms of functionality and manufacturer design, it is not aligned with, let alone optimised for, post-use process steps, such as sorting and recycling. This is because, under today's system, it is impossible to imagine how all the participants in the value chain might benefit from system optimisation, i.e. there is no (monetary) incentive.

To make matters worse, waste legislation and the expansion of recycling structures are largely decided at the national level while the packaging industry acts internationally and consumer goods markets are global. Accordingly, not only national objectives but also **transnational differences** apply to the development of a packaging recyclability strategy, specifically with regard to packaging design and the corresponding recycling infrastructure. There is a lack of internationally uniform concepts for evaluating and auditing processes from a Circular Economy standpoint and thus also of uniform rules for extended producer responsibility. These national differences in the creation of a legal framework present a major challenge to international corporations, as they have to optimise their packaging for each sales market according to different criteria.

At the same time, describing uniform objectives (whether national or international) is a very difficult task. Packaging recyclability is today often assessed on an individual product basis without taking the overall system into account. Holistically evaluating a solution's circularity entails focused data and an awareness of how the various levers affect one another, neither of which are available. Potential interactions, for example between carbon emissions and closed-loop management of the material, require a uniform basis for assessment in the form of a life cycle assessment which, however, must by definition be carried out on a case-by-case basis and may involve considerable cost.[63] This has already led to numerous "Design for Recycling" approaches and guidelines for packaging but, depending on the system boundaries applied, these follow differing rationales for optimisation and so do not map uniform objectives.

The **lack of data** is also a problem from an economic standpoint, there being no information system capable of holistically mapping the individual steps in the value chain. For example, it is accordingly difficult at present to describe recycling rates and recycled material usage rates in the absence of a uniform basis for material reconciliation. Recyclers cannot optimise plants in line with anticipated inputs if no information is available about the volumes placed on the market. The purchase and sale of secondary material on the corresponding raw materials markets are also complicated by inadequate transparency regarding quality and properties (or a lack of corresponding product specifications). Purchases of recycled materials are therefore costly individual purchases. This not only results in high transaction costs but also reduces planning certainty for all the stakeholders involved. In some cases, necessary interfaces between steps in the value chain do not yet exist, and there is insufficient transparency to design them effectively.

3.2.2 Gaps within individual steps in the value chain

In addition to the systemic incompatibilities, there are also challenges in or between individual steps in the value chain.

Packaging recyclability must be taken into account right from the **design phase**. There is a need to develop potential new solutions for the purposes of the waste hierarchy. Avoiding packaging is, for example, the top priority. Where packaging is unavoidable, it should first be checked whether the packaging can be reused; for example, multi-use systems (where supported by a positive life cycle analysis) can reduce waste volumes.[64] While these approaches are already being pursued by individual

63 | See Blum et al. 2020.

64 | This also arises from Directive (EU) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment. The Directive promotes circular approaches which give priority to sustainable and non-toxic reusable products and reuse systems rather than to single-use products, aiming first and foremost to reduce the quantity of waste generated. Such waste prevention is at the pinnacle of the waste hierarchy enshrined in Directive 2008/98/EC of the European Parliament and of the Council.

branded goods companies and retailers, they are not widely established or could still be expanded. One reason for this is the higher costs of an in-house take-back system, which is not economically viable for individual brands. Further factors to be considered right from the design phase are the subsequent separation of the individual packaging components by consumers, the separation of material composites or the use of alternative raw materials.

Consumers can play a vital role here since their needs and requirements can decisively influence the demands placed on the value chain. Sustainable **purchasing decisions** can be promoted by reducing non-sustainable options.[65] Consumer preferences might also conceivably be nudged towards a Circular Economy for example by increasing acceptance of recycled packaging (possibly even with a poorer appearance), by multi-use packaging or alternative materials made from renewable raw materials or even by entirely packaging-free products (where supported by a positive life cycle analysis). Increased acceptance of or demand for standardised package shapes or sizes may also be beneficial if recyclability can be increased as a result.

A further challenge arises at the **transition from the use phase to the post-use phase** of the packaging. **Consumers are key players** here since it is in households that materials are separated and presorted into different collection systems (yellow packaging waste sack, household waste, waste paper). This is at the root of various difficulties: existing consumer habits and a lack of understanding about the necessity for correct separation (e.g. on the assumption that "plastics are plastics" or "everything ends up in the incinerator anyway") lead to "misplacement" or inadequate separation after use (e.g. yoghurt pots are all too often thrown away complete with their paper sleeve and aluminium lid). To further complicate matters, the dual collection system is implemented differently in different local authorities, for example in the form of yellow sacks, yellow bins, recycling centres or neighbourhood recycling bins. As a result, consumers have to learn new household waste separation procedures every time they move. Local authorities, which have a responsibility to provide information and to raise awareness and receive ancillary fees from the dual systems to do so, all too rarely carry out this task of public education.

There are also technical, organisational, economic and infrastructural challenges **at the industrial level** in the **collection and sorting** step in the value chain. The recyclers' primary objective is to achieve the specified recycling rate and not (yet) to ensure better sorting and separation of easily recyclable and reusable material because there are no economic incentives to do so. Only those materials for which there are buyers are sorted. Even mixed plastics can find buyers on the market (e.g. for incineration), despite their being unsuitable for producing high-grade recycled materials. The conflict between higher-quality sorting (slower conveyor belt) and faster sorting throughput is driven by low sales prices for individual fractions and capacity constraints during sorting which may be of both organisational and technical origin. These constraints always lead to suboptimal sorting results because the sensor can only recognise and sort the materials if there is enough space around the particles. Sorting is moreover based only on materials and not on impurities or specifications for subsequent uses. As a result of mixing during collection, all packaging waste is cross-contaminated with residues of food, cleaning agents or personal care products. Quantities sent for **mechanical recycling** are moreover only sorted to the minimum quality in sorting plants since producing a higher quality product results in a larger proportion of residues which then have to be sent for disposal at the sorting plant operator's expense. Single-stage sorting processes can only be configured either for high output of recycled materials or high product quality.[66]

These weak points in the sorting and recycling process lead all in all to extremely variable recycled material quality and have an impact on the next step in the value chain, the **use of secondary raw materials,** there being a lack of transparency in material streams and compositions with regard to toxicology and a corresponding application scenario. The recycled materials market therefore has excess demand for high quality (and specified) recycled material and an oversupply of low-quality, unspecified recycled material.[67, 68, 69] There is a major challenge here in synchronising the expansion of the recycled material market with the expansion of recycling capacity. One major point is the interface between recyclers and processors as well as distributors. Another problem moreover arises with regard to a Circular Economy in that the lower quality of recycled material from packaging materials means that this material increasingly flows into secondary applications for which there is in turn no recycling

65 | See Thøgersen 2014.
66 | See Feil/Pretz 2020.
67 | See IK Industrievereinigung Kunststoffverpackungen e. V. 2019.
68 | See Hahladakis/Iacovidou 2018.
69 | See Milios/Dalhammar 2020.

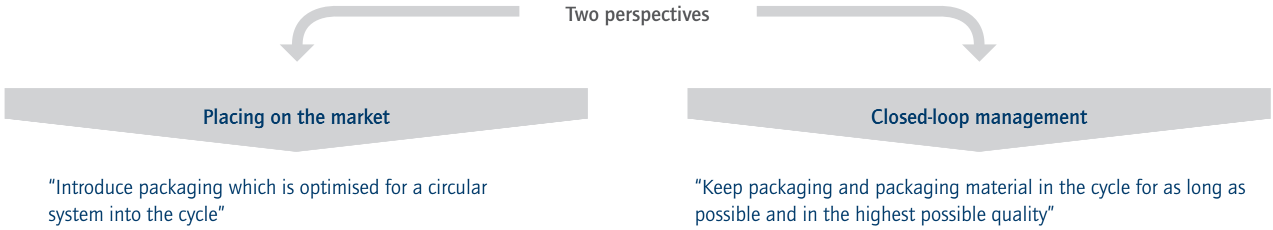


Figure 6: Two perspectives on the Circular Economy (Source: own presentation)

infrastructure. This thus results in downcycling and ultimately incineration (the exception being polyethylene terephthalate (PET) deposit bottles). In terms of circularity, it is also important to avoid drawing material from the deposit stream and then using it for applications for which there are currently no mechanical recycling structures.

Given the existing challenges encountered in collection and subsequent recycling within mixed collection, it is currently difficult to conceive how **compliance with food-contact requirements** might be achieved for food packaging solely through mechanical recycling since the transfer of non-compliant substances from different sources, such as cleaning agents or indeed other foodstuffs, cannot be ruled out. The only permitted recycled material for food-contact applications by the European Food Safety Authority (EFSA) is therefore the recycled material from the deposit bottle material stream. Last but not least, consumers often still do not accept recycled plastics due to their greyish colour and odour taint (in contrast, the brown colour of recycled paper has long been accepted). It is important here to overcome any remaining obstacles in marketing and consumer price sensitivity.

3.3 The vision – what is our destination?

The aim is to build a circular packaging industry. The working group has created a vision to achieve this for 2030 and 2050, on the basis of which the Wuppertal Institute has modelled a 2030/2050 "circularity scenario". Various "circularity levers" on which the vision is based are firstly described below. On the basis of a literature search, the working group then estimated the extent to which the levers can take effect by 2030 and 2050. Finally, a model was used to show the potential carbon savings which can be achieved if all the levers are consistently implemented along the entire value chain and their effects combined.

3.3.1 Levers along the value chain and circularity strategies

As section 3.2 has already made clear, the challenges in the value chain are multidimensional and interdependent. Potential solutions must therefore be examined from a holistic standpoint with an open mind with regard to innovation and technology and in the light of the following important principles:

1. Avoiding packaging is the top priority, providing the overall environmental footprint (i.e. of the package and its contents) does not increase as a result.
2. All unavoidable packaging must be based on efficient and effective resource management by being of a low-resource design and being usable, reusable and recyclable to a high quality for the longest possible period.
3. Material and product design should consistently ensure that no toxic effects occur along the value chain and subsequent use is not impaired.
4. Where appropriate and possible, secondary material or alternatives to fossil-based primary material should be used.
5. All circularity levers are subject to a sustainability and environmental footprint analysis (e.g. life cycle assessment (LCA)).

The potential of the **levers along the value chain** which are presented in the following section resides mainly in their combination. Some market levers are explained below from two perspectives: placement on the market and closed-loop management of packaging.

1. Placement of packaging on the market

This point summarises strategies which ensure that, firstly, only as much material as necessary is used and, secondly, the necessary material is placed on the market in such way that it can be kept in circulation.

Avoidance

There are two main levers for avoiding packaging and packaging waste from the outset:

- eliminating unnecessary packaging and
- saving material by packaging design efficiency.

Since packaging consumption and the resulting waste volumes are constantly increasing, avoiding packaging is an important lever at the beginning of the value chain. In some cases, **(outer) packaging can be completely eliminated** if it is not primarily functional. One example is loose fruit and vegetables: if this lever is also combined with systemic sourcing strategies, for example "regionality" (even with little packaging, regional products last longer and spoil less quickly), or with business models for reuse, for example standardised multi-use packaging in logistics, there is a good chance that packaging can be reduced or avoided entirely. Avoidance strategies are additionally of greater relevance where the recycling infrastructure cannot yet meet demand for recycled material in quantity and quality terms and the processes are not yet significantly powered by renewable energy sources.

One example of the second main lever, **increased material efficiency**, which may be mentioned is beverage bottle closures: the reduction in closure size and thickness over the years means that polymer savings are made for each closure. When it comes to strategies for increasing material efficiency, it must be borne in mind that increased efficiency may also impair packaging recyclability. For instance, while multilayer films use less material, the material can ultimately no longer be separated by type.[70] Packaging material usage can also be reduced by **compressing the package contents.** One example of this is concentrated solutions, for example for detergents. Another approach involves **avoiding unnecessary empty volume**. Possible negative effects of packaging avoidance strategies from a business point of view may arise due to consumers preferring larger packages out of habit because they suggest more content.

Packaging design

If avoidance strategies have already been implemented, there are further levers in packaging design. One fundamental principle applies to packaging design: when it comes to optimising packaging, the entire product, i.e. including the package contents, must be assessed in terms of its life cycle. A classic example of this is considering package size for foodstuffs: if larger quantities of food are packaged than a consumer typically needs, there is a risk of food being thrown away. If smaller packaging units are selected, more packaging material is usually required and thus greater material and energy inputs. The type and size of packaging must therefore be carefully considered and optimised on a case-by-case basis in terms of both product and market factors.

Packaging design is the basis for all **"design for X" strategies**. Packaging must be designed so that its materials can be separated (design for sorting, e.g. component separability) and then recycled (design for recycling, e.g. monomaterial). Developing design for recycling solutions frequently requires a complete transformation of the packaging structure and technical developments. When changing over from non-recyclable multimaterial composites to a recyclable monomaterial, for example, ways must be found to achieve the necessary functional properties of the packaging. Functional coatings for providing complementary properties such as barrier functionality, seal resistance or slip characteristics may be used as an additional printed layer on the monomaterial. Many of these approaches are already known and part of good packaging design practice. Nevertheless, a Gesellschaft für Verpackungsmarktforschung study has shown that one third of all packaging in Germany is not designed (as a minimum) to be recyclable.[71] A closer look is taken at two design levers below:

70 | Producing a composite from a number of films means that properties such as atmospheric humidity or oxygen barrier characteristics, tear strength, UV and light protection or thermal stability, can be varied depending on the package contents by combining different films. As a result, multilayer films are specifically structured depending on the intended application in such a way that the packaging meets the product's requirements with minimum materials usage. However, these films, which consist of many different plastics and additives, are at present not recyclable under real-world conditions. There are solvent-based processes which are also capable of separating multilayer films, but these are not used across the board. At present, replacing a multilayer film with a monolayer material in order to place a recyclable alternative on the market often involves using more material in order to meet the requirements.

71 | See Prognos/Gesellschaft für Verpackungsmarktforschung mbH 2016.

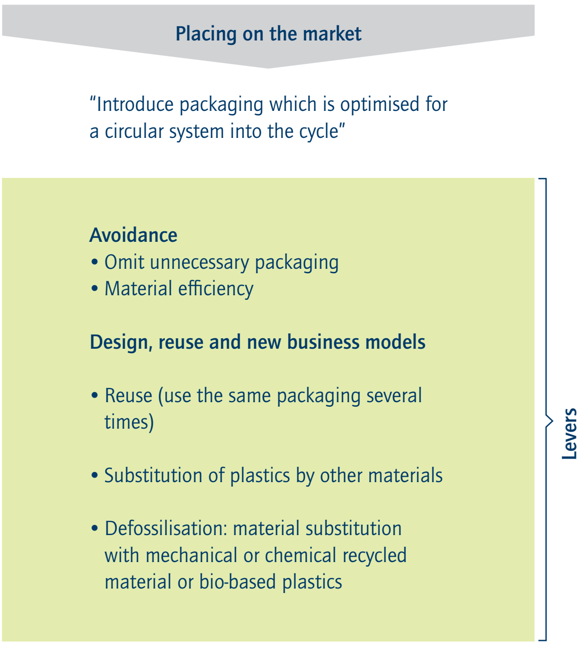


Figure 7: Levers for Circular Economy-compliant placement of packaging on the market (Source: own presentation)

- harmonisation/standardisation and
- material substitution: a) with other packaging materials, b) defossilisation of raw material inputs.

The aim **harmonising or standardising** packaging and types of packaging is to reduce the diversity of packaging (see section 3.2.1). The use of a limited number of standard plastics means that recyclers can better tailor processes to feedstock and so cut processing costs and increase output quality. This standardisation can apply to all levels: polymer base material, additives, colouring, packaging layout and structure. One positive example of this is the polyethylene terephthalate (PET) beverage bottle: (segregated) recirculation thanks to a deposit system and compliance with bottle design standards make it possible to produce a high-grade recycled material which is approved for food contact. In practice, retailers are already a driving force behind packaging harmonisation, having developed packaging design guidelines for and with their suppliers to provide guidance and instructions as to how to maximise packaging sustainability and recyclability. These guidelines are not yet harmonised, however, each retailer having its own.

As has already been stated, packaging design must always be assessed in terms of overall life cycle. This includes selecting the suitable base material (paper, metal, glass, plastic) and possibly adapting it if another material offers better overall performance in terms of raw material origin, manufacture, application and post-use phase (**material substitution**). A case-by-case analysis is always required and blanket statements are not appropriate. Specific functional coatings may be used to meet functional requirements such as fat, water and vapour barrier characteristics or indeed sealability. Care must be taken to ensure that these coatings do not impair paper recycling.

A further level of substitution can be achieved by replacing primary material (in the case of plastics, fossil raw materials) with secondary material (e.g. recycled material) or with alternative starting materials (see excursus "**Bio-based plastics**" on page 30). The underlying, long-term goal is to decouple the plastics packaging industry to the greatest possible extent from fossil-based feedstocks (**defossilisation**).

However, obstacles to defossilisation, in particular of food packaging, still remain to be overcome. At present the only recycled material which is approved for food contact is PET obtained from the PET deposit bottle stream. As a result, using bio-based plastics is considered to be the primary option for defossilising food packaging in the short to medium term. In general, adding recyclable bio-based plastics ("drop-ins") to a blend with recycled material can help ensure the necessary technical suitability of a material without requiring the use of virgin fossil-based raw material. In the long term, it is expected that recycled material from chemical recycling will also match the quality of primary material and contribute to defossilisation (see excursus "Chemical recycling" on page 37).

EXCURSUS: Bioplastics – bio-based and biodegradable plastics

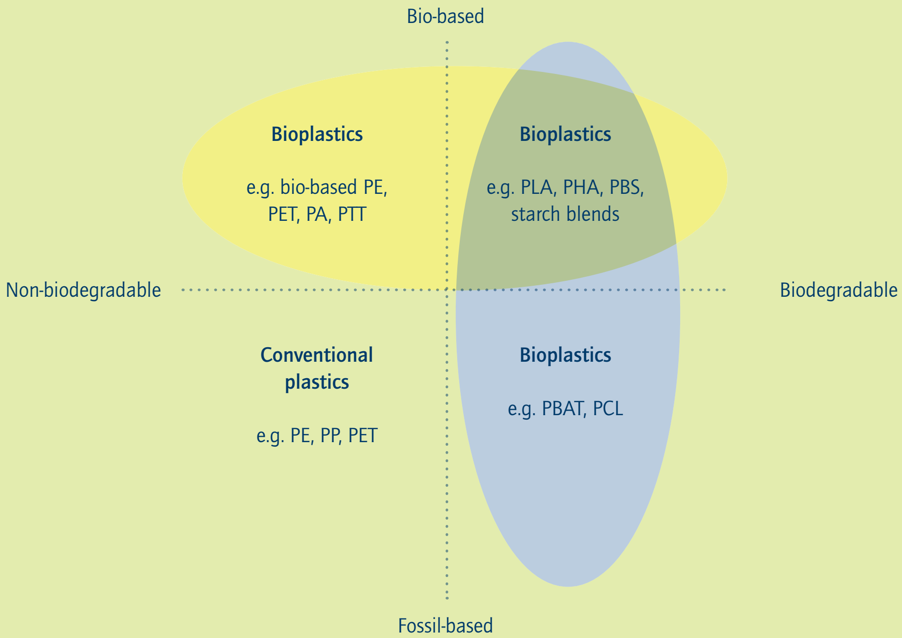


Figure 8: Bioplastics (Source: own presentation, based on European Bioplastics 2016)

The term "bioplastics" has two possible meanings, namely biodegradable and bio-based.

Bio-based plastics are plastics which are produced wholly or in part from non-fossil material sources. Renewable raw materials and their secondary products such as agricultural waste or agricultural by-products are suitable for this purpose.[72]

Biodegradable plastics are compostable under specific conditions (temperature, oxygen supply, moisture, microbial activity etc.). Current technology has as yet failed to identify any compostable plastic which breaks down equally well under all atmospheric conditions. Biodegradable plastics are not necessarily bio-based but may instead be fossil-based. Blends are often involved.[73] Biodegradability should not be confused with oxo-degradability, in which the presence of UV light or heat and oxygen initiates the fragmentation process. It is, however, not known whether complete biodegradation occurs within a reasonable period of time in landfills or in the environment. Where biodegradation is not possible, microplastics are the result.[74] The EU Single-Use Plastics Directive[75] adopted a ban on oxo-degradable plastics with effect from 2021.

Biomass can be used either to produce bioplastics such as polylactides (PLA) or polyhydroxyalkanoates (PHA) or to (virtually) identically replicate fossil-based substances. Bio-polyethylene (PE), bio-polyethylene terephthalate (PET) and bio-polypropylene (PP) belong to the group of "drop-in plastics". Drop-ins are neither biodegradable nor compostable, but as base polymers can be sorted and recycled in dual system plants using standard recycling processes.[76]

72 | See Federal Environment Agency 2020a.
73 | See ibid.
74 | See European Commission 2018a.
75 | See European Union 2019.
76 | See Federal Environment Agency 2020a.

Biodegradable or certified “compostable”plastics are at present interfering materials in many industrial composting plants and are currently excluded from the separate biowaste collection system. It is often impossible to differentiate between compostable and conventional plastics, which is why these plastics are screened out as interfering substances and incinerated.[77] In the absence of industrial recycling infrastructure for compostable plastics, it remains questionable how much environmental sense such solutions make. In addition, the assumption should be for the shortest possible cycles for bioplastics too since manufacturing virgin material consumes not only raw materials but also energy and water.

Bio-based plastics only make sense as a replacement for fossil-based plastics if they use as a raw material biomass which is not cultivated in competition with food. Secondary raw materials, secondary plant material or other raw materials of biological origin which make no use of land which could better be used for producing food are particularly suitable. In addition, illegal land reclamation (e.g. by unlawful rainforest clearance) and genetic engineering must be prevented, i.e. care must be taken to ensure that the biomass is only obtained from traceable and sustainable sources.[78] Further criteria to be considered are the cultivation of raw materials on areas that have already long been used for this purpose, good working conditions or appropriate use of water resources. In practice, demand for bio-based plastics is increasing but they are still distinctly more expensive than conventional plastics.

When it comes to the **carbon footprint** of bio-based plastics, the picture is mixed. A study by the Joint Research Centre (JRC) concludes that bio-polyethylene terephthalate and bio-polyethylene (HDPE) perform significantly worse than conventional fossil-based plastics, especially in terms of their carbon footprint.[79] The Federal Environment Agency has also indicated that bio-based plastics are not necessarily more sustainable.[80] At the same time, for example, another comprehensive study commissioned by the European Commission[81] investigated various specific bio-based plastics products and concluded that they performed significantly better than fossil-based plastics, especially in terms of climate impact, even if they are not as yet separately recycled. The differences are primarily due to how the respective teams of authors defined system boundaries and offset land use changes against the materials in the form of CO_2 factors.

Biopolymers should in principle not be promoted as necessarily being “environmentally friendly/friendlier”, “green(er)” or “(more) sustainable”. This is only legitimate if a predominantly positive life cycle assessment, which takes various impact categories into account, has been determined for a specific product and the raw material has been shown to have been obtained sustainably.

77 | See Institute for Bioplastics and Biocomposites 2020.
78 | See Weiss et al. 2012.
79 | See Joint Research Centre 2020.
80 | See Umweltbundesamt 2020a.
81 | See European Commission 2019a.

Reuse and new business models

Multi-use packaging is used in various applications. Examples include not only well-established multi-use systems, for example for beverage bottles or pallets, but also new business ideas such as zero-packaging shops or using modern technologies to track packaging.

The **reuse** lever begins with the usage and service life of the packaging. Using packaging multiple times saves valuable resources. This is counterbalanced by the costs and carbon footprint for logistics and processing reusable packaging.

There are various kinds of multi-use packaging which are briefly outlined below:[82, 83]

- Large containers for refilling **("refill on the go")**. While ideas such as zero-packaging shops are not new, they still represent a niche in retail and only offer a small selection of brands. Such systems often pose major challenges for retailers, in particular in the food sector, for example in terms of compliance with hygiene regulations and the resulting additional costs for implementation. Nevertheless, there are already many examples of reusable containers being filled from large containers.
- Refillable parent packaging **("refill at home")**. The refill packaging is made with less material than the repeatedly usable parent packaging, so significantly reducing materials consumption and transport costs. These systems are primarily used for cleaning, hygiene and cosmetic products.
- Multi-use system **("return on the go")**. Customers return the empty packaging to the retailer or manufacturer, who reconditions it for future use. Financial incentives provided by an accompanying deposit system can increase participation rates. This is the system used in the distribution of all multi-use deposit bottles.
- Transport packaging **("return from home")**. Customers receive the products they have ordered in reusable packaging by home delivery and have the packaging collected from their home or return it by post. The packaging can be used several times before being returned to the manufacturer.

Other than for beverage packaging, there have so far been few environmental impact assessments of business-to-consumer multi-use systems. However, these assessments do indicate that a multi-use system has a lower environmental impact than single-use packaging under certain conditions. Essentially, the impact and costs associated with production and disposal must be compared on a case-by-case basis with those associated with the additional transport and a decision taken in each individual case as to which systems have the better life cycle assessment. How often the packaging can be reused is a major influencing factor here.[84] The Ellen MacArthur Foundation estimates that reuse would be the optimum environmental solution for approximately twenty per cent of packaging.[85]

82 | See Coelho et al. 2020.
83 | See Ellen MacArthur Foundation 2019.
84 | See Coelho et al. 2020.
85 | See Ellen MacArthur Foundation 2017b.

2. Prerequisites for closed-loop management

This point summarises levers and strategies which ensure that materials are kept in material streams (recirculated) for as long as possible and in the highest possible quality.

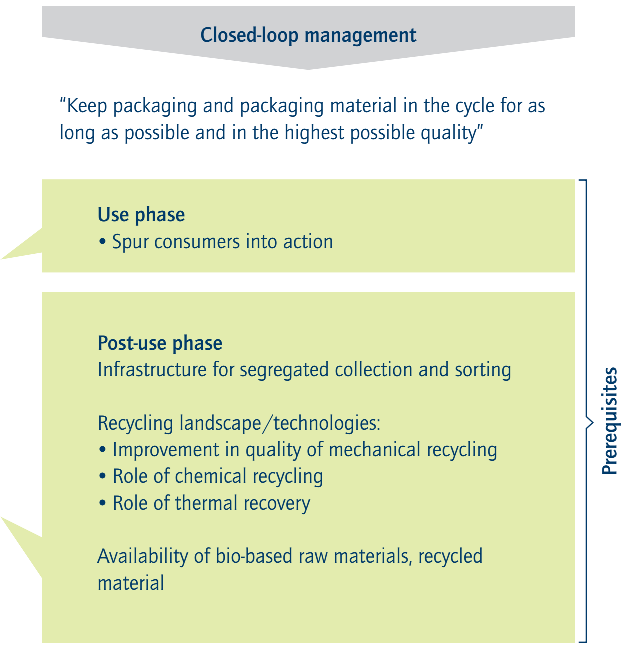


Figure 9: Prerequisites for closed-loop management (Source: own presentation)

Use phase: spurring consumers into action

Consumer behaviour in terms of preparing, possibly cleaning, if necessary separating components and finally correctly allocating packaging to the appropriate recycling stream plays a major role prior to the industrial recycling of packaging. A combination of **positive and negative incentives** for consumers may help to ensure that as many as possible play an active part in these tasks. Such incentives include deposit or reward systems or indeed (higher) fees for unseparated materials. Deposit systems have a particularly high success rate (98.5 per cent return for single-use beverage bottles[86]). It should be made as easy as possible for consumers to make environmentally advantageous purchasing decisions and to separate packaging correctly. Easy-to-understand and unambiguous labelling would be helpful here. One important task in terms of information and education is also to restore citizens' trust in recycling structures.[87] Some are of the opinion that all waste is just incinerated anyway so there is no point in putting any effort into separating it.

Post-use phase: infrastructure for (segregated) collection and sorting

In addition to addressing packaging design, increasing the quality and quantity of captured waste streams also means taking a close look at and, where necessary renewing, the existing collection and sorting infrastructure. Using the latest sorting systems across the board would in itself permit considerable improvements. However, for economic reasons, the investment required is not being made to the necessary extent. Various other optimisation options are also available. **Deposit systems** not only encourage a high return rate by consumers but also ensure a segregated material stream which no longer requires industrial sorting. **Marker-based systems** are another option. This industrial sorting technology enables optimised sorting by material, corresponding processing and colour. It is additionally technically possible to distinguish between food and non-food packaging so that, where regulations permit, recycled materials can also be used in food packaging. Marker-based systems are still at the development stage. Currently, the best known project is HolyGrail,[88] establishing digital watermarking technology. One advantage of digital watermarks over other track and trace methods is that no additional materials (e.g. fluorescent markers) are introduced which would ultimately have to be removed from the system as contaminants. Establishing markers will entail collaboration between manufacturers, who will have to use them, and recyclers, who will have to install appropriate sorting systems on their premises. Markerless sorting technology, for example systems **based on artificial intelligence (AI)**, is being developed as an alternative and highly promising results are already being obtained.

Re-sorting residual waste would increase the volume of material that can be sent for recycling. This approach may make sense where separate collection of packaging is problematic. In the Netherlands, in densely populated conurbations (in contrast to rural areas) post-consumer packaging materials are collected in residual waste, sorted into pre-concentrates using additional

86 | See Albrecht et al. 2011.
87 | See Gemeinsame Stelle dualer Systeme Deutschlands GmbH n.d.
88 | See Procter & Gamble 2019.

technology and then supplied to sorting plants.[89] Similar experiments were carried out in the 1990s with the "Wertstofftonne Plus" collection bins. The recycled materials, however, smelt strongly of residual waste and the necessary rinsing effort rapidly became so great that it was economically unacceptable and often also no longer worthwhile from an environmental standpoint.

Retrofitted sorting and washing functionality and methods for deinking or for delamination (even with separate collection) can assist considerably with decontamination and so increase the quality and yield of recycled material. In practice, however, this has so far proven difficult to make economically viable.

Post-use phase: recycling landscape (technologies)

Complete, high-quality closed-loop recycling of packaging materials requires an all-encompassing recycling landscape. This landscape is defined by (a) the fractions available for recycling after **collection and sorting** (input), (b) the available **recycling technology** (infrastructure) and (c) the **quality and quantity of secondary raw materials** generated for various applications and markets (output). The challenge for the packaging industry resides in building appropriate processing capacity and functioning supply chains from waste to new secondary raw materials.

The quantity and quality of input fractions depend on the many and varied factors described in the preceding paragraphs. Recycling technologies for plastic packaging include mechanical and chemical/raw material recycling and the incineration of non-recyclable fractions.

In reality, some fifty per cent of packaging waste in Germany is thermally recovered.[90] In a Circular Economy, the proportion of waste incinerated should be kept to a minimum (see waste hierarchy) and be limited to those residues (e.g. special waste from medicine or hygiene products) which can be neither mechanically nor chemically recycled. Even in the future, incineration will remain an unavoidable "pollutant sink". Moreover, the anthropogenic stock[91] still includes too many contaminated sites for which thermal recovery is the only solution because they were not designed with the requirements of closed-loop management in mind. In the current transitional phase, in which the electricity mix is still very carbon-intensive and recycling processes are still in need of further development, life cycle analyses (LCA) should be used when deciding on the optimal cycle.

Mechanical recycling[92] is currently the dominant recycling process and due to its relatively low energy input will also in future continue to be the central pillar of the Circular Economy in packaging. The diversity of input fractions does, however, mean that a mix of technologies will be necessary. **Chemical recycling** will make it possible to recover high-grade polymers even from packaging that cannot readily be mechanically recycled and so save on raw materials. Before implementing such chemical recycling, however, it will be necessary for energy balances to be prepared for each process, emissions checked, risks to health analysed and the environmental footprint evaluated on an industrial scale. This is because the various processes and their suitability for a circular recycling landscape should be evaluated with regard to efficiency, effectiveness and their currently often still high energy input. Recycling processes are in need of far-reaching optimisation in order to make it possible also to put **recycled material** to use in higher-quality applications than is usual today.

The following excursus provides an overview of the potential and limits of mechanically recycling plastics packaging.

89 | See Feil et al. 2017.

90 | See Gesellschaft für Verpackungsmarktforschung mbH 2018.

91 | The anthropogenic stock denotes the deposits of raw materials present in human-created infrastructure, buildings and everyday goods. The anthropogenic stock thus contains raw materials which have already been extracted from their natural deposits and are already or still in a product life cycle.

92 | See Gesellschaft für Verpackungsmarktforschung mbH/BKV GmbH 2020.

EXCURSUS: Potential and limits of mechanical recycling for a closed plastics cycle

If plastics are to be sustainable, it is essential to establish closed resource loops, i.e. systems with closed raw material chains, to enable ongoing use of the plastics at constant quality.

Mechanical recycling includes all purely mechanical and physical processes for treating used plastics. Mechanical recycling retains the molecular structure of the polymer molecule.[93, 94]

Mechanical recycling is in principle possible for thermoplastics and packaging produced from them. In addition to many optimisations around the value-added cycle, the central question is whether a desired cycle is achievable, including for reasons of climate protection, using mechanical recycling methods and what material and energy limits apply.

Aside from packaging design, a prerequisite for optimal recycling is the best possible separation and sorting of the individual types of plastics in order to ensure high quality of the recovered secondary plastic,[95] the following definitions applying to packaging plastics:

1. Mechanical recycling of thermoplastic packaging material is in principle also possible in a number of cycles if:
   - the packaging is designed to be recyclable (design FOR recycling),[96]
   - the plastics are as far as possible collected separately after use and are clean,[97] i.e. the packaging facilitates optimum emptying, so remaining as clean as possible after use,
   - the additive package originally used in the plastics does not hamper subsequent use[98] or such use is also possible for additional additive packages in subsequent cycles,
   - the plastic is protected from the outset with additives, in particular antioxidants and UV stabilisers, in such a way that it undergoes the least possible degradation during the subsequent mechanical recycling processes and any antioxidants consumed during recycling can simply be added again,
   - none of the additives and migrated ingredients form degradation products during mechanical recycling which conflict with reuse for equivalent applications,
   - use of recycled plastics is boosted[99] and sacrifices can be made in terms of packaging aesthetics and material efficiency in subsequent uses. One challenge here is that consumers are only to a limited extent willing to accept severe greying or clouding of the packaging or odour taint, in particular if these changes interact incompatibly with the packaged products or limit functionality. Modular approaches for separating decoration and packaging might possibly make it possible here to use even recycled materials which have changed in colour.

2. Mechanical recycling inevitably modifies material qualities because the mechanical and thermal stresses involved in frequent reprocessing can modify carbon chains and networks.[100] This applies not only to the plastics, but also to the additives they contain. These are required to protect the plastic from oxidation (antioxidants) and from photoageing (UV stabilisers) and to enhance performance. When it comes to using recycled material in food-contact applications, impurities such as residues of the package contents, printing inks, adhesives and also breakdown or degradation products arising from thermal stress or degradation represent a challenge. In the light of current gaps along the value chain, purely mechanical recycling is therefore by itself incapable of meeting the requirements of a closed loop in which materials should always be reused for the same purpose. This is ultimately the case for most materials

93 | See Rudolph et al. 2020.
94 | See Hellerich et al. 2010.
95 | See Federal Environmental Agency 2020b.
96 | See European Commission 2018b.
97 | See Federal Environmental Agency 2016.
98 | See ibid.
99 | See ibid.
100 | See da Costa et al. 2007.

(degradation of paper, browning of glass, reduction in the quality of metallic materials).

3. Moreover, even with ideal process control, processing losses will occur.[101, 102] A continuously cycling process accordingly leads to a reduction in the amount of material available in the cycle. Any losses of material have to be continuously offset. If fossil-based virgin material (climate impact) is not to be used for this purpose, other, non-fossil resources will inevitably have to be used for virgin plastics. Chemical recycling technologies or bio-based plastics are possible sources of non-fossil-based virgin plastics.

4. The same climate protection requirements apply to alternative recycling processes as to mechanical recycling. The carbon footprint should be as small as possible and in any event smaller than when using virgin material.[103]

Mechanical recycling offers considerable potential for recycling packaging materials. However, scientific and technical circumstances mean that mechanical recycling alone is not enough to achieve closed resource loops always for the same applications. Even in a Circular Economy for plastics packaging, material and quality losses therefore have to be offset by virgin-grade plastics.

In addition to the use of renewable raw materials, chemical recycling is accordingly currently being widely discussed, in particular for the recovery of plastics, as a non-fossil source of virgin-grade raw materials. The following excursus provides an overview and classification of the technologies involved as well as their significance and potential for a Circular Economy for plastics packaging.

101 | See Allwood 2014.
102 | See Graedel et al. 2019.
103 | See Ellen MacArthur Foundation/Material Economics 2019.

EXCURSUS: Chemical recycling

In both the public and scientific spheres, the debate around chemical recycling is characterised by differing boundaries and the use of differing terminology for processes which have the same process features and therefore overlap or are identical in terms of process technology. The use of terms often linked to a specific objective leads to inconsistencies and prevents a meaningful exchange of views.[104, 105] Explaining and defining terms is therefore crucial for establishing a common basis for work.

The packaging working group has agreed on the use of an unfinished definition. It is based on the preliminary work of "In4Climate", a platform for climate-neutral industry, and also allows the inclusion of future processes, providing they are not purely mechanical and the product is not used as a fuel:

Chemical recycling is an umbrella term for processes that use more than just mechanical or physical processes to prepare the starting material but do not lead to complete chemical conversion (combustion) with atmospheric oxygen.

The currently most discussed chemical recycling processes are outlined below. This list is not exhaustive, but presents the range of processes which fall within the above definition of chemical recycling:

Chemolysis covers processes such as alcoholysis, hydrolysis and aminolysis, phosphorolysis and acidolysis in which polycondensation products (e.g. polyesters, polyurethanes or polyamides) are broken down into their monomers, oligomers or other chemical components with the addition of a solvent, depolymerisation reagent and heat.[106, 107] In comparison with pyrolysis, cracking and gasification, the process parameters of chemolysis, involving pressures of between 20 and 40 bar and temperatures of up to 280 degrees Celsius, are moderate. It is particularly successful for separately collected material streams with low levels of contamination.[108] Glycolysis and acidolysis processes can be carried out under standard pressure at temperatures of up to 220 degrees Celsius.[109] If mixed collected fractions are used as the feedstock for chemolysis, the resultant recovered monomers are also mixed. These then have to be separated from one another again in complex fractionation processes. As a result, the process becomes increasingly uneconomic, the more process steps are required or the greater the desired purity of the product.[110]

The various **thermochemical processes** can be characterised as follows:[111]

Pyrolysis breaks polymers down at temperatures of over 300 degrees Celsius in an inert atmosphere (no oxidation). This generally results in a wide range of products which are obtained by a free-radical chain cleavage mechanism. Depending on process conditions, the products obtained are pyrolysis gas, synthetic crude oil/pyrolysis oil and pyrolysis waxes which can be further processed by distillation and refining steps to yield higher-grade chemicals, such as monomers for polymer chemistry or basic chemicals and fuels. These processing steps can be integrated into the process or carried out downstream in a conventional refinery.

Hydrogenation is the most technically and economically demanding monomer recycling process. Operating at 150 to 250 bar and a temperature of 450 degrees Celsius, the process relies on much more demanding process conditions than those required for chemolysis processes. The greatest advantage of this process is that hydrogenation can be applied to recycling materials of the polyvinyl chloride (PVC) class.[112]

In comparison with pyrolysis, **catalytic cracking** additionally involves the use of a catalyst. This lowers the activation energy of the chain cleavage reaction and influences the range of products. Due their possible action as catalyst poisons, heteroatoms such as nitrogen, oxygen or sulfur may have a problematic effect on the process.

104 | See Crippa et al. 2019.
105 | See Krause et al. 2020.
106 | See Al-Salem et al. 2009.
107 | See Solis/Silveira 2020.
108 | See Ragaert et al. 2017.
109 | See Hanich 2019.
110 | See Ragaert et al. 2017.
111 | See Lechleitner et al. 2020.
112 | See Hellerich et al. 2010.

In comparison with pyrolysis, **hydrocracking** additionally involves the addition of hydrogen at partial pressures of 20 to 150 bar. A bifunctional catalyst is often used. The availability of hydrogen results in the formation of mainly saturated and aromatic hydrocarbon compounds. The process can also be carried out in two stages with upstream pyrolysis and downstream hydrogenation. This offers the advantage that heteroatoms, interfering substances and coke can be removed in an intermediate step following pyrolysis, so protecting the catalyst.

Gasification is carried out by partial oxidation by means of air, oxygen, steam or mixtures of hydrocarbons, conventionally at temperatures of between 700 and 1,600 degrees Celsius and pressures between 10 and 90 bar. The hydrocarbons are generally partially reacted in the process. Depending on process conditions and feedstocks, the product gas contains not only carbon monoxide (CO) and hydrogen (H_2) but also methane (CH_4) and higher-grade hydrocarbons, optionally including heteroatoms. The reaction proceeds autothermally, i.e. exothermic partial reactions in which energy is liberated supply energy to those partial reactions which consume it. As a result, the process requires no external energy supply. Gas purification in the subsequent step is important because the downstream processes in the value chain are predominantly catalytic and therefore sensitive to impurities.

The objective of the naphtha/pyrolysis oil **catalytic reforming** process is to transform its feedstocks into aromatic compounds. This involves four reactions: dehydrogenation of cycloalkanes to aromatics, dehydrocyclisation of paraffins to aromatics, isomerisation and hydrocracking of alkanes to branched or short-chain alkanes.[113]

The described methods are at very different levels of maturity. There is no transparency in terms of efficiencies and costs. Many supposedly objective publications are tendentious or incomplete. No assessment can therefore be made on the basis of publications.

Driven by polymer chemistry's increasing demand for recycling-based basic materials, some initial semi-commercial projects are under way. Competition is helping to develop a market for these new resources. The technical feasibility of the various processes is undisputed, but their efficiency, cost-effectiveness and contribution to climate protection are debatable.[114] It is incumbent on policy makers to provide uniform criteria for assessing sustainability and to encourage investment in the construction and operation of pilot plants. Such plants will then provide data for mass, energy and carbon balances which, evaluated against a uniform model, are the prerequisite for the formulation of regulatory measures on the route towards a Circular Economy. It is essential for the various technologies to be evaluated in comparison with competing recycling routes and in the context of system conditions which are undergoing long-term change. In addition to obtaining a technical perspective on chemical recycling, it is therefore important not to neglect a systemic view of the climate-friendly and resource-efficient characteristics of plastics recycling.

Chemical recycling processes still have considerable development potential. They can be a good option as a recovery route for plastics waste which cannot (any longer) be mechanically recycled and as a more climate-friendly alternative to incineration. Some methods have the potential to reproduce the pure, original (virgin-grade) polymer which can be used as a blend component with mechanically recycled material to ensure that the recycled material meets the necessary quality requirements. Before implementing such chemical recycling, it will still be necessary for energy balances to be prepared for each process, emissions checked, risks to health analysed and the environmental footprint evaluated on an industrial scale.[115] There is then a chance that key technologies will emerge from the broad range of processes which will make a decisive contribution to a climate-neutral Circular Economy.

113 | See Speight 2010.
114 | See Rollinson/Oladejo 2020.
115 | See Tabrizi et al. 2020.

Objectives derived from these two perspectives, namely placement of packaging on the market and the closed-loop management framework, are modelled below in a scenario for 2030 and 2050 with reference to two circularity strategies.

3.3.2 Scenario: What would a circular packaging industry look like in 2030 and 2050?

The scenario presented below was commissioned by SUN Institute Environment & Economics and developed by the Wuppertal Institute. The scenario models the carbon savings achieved by applying circularity strategies for the years 2030 and 2050. Starting from the actual situation, market development to 2050 is projected assuming "business as usual" and this is contrasted with a circularity scenario for 2050.

Base model

The volume of plastics waste generated per capita in Germany has more doubled over the last twenty years. Although the industry is steadily increasing material efficiency, any resultant savings are more than offset by continuously increasing packaging volumes. Assuming sustained annual growth of 1.5 per cent, the volume of plastics processed in the packaging sector would increase to 4.8 million tonnes by 2030 and 6.5 million tonnes by 2050. In the absence of further intervention, annual carbon emissions would rise to approximately 13 million tonnes per year, which would correspond to around 1.6 percent of emissions in 2018.

Achieving a climate-neutral Circular Economy in the packaging industry requires a combination of circularity levers which should be modelled in the circularity scenario:

- replacing primary material with secondary material (repeated material use, using recycled material from mechanical and chemical recycling) where appropriate and where possible taking account of the origin of the recycled material and the current post-use scenario,
- reducing overall consumption (reduced demand through material efficiency and reuse, multiple life cycles for the same packaging).

Circularity scenario

Circularity strategies pay off on two objectives, firstly **reducing the total consumption** of materials placed on the market and secondly decoupling from primary (virgin) plastics **(defossilisation)** by combining a number of the levers presented in the previous section.

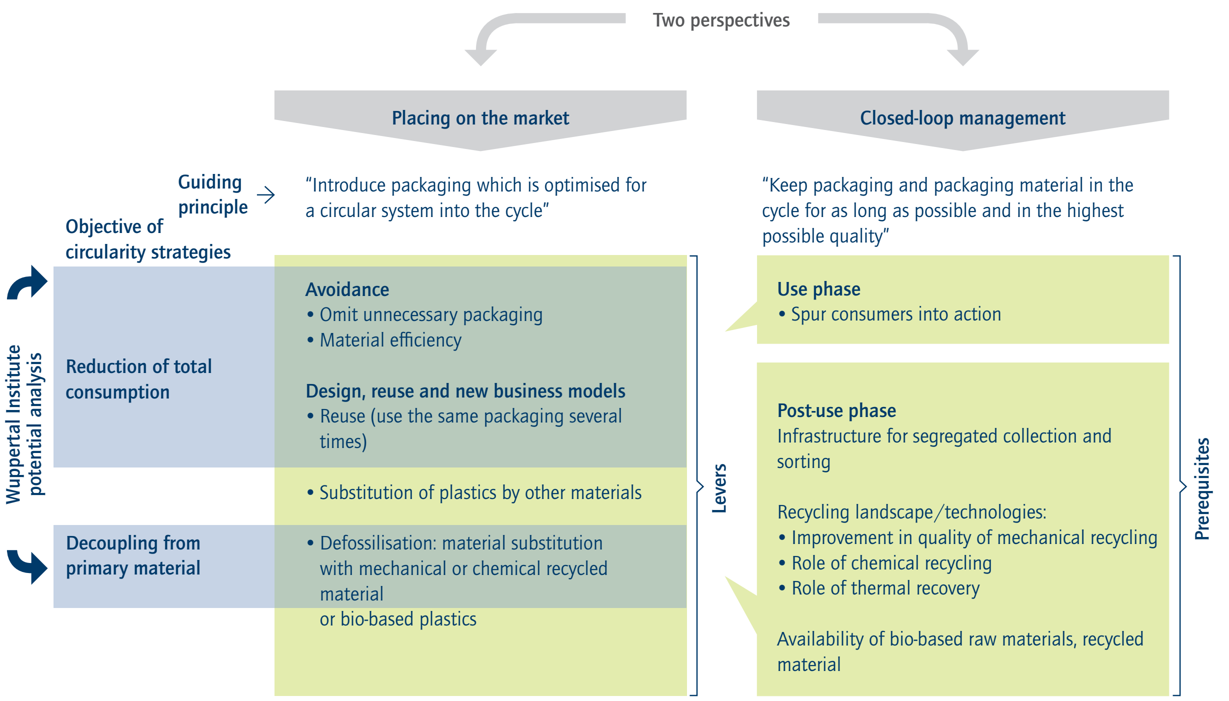


Figure 10: Structure of the 2030/2050 vision and modelling (Source: own presentation)

The circularity scenario takes as a starting point the indicated initial value that 9.1 per cent of recycled plastics was reprocessed into packaging in 2017,[116, 117] and is based on inputs from experts in the working group. Table 1 shows the targets which are to be achieved by 2030 and 2050.

	2030	2050
Recycled material from mechanical recycling	25 %	40 %
Recycled material from chemical recycling	0 %	20 %
Reuse	20 %	20 %

Table 1: Vision for circularity levers for plastics packaging (Source: own presentation)

It must be borne in mind that these values relate to the plastics packaging sector as a whole; especially in the non-food sector, a number of key players have committed to even more ambitious target values,[118] and therefore these values should be understood as an average of food contact and non-food contact packaging. The values are thus of the same order of magnitude as those used as the basis for other packaging sector scenarios.[119, 120, 121] Due to the considerable differences in the life cycle assessment (LCA) of bio-based plastics outlined in the excursus "Bioplastics", this lever was not included in the model.

The carbon savings associated with this vision were evaluated on the basis of life cycle analyses according to standard ISO 14040/14044 of the Association of Plastics Recyclers (APR)[122] which determined the savings for polyethylene (HDPE), polyethylene terephthalate (PET) and polypropylene (PP) achieved by using secondary raw materials. An open loop approach was selected as the allocation mechanism here, i.e. the positive effects of recycling are distributed evenly over all use cycles. Of the range of possible chemical recycling processes, the Ioniqa process developed at Delft University of Technology was used. The savings arising from reuse were calculated using life cycle analyses which differentiate between business-to-business (B2B) and business-to-consumer (B2C) approaches. Appendix E contains a detailed description of the data sets used and the assumptions made.

When it comes to evaluating the greenhouse gas saving potential of the various circularity levers in the future, the development of the electricity mix will be particularly important as the circularity levers' potential savings are dependent to very different extents on process emissions.[123] For instance, analyses in the course of the ChemCycling project have shown that for example chemical recycling is currently associated with distinctly higher process emissions than are fossil-based plastics, but ultimately performs significantly better when energy substitutions are taken into account.[124] It must, however, be borne in mind that the environmental impact assessment of chemical recycling is to a large extent dependent on the future expansion of renewable energies. If renewables account for a greater proportion of energy supplies in future, carbon capture and utilisation processes for the production of polymers, for example, could then also pay off in terms of climate protection.[125]

Discussion of results

Considerable carbon emission savings can be made in the medium- and long-term if greater use is made of mechanically recycled materials, products obtained from the chemical recycling of plastics waste and reusable packaging. If the use of mechanically recycled materials is steadily increased to 40 per cent, an average of approximately 1.9 million tonnes of CO_2e would be saved annually by 2050, while an increase in the proportion from chemical recycling to 20 per cent would save 1.2 million tonnes. Increased use of reusable packaging systems could save around one million tonnes of CO_2e emissions (see Appendix E for underlying assumptions). At the same time, however, these modelling results also show that, in the absence of additional measures, there would still be a substantial shortfall even in 2050 in achieving both climate neutrality and closed-loop management.

The results indicate that, when it comes to protecting the climate and conserving resources, it matters much less which

116 | See Conversio 2018.
117 | The calculations were carried out prior to the publication of the 2020 Conversio study and therefore relate to the 2018 Conversio study.
118 | See Henkel 2020b.
119 | See Ellen MacArthur Foundation 2013.
120 | See Material Economics 2019.
121 | See Kaeb et al. 2016.
122 | See Franklin Associates 2018.
123 | The current European electricity mix was used as the basis for the analyses used here.
124 | See BASF 2020.
125 | See Bringezu 2014.

specific types of polymer have circular alternatives developed for them than that greater use is made of them in principle. For instance, the potential savings from using recycled polyethylene terephthalate (PET), high-density polyethylene (HDPE) or polypropylene (PP) are of very similar orders of magnitude. They all perform significantly better than always using primary plastics. This finding is relevant to the discussion of how the diversity of plastics should be reduced in the future. The types of bulk plastics used in future in packaging should be decided primarily on the basis of the functional requirements applying to packaging. The potential greenhouse gas savings from individual types of plastic can be disregarded when selecting them as the savings hardly differ.

With regard to specific areas of application, it is clear that the ramp-up of circular alternatives will lead to greenhouse gas emission savings in the short term particularly in the non-food sector, because the legal challenges here are comparatively easier to handle than in the case of food-contact packaging. From the standpoint of protecting the climate and conserving resources, it is apparent that still greater potential savings might be made by reusing packaging in particular in B2B applications due to the necessary logistics.

Overall, the modelled potential savings emphasise the need for a systemic approach which, in addition to the functionality of the packaging, must in particular also take account of the actual availability of high-grade recycled materials. Accordingly, greater use of recycled material will only have environmental benefits if additional plastic waste is fed into high-quality recycling for this purpose and these quantities of recycled materials are not diverted from other sectors or imported from abroad.

However, the modelling shows just as clearly that, even in 2050, there will be a shortfall in achieving both climate neutrality and a Circular Economy with defossilised cycles if only the currently available predictions are used. If the target of climate neutrality in the European Union and in Germany is also to be achieved for the plastics packaging sector, mutually compatible technological and economic prerequisites must additionally be met (see excursus "Thought experiment" in section 4.3). Developing a suitable framework is therefore of particular importance.

4 Closing the loop: two case studies – detergent and cheese packaging

If it is to be possible to implement a climate-neutral Circular Economy in the packaging industry, circularity strategies considered at a higher level, as described in section 3, can only provide food for thought. When it comes to implementation under real-world conditions, there is a need for an in-depth consideration of the various (technical) requirements and general conditions which apply to individual packaging applications. It is for this reason that the packaging working group is presenting two case studies in section 4 which it has investigated for their circularity potential and implementation challenges. The practical test subjects are:

- high-density polyethylene (HDPE) detergent bottles and
- polyethylene terephthalate (PET) trays as cheese packaging.

Various criteria were taken into account in the selection of these case studies. Both HDPE bottles and PET trays account for a total of approximately 30,000 to 75,000 tonnes in the waste stream of the dual systems.[126] In the case of HDPE bottles, HDPE material streams from sectors other than packaging also increase the volume of the material stream. In addition to their significance in volume terms, the two examples illustrate different circumstances in the current situation since they differ in terms of packaging content (foodstuff versus cleaning agent) and their current recycling route (mainly mechanical recycling versus incineration). The findings obtained therefore cover the requirements of many other packaging structures and, combined, are suitable for drawing general conclusions.

4.1 Detergent packaging (HDPE bottle)

Bottles made from high-density polyethylene (HDPE bottles) are among the types of packaging which, right across Europe, have longest been systematically collected, sorted and recycled. The bottle design has furthermore already very largely been optimised for easy sortability and recyclability. However, most of the resultant recycled materials are removed from the packaging market, used in other areas, for example in waste water pipes, and so lost to further use cycles. Moreover, most of the recycling technology used is not adapted to the requirements of the packaging market and is therefore incapable of delivering appropriately high quality materials. There is therefore a considerable need for technological adaptation of existing capacity or for new capacity adapted to the reuse of recycled materials to produce bottles.

4.1.1 Detergent bottle functionality requirements

The following diagram summarises the requirements which apply to detergent packaging through its life cycle. They define the framework for any innovation to rethink detergent packaging in the context of circularity.

126 | There are no reliable data on the volumes of HDPE bottles or PET trays placed on the German or European market. The LUCID packaging register should make this possible for Germany in the near future and so offer greater transparency. On the basis of an unpublished investigation by the Pforzheim University of Applied Sciences, approximately 2.3 per cent of HDPE bottles and 2.8 per cent of PET trays are to be found in the waste stream of the dual systems. Fluctuations of between 2 and 5 per cent are assumed here. Given that Germany's dual systems collect 1.5 million tonnes of waste, this amounts to inputs of 30,000 to 75,000 tonnes of HDPE bottles and of PET trays into Germany's dual systems.

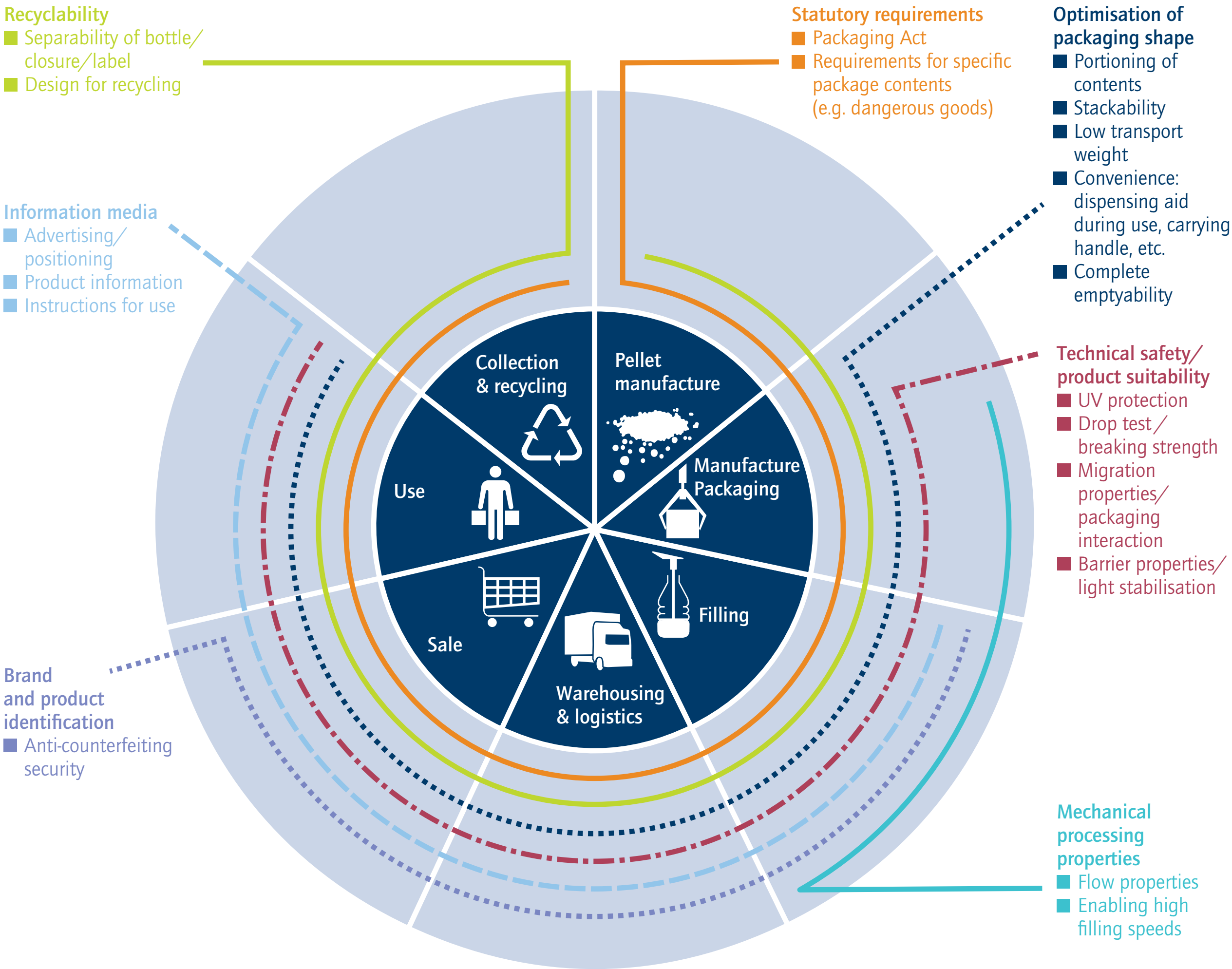


Figure 11: Examples of requirements applicable to detergent packaging (Source: own presentation)

4.1.2 Current situation

There is a huge variety of packaging designs for polyethylene (HDPE) detergent bottles in common use today. The bottles have various colours, are provided with an adhesive label (paper, polyethylene (PE), polypropylene (PP)) or a film label over the entire bottle, a full body sleeve (polyethylene terephthalate (PET), polystyrene (PS), polyolefins (PO)), have different types of closures (PE, PP) and possibly other additions such as dispensing systems.

Most polyethylene bottles are collected with all other packaging in the “yellow sack” or “yellow bin” schemes. After collection, the dual systems’ waste stream is sent to the sorting plant, where it is sorted into different types of material (fractions). A screening drum firstly removes small parts and an air classifier removes films, and near-infrared spectroscopy is used to sort the remaining stream into fractions. As a result, a high-density polyethylene (HDPE) fraction is obtained which is compressed into a bale and sold on by the sorter.

Since automated HDPE bottle sorting is a long-established technology, it may be assumed that a large proportion of HDPE bottles, once collected, are also sorted and recycled. Since the HDPE fraction generates earnings, German sorters make sure that the bottles do not end up in the mixed plastics fraction.

The HDPE fraction passes through various processing steps. Depending on the application intended for the recycled material and the grade of material required, processing may involve just a few or a number of process steps. These are combined in different ways depending on the recycling process. In plants for high-grade recycled HDPE, the incoming HDPE bales are shredded, hot washed and resorted. The colourful mixture of washed flakes is sorted by colour. The material is then melted in an extruder and additionally melt-filtered to purify it further. The recovered HDPE pellets can be used, for example, to produce new non-food HDPE bottles.

However, this multistage process is used for only some 7 to 9 per cent of the HDPE fraction. The remaining recycled HDPE is primarily used in lower-grade applications, such as building materials, pallets or irrigation pipes. Reprocessing is significantly simplified for these applications, the hot washing or flake sorting for example being omitted.

A balance must be struck between the costs of reprocessing and the prevailing market price for recycled material. The more complex the reprocessing process, the more expensive the recycled material. High-grade recycled material ("natural" or "white") currently accounts for a much smaller share of the market. The majority of recycled material in volume terms ("grey/black") is of lower quality (colour and odour) and generally unsuitable for primary packaging for consumer goods. High-grade recycled material is almost always traded at higher prices than the (better quality) virgin material because of strong market demand (due to the voluntary pledges made by manufacturers[127]). Lower-grade recycled material has to be directed into downgraded applications, such as building materials, sewage pipes or flower pots. In this case, oversupply and poor quality means that prices are significantly below those of virgin material. If the mixed price achievable by recyclers, including a profit margin and revenue from the dual system, is nevertheless inadequate, they lack the financial resources to invest in better sorting and reprocessing technology which can be used to produce more high-grade recycled material with a corresponding price premium.

One approach to striking this balance is to reduce packaging complexity. The more standardised the packaging design (structure, material, colour, etc.), the leaner the sorting and reprocessing process can be, even when producing high-grade recycled material. The conflict of interests which has to be resolved here is how to motivate the early links in the value chain to modify the packaging design, if initially the "only" beneficiaries of this change at the bottom of the chain are the recyclers. It is clear here that a closed loop can only be established along the entire value chain. The Packaging Act defined compliance fees on an environmental basis[128] so taking the first step towards the necessary redistribution of costs. However, this instrument is not yet being put to full use and there is a need for regulatory readjustment. Bonuses for recyclable packaging are currently low and possible bonuses for using recycled material are not even offered.

4.1.3 Circularity strategies and levers for detergent packaging

Despite the stated challenge that every stakeholder in the value chain has to make its contribution, numerous circularity strategies and levers for detergent packaging are already being trialled or are in use.

Detergent concentrate solutions are one example of a **prevention strategy**. They make it possible to offer a quantity of product for a given number of washing cycles in distinctly smaller packaging and at the same time hugely reduce transport weight. This concept has for example already been implemented by Truman's[129] in the USA, Splosh[130] in the United Kingdom and everdrop[131] in Germany. Zero-packaging concepts in the form of filling stations in retail outlets are already undergoing real-world trials, for example at German retailers Kaufland,[132] Rossmann and DM.[133]

While the previously mentioned solutions are only used in niche markets, refill systems, for example with stand-up pouches, are already well established. Producing such pouches requires far

127 | See New Plastics Economy 2019: As part of the *New Plastics Economy Global Commitment* initiative by the Ellen MacArthur Foundation, 450 organisations which produce 20 per cent of the world's plastic packaging have committed to reducing plastics consumption and promoting its circularity.
128 | See Bundesanzeiger 2017.
129 | See Truman's n.d.
130 | See Splosh 2020.
131 | See everdrop n.d.
132 | See Teraz Media 2020.
133 | See MDR 2020.

less material than polyethylene (HDPE) bottles. Customers can therefore (re)purchase the detergent in the stand-up pouch and transfer the detergent into their HDPE bottle at home. By also offering the refills in large sizes, further packaging material can be saved. However, if a refill system is to make sense, it must be possible to use secondary material, also taking account of the origin of the recycled material, and the pouches themselves must be recyclable. While there is already a well-established recycling stream for HDPE bottles, it must be ensured across the board firstly that the pouches are recyclable and secondly that recyclers actually have an interest in recycling them.

A **recyclable design** is an important lever for keeping the polyethylene bottle itself in the loop. Guidelines have already been developed, for example by RecyClass[134] and by University of Applied Sciences Campus Vienna.[135] Using a monomaterial is thereby a major factor. In addition, **components**, for example bottle and label, must be **separable**. For example, the labels must be soluble and it must be ensured that the adhesive remains on the label when it is separated, so that it is discharged with the label and does not interfere with the recycling process.[136] To facilitate the currently usual near-infrared sorting process, the labels should also occupy at most fifty per cent of the surface of the packaging or be made of the same material, so allowing proper identification of the packaging material. As sorting technology develops, these requirements may change. Digital watermarks on the packaging can provide the necessary process control information for sorting and recycling (see section 4.3 for further details).

Recycled material quality can also be increased by dispensing with colouring. Overall, the **variety of colours** should be reduced, opaque and carbon black-based colours avoided if possible and white or natural-coloured solutions given preference. An industry-wide, common approach would be to standardise colours, which could stop recycled materials from turning grey as quickly. However, marketing aspects stand in the way of such standardisation, for example brand recognition on the basis of a specific colour. Consumer acceptance of grey packaging is also sometimes low. Grey ought here to become established as the identification colour for recycled material, similarly to the association between brown and recycled paper. One possible remedy is full body sleeves, since they permit printing but avoid through-colouring of the HDPE.[137, 138] However, in many cases new sleeve materials would first have to be developed and used or digital watermarks would have to be established as a sorting technology so that bottles with sleeves can be correctly sorted.

Not only recyclability but also the **use of recycled material** are already established in practice for detergent bottles. Some manufacturers are already using post-consumer HDPE recycled material, either pure recycled material or mixed with virgin material, to produce new bottles.[139, 140] One challenge thereby is to generate a sufficiently large quantity of high-grade, consistent recycled material.

4.2 Cheese packaging (PET tray)

The stringent food technology requirements applicable to cheese packaging complicate the use of polyethylene terephthalate (PET) trays for this purpose. Unlike polyethylene bottles, almost no cheese packaging has yet been designed to be recyclable, since in particular the trade-off between food storage life and a recyclable packaging design presents a major challenge. The recycled material currently found in the trays is obtained from the PET deposit bottle stream. Separate deposit collection yields a largely harmonised material stream in which cross-contamination can be ruled out and consequently, thanks to an additional cleaning step, this recycled material is of reliable quality and, complying with statutory requirements, can be used in food packaging. However, since the recycled material is extracted from the bottle stream and is incinerated after its second life cycle as a tray, this development must be viewed critically.

4.2.1 Cheese packaging functionality requirements

The following diagram summarises the requirements which apply to cheese packaging through its life cycle. They define the framework for any innovation to rethink cheese packaging in the context of circularity.

134 | See RecyClass 2020.
135 | See FH Campus Wien 2019.
136 | See Henkel 2019.
137 | See Vernel n.d.
138 | See Packaging Journal 2020b.
139 | See Werner & Mertz Gruppe 2016.
140 | See ALPLA 2018.

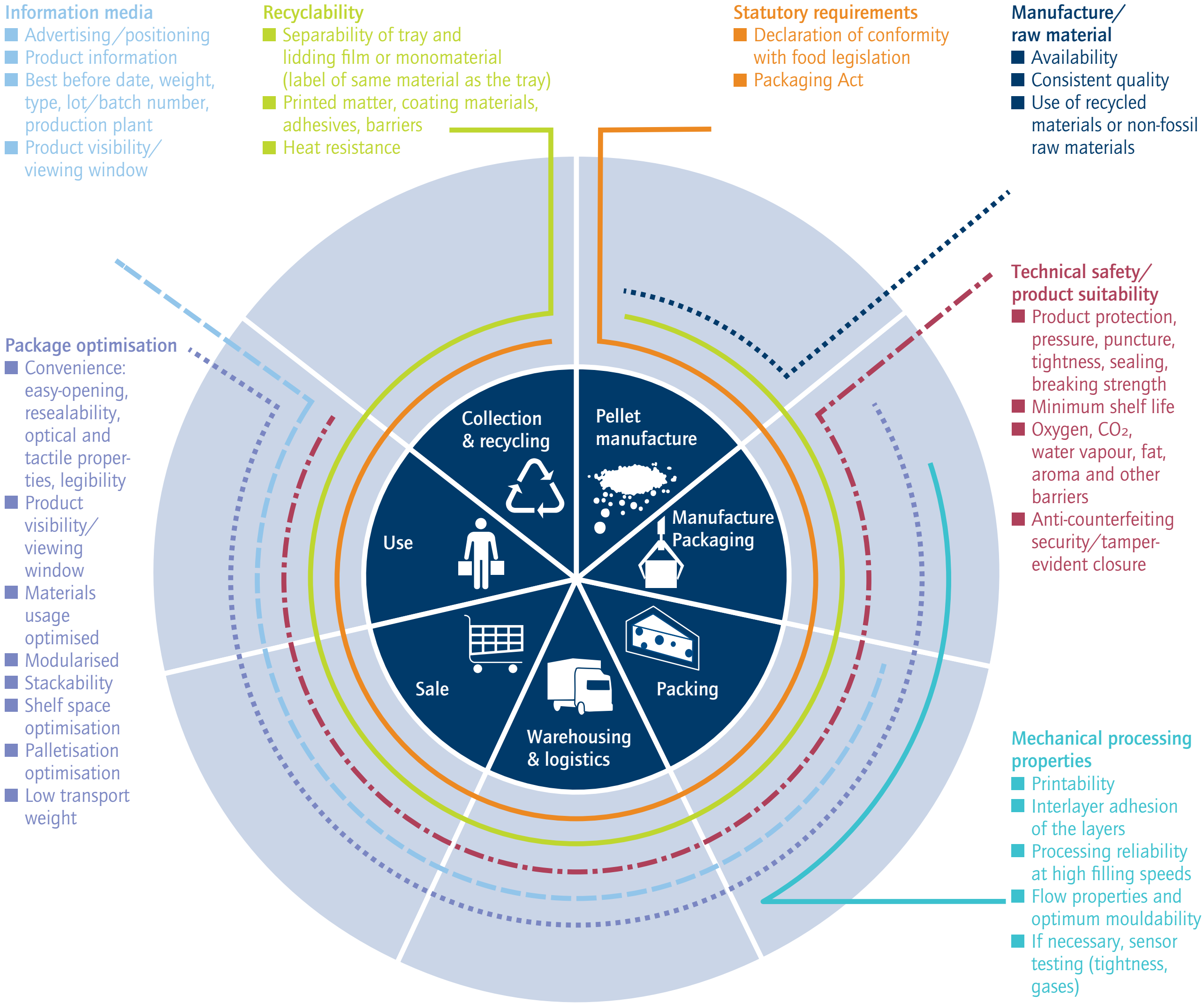


Figure 12: Examples of requirements applicable to cheese packaging (Source: own presentation)

4.2.2 Current situation

There are various packaging designs in circulation for polyethylene terephthalate (PET) cheese trays as well. Depending on requirements, the trays are produced with a polyethylene (PE) heat-sealing layer or additionally with an ethylene/vinyl alcohol copolymer (EVOH) barrier layer and the necessary laminating adhesive. The polyethylene (PE) heat-sealing layer primarily serves to seal the film while the ethylene/vinyl alcohol copolymer (EVOH) barrier layer provides protection from oxygen and water vapour among other things. The trays moreover often have paper labels applied to them. The printed lidding films for closing the cheese packaging are conventionally produced from biaxially oriented polyester films (PET-BO) which are themselves likewise provided with a PE heat-sealing layer and optionally an EVOH barrier layer. In addition, a resealable adhesive is commonly applied to enhance consumer convenience or a tactile coating to improve visual properties.

The PET trays currently in use for cheese are therefore not recyclable. While monomaterial PET trays do indeed exist, they are only in established use for applications with low requirements, for example fruit and vegetable packaging. Moreover, using bio-based raw materials is technically feasible but not yet attractive in price terms.

It would be technically possible to sort PET trays separately by near-infrared sorting (NIRS) after collection in the dual system. There is a recycling stream for PET in general. For the trays in question, however, the colour restrictions due to the introduced multilayers and printing inks are so strict that the trays are usually screened out and incinerated. Another reason why PET trays are not currently recyclable across the board is the adhesive.

A closed loop for cheese packaging would in any event not be possible under the current collection and sorting system because the potential cross-contamination due to the mixed collection of food and non-food packaging waste means the recycled material is not permitted for use in food-contact applications. Current advice on the food safety of PET packaging specifies that no more than five per cent of recycled PET may come from non-food applications.[141] Guidelines from the RAL Quality Assurance Association for recyclable PET go even further and effectively rule out the use of material from the dual system.[142] This means that practically the only recyclable material which can be used in direct food-contact applications is polyethylene terephthalate obtained from single-use bottles recycled under the Deutsches Pfandsystem GmbH (DPG) deposit system. The recycled content of today's commercially available PET trays may constitute more than fifty per cent of the total plastics content. From a technical standpoint, this proportion could be increased still further, possibly at the expense of the transparency of the trays and films.

4.2.3 Circularity strategies and levers for cheese packaging

A few strategies and levers are already being implemented or tested to improve the circularity of cheese packaging.

Some retailers with fresh food counters are trialling **reuse systems**, in which customers pack the cheese in containers they have brought with them, in order to avoid packaging.

A **recyclable packaging design** provides an opportunity to conserve resources. To achieve this, the lidding film, the tray and the label should either consist of the same material, for example of amorphous polyethylene terephthalate (APET) instead of biaxially oriented polyester film (PET-BO), or it should be immediately apparent to consumers how they can be correctly separated. Substituting barrier plastics can ensure a purer recycling stream by avoiding foreign barrier layers such as ethylene/vinyl alcohol copolymer (EVOH) and replacing them with plasma coatings, for example a silicon oxide (SiO_x) layer.[143] In order to obtain a high-grade recycled material, it would be advisable to ensure that any print can be removed during the recycling process. Otherwise, limiting the amount of print and colouring of the packaging is generally of assistance for recycled material quality. Care should also be taken not to use any fillers which change the material's density.

Even if monomaterial polyethylene terephthalate (PET) cheese packaging is produced, the question of recycling remains. As things stand today, even a monomaterial PET cheese tray would be incinerated in most plants because the colour requirements relating to recycled PET are so stringent that PET recyclers screen out all trays by way of precaution. In implementing this solution, distributors would therefore have to work closely with recyclers to ensure that "recyclable" does actually mean "recyclable under real-world conditions". Initial PET tray sorting schemes are currently being introduced.

141 | See EFSA CEF 2011.
142 | See Kauertz/Detzel 2017.
143 | See RecyClass n.d.

One possible strategy, building on established recycling streams, is to **replace polyethylene terephthalate (PET) trays with monomaterial polypropylene (PP) trays**.[144] The advantage of the polypropylene solution is that these trays are not thermally recovered but instead sorted into the PP fraction and are therefore also recyclable under real-world conditions. While the recycled materials cannot currently be reprocessed into new cheese packaging for the legal reasons already mentioned, they can be given new life in products and packaging with lower requirements. Closing the loop for polyolefins in the future means that further possibilities must be evaluated, for example by separately diverting corresponding material streams. In addition, in-depth investigations into the use of second or third generation bio-based raw materials (i.e. obtained from residual materials) are currently under way for polypropylene.[145, 146] Changing the material may, however, also mean that barrier properties have to be adjusted or thickness increased compared to a PET tray or a higher temperature used for sealing.[147]

Monomaterial packaging, whether made from polyethylene terephthalate (PET) or polypropylene (PP), is not a truly recyclable solution under the present circumstances. If PET continues to be used, recycled material from the bottle stream can be used as input material, but the cheese packaging will be incinerated after use. If PP is used, the packaging must be made from virgin material, as there is no recycled PP which complies with food-contact legislation. Any recovered secondary raw materials may, however, be used for other applications.

Another approach is to **use fibre-based packaging** with an appropriate barrier coating.[148, 149] Highly effective collection, sorting and recycling infrastructure for paper is in place in many countries (more than eighty per cent of paper is recycled in Europe), which means that the majority of the packaging would then be recycled. However, the greater the functional requirements which apply to the packaging, the more difficult it is to produce fibre-based packaging in such a way that the main material is recyclable paper. Functional finishes and coatings might help to provide a solution for equipping recyclable paper packaging with barrier properties (against grease, water and oxygen) and sealability or seal strength. In this case too, it is thus not possible to make any blanket statements regarding environmental benefits. Instead, each case must be considered individually, taking various impact categories into account.

4.3 Systemic approaches

The previously presented circularity strategies from sections 4.1 and 4.2 reflect the current status of some attempts at implementation and potential solutions for placing packaging on the market. Further systemic closed-loop management solutions which primarily apply to collection and sorting should not be devised on the basis of one particular application; the infrastructure must as far as possible be functional for all packaging in order to exploit economies of scale. In other words, in the past, when placing packaging on the market, the starting point has been product requirements, with applicable design, substitution and avoidance strategies only being investigated afterwards. This subsection explains the approaches under public discussion which can be used to optimise the collection and sorting infrastructure. The listed examples are based on situations where room for manoeuvre is already known to be available. Possible future technological developments, such as a smart waste bin,[150] should be regularly evaluated to determine whether they are also capable of providing a systemic solution. Where possible, conclusions applicable to the case studies are drawn for the approaches described here. The four approaches presented in this section are not mutually exclusive, but can also be combined, for example a multi-use solution with a deposit system or a bin for recyclables with packaging comprising markers.

Deposit systems

The purpose of the first approach is to ensure segregated collection of increased volumes of packaging. **Deposit systems** provide financial incentives to encourage consumers to return containers and so ensure a high packaging return rate. Germany already has well-established deposit systems both for single-use packaging (polyethylene terephthalate (PET) beverage bottles) and multi-use packaging (e.g. water bottles, beer bottles, yoghurt jars). Deposit systems ensure segregated material streams.

144 | See Borealis 2019.
145 | See Carus/Dammer 2018.
146 | See Frischenschlager et al. 2018.
147 | See Plastics Europe n.d.
148 | See neue Verpackung 2019.
149 | See Siegwerk n.d.
150 | See reCIRCLE n.d. b.

Large, segregated material streams have advantages but involve challenges too. For instance, a take-back system occupies a lot of retail space and so increases costs. An effective deposit system requires transparent and careful management of material and cash streams. Another challenge is consumer acceptance, which would be increased by optimised take-back systems. Initial considerations are focusing on more widespread take-back stations which are not limited to retail outlets but are also available, for example, at petrol stations or underground railway stations. Deposit payouts should also be made, for example, by a mobile phone app instead of a voucher at the supermarket checkout. The long-term economic objective ought to be for the system to fund itself by the high-quality recycled material obtained and by the reduction in sorting costs.

In relation to the case studies, deposit systems are primarily of interest for cheese trays. Today's established sorting processes already enable effective segregation of polyethylene bottles: since consumers use the bottles at home and they are clearly recognisable as plastics packaging, it can be assumed that the misplacement rate is low and thus the majority of bottles are collected. In the case of cheese packaging, however, a deposit system would ensure a material stream suitable for food contact which meets the regulatory requirement that only recycled material from food-contact applications can be reused in these applications, assuming that the packaging design was designed with this in mind. Since re-sorting is also not permitted, deposit systems are currently the only practical way to create a closed loop for recycled material for food-contact applications.

In a **multi-use system,** customers return the empty packaging to the retailer or manufacturer, who cleans it and then reuses for selling the next product. Well-established examples are water bottles, beer bottles and yoghurt jars. Numerous projects and start-ups are currently setting up new multi-use deposit systems, especially in the take-away sector of the catering industry.[151, 152, 153, 154] Design projects are, however, also on the rise in the retail sector.[155, 156, 157, 158] It is important, from both an environmental and an economic standpoint, to introduce packaging as widely as possible and to have an open pool so that transport distances can be kept short and consumers also have the option of returning their packaging everywhere. This need for a large-scale rollout is at the same time the major challenge facing the development of a multi-use system which all manufacturers will want to use. This is not only inconsistent with marketing aspects, but also requires that filling machines be converted and multi-use containers purchased, and that a complete infrastructure with cleaning plants be set up. The organisational challenges involved with deposit schemes have already been mentioned in the previous paragraph. In particular, existing single-use packaging industries would lose out. However, a well-established, systemically optimised multi-use concept could have long-term cost-saving potential compared to single-use concepts and could also open up the possibility of conserving resources and protecting the environment.[159 160]

With regard to the two described case studies of detergent and cheese packaging, a multi-use solution would in principle be conceivable for both products. In the case of cheese packaging, the high barrier requirements make it a major challenge to develop multi-use packaging and an accompanying cleaning concept without having to accept some loss in shelf life. In the case of detergent bottles, the question arises as to whether a refilling station in which the bottle does not pass through reverse logistics but instead remains with the consumer might not be the simpler, lower-carbon alternative.

Bin for recyclables

The **bin for recyclables** is another potential method for uniform collection from households throughout Germany and some local authorities already have such bins. In contrast to the currently widespread yellow sack or yellow bin collections, in which waste is separated according to use (e.g. packaging) and not according to material (e.g. plastics), the intention is for all plastics (and metal) waste to be collected in the bin for recyclables. This means, for example, that items such as plastic toys or flower pots, which today have to be disposed of in residual waste,

151 | See Recup n.d.
152 | See Essen in Mehrweg n.d.
153 | See reCIRCLE n.d. a.
154 | See REBOWL n.d.
155 | See Packaging Journal 2020a.
156 | See Circolution n.d.
157 | See Mehrwelt n.d.
158 | See Loopstore n.d.
159 | See Coelho et al. 2020.
160 | See Ellen MacArthur Foundation 2019.

may also be collected in the bin. The bin for recyclables would make significantly more plastics material available for the recycling process. Germany's Nature and Biodiversity Conservation Union (NABU) says that some seven kilograms more plastics waste would be collected per year and per household.[161] Waste separation would be considerably simplified for consumers and misplacement rates reduced. At present, while local authorities can introduce abin for recyclables in agreement with the relevant dual system, they cannot oblige the dual system to do so.

Disposal would not change for the stated applications, but there would be an increase in the volume of recycled material available for use at least as non-food packaging. Possible cross-contamination due to different limit values for individual product groups must be taken into account here.

Marker-based systems

Marker-based systems are another approach to optimising current sorting practice under discussion in the industry. Using near-infrared spectroscopy, today's usual technology, to sort mixed materials often results in just one material being recognised or no clear prism image being captured. Markers, in contrast, ensure unambiguous technical detectability and so enable optimised sorting, including of mixed materials, by material, corresponding processing and colour. In this way, they generate a more highly segregated starting material (feedstock) for recycling and increase sorting yield. This could in particular be significant if, in addition to mechanical recycling, other recycling technologies capable of further processing presorted mixed plastics become established.

Digital watermarks are currently considered the most promising marker-based technology. The HolyGrail[162] project has already conducted sorting tests at industrially appropriate speeds. One advantage of this technology is that it can be retrofitted to existing sorting plants so there is no need for new processes and plants. What makes digital watermarks particularly promising is that they also add value in other areas, such as cost benefits in logistics, inventory, checkout ("items per minute") and consumer communication.

In our use cases, markers are of interest as a solution for an uncoloured recycled polyethylene bottle with a full-sleeve film label. The digital watermark contains the information required for process control during sorting and recycling. A sleeve solution would thus be easy to sort and could be kept in circulation. What is of fundamental interest in the case of the cheese tray is that digital markers make it technically feasible to distinguish between food and non-food packaging. However, since European Food Safety Authority (EFSA) regulations state that re-sorting is not sufficient to permit use of the resultant recycled material for food-contact applications because cross-contamination cannot be ruled out, under the present circumstances markers are of no help in obtaining more recycled material for food-contact applications.

Recycled material standards

A final approach discussed here is **recycled material standards.** The standards currently in place are not yet sufficient to allow recycled material markets to function, which is why transaction costs are high compared to the use of virgin material. This is because buyers have to ensure prior to each purchase that the recycled material does meet their requirements. Even finding a suitable vendor in the first place presents a challenge. This means that buying recycled material today is preceded by a time-consuming and costly process of identifying vendors and obtaining hand samples. Standards backed by appropriate guarantees can remedy this situation. DIN, the German Institute for Standardization, has accordingly initiated a standardisation process directed at enabling proper functioning of recycled material markets.[163]

In fact, there are already a number of DIN standards for characterising recycled plastics, for example DIN EN 15342 for polystyrene (PS), DIN EN 15344 for polyethylene (PE), DIN EN 15345 for polypropylene (PP), DIN EN 15346 for polyvinyl chloride (PVC) and DIN EN 15348 for polyethylene terephthalate (PET). These define physicochemical properties which can be used to describe recycled materials and the methods with which the properties can be determined. However, the stated standards are outdated in places and no longer of great relevance to the current state of technical requirements for recycled plastics. They also have gaps in terms of the functioning of recycled material markets. Selection of the necessary criteria will also be heavily dependent on a recycled material's intended application. This is all the more true if there is an increase in the share of recycled material in the total volume of plastics used and thus in applications for mechanically recycled plastics and if attempts are

161 | See NABU 2020.
162 | See Procter & Gamble 2019.
163 | See Deutsches Institut für Normung 2020.

made to raise the number of mechanical recycling loops prior to chemical recycling.

Ensuring proper functioning of recycled material markets requires property profiles to be completed. There is also a need for recycled materials to be classified into commercial classes for which a specific selection of lower and upper limits for physicochemical properties is defined. Finally, criteria, in particular those relating to a recycled material's origin and processing history, must also be certified.

EXCURSUS: Thought experiment – a circular plastics packaging industry by 2030

This thought experiment is an unconventional approach by the working group to address the question of what changes would have to be made to the technical, economic and regulatory framework by 2030 for the purchase and use of fully defossilised plastics to be the more economically advantageous choice for a company. Factors such as the availability of recycling capacity, recycled material origin and restrictions on the use of recycled material are deliberately set aside. It is also not a comprehensive systemic study and/or modelling exercise. Instead, the intention is to outline and analyse key points for an ambitious circular plastics packaging industry in 2030. For the purposes of this look into the future, the working group has broken away from the current situation and, drawing on its combined industry expertise, has made assumptions about carbon footprints, materials prices and policy instruments from which conclusions can be drawn about the possible composition of plastics prices in 2030. The three most influential factors on the overall price are identified by means of a sensitivity analysis. The changes in these three factors which would have to occur to make the "circular" scenario the economically more attractive one are then identified.

The thought experiment compares the following two scenarios: the "base" scenario uses 70 per cent virgin material and 30 per cent mechanically recycled material. These values are consistent with the vision presented in section 3.3.2 and are intended to represent a realistic scenario. In the "circular" scenario, materials usage is completely defossilised. The second scenario is thus much more ambitious. Chemical recycling is an integral part of the scenario, on the assumption that all the environmental and human toxicity issues will have been resolved by 2030 and chemical recycling has a footprint at least 50 per cent smaller than using virgin material (see Appendix F, 1 for all assumptions).

The thought experiment is intended to reveal the impact of the ambitious scenario and to identify the circumstances under which the ambitious circular scenario would be advantageous. The following assumptions were made to enable this calculation:

- **Carbon footprints** for virgin material, mechanically recycled material, chemically recycled material and bio-based material for each of polyethylene terephthalate (PET), polypropylene (PP) and polyethylene (PE) in 2030
- **Material prices** for virgin material, mechanically recycled material, chemically recycled material and bio-based material for each of PET, PP and PE in 2030
- **Material demand** for the three bulk plastics PET, PP and PE in 2030

	Use of virgin material			Use of mechanically recycled material			Use of chemically recycled material			Use of bio-based plastics		
*	PET	PP	PE	PET	PP	PE	PET	PP	PE	PET	PP	PE
1) Base	70 %	70 %	70 %	30 %	30 %	30 %						
2) Circular				70 %	60 %	60 %	30 %	20 %	20 %		20 %	20 %

* PET = polyethylene terephthalate, PP = polypropylene, PE = polyethylene

Table 2: Thought experiment scenarios (Source: own presentation)

- **Policy instruments:** a) environmental configuration of compliance fees (for short: EPR levy) through a bonus for using defossilised plastics and b) a carbon levy in 2030

The assumptions made and an explanation for them can be found in Appendix F, 1 and 2. These assumptions give rise to the following **additional costs** for the two scenarios considered compared to the current situation. The precise calculation is shown in Appendix F, 3).

1. Additional costs for base scenario: 2,933,000,000 euro
2. Additional costs for circular scenario: 3,059,000,000 euro

This means that development of the parameters in line with the working group's assumptions would be insufficient to make the circular scenario the most attractive. A sensitivity analysis (see Appendix F, 4) is therefore used to identify which parameters have the greatest influence on price and how they must be adjusted to make the "circular" scenario more attractive than the "base" scenario. Varying the assumed parameters reveals that (1) a bonus for using recycled material, (2) a carbon levy and (3) the additional costs for chemical PET recycling are the greatest influencing factors on the overall additional costs. The percentage by which each of the three most highly influential factors would have to change to equalise the costs of the scenarios is therefore determined:

	Original assumption	Additional costs identical at	Additional costs identical in the event of change by	Additional costs in both scenarios (cost equality)
Bonus	€ 200	€ 260	30 %	€ 2,879,000,000
Carbon levy	€ 100	€ 146	46 %	€ 3,169,000,000
Additional costs, chemical recycling of PET	€ 600	€ 180	–70 %	€ 2,933,000,000

Table 3: Equalisation of additional costs for the two scenarios (Source: own presentation)

This means if in each case just one parameter were to be raised or lowered by the minimum amount indicated in the table, the circular scenario would be economically equivalent.

- A bonus would be more advantageous from 260 euro per tonne.
- A carbon levy would be more advantageous from 146 euro per tonne of CO_2.
- Costs for chemically recycling PET would be more advantageous from a price of 1,380 euro per tonne for chemically recycled PET.

While changing just one individual parameter by a large amount is mathematically possible, it is not compatible with an economically and socially acceptable configuration. The thirty percent increase in the bonus for using non-fossil-based plastics is desirable because overall system costs are reduced. However, it is questionable whether in 2030 the licensees of the dual system will be able, with license revenue to a value of around 540 euro per tonne, to meet the requirement for collection of the volumes of packaging involved. Depending on trends and scarcity in the overall EU emissions trading system, a carbon levy of approximately 150 euro per tonne of CO_2 is certainly conceivable but its main effect would be to make the base scenario more expensive. The least likely change is a price for chemically recycled material of 1,380 euro per tonne, which is slightly above the assumed price for virgin material (1,200 euro per tonne). The working group was very aware that even assuming chemically recycled material to be fifty per cent more expensive than fossil-based virgin material is very optimistic.

The rational and practical solution is therefore to make moderate adjustments to as many parameters as possible. This is also in line with the policy recommendations made in this report: only by gradually shifting all the parameters towards circularity from today onwards will the economic requirements also be met. If, for example, the initially assumed bonus rises by approximately 10 per cent, the carbon levy is 15 per cent higher and the additional costs for all non-fossil-based plastics are in each case 10 per cent more favourable than originally assumed, a circular scenario has a slight economic advantage (see Appendix F).

Overall, the thought experiment once again highlights the existing challenges in the production of non-fossil-based plastics: the costs for high-grade mechanically recycled material, the carbon footprints and the costs for chemically recycled material and bio-based plastics are not yet at the target values suitable for 2030. Accordingly, research must be intensified and investment support boosted (see section 5.5).

5 Policy recommendations

Sections 1 to 4 may be summarised as follows: **a Circular Economy requires (1) a paradigm shift with comprehensive changes in mindset, organisation and strategy. There is a need for (2) systemic change to our patterns of economic activity and consumption and (3) the only way to formulate and implement this change is a joint effort by policy makers, business and civil society. New forms of cooperation and communication are indispensable here.**

1. A new value creation philosophy must be established which recognises the enduring intrinsic worth of products and materials.

Plastics packaging has become a highly charged social, political and environmental issue. A radical rethink is needed so that packaging is no longer seen as a disposable product. Material should be used not only in the smallest possible quantities but also as efficiently and for as long as possible: in a Circular Economy (CE), packaging is transformed from a short-lived waste product into a valuable material. Consistently implementing this paradigm shift will mean moving away from the outdated mindset that closed-loop management is synonymous with mechanical recycling and establishing a diverse landscape of Circular Economy innovation and reuse which successively draws the greatest potential from each step of reducing, reusing and recycling. Circular Economy measures are not end-of-life optimisation, but are primarily intended to reduce the use of primary materials, intensify use phases and focus on keeping products and materials in high-quality material streams.

Business models must be configured in such a way that profit is maximised not by increasing material throughput, but by optimising resource utilisation. Such a value creation philosophy also offers the packaging industry the chance to transfer competition from an established market with existing margins to a new market where it can tap new value creation potential.

2. Changes must optimise the overall system, which will require expansion of established system boundaries.

System boundaries for Circular Economy transformations are not the established industry structures and value chains. The offer must be rethought on a needs basis, with the reduction in system losses also reducing greenhouse gas emissions from the packaging industry. In line with the waste hierarchy, avoiding packaging has the highest priority, provided that the environmental footprint of the package (i.e. of the product and packaging as a whole) does not increase as a result. Similarly, there may be potential in decoupling from fossil raw materials as feedstocks, provided that the non-fossil raw materials achieve better results in a life cycle assessment (LCA). Packaging placed on the market should be designed for efficient and effective resource management which aims at achieving the longest possible use phase, enables recycling in high-quality material streams and ensures proper disposal.

The ultimate goal of transformation must always be an optimised overall system. When it comes both to seeking out and to evaluating transformation strategies, it is therefore necessary to always think beyond individual industrial sectors and to interlink industries and processes, with sector coupling as the watchword.

3. Broad stakeholder dialogue and new forms of cooperation between all parties are essential.

All stakeholders have a part to play in implementing this transformation. Cooperation is required both across stakeholder groups as well as within the value chain.

Cooperation across stakeholder groups involves system designers and framework providers (policy makers), the entire packaging value chain (industry), the drivers of innovation and research collaboration (academia and industry) and end consumers (civil society). Together, they must define a common, unified direction and objectives in order to set the appropriate course and create investment certainty.

Also required is still closer cooperation within the value chain, because changes in individual links of the chain (e.g. material selection, packaging design, recycling infrastructure) have an impact on the entire system. Implementing circular approaches therefore requires a sharp focus on the entire product life cycle and any associated systems in order to take account of interactions and optimise them holistically. For example, bridges need to be built between waste management and process chemistry and in general greater transparency created with regard to material streams across different steps in the value chain. Establishing new solutions, for example packaging-as-a-service models, will mean identifying new alliances of stakeholders.

Educational institutions, especially schools, will be called upon to teach appropriate content and skills in order to create the basis for such overarching cooperation with a changed value creation philosophy.

Dimensions	From linear value creation ...		... to a climate-neutral Circular Economy
Value creation philosophy	Waste	→	Resource
	Material throughput	→	Resource utilisation
	Linear use	→	Closed-loop management
System boundaries	Value chain	→	Need
	Sector	→	Sector coupling
	Product property	→	System behaviour
Mode of cooperation	Individual decision	→	Product life cycle
	Competition	→	Value creation cooperation
	Opacity	→	Transparency
	Short-term decision horizons	→	Long-term, shared objectives

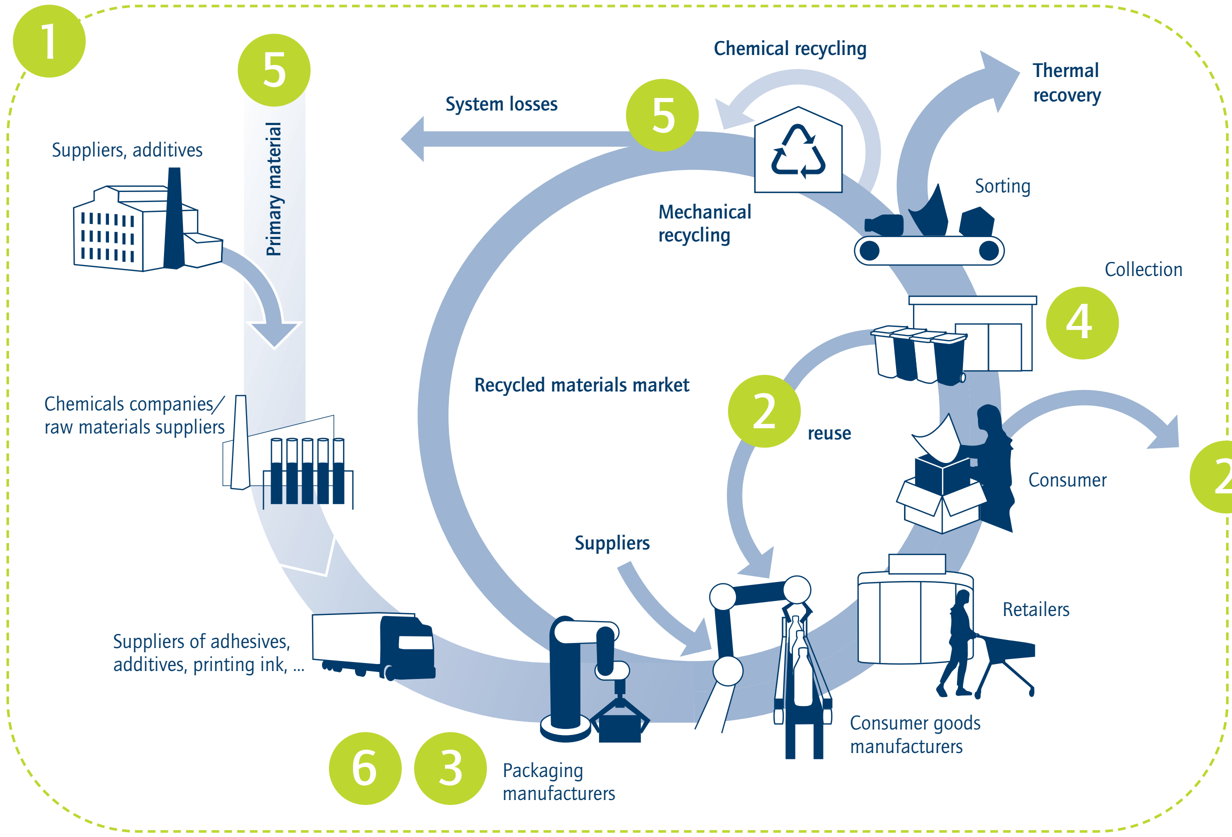
Figure 13: A Circular Economy means transforming the economy along various dimensions (Source: own presentation)

Starting points for action

Transforming the packaging industry into a system based on circular value creation means implementing measures which take effect along the entire value chain. The working group has identified six starting points which are used as the basis for structuring the packages of measures:

1. There is a need for an objective and generally accepted **decision-making aid** to enable comparison between different packaging alternatives.
2. Top priority must be given to **avoiding packaging, unnecessary use of resources and packaging waste.**
3. Packaging distributors must reassess the functional requirements of their packaging on the basis of product function and bring the design of existing packaging into line with the principles of **design for circularity and sustainability.**
4. Investment in **modern collection and high-quality sorting capacity**, including funding for track and trace technologies, is required to improve the separation of value streams. Consumer support and commitment (long-term behavioural change) also need to be strengthened.
5. The **supply of defossilised materials** must be expanded. There is a need for suitable qualities, reliable volume availability and a competitive price – all while taking account of origin and the post-use phase.
6. More **applications for defossilised material** need to be opened up to stimulate demand in the long term. This requires technical innovation and an appropriate regulatory framework.

The packaging working group of the *Circular Economy Initiative Deutschland* (CEID) is in agreement that a circular packaging industry is a European question. The policy recommendations set out in detail below are therefore not restricted to Germany, but also indicate how Germany as a central player in the debate should show the way forward for Europe.



1. Creating decision-making aid for packaging alternatives
2. Avoiding packaging and packaging waste
3. Implementing design for circularity and sustainability
4. Enabling better and harmonised collection and sorting
5. Increasing the supply of defossilised materials
6. Increasing the demand for defossilised material

Figure 14: Starting points for action (Source: own presentation)

5.1 Creating a generally accepted decision-making aid for packaging alternatives

The trade-offs described in the report between different sustainability goals and different packaging alternatives mean that there is no universal way to determine which packaging alternative is the "most sustainable". As a result, the decision as to which is the best packaging alternative for a product often has to be made on a **case-by-case basis** because the answer depends on many different product, process and market factors, such as the requirements of the package contents, modes of transport, the number of possible reuses or the recycling infrastructure accessible under real-world conditions. However, **there is a lack of a uniform decision-making basis** which specifies objective criteria and uniform system boundaries for making the evaluation in order to ensure comparability of results from individual case studies. In a first step, not only the avoidance of greenhouse gas emissions but also the reuse rate or the associated direct avoidance of primary raw materials can be used as the foremost evaluation criteria. Other parameters must, however, be included to create a broad basis for decision-making. The *Circular Economy Initiative Deutschland* proposes to be guided by the objectives it has proposed in this respect.

However, a standardised individual case assessment alone would appear not to be enough to support companies in deciding which packaging alternative is the best for their product. First of all, a life cycle assessment would have to be carried out for all potential types of packaging (and their potential infrastructure), something which is not possible in practice. Secondly, a case-by-case evaluation can only model the environmental potential of systemic changes, for example of an open-pool, multi-use system, to a very limited extent. Research funding is therefore also necessary in order to develop such a holistic and practically usable decision-making aid.

A generally **accepted decision-making aid** can also be the basis for a dedicated "packaging label" which, as an easily understandable and credible means of communication, could steer demand towards sustainable and circular packaging. Developing such a label with appropriate criteria and indicators (as a meaningful supplement or replacement for all existing labels) will require an interdisciplinary, scientific consortium.

5.2 Avoiding waste

In the past, gains in efficiency in packaging design have been incapable of offsetting the rapidly growing volume of (plastics) packaging waste. The primary objective of the Packaging Act (formerly the Packaging Ordinance) of **avoiding packaging waste**, has therefore not been achieved for years. Increased avoidance of waste must therefore be made a particular priority. This entails a plan with **specific targets, measures, economic incentive systems and a defined timeline**. Research can make a contribution here by proposing appropriate indicators for setting and monitoring targets. In general, the targets and requirements set out in the Packaging Act must be implemented in a binding manner. Such a plan should include **independent monitoring bodies** which a) provide information about the transparent presentation of interim results on defined targets and requirements, b) initiate appropriate measures in the event of impending failure of the corresponding measures and c) are entitled to impose sanctions for non-compliance.

A further step towards avoiding packaging waste is to **expand opportunities for reusing packaging.** There is a need to further develop, test and implement reuse concepts suitable for large-scale application which are environmentally advantageous and economically viable. This requires increased industrial cooperation, also in new alliances of stakeholders. Multi-use systems, for example, are particularly environmentally advantageous if many stakeholders make use of **standardised packaging in an open-pool system**. It is important to verify the environmental advantages of reuse concepts. Policy makers should provide greater support here, for example by offering **dialogue platforms** and intensifying **startup support** in this area. When designing such environmentally and economically optimised reuse concepts, one further measure would be a gradual rollout, to beyond the beverage sector, of binding usage rates for multi-use food, transport and shipping packaging.

5.3 Implementing design for circularity and sustainability

A major obstacle to closing the loop is the lack of **attention paid to Circular Economy principles in the design of packaging** (see section 3.3.1). During product design, greater consideration must be given to the use and post-use phases of packaging, i.e. all unavoidable packaging should be usable, reusable and recyclable to a high quality for the longest possible period, and thus designed for efficient and effective resource management. In addition, material and product design should consistently ensure that no toxic effects occur along the value chain and subsequent use is not impaired. Where environmentally appropriate and possible, secondary material or alternatives to fossil-based primary material should be used while taking account of the overall system.

At the political level, **section 21 of the Packaging Act** introduced an important lever for improving design. This section requires **bonuses in the compliance fees** for recyclability, the use of recycled materials or the use of renewable raw materials. Adjustments are, however, required in order to align reward systems in a targeted and consistent manner with environmental benefits, taking account of the packaging system as a whole. A **properly functioning funding mechanism with unambiguous and uniform rules** is also needed, if this incentive in section 21 of the Packaging Act is to be truly effective. This is because, if differing regulations mean that the dual systems are in competition with one other, there is no way for them to have ambitious steering effects. One option for a uniform solution here would for example be to establish a fund financed by private and public stakeholders from which such bonus incentives could be financed.[164] There is an urgent need to find a solution which complies with antitrust law and specifically promotes sensible avoidance approaches and multi-use systems.

The requirements for dual systems ought to be reworded to ensure a targeted effect. **Compliance fees should be consistently calculated** on the basis of Circular Economy objectives and be aligned accordingly. Reduced use of resources (e.g. by using recycled materials) and good recyclability or a uniform packaging

164 | See RecyclingNews 2020.

design should be incentivised. **Flat-rate quantity discounts without reference to such packaging design factors are not very useful.** They disadvantage small suppliers and obstruct their innovative efforts. The evaluation criteria for establishing surcharges and discounts on licences must be transparent. A systematic approach must be developed for this purpose which can be adapted as required while still safeguarding previously agreed fees.

Harmonisation of the **legal requirements** applicable to a product and its packaging, for example product (protection) and waste legislation, would also help to make it easier for companies to achieve the potential of a Circular Economy. These regulations should also be harmonised internationally so that there is no need for isolated national solutions but economies of scale can instead be exploited and closed-loop management becomes economically viable. There is therefore a need for EU-wide standardisation of definitions and requirements, as well as harmonisation of specifications at the national and local authority level.

Obtaining segregated material streams in large volumes for mechanical recovery would require packaging to be designed in such a way that consumers can easily separate it or to be consistently made from monomaterial. In future, composite packaging could also contribute to harmonised material streams once scaled-up separation processes are available and implemented in practice. Overall, however, the variety of packaging on the market must be reduced. Minimum standards for EU-wide **harmonisation of packaging materials** and their components should be defined in order to achieve this. A first step is to draw up lists of recommended materials, components and substances, taking account of toxicological aspects and their behaviour in the use and post-use phase. In addition, it should be investigated whether colour standardisation makes sense for certain large-volume types of packaging (e.g. polyethylene (HDPE) hollow items) in order to achieve quality improvements in post-consumer recycled material. Implementing minimum requirements for packaging in order to harmonise material streams can likewise be controlled by means of the compliance fees. Should this not prove successful, straightforward bans of specific materials, material composites or chemical components may be a complementary measure if no recycling method is available for them and recycling structures are in place for other materials which meet the same product requirements.

If design for circularity and sustainability aspects are to be taken into account in the long term, core Circular Economy ideas must for example also be enshrined in curricula and corresponding specific **training content** must be provided, for example for early-career industrial designers or material developers.

5.4 Enabling better and harmonised collection and sorting

Despite increased communication efforts by the dual systems, the **misplacement rate of post-consumer packaging waste is high.** Too much packaging still ends up in the residual waste because of excessive soiling in the yellow sacks and bins. On the one hand, this reduces the quality of the recycled material and, on the other hand, considerable volumes of material, which might potentially be recyclable, also fail to reach the dual system and are instead incinerated by being disposed of with residual waste. In order to make sorting easier for citizens, waste should in future be entirely separated by material type in German households. Additional incentives should also be provided for households to maximise segregation of used packaging, for example on the basis of an analysis of sorting quality, an approach currently being tested in Austria.[165]

Numerous factors can help to **support consumers** in sorting packaging waste. If packaging is to be viewed as a material with intrinsic worth and not as waste, (early childhood) **education** and consistent factual and pragmatic communication are important in order to reduce frustration among customers due to confusing recycling systems. Mandatory labelling, for instance a uniform traffic light-coding system for separation, would enable more informed purchasing decisions. "Circular purchasing decisions" can be encouraged by positive incentive systems such as a points account or deposit systems. Barriers to correct disposal should also be broken down. This can be achieved by standardising disposal systems across districts, increasing the provision of drop-off stations, and using smart bins or digital labelling for recycling at sorting plants.

Modern, for example marker-based, sorting technologies can support consumers in sorting or optimise their sorting results. Using these technologies could also help to build up sorting and recycling infrastructure internationally, which has so far largely been impossible due to national and regional differences in waste legislation.

One incentive system for segregated collection which is already functioning excellently is the **deposit system**. The extent to which it makes sense to extend mandatory deposits to other types of packaging, not only in the beverage sector but also

165 | See Stadt Villach/Saubermacher Dienstleistungs AG 2018.

for further product groups which generate significant streams of packaging waste, merits investigation. The prerequisite is that the deposit packaging is standardised and designed to be recyclable from the outset.

5.5 Increasing the supply of defossilised raw materials

At present, there are insufficient supplies of high-grade recycled plastics materials and bio-based materials for replacing fossil-based virgin material. Supplies of defossilised materials in the necessary quality and quantity must therefore be built up.

As this report shows, the packaging industry is only just beginning to exploit the **potential of mechanical recycling.** In particular, implementation of the policy recommendations for the design of packaging is playing a decisive role in recycled material quality. At the same time, there is a need for significant **investment in recycling technology and infrastructure** to modernise plants (e.g. through uniform material stream management, the integration of multistage sorting processes, hot washing processes, deinking) and to build up the necessary capacity. Achieving this will require further development not only of quality-oriented business models but also of technological measures for targeted handling of packaging material streams. It is apparent at this point just how important it is to **intensify cooperation** along the value chain so that high-grade recycled material can be produced. At present, there is an oversupply of low-quality recycled material and a shortage of high-grade recycled material, a situation which is not beneficial for either packaging manufacturers or recyclers.

The current statutory mechanical **recycling rate** with its purely quantitative targets has also contributed to this situation. If quality is to be improved, the focus must in future be not only on improving inputs into recycling systems but also on output quality. In addition, **recovery and recycling rates**, especially for plastics, should be broken down into **specific types**. This allows more accurate consideration of the fact that more ambitious targets can be set in some areas than in others (e.g. food packaging versus packaging for electrical appliances). To this end, efforts should be made to ensure uniform regulations within the European Union (EU).

Mechanical recycling offers significant and as yet far from exhausted potential for making renewed use of packaging materials. However, as the excursus on mechanical recycling shows, permanent, closed loop management of packaging materials for the same applications cannot be achieved by mechanical recycling alone. Further research is required to determine which materials are particularly suitable for closed-loop management and how the number of cycles can be increased. There would nevertheless be a need in a closed Circular Economy model to offset material and quality losses in mechanical recycling with **virgin-grade defossilised plastics.** Chemical recycling and bio-based plastics are, however, only solutions if they offer environmental advantages; in other words, the specific situation must always be individually considered. For bio-based plastics, for example, competition with foodstuffs must be ruled out. Sustainability criteria should be implemented in the form of credible certification schemes. It must be ensured that chemical recycling is not considered equivalent to mechanical recycling, but rather is defined as a possible complementary technology where mechanical recycling is more environmentally advantageous. In addition to energy inputs, further factors such as for example toxicity and purity and raw materials costs or inputs still need to be evaluated in comprehensive studies. Given that the chemicals industry has a future feedstock problem to solve and recognising that huge international effort is being put into scalable chemical recycling processes, Germany should, however, be more than simply an observer when it comes to producing and supplying sufficient high-quality feedstocks. Germany could forge ahead innovatively and point the **way forward to climate-neutral chemical recycling.** In particular, cross-technology processes and cascading use will in future be of significance in providing secondary raw materials for a more efficient Circular Economy. Gaining a better understanding of the purposes for which and volumes in which chemically recycled and bio-based virgin materials are required entails investigating what an **environmentally optimised and technically meaningful defossilised material mix** might be. To enable applicational research into these issues and for example allow integrated sustainability analyses to be carried out, pure research funding could be complemented by also setting up a **real-world laboratory.**

At the same time, funding should be provided for projects which **open up new and responsible bio-based raw material sources.** The focus should be on harnessing existing residues, for example available agricultural, commercial and household waste, as well as biological side streams such as waste wood, whey components and biowaste, as feedstocks for synthesising bio-based plastics.

During the changeover from chemical processes for purely fossil-based natural resources to completely defossilised raw materials, mixed forms will arise that require a certified **mass balance approach,** for both bio-based and chemically recycled materials. This is because the conversion products will gradually be integrated into the existing chemical infrastructure in order to finance the changeover. This means that the defossilised starting material streams are not kept physically separate from fossil raw materials and it is therefore not possible to trace what percentage of which starting material ends up in which finished product. To a certain extent, the mass balance approach replaces this unachievable transparency with rules of apportionment. It defines how the quantity of input defossilised material may be apportioned to the finished products and thus also determines what may be marketed as "recycled" or "bio-based". To ensure general acceptance of the mass balance approach, it is essential for it to be developed by an independent consortium according to scientific principles and to be independently certified.

There is a need for an in-depth discussion from different perspectives about the extent to which **offsetting against statutory recycling rates** makes sense in order to stimulate investment in chemical recycling, or whether conversely such offsetting means there is a greater risk of the full potential of mechanical recycling not being fully utilised. Given that the aim of implementing Circular Economy measures is to reduce greenhouse gas emissions, any regulations which are adopted should in particular not rule particular technologies in or out but instead promote those solutions which can demonstrate the smallest carbon footprint.

5.6 Increasing the demand for defossilised material

Defossilised material, i.e. recycled materials and virgin material from renewable raw materials, competes with fossil-based virgin material in terms of price. As a result, especially in times of low oil prices, economic incentives are necessary in order to increase the use of defossilised material and create stable demand. There are two fundamental ways of achieving this: increasing the price of fossil-based virgin material or subsidising defossilised alternatives.

The price of fossil-based virgin material could be increased by a general **carbon levy** or a **raw materials tax on all packaging materials.** The impact of such instruments should first be evaluated. The "EU plastics levy",[166] which has already been adopted and which, if appropriately designed, could have a similar effect to a raw materials tax, does not go far enough. Since it is the volume of non-recycled waste from plastics packaging which serves as the basis for calculating the level of national contributions, the levy starts from the wrong place from an environmental standpoint. Such a levy has an incentive effect towards less waste requiring thermal recovery only if the additional costs burden the distributor of non-recyclable packaging made of primary material. The costs would therefore have to be apportioned, something which should be taken into account in the national embodiment of the levy. Since only plastics are affected by the levy, there is a risk that they will be replaced by other materials which are less or not at all recyclable or have a larger environmental footprint. The levy is also not earmarked, for example to finance necessary improvements in materials management and recycling infrastructure. These areas thus still lack the necessary investment.

In order to provide an appropriate level of stimulus for the recycled materials market, it makes sense to gradually roll out a fixed **minimum proportion for the use of post-consumer recycled plastics** in certain sectors. These mandatory usage rates would lead to an increase in demand for recycled materials and the emergence of a genuine recycled raw materials market. However, when determining this minimum proportion, it must be ensured that the recycled materials are also available on the market in the necessary quality. It would be helpful if recycled material usage rates and quality standards could be defined at an appropriately early stage in order to provide investment certainty for construction of the required capacity. A nuanced approach should, however, be taken. As explained in section 4, for food products the only source for such a recycled material content is the deposit bottle stream. Under the German DPG deposit system, this material could be kept in a genuinely closed loop but, if used for food packaging, would be removed from a high-quality material stream and in many cases incinerated after its second life cycle. This example is representative of a systemic problem that using recycled material in packaging does not necessarily in itself make sense or that the actual subsequent use of the recycled material must always be taken into consideration in addition to its origin and quantity.

As the cheese packaging use case (section 4.2) also shows, the European Food Safety Authority (EFSA) requirement that at most five per cent of the polyethylene terephthalate (PET) recycled material for food packaging may originate from non-food applications is a major obstacle to the use of recycled material. This condition should be subjected to critical review. There is a fundamental need to devise mechanisms and strategies for

166 | The levy was adopted in July 2020 and serves as a tool to calculate national contributions to the corona-battered EU budget. The volume of non-recycled plastics packaging waste is to be used as the basis for calculating the level of national contributions.

the future as to how further recycled materials, in addition to polyethylene terephthalate (PET) from the deposit stream, can be approved as a **secondary raw material for food contact,** for example by separately diverting previously optimised polyolefin food packaging. The development of suitable barrier coatings as migration barriers may also play a role. The restriction that only recycled materials from the PET deposit bottle stream can be used for food packaging must be overcome.

Establishing **safety requirements and standards for recycled materials** applicable across the EU would simplify the use of recycled materials. Such common standards should ensure that recycled materials are always used in a specific quality for a particular product group and are produced accordingly. For example, the same quality standards are not required for cleaning products as are required for food-contact packaging. Minimum qualities should therefore be defined for different product groups (cosmetics, cleaning products, food). Clearly defined standards would also contribute to better planning of demand and so ensure availability of sufficient recycled material of the appropriate qualities. This is because standardisation enables **purchase guarantees** to be agreed in the industry, so in turn creating investment certainty for recycling companies. Policy makers should promote the establishment of these standards, for example by using and, where appropriate, mandating established standardisation organisations. By developing **test methods,** research can contribute **to ensuring material and product safety standards.**

6 Roadmap and outlook

The members of the working group have prioritised the policy recommendations for policy makers, business, science and civil society set out in detail in the previous section and scheduled them into the following roadmap for achieving the outlined vision for a Circular Economy for packaging.

Projects | **2021–2024: short term "Setting the course"**

Public policy

1. Initiation of development work on a scientifically based **decision-making aid** for the sustainability of packaging
2. Development of binding **waste prevention concepts** and establishment of an independent control body
3. **Finalisation** of **section 21 Packaging Act** (aligned with EU requirements)
4. Establishment of a uniform national **collection system** with separation **by material**
5. Submission of a binding EU-wide plan for expanding and optimising **collecting, sorting and recycling infrastructure**
6. Investment support for **sorting and recycling technologies**
7. Initiation of **recycled material and recycling standardisation processes** at the EU level
8. **Clear communication** and **uniform labelling** for consumers
9. Provision of **education** and **training**

Business

10. Development and **scaling up of (business model) innovations** in which **active avoidance of non-necessary packaging** is the top priority
11. Ensuring packaging is reused or mechanically recovered to the highest possible quality by means of **appropriate design**
12. Consistency of material and product design such that **no toxic effects** occur along the value chain and impair subsequent use
13. Collaborative introduction of common **(minimum) standards for harmonising** packaging and its components
14. Collaborative development of common **recycled material and recycling standards**
15. Optimisation of **educational work** with regard to purchase decisions in favour of the most sustainable product as well as the functioning of the separate collection of recyclable materials

Sciene

16. Provision of an **assessment basis or decision-making aid** for the sustainability of packaging (taking account of overall systemic effects)
17. Creation of potential analyses for **reuse systems**
18. Further research into **consumer behaviour**
19. Compilation of **suitability lists for recommended materials**, components and substances in the light of human and ecotoxicology and their behaviour in the use and post-use phases
20. Research and further development of **recycling technologies and alternative raw materials** and their suitability for packaging
21. Provision of appropriate **training content** (e.g. recyclable product design)

Civil society

22. **Change of attitude:** packaging has intrinsic worth
23. Avoidance of **product and food waste**
24. Avoidance of **unnecessary packaging** by aware and responsible consumption
25. **Proper pre-sorting** and disposal, in particular no littering

Projects ▷ **Up to 2027: medium term "Creating structure"**

Public policy

26. Harmonisation of national and transnational **regulatory framework** (e.g. product protection and waste legislation)
27. EU-wide introduction of binding minimum standards for **harmonising packaging materials** and their components
28. Use of **decision-making aids** to design **economic incentives** (bonus/penalty systems, carbon levy, etc.)

Business

29. Common development and rollout of technologies and tools for creating **transparency in material streams**
30. Greater **collaborative development** of circular economy system innovations
31. EU-wide coordinated expansion of **collection, sorting and recycling infrastructure**
32. Active participation in and funding of the development and optimisation of collection, sorting and **recycling technologies**
33. Use and ongoing development of **alternative raw materials**

Sciene

34. Provision of tools and methods for **monitoring of avoidance and reduction** of packaging volumes
35. Provision of tools and methods for determining the **environmentally optimum defossilised material mix**

Civil society

36. Acceptance and support of **new packaging alternatives**
37. Willingness to bear what may sometimes be higher **costs** of the transformation to a Circular Economy in order to shape a sustainable system and reduce costs (including external effects) for society as a whole

Projects ▷ **Up to 2030: long term "Breaking through"**

Public policy

38. Long-term **increase in recycling rates** (coupled to qualities and types of material) and adjustment of the **licensing fee**
39. **Paradigm shift**: ongoing prioritisation of the goals of a CE in schools, in the media and in policy action
40. Transfer of measures in **a global context** for leading markets on the one hand ("race to the top") and developing economies on the other (development cooperation)

Business

41. Establishment of **transparent and trustworthy value networks**
42. Expansion of system **innovations worldwide**

Figure 15: Roadmap for achieving the vision (Source: own presentation)

Implementing this roadmap can enable system change towards a Circular Economy for packaging. The key to success will be to set an ambitious course in the short term and so create investment incentives and certainty. Establishing a circular model is essential to meeting society's high expectations. Above all, however, tackling the transformation early and with determination will also have long-term economic benefits as environmental regulation becomes increasing stringent.

The members of the packaging working group of the *Circular Economy Initiative Deutschland* hope that this report has made a useful contribution to the dialogue in favour of a Circular Economy for packaging. The transformation is still at its outset and is dependent on further collaborative exchange. It is now up to all the various stakeholders from politics, business, science and civil society to make a concerted effort to put the proposed policy recommendations into practice.

Circular Economy Initiative Deutschland

Appendix

A List of abbreviations

APET	Amorphous polyethylene terephthalate
APR	Association of Plastics Recyclers
B2B	Business-to-business
B2C	Business-to-consumer
BAU scenario	Business-as-usual scenario
BMBF	Federal Ministry of Education and Research
CE	Circular Economy
CEID	*Circular Economy Initiative Deutschland*
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
DPG system	Deutsches Pfandsystem GmbH's deposit system for single-use plastic bottles
EFSA	European Food Safety Authority
DPC	Disposable plastic crate
EPR	Extended Producer Responsibility
EU	European Union
EVOH	Ethylene/vinyl alcohol copolymer
SUP system	Single-use packaging system
H_2	Hydrogen
HDPE	High-density polyethylene
ISCC	International Sustainability and Carbon Certification
JRC	Joint Research Centre
KrWG	Circular Economy Act
LCA	Life cycle analysis
LPDE	Low-density polyethylene
RPC	Reusable plastic crate
MUP system	Multi-use packaging system
NABU	Nature and Biodiversity Conservation Union, Germany
NIRS	Near-infrared spectroscopy
PE	Polyethylene
PET	Polyethylene terephthalate
PET-BO	Biaxially oriented polyester films
PHA	Polyhydroxyalkanoates
PLA	Polylactides
PO	Polyolefins
PP	Polypropylene
PS	Polystyrene
PVC	Polyvinyl chloride
SiOx	Silicon suboxide

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D About the Circular Economy Initiative Deutschland

The *Circular Economy Initiative Deutschland (CEID)* brings together stakeholders from business, science and civil society with the aim of developing a joint vision for Germany and identifying the existing circumstances and future requirements. The *Initiative's* work is carried out in various committees, with the steering committee taking responsibility for management and strategy. The task force consists of representatives from those businesses, academic institutions and civil society organisations represented on the steering committee as well as staff members from the *Circular Economy Initiative Deutschland* office and from collaborative partner SYSTEMIQ. The task force's main role is to develop a Circular Economy roadmap. The working groups discuss specific issues such as packaging or batteries and elaborate opportunities and challenges in terms of implementation of the Circular Economy.

Funding for the project is provided by the Federal Ministry of Education and Research (BMBF). Involving the relevant government departments in the steering committee ensures wide-ranging links with policy makers, while acatech and SYSTEMIQ, as the Initiative's office, coordinate the Initiative and undertake independent, substantive preparatory work. acatech's Vice-President Thomas Weber chairs the Initiative.

The work of the *Circular Economy Initiative Deutschland* is divided between three working groups:

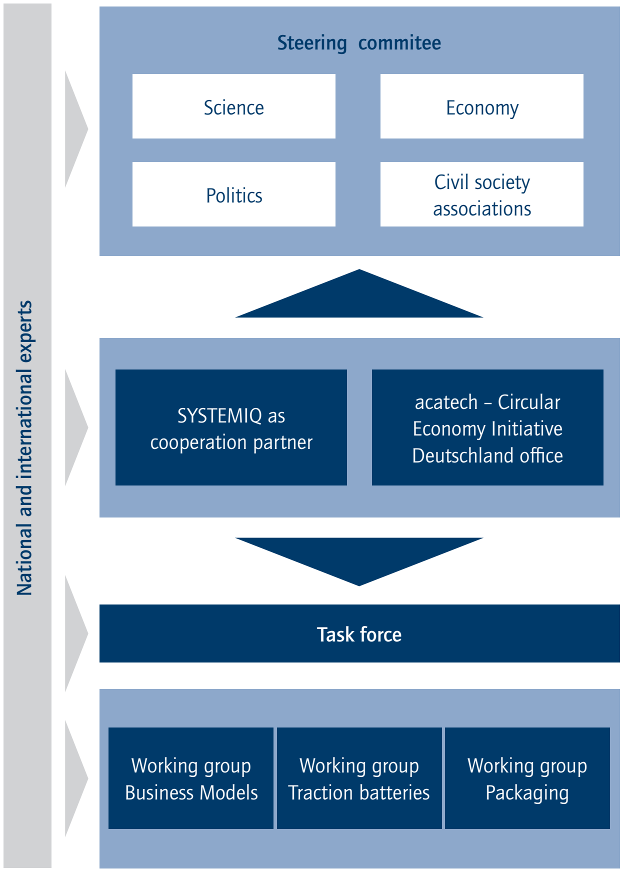

Figure 16: Organisational chart and areas of focus of the *Circular Economy Initiative Deutschland* (Source: own presentation)

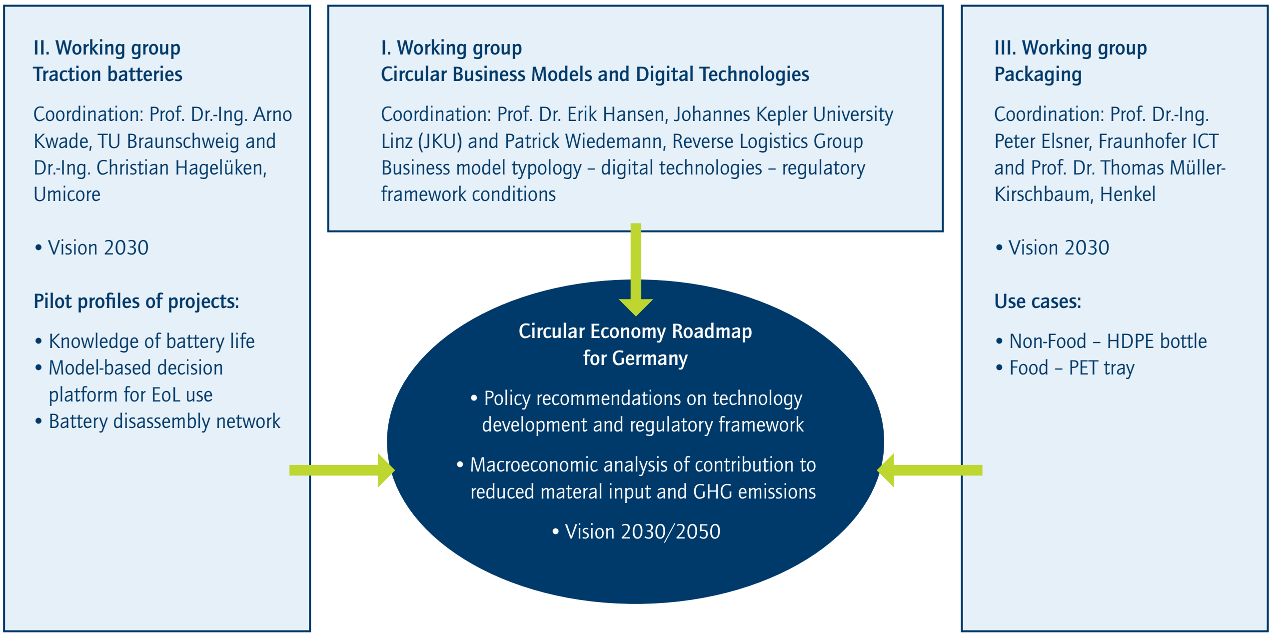

Figure 17: The *Circular Economy Initiative Deutschland* links specific case studies with overarching issues (Source: own presentation)

- The business models working group works on a conceptual level to address the potential for circular business models and digital technologies for driving innovation.
- The other two working groups focus on the sector-specific functional systems of traction batteries and packaging.

Various criteria were applied when selecting the two functional systems for the traction battery and packaging working groups, these being in particular

- relevance to Germany as a location for business,
- potential for real-world implementation in the form of collaborative business projects over the life of the Initiative,
- possibility of establishing new, cross-sectoral value networks, and
- achievable added value in an international context, for example by approaching Europe's Circular Economy debate from a new angle or through links with European business partners.

E Fundamentals for developing the vision

Plastics packaging has become a central pillar of our consumption patterns and serves a very wide range of functions which make a significant contribution to climate protection and resource conservation. Among other things, in the absence of plastics packaging, our current food system would involve even higher levels of food waste and substantially greater losses of resources than would be involved in the production, use and recycling of packaging.[167]

At the same time, however, the plastics packaging system is faced with the challenge of moving from a linear "Make – Use – Dispose" system to circular solutions in which the greatest possible proportion of the value of the packaging product itself and the natural resources used to produce it is retained.[168] Against this background, the Circular Economy action plan focuses specifically, among other things, on the issue of plastics packaging, which it sees as having particular potential for achieving the stated objective of a "cleaner, more competitive Circular Economy" for Europe.[169]

The aim of this report is to build a data set which can be used as the starting point for the work of the *Circular Economy Initiative Deutschland's* packaging working group. To this end, the central assumptions for a potential "optimised packaging system" vision for the years 2030 and 2050 are discussed below, together with the associated environmental impact.

Methodology and procedure

With this goal in mind, a number of possible scenarios are considered below which result from the optimisation of key individual levers such as the use of secondary raw materials or bio-based plastics. The analysis, based on otherwise constant parameters, is thus incomplete and does not avert the need to develop forecasts, in particular in terms of 2050. The underlying assumptions were made on an exogenous basis, being based either on the academic literature as it stands or the results of the expert discussions within the relevant working group (the central assumptions and their sources are stated transparently here). For particularly relevant points or those issues where different perspectives are to be found even within the working group, sensitivities were calculated and the results juxtaposed, without any statement being made as to which might be considered the more probable or realistic.

For these considerations, the quality and functionality of the packaging have in particular been assumed to be constant, i.e. no trade-offs are made, for example, in terms of the occurrence of food waste. At the same time, it is assumed with regard to packaging that no disruptive innovations are to be expected in the run-up to 2050 which might for example make the use of packaging superfluous due to new food production methods. The focus is on packaging placed on the market in Germany and the associated effects along the entire value chain; any deviations from this system limit are explicitly stated.

Scenario 2030/2050

Against the described background of plastics packaging circularity in Germany, the intention is to develop an optimised packaging system scenario for the period 2030/2050. The parameters considered include the following points:

1. Developments in the volume of plastics packaging used in a business-as-usual (BAU) scenario to 2030/2050 in line with growing demand
2. Developments in material efficiency when using plastics for packaging
3. Developments in the proportion of recycled materials in the packaging sector, differentiated by volume from chemical and mechanical recycling
4. Developments in the proportion of bio-based plastics in the packaging sector
5. Developments in the proportion of reusable packaging.

167 | See Markwardt/Wellenreuther 2017.
168 | See Ellen MacArthur Foundation 2017a.
169 | See European Commission 2020.

1. and 2.: Developments in a business-as-usual scenario and packaging material efficiency

As described, the volume of plastics packaging placed on the market has been constantly increasing in recent years. Moreover, some current trends are likely to lead to increasing volumes of packaging in the future, for example the trend for packaged sliced sausage and cheese.[170]

At the same time, manufacturers and retail have in recent years invested massively in optimising packaging material efficiency, so as to save on material and logistics costs. For this reason, a marked reduction in finished weights especially in dimensionally stable plastics packaging has been observable on the market, alongside a slight decrease in film basis weights. Private final consumption of plastics packaging in year 2013 would have been a total of 955,000 tonnes higher had finished weights remained the same as they were in 1991.[171]

The BAU scenario thus represents the net effect of volume growth combined with increasing material efficiency. Assuming the current situation, the results for 2030/2050 for volumes of relevant types of plastics would be as follows.

	Total in 2017 [Volumes in T t]	Proportion packaging [Volumes in T t]		
		2017	2030	2050
HDPE	1,828	731.2	887	1,195
LDPE	2,144	1,286.4	1,561	2,103
PS	452	113	137	185
PP	2,453	809.49	982	1,323
PVC	1,843	276.45	335	452
PET	916	732.8	889	1,198
Total	9,636			
of which packaging		3,949.34	4,793	6,455

Table 4: Extrapolated plastics volumes in the business-as-usual scenario for 2030/2050 (Source: own presentation) Data of Conversio 2018 and Schüler 2019

170 | See Schüler 2020.
171 | See Schüler 2019.

3. and 4.: Assumptions relating to proportions of recycled material from mechanical and chemical recycling

One of the central levers for plastics packaging sector circularity is, as described, the proportion of non-fossil-based, primary plastics. Against this background, the working group has agreed on a vision intended to provide the basis for the scenario calculated here.

Starting from a value of 90.9 per cent primary plastics in 2017,[172] the intention is to achieve the targets listed in the following table by 2030/2050. It must be borne in mind that these values relate to the plastics packaging sector as a whole; especially in the non-food sector, a number of key players have committed to even more ambitious target values,[173] and therefore these values should be understood as an average of food contact and non-food contact packaging. The values thus reflect orders of magnitude as used in other scenarios relating to the packaging sector.[174, 175, 176]

The associated CO_2 savings were assessed with reference to a study by the Association of Plastics Recyclers (APR) in which comprehensive life cycle analyses were carried out for individual materials.[177]

The figure below shows the very marked differences in the ratio of primary to secondary material depending on the allocation mechanism used: the framework for carrying out life cycle analyses makes it possible to assign the savings enabled by using recycled material to both the starting product and the product in which the recycled material is used. Since the vision developed is directed towards recycling material as often as possible, the audit was prepared using an open-loop methodology.

	2030	2050
Recycled material from mechanical recycling	25 %	40 %
Recycled material from chemical recycling	0 %	20 %
Bio-based plastics	5 %	20 %

Table 5: Vision 2030/2050 (Source: own presentation)

172 | See Conversio 2018.
173 | See Henkel 2020a.
174 | See Ellen MacArthur Foundation 2013.
175 | See Material Economics 2019.
176 | See Kaeb et al. 2016.
177 | See Franklin Associates 2018.

	PC resin collection & sorting	PC resin transport to reclaimer	Process water & chemicals	Process energy, bale to flake	Process energy, flake to pellet	Process emissions & wastes	Recycled resin pellet total
CUT-OFF							
MJ (Megajoule) per kg of resin							
Recycled PET	1.19	0.87	0.21	6.44	6.14	0	14.8
Recycled HDPE	1.52	0.92	0.13	2.55	3.57	0	8.69
Recycled PP	1.64	1.04	0.11	6.09	6.09	0	8.89
OPEN LOOP							
MJ per kg of resin							
Recycled PET	0.60	0.43	0.10	3.22	3.07	0	42.3
Recycled HDPE	0.76	0.46	0.067	1.27	1.78	0	42.0
Recycled PP	0.82	0.52	0.057	3.04	3.04	0	41.6

	Virgin pellet (including feedstock energy)	Recycled % of virgin	Recycled resin % reduction from virgin	Virgin pellet (excluding feedstock energy)	Recycled % of virgin	Recycled resin % reduction from virgin
CUT-OFF						
MJ per kg of resin						
Recycled PET	69.8	21 %	79 %	33.3	45 %	55 %
Recycled HDPE	75.3	12 %	88 %	25.0	35 %	65 %
Recycled PP	74.4	12 %	88 %	25.1	35 %	65 %
OPEN LOOP						
MJ per kg of resin						
Recycled PET	69.8	61 %	39 %	33.3	72 %	28 %
Recycled HDPE	75.3	56 %	44 %	25.0	67 %	33 %
Recycled PP	74.4	56 %	44 %	25.1	68 %	32 %

Figure 18: Total energy results for recycled resin compared to virgin resin, with and without feedstock energy (Source: Franklin Associates 2018)

It was assumed here, for simplicity's sake, that the different greenhouse gas effects of different materials for otherwise identical packaging result solely from the production process for the starting materials (polymer production stage), i.e. that both the further processing process and the product design or post-use phase remain unchanged.

In this context, the Joint Research Centre of the European Commission made use of the Comparative Life-Cycle Assessment of Alternative Feedstock for Plastics Production study, the aim of which was to develop a comprehensive data set for the assessment of different packaging starting materials.[178] This project was initiated by the European Commission in the context of the Strategy for Plastics in the Circular Economy and looks at the overall effects of recycled material usage, among other things, in relation to packaging as a functional unit. It is clear from this that the differences between primary material and recycled material are much smaller than might be expected, the reason being, inter alia, the more complex processing of plastics with higher recycled material contents, which for some kinds of packaging need greater wall thicknesses, for example.

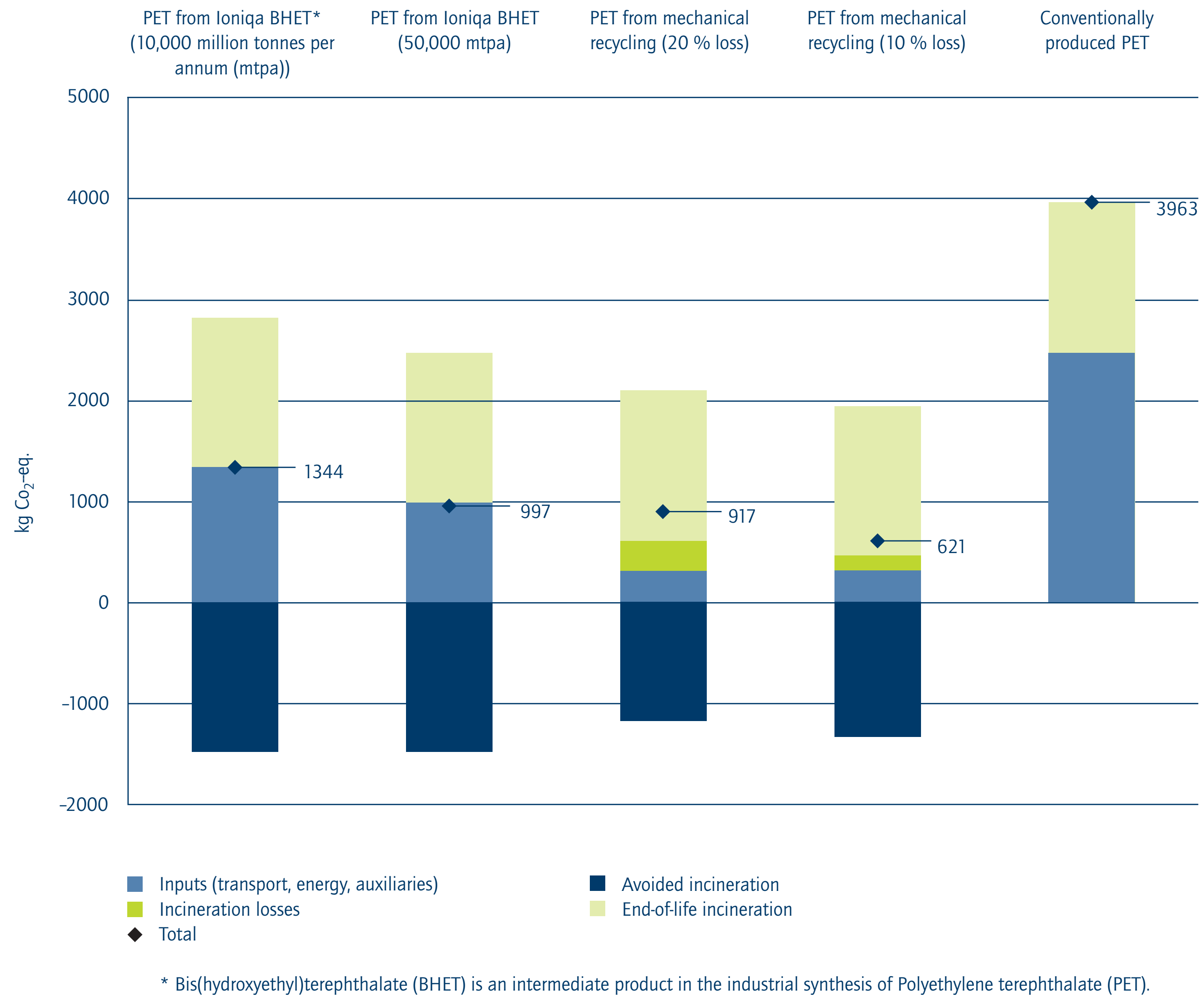

Figure 19: Greenhouse gas reduction potentials for different recycling routes (Source: Bergsma/Lindgren 2018)

178 | See Nessi et al. 2020.

Even chemical recycling is subject to widely varying definitions and thus also different evaluations (see excursus "Chemical recycling", page 37).[179] For evaluation purposes, a method developed by Delft University of Technology was used, for which a comprehensive life cycle analysis for polyethylene terephthalate (PET) was performed.[180] For simplicity's sake, the determined relative reduction potentials were also applied to the other types of plastics under consideration here.

5) Multi-use packaging

One possible way of optimising the plastics packaging system is to establish multi-use systems in which the same item of packaging can be used repeatedly for the same purpose, instead of being disposed of after a single use.

Studies have shown that the consumption of packaging materials in the business-to-consumer (B2C) and business-to-business (B2B) sectors drops considerably in principle as a result of increased use of multi-use packaging (MUP) systems, with a consequent reduction in negative environmental impact.[181] In general, although MUP systems are more commonly used in the B2B sector, there are also long-established systems in some B2C markets (beer, mineral water etc.).

However, a comprehensive analysis of environmental impact in the form of a life cycle analysis is needed in each case when it comes to deciding whether an MUP is preferable to a single-use packaging (SUP) system. Against this background, a distinction was drawn for assessment purposes between end consumer packaging and commercial packaging, the potential savings being looked at on the basis of the following product examples:

a) Beverages (single-use PET versus multi-use PET)
b) Plastic cartons for transporting foodstuffs

Reusable plastic crates

In Italy, approximately 36 per cent of fruit and vegetables are distributed in reusable plastic crates (RPCs), as is revealed by a comprehensive life cycle analysis for assessing environmental performance.[182] A comparison of RPCs for transporting fruit and vegetables with a system based on disposable plastic crates (DPCs) makes it clear that their environmental impact is primarily

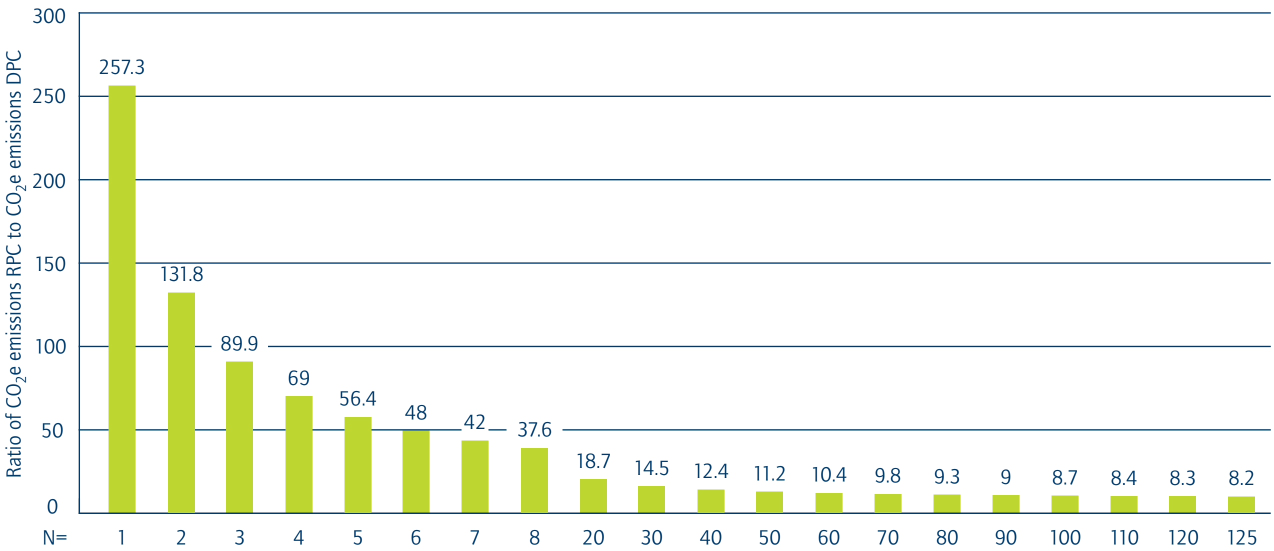

Figure 20: Emission of CO_2 equivalents from RPCs in comparison with DPCs (Source: Tua et al. 2019)

179 | See Ramesohl et al. 2020.
180 | See Bergsma/Lindgreen 2018.
181 | See Coelho et al. 2020.
182 | See Tua et al. 2019.

dependent on the number of times they are used.[183] The figure below shows that it is only after their third use that RPCs have a better life cycle assessment than DPCs.

Disposable plastic crates carry the same volume as reusable plastic crates, but are sixty per cent lighter, meaning that their production causes significantly lower CO_2 emissions. If used only once, the climatic impact of reusable plastic crates is thus 2.6 times higher than that of disposable plastic crates.[184] In contrast, after 125 uses, the carbon emissions of reusable plastic crates are just 8.2 per cent of those of disposable plastic crates.

Multi-use PET bottles

When considering multi-use systems for beverages too, various assumptions have to be made which have a critical effect on the relative advantages of specific systems. A life cycle analysis relating to the environmental impact of multi-use and single-use bottles within the German mineral water market, which specifically investigated carbon footprint as a function of respective transport distances, revealed that the negative environmental impact of single-use bottles is significantly higher than that of multi-use PET bottles.[185]

As the figure shows, the carbon emissions of multi-use PET bottles per 1,000 litres are approximately 30 per cent lower than the emissions arising from single-use PET bottles. Consistently using multi-use PET bottles for packaging alcohol-free beverages could save considerable quantities of carbon emissions. These potential savings result above all from the fact that the primary consumption of fossil resources can be reduced by over a third through repeated use of PET bottles.[186] Just how advantageous multi-use PET is over single-use PET is primarily dependent on the respective trippage rates of the bottles.[187] The Genossenschaft Deutscher Brunnen eG uses a multi-use PET system with standard bottles which can be refilled up to 25 times for distribution in regional circuits.[188] So far there is no exact

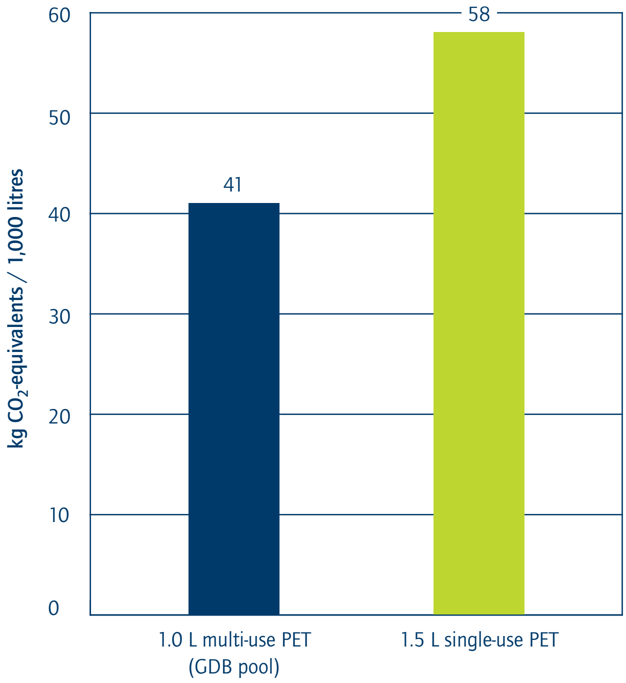

Figure 21: Comparison of greenhouse gas emissions of multi-use PET and single-use PET (Source: own presentation, based on: ifeu 2020)

data available about the frequency of reuse needed to make the multi-use PET bottle preferable to the single-use variant from an environmental standpoint. Because the material of single-use PET bottles is thinner, they are somewhat lighter and thus consume less material, but on average they are transported over significantly longer distances. It should therefore be assumed that the multi-use PET bottle is superior to the single-use bottle environmentally speaking from the second use onwards.[189] Also, according to the Federal Environment Agency, the resource and energy consumption associated with the regional transport and cleaning of multi-use bottles is significantly lower than the cost of recycling and producing single-use PET bottles.[190]

183 | See Tua et al. 2019.
184 | See European Commission et al. 2010.
185 | See Genossenschaft Deutscher Brunnen eG 2008.
186 | See ibid.
187 | See Kauertz/Detzel 2017.
188 | See Genossenschaft Deutscher Brunnen eG 2020.
189 | See Kauertz/Detzel 2017.
190 | See Umweltbundesamt 2018.

F Assumptions and calculations for the thought experiment 2030

1. Assumptions regarding plastics demand, prices and carbon footprints

The thought experiment ventures a look into the future and is based wholly on assumptions. First of all, the current situation was researched in relation to the necessary parameters. Building on this, the working group then discussed how the parameters might develop and agreed on values. These assumptions are therefore based on the combined sectoral expertise of the members of the working group and their evaluation of future developments.

a. Material demand

Only the three bulk plastics polyethylene terephthalate (PET), polyethylene (HDPE) and polypropylene (PP) are considered here. Each of these three materials is assumed to have annual demand of around one million tonnes, which approximately corresponds to the order of magnitude in 2020 and thus includes a reduction in absolute terms in plastics consumption given that it is assumed packaging demand will increase.

b. Secondary material footprints

The assumed footprints are explicitly not the most realistic possible forecast based on current developments. Rather, the assumptions are an attempt to tread the fine line between the necessary reduction in carbon footprint and technical feasibility.

It was assumed that 2030's virgin material footprint will match today's.

When forecasting the CO_2 savings associated with mechanically recycled material, reference was made to a study by the Association of Plastics Recyclers (APR) in which comprehensive life cycle analyses were carried out for individual materials.[191]

The footprint of chemically recycled material was forecast on the basis of a chemical method developed at the Delft University of Technology, for which a comprehensive life cycle analysis for PET was performed.[192] For simplicity's sake, the determined relative reduction potentials were also applied to the other types of plastics material under consideration here. These data from the literature were related to sector knowledge and expectations. For example, individual companies have set internal objective requiring the footprint for chemical recycling to be at least fifty per cent below that of virgin material by 2030.

	PET	PP	PE
Assumptions regarding material demand (in t/a)			
	1 million	1 million	1 million
Assumptions about carbon footprints (in kg CO_2e/kg)			
Virgin material	2.8	1.8	1.9
Mechanically recycled material	0.9	0.5	0.6
Chemically recycled material	1.0	1.0	1.0
Bio-based virgin material	1.0	1.0	1.0
Assumptions about material prices (in euro/t)			
Virgin material	1,200	1,100	1,000
Mechanically recycled material	1,440	1,320	1,200
Chemically recycled material	1,800	1,650	1,500
Bio-based virgin material	1,800	1,650	1,500

Table 6: Assumptions regarding plastics demand, prices and carbon footprints (Source: own presentation)

191 | See Franklin Associates 2018.
192 | See Bergsma/Lindgreen 2018.

The working group assessed the footprint of bio-based virgin material at the same level as that of chemically recycled material.

c. Prices

It is assumed that the price of virgin material will approximately match today's in 2030. The necessary technology improvements and investment needs mean that the costs for mechanically recycled material will be 120 per cent those of virgin material. The costs for chemically recycled material are assumed to be 150 per cent those for virgin material, which, in light of the necessary investment, would appear to be an optimistic lower limit. For bio-based PET, HDPE and PP the price level is assumed by the working group to be around 150 per cent that of virgin material.

2. Assumptions about policy instruments in 2030

Policy instrument	Assumed level in 2030
EPR basic amount (in euro/t)	800
EPR bonus (in euro/t)	200
Carbon levy (in euro/t CO_2)	100

Table 7: Policy instruments 2030 (Source: own presentation)

A basic amount of 800 euro per tonne is assumed for the extended producer responsibility levy **(EPR levy).** The use of defossilised plastic is remunerated with a bonus of 200 euro per tonne. In the thought experiment, it is thus calculated that the bonus is paid for each type of recycled material and also for bio-based plastics or this amount is deducted from the EPR levy.

Based on current developments, a **carbon levy** on all fossil carbon content of 100 euro per tonne CO_2 is assumed. The lower limit appears compatible with the development of a carbon tax or of an expected carbon price within an EU emissions trading scheme expanded to all fossil carbon sources. Reference was made to the studies carried out by the Mercator Research Institute on Global Commons and Climate Change[193] and the Federal Environment Agency[194] for the purpose of calculating this amount and the development of prices within the sensitivity analysis.

3. Calculation of the additional costs for the scenarios on the basis of the stated assumptions

[Sums in million euro]	Base	Circular
Licensing costs (EPR base price)	2,400	2,400
Bonus for use of recycled material	-180	-600
Additional costs for mechanically recycled material	198	420
Costs for chemically recycled material	–	390
Costs for bio-based virgin material	–	210
Carbon levy	515	239
Additional costs	**2,933**	**3,059**

Table 8: Cost calculation (Source: own presentation)

193 | See Edenhofer et al. 2019.
194 | See Burger et al. 2019.

4. Variations in the central parameters

Figure 22 shows which parameters have the greatest influence on additional costs.

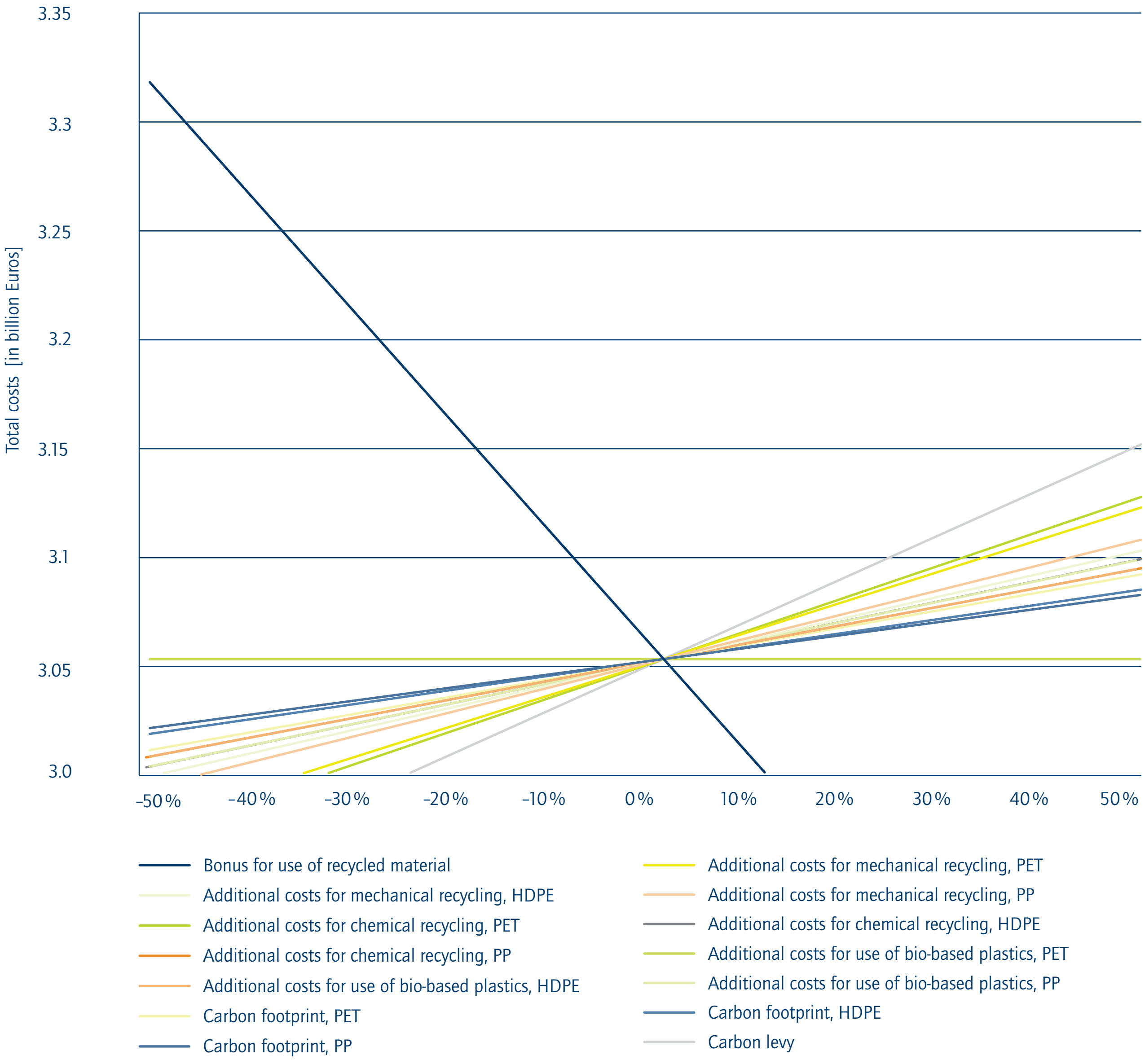

Figure 22: Variations in central parameters (Source: own presentation)

Varying the assumed parameters reveals that (1) a bonus for using recycled material, (2) a carbon levy and (3) the additional costs for chemical PET recycling are the greatest influencing factors on total costs.

5. Calculation of the additional costs for both scenarios with adjusted assumptions

The following calculation was drawn up to obtain a set of example assumptions which would make the resultant economic requirements for the circular scenario more advantageous.

[Sums in million euro]	Base	Circular
Licensing costs (EPR base price)	+ 2,400	+ 2,400
Bonus for use of recycled material **(10 % higher bonus)**	– 198	– 660
Additional costs for mechanically recycled material **(10 % lower additional costs)**	+ 178	+ 378
Costs for chemically recycled material **(10 % lower additional costs)**	–	+ 351
Costs for bio-based virgin material **(10 % lower additional costs)**	--	+ 189
Carbon levy **(15 % higher)**	+ 592	+ 275
Additional costs	**2,972**	**2,933**

Table 9: Cost calculation with adjusted assumptions for making the "circular" scenario more economically advantageous (Source: own presentation)

This provides the target values for the individual parameters listed in Table 10 and Table 11. Although the calculations carried out for the thought experiment as a whole are greatly simplified, it is clear that all stakeholders from the worlds of politics, business, academia and civil society must make significant efforts if a circular plastics packaging industry is to be achieved (see section 5, Policy recommendations).

	PET	PP	PE
Target values for carbon footprint (in kg CO_2e/kg)			
Virgin material	2.8	1.8	1.9
Mechanically recycled material	0.9	0.5	0.6
Chemically recycled material	1.0	1.0	1.0
Bio-based virgin material	1.0	1.0	1.0
Target values for material prices (in euro/t)			
Virgin material	1,200	990	900
Mechanically recycled material	1,416	1,298	1,180
Chemically recycled material	1,740	1,595	1,450
Bio-based virgin material	1,740	1,595	1,450

Table 10: Necessary target values for plastics prices and carbon footprints for making the "circular" scenario more economically advantageous (Source: own presentation)

Policy instrument	Adjusted assumption for making the "circular" scenario more economically advantageous
EPR basic amount (in euro/t)	800
EPR bonus (in euro/t)	220
Carbon levy (in euro/t CO_2)	115

Table 11: Necessary policy instruments for making the "circular" scenario more economically advantageous (Source: own presentation)

G The impact of the COVID-19 crisis on the packaging industry

In early 2020, the coronavirus pandemic hit Europe. A lockdown has been imposed on virtually all the member states of the European Union which has had a serious impact on the various spheres of everyday life and the economy. This section examines the effects on the packaging industry in Germany, with a particular focus on plastics packaging, which is in the transformation phase towards a circular economy.[195]

Observable phenomena

After the outbreak of the pandemic, similar purchasing behaviour was observed in a number of countries, depending on the phase of the pandemic the country was in. Non-perishable foods and hygiene articles, in particular, were stockpiled.[196] In addition, there was a sharp rise in online retail demand for clothing, beauty and household cleaning products and food.[197]

A change in perspective was observed in relation to packaging: the pandemic was accompanied by greater acceptance of single-use plastics products, for example face masks and food packaging, supported by arguments such as hygiene, product safety and breaking chains of infection.[198] In contrast, multi-use systems, for example drinking cups or carrier bags, were regarded with more suspicion because, depending on the surface, the virus has a lifespan of several days.[199] At the beginning of the crisis, politicians classified the packaging industry as systemically important in order to maintain the population's security of supply with food and everyday products.[200]

Social distancing during lockdown and resultant changes in everyday life also highlighted the importance of a properly functioning waste management system. While mountains of waste piled up, even away from collection points, industries with high recycling rates suffered shortages of important resources.[201]

Impact on the plastics and packaging industries

A sometimes enormous increase in demand for food and beauty and household cleaning products, with an accompanying surge in the use of plastics packaging, contrasted with a significant loss of business in other sectors, such as plastics for industrial goods not classified as systemically important.[202] The impact of the pandemic on plastics packaging manufacturers is thus variable. In a survey carried out by EUWID in May 2020,[203] 37 out of 120 companies surveyed reported sharp declines in sales, while over half reported sales increases. Eighty per cent of the companies are still able to fulfil their orders.

In parallel, oil prices fell to a low, in the wake of which the prices of oil-based products also fell.[204] It should, however, be borne in mind here that plastics prices typically lag several months behind oil price trends as a result of pricing formulae in fixed supply relationships. Initial renegotiations between raw material producers, converters and brand owners are already under way.

This development has hit the plastics recycling industry particularly hard, as production costs are not linked to the oil price and recycled materials have accordingly become more expensive in relation to virgin material. In addition, some losses have been recorded as recycled materials are currently produced almost exclusively by means of mechanical recycling processes and, for quality reasons (dark colour, odour taint), can be used almost exclusively in industrial applications (e.g. construction sector, damp-proofing membranes or irrigation pipes), which have, however, been hardest hit by the slump in sales.[205]

The use of recycled materials in consumer goods packaging, which many branded goods companies have committed to do, continues to be characterised by excess demand. The recycled materials market for polyethylene terephthalate (PET) is primarily based on material streams from PET deposit bottle collection and has been unaffected by the pandemic. Recycled materials from the lightweight plastics packaging fraction (yellow bin/sack) could not be used to any great extent due to the lack of

195 | See Newsroom.Kunststoffverpackungen 2020.
196 | See Strobl 2020.
197 | See Statista 2020.
198 | See Kaufman 2020.
199 | See Miyares 2020.
200 | See Folkesson 2020.
201 | See Roberts et al. 2020.
202 | See Folkesson 2020.
203 | See EUWID Recycling und Entsorgung 2020c.
204 | See Krishnamoort 2020.
205 | See Messenger 2020.

availability in the quality required for consumer goods packaging (natural/white, odourless). The surplus of grey-black and sometimes odour-tainted material could therefore not be offset by demand for recycled material for consumer goods packaging. A coronavirus-related decline in demand for recycled material in the consumer goods sector has as yet not been observed, despite a worsening price gap, even if isolated declines have been reported primarily due to falling prices of virgin material.[206, 207] A further increase in demand for recycled material is expected. These trends currently do not appear to be affected by the pandemic.

In summary, it may be noted that only some of the packaging industry in Germany has been affected by the first wave of the coronavirus crisis (the impact differing by product). The recycling industry was already experiencing some difficulties and the coronavirus crisis has only made them more apparent: waste volumes have risen dramatically, the system gaps between disposers/recyclers and plastics manufacturers have widened, and the dialogue in the recycling industry about the value of established and new technologies is intensifying. There are some opportunities in digitalisation which, given new impetus by the pandemic, is now also making greater inroads into waste management and could provide the packaging industry with an urgently needed interface to raw materials markets. All in all, the crisis has exposed existing fractures in the system and is pointing a path to a more resilient future. This is the path that must now be followed. After all, the packaging industry is of systemic importance for safely supplying the population with food and consumer goods. The target system of the future is a Circular Economy. This means that areas of systemic importance must also pursue this goal - in other words the packaging industry has an obligation to be compatible with a circular future.

206 | See EUWID Recycling und Entsorgung 2020b.
207 | See EUWID Recycling und Entsorgung 2020a.

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