Circular Economy Roadmap for Germany

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

Update December 2021

Circular Economy Initiative Deutschland

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NATIONAL ACADEMY OF SCIENCE AND ENGINEERING

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Preface

Since the European Green Deal, at very latest, it has been clear that the only way a greenhouse gas-neutral Europe can be achieved is by fundamental structural transformation of our economic activity. The "Circular Economy", a term now used in German too, proposes a framework for guiding and appropriately configuring this necessary systemic structural transformation of value creation from the linear, resource-intensive to the circular, resource-efficient.

With this aim in mind, in 2019 we established the *Circular Economy Initiative Deutschland* (CEID). With the involvement of three ministries, 24 businesses, 22 research institutions and further relevant civil society organisations, we have set a dialogue in motion as to how to this comprehensive turnaround from the linear to the circular can be achieved.

Two years on, we can now take a look at the findings of this wide-ranging work, the fruit of dedicated hard work by over 130 experts working together. Through far-reaching discussions at steering committee and task force level, reviews and the presentation of findings at national and international conferences, the compiled content has already given impetus to new discussions and has been continuously further refined. Detailed presentations of the findings and discussions at set out in the respective findings reports published by the three working groups "Circular Business Models", "Packaging" and "Traction Batteries". These describe, among other things, how Germany can use new business models to become a supplier of "Circular Services" (instead of products), how a circular plastics economy can counter the problem of waste by designing a new circular industry and how circular battery management can create a new services branch from a resource bottleneck.

The report describes the potential of circular value creation not only in achieving environmental and economic objectives, but also in improving prospects for sustainable living conditions. The present Circular Economy Roadmap for Germany brings together the working groups' findings, develops a vision for a Circular Economy in Germany, models possible implementation paths and derives overarching policy recommendations for policy makers, business and academia. These policy recommendations now point the way for Germany's progressive transition to a Circular Economy by 2030.

The transition to a Circular Economy is a fundamental process of transformation for the whole of society, which can only succeed with the participation and cooperation of all stakeholders. Against this background, the present Circular Economy roadmap can and must be understood and used as a "living document". On the one hand, it offers a comprehensive guiding framework and describes the practical implementation steps which need to be taken by policy makers and businesses. On the other hand, however, this roadmap does not conclude the description of the transformation process, but rather constitutes the foundation for further work on a concrete system of objectives for a national Circular Economy strategy, as well as on issues surrounding the measurement of progress, the effects of economic incentives, the transferability of insights to other applications and embedding into a European framework.

We hope that this roadmap can present a positive vision for Germany as a location for business at a time when German and Europe face important policy decisions.

We would like to thank the Federal Ministry of Education and Research (BMBF), without whose support *Circular Economy Initiative Deutschland* could not have come into being. We would also like to thank our founding and member companies for supporting the initiative and the SUN Institute Environment and Sustainability, which has provided support to the work of the Wuppertal Institute on the environmental and economic potential of a Circular Economy. And last but not least, we would like to thank everyone involved for their willingness to work together, their many ideas and often outstanding levels of commitment.

The *Circular Economy Initiative Deutschland* was coordinated by acatech (lead institution) in collaboration with SYSTEMIQ.

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Summary*

We are living through times of great change: innovative technologies are being developed at breakneck speed, patterns of consumer behaviour are changing fast, value chains which have hitherto been separate are linking up to create new solutions, capital markets are driving an enthusiasm for new business models and, last but not least, the state is providing more direction and investment.

At the same time, the "Take, Make, Waste" production and consumption mindset, also known as the "throwaway society", which has prevailed in recent history is increasingly coming up against planetary boundaries. The need for economic transformation is now particularly urgent, given the multiple, exponentially intensifying crises facing the planet. Specifically, the extraction and processing of natural resources is the cause of 50 per cent of global greenhouse gas emissions and 90 per cent of biodiversity loss and water stress.[1]

In this context, the Circular Economy offers Germany an overarching narrative which, in response to ongoing dynamic change, can bring together economic and environmental policy and so significantly help in achieving the objectives of the European Green Deal (in particular climate neutrality by 2050). This is because the Circular Economy can, if implemented consistently and in good time, provide a holistic solution for simultaneously addressing the interrelated existential crises of climate, resource utilisation, biodiversity and global health. Successful implementation of a Circular Economy is thus not an end in itself, but rather connects climate protection and resource conservation with cultural change, increasing competitiveness and independence from raw material imports as well as job creation and local value creation – a sustainable win-win situation.

Germany is starting from a favourable position. As an internationally renowned manufacturing base, Germany is in a better position than just about any other country to secure its future as a location for industry with not only digital (Industry 4.0) but also circular (Circular Economy) products, while increasing competitiveness, raw material productivity and local value added and creating high-quality jobs. Policy makers can use their COVID-19 stimulus packages to accelerate this change significantly. In this respect, the advantages of a successful transformation to a Circular Economy for Germany encompass

- a new value proposition which puts Germany forward as a political and economic partner, moving from "Made in Germany" to "Made with Germany" as a symbol of reliable, collaborative cooperation with German companies for resource-productive, high-quality circular product solutions,
- international repositioning of German industry as the world's leading exporter of profitable Circular Economy solutions and
- a rebranding of German industry with a focus on circular business models via X-as-a-service and design for reuse/remanufacturing/recycling etc.

Starting from the overarching narrative of bringing together environmental, economic and social perspectives, *Circular Economy Initiative Deutschland* (CEID) has defined a vision.

> *"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 absolutely decoupled from resource consumption. It will ensure planetary limits are respected and sustainability goals achieved and help to enhance quality of life and ensure equitable prosperity through collaborative, inter-company value creation and innovation."*

Modelling shows that this vision of a climate-neutral and simultaneously resource-productive Germany can only be achieved by a comprehensive transformational approach. The modelling carried out in the context of *Circular Economy Initiative Deutschland* assumed a 50 per cent reduction in natural resource consumption for 2050 compared with 2018, in addition to net zero greenhouse gas emissions. The findings show that comprehensive application of Circular Economy levers designed to extend and increase useful life and a significantly greater rate of recycling (including significantly higher energy efficiency) would reduce the total quantity of primary raw materials used by 2050 by 68 per cent compared with 2018. The secondary material provided by recycling contributes just under 50 per cent to the raw materials savings achieved. It is, moreover, clear that the radical reductions in greenhouse gas emissions needed for a 2 degree-compatible development pathway[2] can only be achieved by using Circular Economy levers. Economically, modelling to 2030 alone suggests cumulative savings resulting from the use

* | The original text of this publication was written in German and translated into English.

1 | See International Resource Panel 2019.

2 | See Prognos et al. 2020b.

of high-quality secondary raw materials of around € 32 billion. The potential for savings would be significantly higher again if Circular Economy levers were applied earlier in the value chain: the associated cost savings or macroeconomic productivity gains could be higher by a factor of ten by 2030 than the direct cost savings from recycling. At the same time, the new circular business models and innovative processes needed make quantification markedly more uncertain and compensatory (rebound) effects do have to be taken into account.

A look at the current situation shows, however, that in Germany the consumption of resources has not so far been decoupled from economic growth. Although total raw material productivity rose by 35 per cent between 2000 and 2016, corresponding to an average growth of 2.4 per cent per year, this increase was not down to a reduction in absolute resource consumption, but rather to growth in gross domestic product and thus corresponded to a relative decoupling. In Germany, the use of secondary raw materials currently saves only around 13 per cent of resource consumption (savings amount to 18 per cent if all upstream processes are taken into account), and this proportion remained virtually unchanged over the period from 2010 to 2014. If absolute resource consumption is to be reduced and decoupled from economic growth, there is accordingly a need for a transition from "circular waste management" to a systemic Circular Economy.

To achieve transformation to a Circular Economy, there is a need for a clearly defined package of measures featuring a number of cross-sectoral aspects which will influence various policy areas. By way of example, higher-level regulatory measures such as carbon pricing and resource utilisation support both climate protection and the development of Industry 4.0-inspired innovative digital business models. It has also become clear that the conditions for achieving a Circular Economy are in many instances already present, and have merely to be put into practice and combined appropriately for their full effect to be seen. One such opportunity is provided by the possibility of combining existing digital technologies with suitable standards to develop product passports, which would enable rapid improvement in the circular management of products.

The present Circular Economy Roadmap for Germany sees itself as a scientifically sound framework for action providing a systemic description of the steps Germany needs to take to become a Circular Economy. It contains policy recommendations intended to guide decision makers from the realms of politics, business and academia.

The transformation pathway derived from the Circular Economy Roadmap Germany is based on the insights of three *Circular Economy Initiative Deutschland* working groups, one which has been looking at circular business models from a general perspective and two which have looked at the specific examples of the packaging and traction battery sectors.

Overarching and sector-specific findings of the working groups

The Initiative's three working groups worked on overarching and sector-specific analysis and policy recommendations, which are described in detail in the respective findings reports. The central insights are summarised below:

"Circular business models"

Business models are central to making the Circular Economy acceptable to businesses. Ideally, a business model matches up circular value creation activities with entrepreneurial opportunities to create economic value. The isolated optimisation and profit maximisation opportunities offered by individual actors' business models has long failed to meet the requirements of a Circular Economy. Effectively converting existing value chains into value cycles requires an integrated approach, with circular ecosystems being designed in which value-creating actors complement one another.

Twenty-two examples of business model patterns were examined which offer decision makers a guiding framework for determining system-optimal configurations. These patterns are made up of a) role in the value cycle, b) basic circular strategy and c) related service level. As well as looking at types of barrier (regulatory, financial, technical etc.), mutually reinforcing barriers were often identified for central Circular Economy strategies: between a) sellers (suppliers, producers, retailers, repair providers, logistics providers etc.), b) users (professional users such as businesses and consumers) and c) the product (technology, design) together with associated services.

From retrospective evaluation to AI-assisted data forecasts, digital technologies have far-reaching potential for comprehensively interlinking "smart" Circular Economy strategies. Through the targeted provision of relevant information, digital technologies can play a central role in overcoming barriers to circular business models and so enable the operationalisation of circular material, component and product flows.

There is as yet no uniform regulatory framework for a Circular Economy. Rather, the Circular Economy is touched on in various pieces of, sometimes even contradictory, legislation, such as the European Union's waste legislation and Ecodesign Directive. It is therefore important to develop an integrated legal framework which places waste prevention at the centre by extending product service life, by reuse and remanufacture and by defining circular product design requirements and standards.

The working group's complete findings including their policy recommendations are presented in the circular business models findings report.[3]

"Packaging value creation system"

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 because it places a considerable burden on the environment.[4, 5] 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, mechanical recycling rates for plastics packaging are a comparatively low 47 per cent even in Germany with its reputation for efficient recycling. In addition, the vast majority of recycled materials are of significantly lower quality than the original materials. As a result, it is more like downcycling, which cannot usually replace virgin material. Only 10.9 per cent of the volumes of plastics processed in the packaging industry are recycled materials.[6]

With the aim of achieving a climate-neutral Circular Economy, the vision for plastics packaging is focused on mitigation strategies to reduce overall consumption of packaging, as well as on efficient and effective resource management in closed cycles. Results from a model calculation, based on expert-verified assumptions, show that increasing the share of mechanical recycling to 40 per cent, the share of chemical recycling to 20 per cent and the share of packaging reuse to 20 per cent by 2050 would enable savings of on average some 4 million tonnes of CO_2 equivalents annually compared to a business-as-usual scenario. However, the modelling also shows that, in the absence of additional measures, there would still be a substantial shortfall even in 2050 in achieving both climate neutrality and true circularity.

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

- Creating comparability with a **generally accepted decision-making aid for packaging alternatives;**
- Setting concrete, and binding **targets for avoiding packaging and packaging waste;**
- Implementing **design for circularity and sustainability** by EU-wide packaging material harmonisation and accompanying economic incentives;
- **Harmonising collection and sorting infrastructure** with separation by material and using new digital solutions;
- **Expanding** sources of **defossilised materials** by modernising existing recycling infrastructure and further developing recycling technologies;
- 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 working group's complete findings including their policy recommendations are presented in the packaging findings report.[7]

"Traction batteries value creation system"

Ongoing and further anticipated strong expansion in the global traction battery market has great potential for decarbonising road traffic while simultaneously creating new economic value and wealth. On the other hand, there is a need from the outset to minimise ecosocial challenges such as environmental impact and issues of occupational safety and human

3 | See Circular Economy Initiative Deutschland 2020a.
4 | See Jambeck et al. 2015.
5 | See Geyer et al. 2017.
6 | See Conversio 2020.
7 | See Circular Economy Initiative Deutschland 2021.

rights abuses which can arise along international supply chains from raw material extraction (especially in countries with less well developed environmental and social standards) to recycling.

Circular Economy measures promise to make significant inroads here. Results from a model calculation based on expert-verified assumptions[8] show that, by 2030, a total of 8,100 tonnes of lithium, 27,800 tonnes of cobalt and 25,700 tonnes of nickel will be recovered from vehicles placed on the market in Germany. For lithium, for example, approximately 13 per cent of demand could be met in this way by 2030. By 2050, a total of 109,000 tonnes of lithium, 180,000 tonnes of cobalt and 576,000 tonnes of nickel could be recovered. At current raw material prices, this would correspond to an economic value of 1.2 billion euro by 2030 or 13.8 billion euro by 2050. Carbon emission reductions could thus amount to around 36 million tonnes by 2030. By 2050, refurbishment could even generate savings of around 5.3 billion euro and 282 petajoules of energy demand (corresponding to 31.4 million tonnes of CO_2-equivalents), while, under optimistic assumptions, second-life applications would result in cumulative energy requirement (CER) savings of 655 petajoules (73 million tonnes of CO_2 equivalents). **However, the current regulatory and economic framework is not conducive to supporting productive use and effective circularity of key battery materials.** Shortcomings in this respect include for example low recovery rates which are undifferentiated by material, an absence of value networks for circular business models including after-use options and a lack of investment in the necessary infrastructure. There is accordingly a need to adjust the framework. The EU Commission's[9] draft revision of the EU Battery Directive, which was being discussed at the time of writing (early 2021), is a promising approach in this respect.

Transitioning to circular, sustainable battery value creation means implementing measures which take effect along the entire value chain. The members of the working group support the principles outlined by the Global Battery Alliance and summarise the key lessons learned as follows:

- **Adaptation of hardware and software:** There is a need to consider both constructive (design for repair) and destructive (design for recycling) design principles and to review the role which greater modularity can play. Standards for providing relevant data must be technically feasible and agreed upon industry-wide if efficient circular management is to succeed. Material and product (battery) passports deserve particular mention as a solution here.
- **Implementation of Circular Economy strategies and adaptation of policy framework:** If spent batteries are to be used for second-life applications or recycled, they must be recorded as completely as possible, which will require suitable policies and economic structures. Central definitions, such as legal provisions for vehicle batteries, the standardisation of the calculation of carbon footprints and recycling rates, and the definition of minimum standards, for example with regard to data protection and occupational safety, as well as binding recovery rates, are of great importance and must be specified accordingly.
- **Development of process and product innovations:** The development of automated disassembly systems, safe discharging technologies and new recycling processes focusing on efficient recycling chains as well as robust material synthesis processes is just as important for higher-quality circularity as the provision of efficient and reliable tests for the second-life suitability of batteries. Smart charging, vehicle-to-grid and vehicle-to-X (V1G/V2G/V2X) are potentially the most promising measures for increasing productivity by generating additional turnover via various network services.
- **Education and research:** It is important to develop sound **basic and applied knowledge** by appropriately integrating it into relevant courses of study, for example by means of lectures on the Circular Economy, Circular Economy-related Master's degrees and in-depth courses of study.

The working group's complete findings, including the issues with practical implementation specified in pilot profiles and the derived policy recommendations are set out in detail in the traction batteries findings report.[10]

Principles of transformation

Short-lived, lower-value and long-lived, higher-value products place sometimes similar and sometimes fundamentally different demands on circular product and material management. For short-lived products such as packaging, the focus of the solution adopted is on putting products optimised for circularity into circulation ("designing out waste and pollution") and making use of them for as long as possible in the highest possible quality

8 | See the Traction Batteries working group's report for the underlying assumptions; however, due to the significant uncertainties regarding the forecast development of technologies and markets, the values should only be regarded as indicative.

9 | See European Commission 2020c.

10 | See Circular Economy Initiative Deutschland 2020b.

applications ("keeping products and materials in use"). One challenge for implementation is the extremely fragmented structure of the industry, which complicates both harmonising material streams and developing and setting up technologies and infrastructure. In addition, circular solutions are often not economically viable since virgin material is cheaper than high-quality recycling of materials. In the case of traction batteries, on the other hand, the focus is primarily on using products as productively as possible and keeping them in circulation for a long time in high-quality applications ("keeping products and materials in use"). Higher-value, longer-lasting products are very much more complex and potential solutions arise primarily at the business model level. At the same time, their long lifetime (on average over ten years) poses a challenge; for instance because of significant uncertainties regarding future technical requirements in terms of higher-quality continued use of the products, for example as stationary storage, or of future demand and corresponding material values for the recoverable recycled materials.

At an overarching level, these two sector-specific assessments on the one hand reveal special requirements for the respective value chains if it is to be possible to bring value networks into line with a Circular Economy. The analysis of Circular Economy strategies and the various business model typologies of the Circular Business Models working group underlines the need for a case-by-case approach. On the other hand, there are numerous universal principles which are reflected equally in the approaches of the sector-specific working groups and the overarching Circular Business Models working group. These include, for example, the need to create uniform terminology and definitions as well as industry standards of relevance to the Circular Economy, to correct misguided subsidies or to promote the broad application of digital technologies and business models for resource-productive management.

Roadmap to a German Circular Economy

The *Circular Economy Initiative Deutschland* defines the following action points for decision makers from the realms of politics, business and academia. These action points are based on detailed stakeholder-specific policy recommendations (see section 5), which are summarised in figures 1 to 3.

1. **Circular business models:** Business needs to build on the successful model of Industry 4.0 to develop a resource-productive, data-driven circular economic model. The objective should in particular be to develop and scale **data-driven use- and results-oriented service business models** based on circular strategies, in line with the narrative envisaged in the European Green Deal. To support the development of such business models, economic actors need to create **new innovation spaces** and initiate **lighthouse projects** both within their organisations and in partnership with others, for instance in suitable industrial alliances. They also need to provide support for setting up long-term collaborative efforts and cross-sectoral value networks as well as consistent design for circularity policies.

2. **Standardisation:** Policy makers need to define key Circular Economy objectives, for which businesses can **work on corresponding norms and standards within established national and international committees**. Responsibilities and procedures for developing these norms and standards will vary depending on the product systems in question. The aim of such initiatives is to exploit synergistic potential at various impact levels. These initiatives include the development of standards in order to classify the status of used or remanufactured products, the development of quality standards for remanufactured products and recycled materials and their deployment processes (e.g. audited remanufacturing processes), specifications for recycled material content and the development and adaptation of measured business variables (e.g. Circular Economy metrics, key performance indicators (KPI), incentivisation systems, accounting processes). In addition, basic principles need to be defined for open data formats and media, such as product and material passports.

3. **Transparency:** Policy makers need to develop measures which make **Circular Economy-relevant information**[11] **commercially available**. To this end, they need to ensure data protection and security and call upon or oblige economic actors to provide specific (standards-based) data and information. Economic actors need to encourage a **collaborative exchange of relevant information and data,** for example using new digital systems (such as distributed ledger technologies and product passports). Furthermore, the information must be presented in a transparent, accessible and comprehensible form, to encourage purchase decisions in favour

11 | Such as the raw materials contained in a product and their origin and environmental footprints, proportion of recycled material, corresponding repair instructions etc.

of sustainable products and business models. This needs to be supported by the consistent rollout of meaningful sustainability reporting.

4. **Regulatory instruments: policy makers both on a national level and at European Union level should define a coherent product policy for the Circular Economy**, to enable product value retention. This should cover, among other things, the need for 1) clear and compulsory specifications to be defined for producing products according to design for circularity principles, 2) product features to be made easily accessible by a digital product ID (see also point 3 "Transparency"), 3) liability and warranty rules and return and take-back obligations throughout a product life cycle to be clearly defined, 4) the burden of proof to be reversed from the existing end-of-waste status to an end-of-life status, with the aim of using products for as long as possible, 5) statutory and/or commercial product service life guarantees to be established and 6) qualitative recycling rates (in addition to quantitative rates) to be introduced. Implementation should in particular proceed within the framework of the EU Commission's Sustainable Product Policy[12] and Sustainable Products Initiative[13].

12 | See European Commission s.a.
13 | See European Commission 2020d.

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By 2024	By 2027	By 2030
Standardisation: • Clear and binding definitions and standards **Economic incentives:** • Incentives and targeted financial support for implementing Circular Economy business models and relevant R&D • Basis for overhauling financial incentives in particular in the tax system • Development of a waste prevention plan **Regulatory instruments:** • Support for the reform of the EU Ecodesign Directive • Clear definition of the rights and obligations of relevant actors within value networks • Extension of statutory and/or commercial product guarantees **Infrastructure for reuse, continued use and recycling:** • Development of a binding EU-wide common approach to expanding and optimising Circular Economy infrastructure • Investment support for setting up and operating reuse, further use and recycling networks **Technical development and research:** • Strengthening and expansion of R&D in material, product and process innovation, digital technologies, decision-making aids and relevant metrics • Targeted promotion of radical innovation and business models **Public procurement:** • Development and escalation of (minimum) targets and (minimum) rates for circular products and business models **Institutionalisation:** Creation of an institutional body to oversee the transformation to a Circular Economy **Education and knowledge transfer:** • Initial and in-service training and rapid application of basic and applied knowledge • Creation of experimental spaces and support of bottom-up activities and social innovation	**Standardisation:** • Increasing transparency for actors in value networks **Economic incentives:** • Overhaul of pricing and taxation regulations relating to resource use **Regulatory instruments:** • Circular Economy criteria as a prerequisite for market access • Adjustment of EPR regulations for take-back of consumer durables • Revision of waste legislation (Circular Economy Act (KrWG)) • Harmonisation of national and transnational regulatory framework • Transition to "safe by design chemicals" where technically feasible • Introduction of recycling rates differentiated by individual materials including definition of quality levels for materials and processes • Setting a minimum content of recycled components in products **Technical development and research:** • Targeted economic and scientific support for technologies, business models and knowledge building, in particular in SMEs	**Economic incentives:** • Further development of appropriate incentive systems within the framework of tax law • Application of further-reaching economic incentive systems to achieve recycling targets **Regulatory instruments:** • Further increase in recycling rates in conjunction with requirements of quality levels for materials and processes **Education and knowledge transfer:** • Transfer of measures into a global context for leading markets ("race to the top") and for development cooperation

Figure 1: Overview of short-, medium- and long-term policy recommendations for policy makers (Source: own presentation)

By 2024

Circular business models:
- Establishing design for circularity to maximise product longevity
- Development and scaling of circular (business model) innovation
- Creation of innovation spaces and lighthouse projects to develop new use- and results-oriented business models
- Acceleration of digitalisation for the provision of product, component and material data

Standardisation:
- Collaborative initiation of common (minimum) standards and systemic design for circularity at material, product, process and system levels
- Industry-wide agreements for operational and macroeconomic measurement of circularity

Transparency:
- Provision of relevant data and offerings to support circular business models
- Active communication and provision of information to encourage customer decisions in favour of Circular Economy offerings
- Expansion of sustainability reporting with regard to consistent and Circular Economy-relevant aspects

Education and knowledge transfer:
- Development and implementation of basic knowledge, education, initial (and technical) training to enable scaling of the Circular Economy

By 2027

Circular business models:
- Further and new development as well as scaling of circular use- and results-oriented business models
- Formulation of requirements for promoting new Circular Economy business models
- Acceleration of digitalisation for the trustworthy exchange of data for evaluating the condition of products, components and materials

Transparency:
- Greater investment in collaborative commercialisation and scaling of technologies and tools for creating transparency of material flows
- Creation of metrics and evaluation rationales for defining and achieving Circular Economy targets

Infrastructure for reuse, continued use and recycling:
- EU-wide coordinated expansion of pan-European infrastructure for reuse, continued use and recycling
- Demonstration and dissemination of digital technologies to improve material identification and sorting

Technical development and research:
- Greater investment in the collaborative development of necessary technologies for the Circular Economy (e.g. collection, sorting and recycling technologies)

By 2030

Circular business models:
- Use of integrated decision-making processes taking account of systemic resource, energy, environmental and social effects throughout the value cycle
- Comprehensive application of service-oriented business models
- Widespread dissemination of collaborative business activities and value networks

Standardisation:
- Broad adoption of technologies and technical standards for the provision and exchange of digital data with relevance to R strategies

Transparency:
- Embedding recognised metrics for sustainable circular business practices in a comprehensive incentive and control system

Figure 2: Overview of short-, medium- and long-term policy recommendations for business (Source: own presentation)

5. **Economic incentives:** policy makers at both national and European Union level need to **redesign financial incentives to encourage climate- and resource-optimal business decision-making**. This is because, in principle, targeted expansion of circular business models can contribute to strengthening a business's market position. In addition to **direct financial assistance** (inter alia for pilot projects or research) or the **promotion of new business models** (e.g.

deposit systems and repair schemes), a more in-depth **overhaul of tax rules** is also needed. This should pursue the aim of making Circular Economy-relevant products and services proportionally more attractive than the carbon-intensive use of primary raw materials by a **targeted redistribution of the tax burden**. This aim could be achieved, on the one hand for example **by levying higher duties on resources and emissions** and **by dismantling environmentally harmful subsidies**. The resultant increase in tax take could, on the other hand, be used to **reduce the tax burden for businesses** (e.g. by lowering staff social security costs, tax benefits for taking on new staff members and investment in Circular Economy-relevant sectors) and consumers (e.g. by reducing VAT on specific Circular Economy services such as repair and maintenance).[14] The stated measures also need to be applied outside **the European Union and the European Economic Area (EEA)**, if a global level playing field is to be achieved.

6. **Infrastructure for reuse, continued use and recycling:** policy makers and business need to accelerate the **expansion and development of infrastructure for reuse, continued use and recycling**. Only in this way can the necessary networks and capacities be created for collecting and/or handling products effectively and efficiently at the end of their first life cycle. With a suitable Circular Economy-appropriate structure, products may additionally be evaluated to establish whether they are suitable for further use or indeed a change of use or whether high-quality material recycling is possible. **Digital technologies must** also **become more widespread** to improve material identification and sorting as the basis for high-quality circular management including recycling.

7. **Technical development and research:** policy makers, businesses and academia need to adopt a **technology-neutral attitude to the development of relevant material, product and process innovations – the focus should be on environmental benefits, digital technologies for producing transparency and methods and tools** for implementing the Circular Economy. These include the development of metrics (at product, business and macroeconomic level) for evaluating Circular Economy strategies and measures, the development of model-based decision-making platforms for the circular after-use of products, the development of digital technologies for the Circular Economy (e.g. digital market platforms or artificial intelligence) and the continuing development of product and material technologies. Policy makers should also be providing targeted economic and scientific support for the Circular Economy. This should encompass concrete projects for (further) development of Circular Economy-relevant technologies and business models, for which the necessary financial resources (inter alia through start-up support) need to be provided, and suitable (interorganisational) infrastructure (e.g. by building "innovation spaces" designed specifically to support radical innovation and business models). The wide-ranging issues around the implications of a Circular Economy for society must also be addressed under this action point.

8. **Public procurement:** policy makers need to boost demand for circular products and business models by setting strategic objectives and targets for used, remanufactured and recycled products using a practical, science-based decision-making aid. The definition of (minimum) targets and rates should become part of budgetary planning at every level of the public sector.

9. **Institutional embedding:** Policy makers need to set up a **central institutional body** with the aim of ensuring Germany's transformation to a Circular Economy. The body should explore the topic of this transformation in Germany in greater depth across legislative periods, identify innovative potential, create new connections and thus embed the Circular Economy more widely and set it in a European context. The institutional body could support the activities of political, economic and civil society stakeholders and, in the long term, bring them into line with one another. Support for knowledge sharing and the creation of technically sound Circular Economy-related product requirements can also make a contribution.

10. **Education and knowledge transfer:** policy makers, businesses and academia must provide **Circular Economy-relevant education and training** to raise public awareness of the Circular Economy and develop skills. This can be achieved, for example, by including the Circular Economy in curricula, establishing in-depth Circular Economy-related courses of study, degree programmes and professorships,

14 | The stated measures are based on proposals from the Ex'tax Project.

By 2024	By 2027	By 2030
Technical development and research: • Provision of a decision-making basis for evaluating possible trade-offs • Co-development of operational and macroeconomic circularity indicators • (Further) development of application-oriented, interdisciplinary (digital) solutions for optimising overall systemic effects at the material, product and process levels • Development of a long-term inter- and transdisciplinary research strategy on the societal implications of a Circular Economy **Education and knowledge transfer:** • Integration of the Circular Economy into various courses of study • Establishment of professorships/university departments, targeted support of transdisciplinary research partnerships and real-world laboratories and further development of research infrastructure in dialogue with policy makers	**Technical development and research:** • Development and provision of Circular-Economy-relevant modelling, simulations and (digital) tools	**Technical development and research:** • Continuous development of materials and process technologies

Figure 3: Overview of short-, medium- and long-term policy recommendations for academia (Source: own presentation)

creating learning factories, collaborative research and appropriate training provision for skilled occupations. A holistic educational package also includes the promotion of transformative learning in the context of Circular Economy-related bottom-up activities and social innovations such as repair initiatives, open workshops, prosumer initiatives and consumer citizenship networks. The **measures should also be transferred globally** in the context of international collaboration and development cooperation.

Conclusion and looking ahead ...

Over and above existing measures, the Circular Economy is an important tool for achieving Germany's climate, resource and development goals. It is a critical prerequisite for market acceptance in some industrial sectors (packaging), while in others (traction batteries) it is also a critical competitive advantage. A concrete market model for greater circularity can only be developed jointly by policy makers and business. The Circular Economy should therefore become a central pillar for Germany's future viability in the policy debate across all parties. New business models for a more Circular Economy and greater resource decoupling provide a framework for Germany's digitalisation, for which the *Circular Economy Initiative Deutschland* has laid the foundation.

To become a leading nation for circular industrial development, Germany must set itself measurable Circular Economy targets. Germany should to this end become a driving force behind a Circular Economy within the European Union. Businesses should explicitly support such an industrial and environmental policy direction and in turn actively work to enable the implementation of the Circular Economy by product and business model innovations (in particular digitally assisted).

A start should in the near future be made on implementing the roadmap developed here so that the potential of the Circular Economy can be exploited and Germany's climate, resource and sustainability goals thus also achieved while the international competitiveness of the country's economy is maintained and enhanced. Suitable measures in this context are in particular:

1. Embedding the recommendations of the *Circular Economy Initiative Deutschland* in an integrated, comprehensive Circular Economy strategy for Germany, including concrete, complementary targets among other things for waste prevention, recycling and overall resource consumption,
2. Establishing interdepartmental coordination in order to implement the measures at the highest possible level, with support from a high-calibre, transdisciplinary expert advisory board,
3. Implementing effective real-world pilot projects, for example the project outlines developed by the Traction Batteries working group ("knowledge of battery life", "model-based decision-making platform" and "disassembly network"),
4. Exploring, piloting and scaling concrete business models serving to initiate higher-quality circular strategies and use- and result-oriented business models,
5. Quantifying Circular Economy measures at the macroeconomic and enterprise level, primarily focusing on their environmental, economic and social effects, analysing the impact of carbon prices and realigning tax rules to support climate- and resource-optimised economic decisions,
6. Intensifying the networking with other European initiatives, science academies and research networks initiated in the course of the *Circular Economy Initiative Deutschland* and
7. Carrying out further leading projects similar to the *Circular Economy Initiative Deutschland*, in order to gain in-depth insights into further functional areas (such as buildings and infrastructure, foodstuffs, agriculture and forestry, textiles and clothing, electrical appliances) in close cooperation with other (also European) initiatives.

The members of the *Circular Economy Initiative Deutschland* hope that their work which is presented here has contributed to the Circular Economy transformation and are ready and willing to support the above initiatives.

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1 Introduction

The "Take, Make, Waste" production and consumption mindset, also known as the "throwaway society", which has prevailed in recent history is increasingly coming up against planetary boundaries. Few figures demonstrate the alarming impact of linear economic activity more starkly than the fact that, as a global average, we humans are currently consuming the natural resources of 1.6 Earths.[15] A look at Germany, with its annual consumption of roughly three Earths[16, 17], also illustrates the urgent need for action: if we want to enable future generations to live with dignity on our planet, we must fundamentally rethink our way of doing business and our consumption behaviour - and we must do it now.

The linear economic paradigm, long the driving force behind growing economic prosperity, is visibly losing its socially cohesive power and is coming under increasing pressure to legitimise itself both socially and environmentally. For instance, the Inclusive Wealth index proposed by the United Nations to achieve the Sustainable Development Goals illustrates the limits and costs of the current linear growth path. The aim of the index is to provide as holistic a picture as possible of the development of social prosperity by understanding and comparing the stock of "human capital" (for instance knowledge, training, skills and health) and of "natural capital" (e.g. forests, fossil energy sources, agricultural land or ecosystem services) as the productive basis of an economy, in addition to "produced capital" (e.g. roads, buildings, machinery or physical infrastructure). On a global average, it is apparent that in recent decades the growth in produced capital has no longer been accompanied to the same extent by increases in the value of human capital and has also been associated with high costs, i.e. losses in the value of natural capital (see figure 4). In order to bring macroeconomic development more closely back into line with the social promise of prosperity made by our market economy and to stop living "on the credit of future generations", there is a need for a wholesale socioecological overhaul of our economy.

The need for socioecological transformation of how we do business is now particularly urgent, given the multiple, exponentially intensifying crises facing our ecosystem. Specifically, the extraction and processing of natural resources (biomass, metallic and non-metallic minerals and fossil fuels) causes 50 per cent of global greenhouse gas emissions and 90 per cent of biodiversity loss and water stress.[18] The fact that the associated environmental crises are having an increasingly fundamental impact on our globalised economy based on the division of labour has most recently become apparent over the course of the coronavirus pandemic, which has itself been assumed to have its origin in ecosystem destruction.[19] Merely the absence of an ambitious climate policy and an associated temperature rise of 3.5 degrees Celsius could lead to a loss of 7 to 14 per cent of global economic output in 2100 without even taking account of any harm to ecosystems and biodiversity.[20]

Implemented consistently and in good time as a holistic system solution, the concept of the Circular Economy is capable of simultaneously addressing many of the above-mentioned crises. In the light of the intensifying resource crisis, a Circular Economy can directly assist with decoupling the consumption of natural resources from economic growth by establishing and closing cycles.[21] While relative decoupling can indeed often be achieved by improving efficiency, more comprehensive strategies will in future be required to achieve absolute decoupling from resource consumption while ensuring global prosperity continues to rise.

Increasingly, however, an indirect link is also being made between the potential of a Circular Economy and combating the climate crisis. For example, findings from the International Resource Panel indicate that corresponding strategies in the G7 nations could cut greenhouse gas emissions from buildings and vehicles by up to 40 per cent each by 2050.[22] Another study by Material Economics shows that European industry can achieve up to 60 per cent greenhouse gas savings in the use of its four highest-emitting materials (steel, plastics, aluminium and cement) in 2050 compared to a business-as-usual scenario if

15 | See Earth Overshoot Day 2020b.
16 | See Earth Overshoot Day 2020a.
17 | See Earth Overshoot Day s.a.
18 | See International Resource Panel 2019.
19 | See Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit 2020a.
20 | See Kalkuhl/Wenz 2020.
21 | See Glossary.
22 | See International Resource Panel 2020.

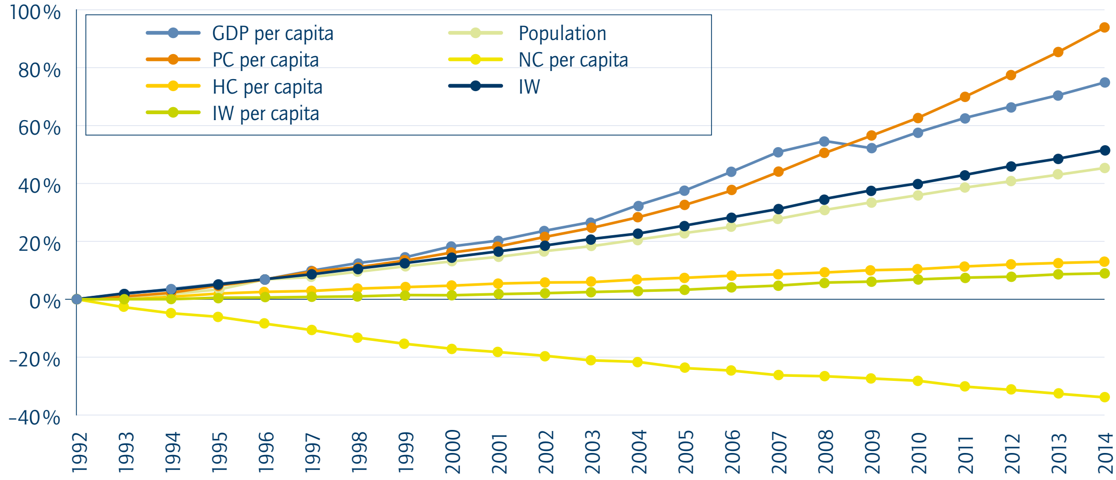


Figure 4: Global comparison of the development of gross domestic product (GDP) and the "Inclusive Wealth" (IW) index together with its sub-indicators "Produced Capital" (PC), "Natural Capital" (NC) and "Human Capital" (HC), percentage change compared to the reference year 1990 (Source: Managi/Kumar 2018)

opportunities to close material cycles are seized, material efficiency is increased and the potential of circular business models is exploited.[23]

By combining efficiency, consistency and sufficiency strategies, a Circular Economy can reconcile the objectives of different social stakeholders and so overcome apparent contradictions between economic, environmental and social concerns.[24] Using a consistency strategy, the aim of a Circular Economy is to design economic systems in a way which is compatible with nature and ecosystems. This involves using safe and harmless chemicals in material and product development and closing material cycles[25] (redesign, recycle). In relation to a sufficiency strategy and a concentration on qualitative growth, the intention is to postpone the purchase of new products for as long as possible by measures to extend product service life and the provision of corresponding services (reuse, repair, remanufacturing). By intensifying use, sufficiency strategies also help to ensure that the focus is on the benefits offered by products rather than their ownership (rethink/share). In line with the efficiency strategy approach, the intention is for products designed for longevity and closed material cycles to make the most efficient use of resources possible (reduce).

Successful implementation of a Circular Economy is not an end in itself, but rather connects climate protection and resource conservation with cultural change, increasing competitiveness and independence from raw material imports as well as job creation and local value creation – a sustainable win-win situation. Demonstrating the economic advantages of a Circular Economy will not only create a competitive advantage for the economy putting it into practice but will also accelerate implementation in global systems organised along market economy lines. A constructive, critical debate on the role of social, policy and

23 | See Material Economics 2018.

24 | The term Circular Economy covers more than just recycling-oriented waste management. In addition to pure recycling, a Circular Economy also takes account of the value creation potential of further circularity strategies such as maintenance and upgrade, repair, reuse or remanufacture.

25 | It is not sufficient here to comply with existing chemical control legislation (for instance REACH, see European Commission 2006) because recycling can lead to the accumulation of unwanted contaminants and thus to a reduction in material quality. In turn, this reduces the number of possible cycles. Designing products to be suitable for the Circular Economy means selecting materials in such a way that no toxic effects occur even after several life cycles.

technological innovation is a prerequisite for such a transformation.

Given the manifold integrative potential of a Circular Economy as a new overall vision for society, the European Union and numerous member states have already developed strategic plans for a transition to a resource-efficient approach based on Circular Economy principles.[26] The European Commission has most recently taken decisive steps towards the concrete implementation of circularity with the European Green Deal[27] and the second Circular Economy Action Plan[28]. However, coordinated interaction between national and European efforts in the context of global supply chains remains crucial for the overall success and actual effectiveness of these initiatives. It is precisely within the borders of the European internal market that substance, material and product cycles can be effectively established and closed.

Germany is in a good position to pave the way for a European Circular Economy and to play an active part in shaping it. It is important here for Germany to play to and develop its existing strengths, which are particularly valued by its European partners, in favour of a Circular Economy. At the national level, Germany's progressive approach to the collection and recycling of paper, glass and packaging in particular formerly became something of a copybook example. More in-depth examination reveals, however, that Germany still has a long way to go before achieving genuine circularity (see section 2) and that the innovation system necessary for establishing a comprehensive Circular Economy is still at an early stage of development with little momentum of its own.[29] Nevertheless, the expertise we have already gathered can serve as a starting point for thinking about the Circular Economy even more comprehensively in the future, for exploiting the potential of a Circular Economy with further circularity strategies such as repair, reuse or remanufacturing, and for actually closing recycling loops physically at the material level.[30] Germany's world market leadership in plant and mechanical engineering combined with the ongoing digitalisation of industrial production (Industry 4.0) opens up an additional transformation opportunity and a significant export market for the country. Whether Europe will once again be reborn from a crisis will therefore be decided precisely by the question of what role Germany will play in implementing a European Circular Economy in response to the multiple crises facing the contemporary world.

The present Circular Economy Roadmap for Germany sees itself as a scientifically sound framework for action which for the first time provides a systemic description of the steps Germany needs to take to become a Circular Economy. Nevertheless, this roadmap must be understood as a "living" document because the necessary transformation is linked to an ongoing learning process, for which this publication is the starting point. As the central final document of the *Circular Economy Initiative Deutschland* (CEID), which was established in 2019 with funding from the Federal Ministry of Education and Research (BMBF), it brings together the findings from the various working groups and summarises them as a consolidated position paper aiming to shape overall social policy. Developed and supported by numerous societal stakeholders from business, academia and civil society, the focus of this roadmap has thus from the outset been on developing a uniform, common vision for a Circular Economy in 2030 and formulating concrete policy recommendations.

Will Germany in future succeed in redefining its social wellbeing and economic prosperity within planetary boundaries and maintaining its wealth creation? Germany holds the answer to this question in its own hands because it will in future measure economic, social and environmental wellbeing by means of multidimensional indicator systems which are still under development (e.g. with the assistance of the Inclusive Wealth index) and will view the restructuring of its economy on a resource-efficient and climate-neutral basis to be a task for society as a whole which must be vigorously pursued and efficiently coordinated. Many members of the initiative have already set out to make the Circular Economy a reality in their respective fields of activity. What is now additionally required is a coordinated German agenda for the implementation of a Circular Economy in the best European spirit which will provide guidance in times of economic and social upheaval in order to renew the promise of prosperity in our economy.

26 | See Weber/Stuchtey 2019.
27 | See European Commission 2019b.
28 | See European Commission 2020a.
29 | See Gandenberger 2021.
30 | See Ellen MacArthur Foundation 2013.

The present report firstly outlines the initial situation in Germany with regard to a Circular Economy (see section 2). The opportunities inherent in the transformation to a Circular Economy for Germany are described in the vision for 2030 (see section 3). The findings of the Circular Business Models, Traction Batteries and Packaging working groups offer examples of ways to shape this transformation (see section 4). Finally, a roadmap with policy recommendations describes concrete measures for policy makers, industry and academia (see section 5).

2 Current resource consumption situation in Germany

It is clear from the current situation that Germany has not as yet experienced any absolute decoupling of resource consumption and economic growth. Although Germany was and is a pioneer when it comes to hitherto only vaguely defined recycling rates (quantity), which in reality are more collection rates, no or as yet only insufficient consideration has been given to central aspects of a systemic Circular Economy such as the extension and purposeful circularity of product life cycles (quality) and the resultant whole system effects (exergy).[31] At present, Germany's Circular Economy could therefore be more accurately described as "recycling-based waste management"[32]. The systemic perspective of a Circular Economy is essential in order to enable the climate protection and resource conservation required for remaining within planetary boundaries.

2.1 Recycling-based waste management

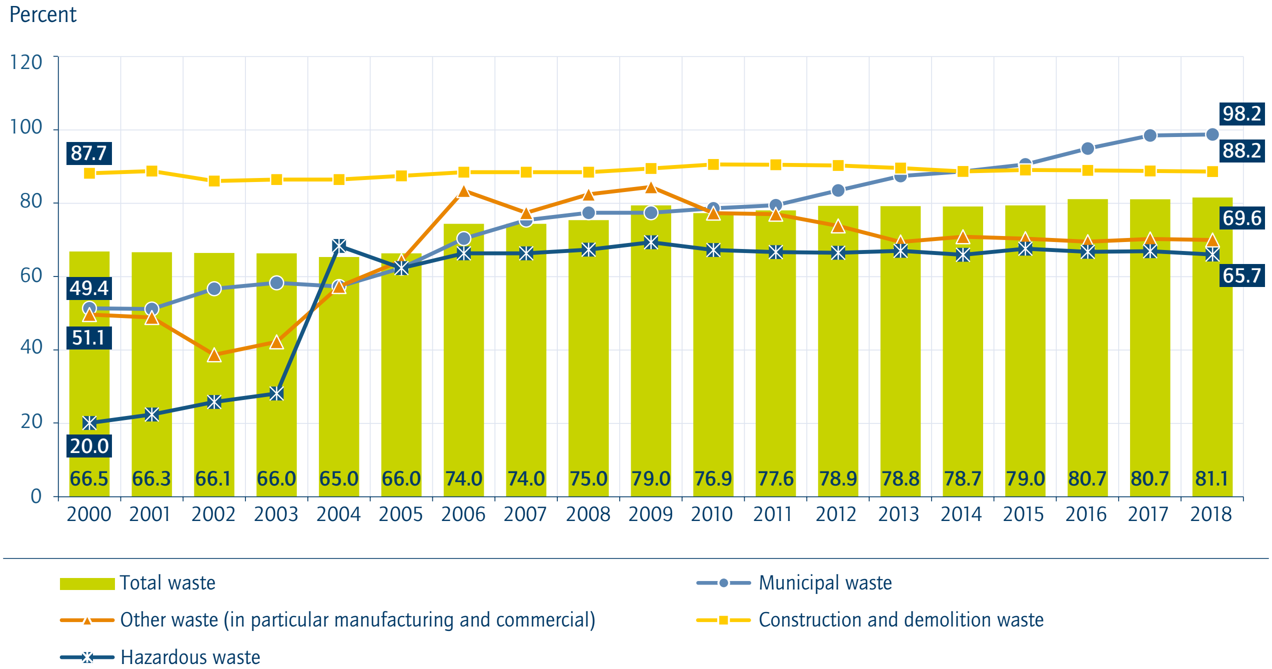
The measures in Germany's Circular Economy Act focus above all on waste prevention, recycling and disposal. Extension of the use phase and better resource exploitation within a Circular Economy are currently largely disregarded, however. As a result of this narrow understanding of a Circular Economy, the measures focus primarily on physically inadequately defined recycling rates and thus on end-of-life solutions.

Although the amount of waste recycled or sent for energy recovery as a proven proportion of the waste generated in Germany has been increasing continuously since 2006 and currently amounts to approximately 81 per cent (see figure 5), the total volume of waste generated has also risen, growing in 2018 by the highest amount since the Federal Statistical Office started collecting data in 2006.[33] The proportion of recycled waste in relation to the total amount of waste generated, however, remained roughly unchanged.

It should additionally be noted that the focus of waste management in Germany has hitherto been on input quantities for recycling plants and not on output quantities and the mechanical recovery quality achieved. For example, calculations relating to plastics recovery show that of the initial quantity of plastics processed in Germany in 2019 only approximately seven per cent is covered by the use of post-consumer recycled materials.[34]

A first step towards reorientation to output-focused recycling rates has already been taken in the form of the amended EU Waste Framework Directive[35]. In addition to the quantities available, it must also be taken into consideration that the quality of secondary raw materials is significantly more difficult to assess, while at the same time the use of recycled materials in manufacturing is limited by the quality of those materials.[36] The current focus on quantity, with often low material quality, leads to somewhat open loops or downcycling.[37] This, in addition to the loss of materials, is not ideal even from a thermodynamic standpoint, because electrochemical value (exergy) is lost as a result. The high energy inputs needed to restore material quality, once lost, further impair the energy balance. However, to be able actually to replace primary raw materials in manufacturing and achieve better energy conservation throughout the system (and so enable effective climate protection and resource conservation), there is a need for closed, quality-maintaining loops[38] which take account of thermodynamic effects.[39]

31 | See Sachverständigenrat für Umweltfragen 2020a.
32 | See ibid.
33 | See Statistisches Bundesamt 2020b.
34 | See Conversio 2020.
35 | See European Union 2008.
36 | See BGR – Bundesanstalt für Geowissenschaften und Rohstoffe 2018.
37 | See Glossary.
38 | See Hansen/Revellio 2020.
39 | See Abadías Llamas et al. 2020.



2000: Hamburg with data from 1999
2002: Introduction of European Waste List with shifts between wastes not requiring special supervision and those requiring special supervision and within municipal waste.
2006: Changeover from net to gross calculation method for waste balance.
Hazardous waste: From 2004 including treatment for recovery.

Source: Federal Statistical Office, waste balance, Wiesbaden, various years; German Environment Agency, own calculations

Figure 5: Recycling rates for the most important types of waste (Source: Umweltbundesamt 2020a)

Merely looking at recycling rates as the sole indicator of progress towards a Circular Economy therefore falls short. The problem with focusing on input-related recycling rates, without taking account of recycled material quality, is clear from the indicators DERec and DIERec[40] mentioned in the Federal government's Resource Efficiency Programme. Germany's use of secondary raw materials generates a resource consumption savings of only around 13 per cent. If the resource savings from all upstream processes are also taken into account, the savings amount to 18 per cent.[41] Over the period from 2010 to 2014, the proportion of these indicators in relation to total natural resource usage remained virtually unchanged.[42] The recycling of natural resources thus still has considerable potential as one of the central Circular Economy levers.

While the savings in Germany are currently first and foremost achieved by the use of recycled non-metallic minerals,[43] globally it is primarily recycled metals that take the strain, as these have a markedly smaller environmental footprint than primary raw materials. This closure of material loops is currently generating savings in cumulative energy input (including upstream processes outside Germany) of 1,406 petajoules per year,[44] which corresponds to around 12 per cent of Germany's primary energy consumption in 2020.[45] Indeed, progress towards a Circular

40 | DERec (Direct Effects of Recovery) and DIERec (Direct and Indirect Effects of Recovery) are indicators for recovery and recirculation of secondary raw materials and the associated primary raw material savings. While DERec takes account only of direct national resource savings, DIERec includes resources savings in global value creation chains.
41 | See Steger et al. 2019.
42 | See Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit 2019.
43 | See Steger et al. 2019.
44 | See ibid.
45 | See Umweltbundesamt 2020d.

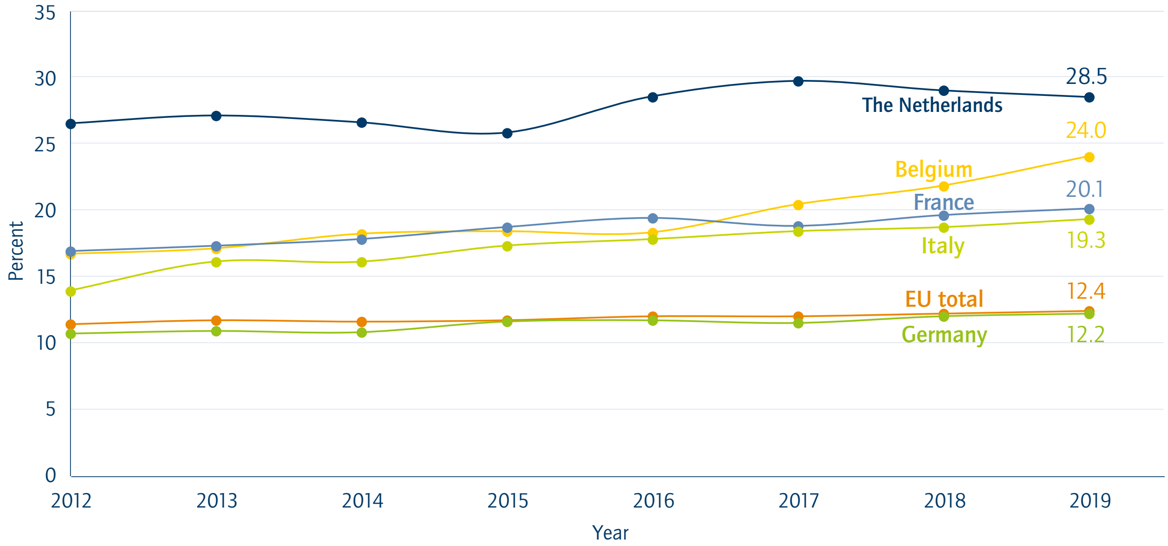


Figure 6: Development of circular material use rate in selected EU countries, 2012 to 2019 (Source: own presentation; data: Eurostat 2020)

Economy actually seems to be stagnating in Germany. Although, in terms of the circular material use rate (a key indicator for the European Commission), Germany did succeed in increasing the proportion of recycled raw materials used in industry from 10.7 to 11,6 per cent between 2012 and 2017 (see figure 6), countries such as the Netherlands can evidence significantly higher rates of up to 30 per cent. These higher rates result, among other things, from high levels of building materials recycling (promoted by, among other things, circularity-oriented construction methods and dismantling practices) in combination with a relatively low level of national material consumption.

The data sets that would allow a similarly differentiated consideration of further Circular Economy levers such as reuse or repair are as yet unavailable. Accordingly, the legal bases intended to provide data on reuse to EU Member States from 2022 were still pending in January 2021.[46] Total resource consumption provides the best reflection thus far of the impact of all Circular Economy levers overall. Indicators of natural resource consumption such as RMC (primary raw material use for domestic consumption and investment, see section 2.3, p. 8) also take into consideration the natural resources used globally in upstream processes.[47]

2.2 Resource efficiency as an approach to resource conservation

In addition to its waste recovery targets, in February 2012 the Federal government adopted the first national Resource Efficiency Programme (ProgRess), with the objective of decoupling economic growth from resource use and strengthening the circulation of resources.[48]

Furthermore, the positive environmental aspects, decoupling is also of economic significance. German industry is heavily dependent on specific materials and natural resources, in particular metallic raw materials.[49] In 2015, raw materials accounted for around 55 per cent of the total volume of German imports (approximately 9 per cent of the total value of imports), while approximately 77 per cent of all exports were semi-finished or finished

46 | See European Union 2018.
47 | See Umweltbundesamt 2020b.
48 | See Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit 2020b.
49 | See European Environment Agency 2019.

goods (approximately 99 per cent of the total value of exports).[50] In recent years, the dependency of Germany and the EU overall on raw material imports and the associated price and supply risks have increased again.[51] In particular, the availability of metals is crucial to German industry for the manufacture of high-tech products for digital transformation.[52] Germany is 100 per cent dependent on imports of metal ore and concentrates.[53]

One of the aims of the Resource Efficiency Programme, which is updated every four years, is therefore to increase raw material productivity[54] to twice 1994 levels by 2020 and to raise overall raw material productivity[55] annually by 1.5 per cent,[56] to achieve greater independence from raw material imports in future. However, raw material productivity increased by approximately only 56 per cent between 1994 and 2015. On the basis of these data, the target defined in the Resource Efficiency Programme will clearly be missed.[57] This is particularly crucial given that increasing raw material productivity has hitherto been the sole objective to which the Federal government has committed itself in the area of resource efficiency.

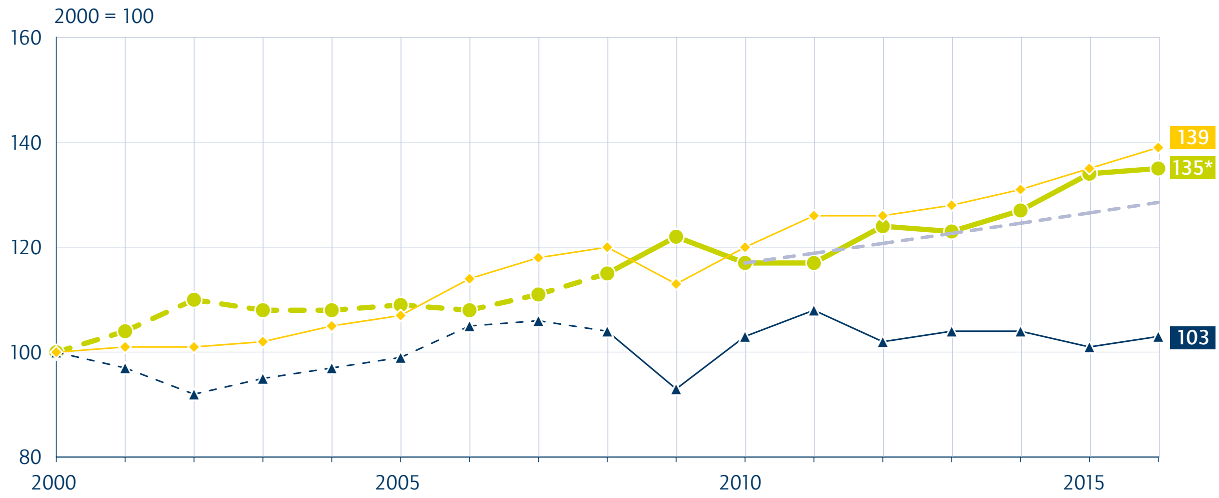
The development of Germany's total raw material productivity also needs to be looked at in nuanced terms. On the one hand, total raw material productivity increased by 35 per cent between 2000 and 2016, which corresponds to average annual growth of 2.2 per cent (see figure 7)[58] and means that Germany has officially reached the target set. However, this has not been achieved by a reduction in absolute resource consumption, but rather by the growth in gross domestic product.[59 60] Raw material consumption in Germany is still almost double the international average of 12.2 tonnes per capita per year.[61, 62] Germany's domestic raw material usage is thus still too high.[63] It may thus be concluded that increased raw material productivity does not necessarily lead to a reduction in resource usage in absolute terms, since increased productivity in turn does not necessarily go hand-in-hand with an absolute reduction in primary material usage, but may instead also be caused by increased economic growth.[64, 65] The objective of decoupling resource consumption from economic growth has thus not been achieved.

It should also be taken into account that the savings in resources achieved when focusing solely on efficiency measures can lead to rebound effects and higher resource consumption at other points in the chain.[66] However, rebound effects also remain a challenge in a Circular Economy, especially if external environmental costs are not sufficiently considered and the focus is placed solely on economic growth.[67] In addition, due to path dependency and lock-in resulting from monetary success, first technologies may retain their market position despite being inefficient,[68] for which reason a systemic approach is particularly significant in this context.[69]

50 | See Lutter et al. 2018.
51 | See Bundesministerium für Wirtschaft und Energie 2010.
52 | See Diermeier et al. 2017.
53 | See BGR – Bundesanstalt für Geowissenschaften und Rohstoffe 2018.
54 | Raw material productivity is calculated from the quotient of gross domestic product (GDP) and of abiotic direct materials usage (domestic raw material extraction and imported raw materials). This indicator demonstrates how efficiently resources have been used to achieve GDP.
55 | Total raw material productivity also includes raw materials which were needed in the production of imported goods. This indicator is the sum of GDP and the monetary value of imports, divided by (abiotic and biotic) primary raw material usage.
56 | See Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit 2016.
57 | See Umweltbundesamt 2020e.
58 | See Umweltbundesamt 2020a.
59 | See ibid.
60 | See Umweltbundesamt 2020b.
61 | See Sachverständigenrat für Umweltfragen 2020a.
62 | In the present context, calculations are based on the Global Material Flows Database of the International Resource Panel IRP, see International Resource Panel s. a.. Because of different data sets and in particular different calculation methods for raw material consumption along global value chains, the results stated here for RMC are not directly comparable with the Federal Environment Agency's calculations, which are presented in section 2.3 and figure 8. The IRP's calculation method gives an RMC for Germany of 22.8 tonnes per capita for 2017.
63 | See Umweltbundesamt 2020a.
64 | See Geng et al. 2013.
65 | See Rodriguez et al. 2020.
66 | See Golde 2016.
67 | See Zink/Geyer 2017.
68 | See Korhonen et al. 2018.
69 | See Kirchherr et al. 2017.

Total raw material productivity

Sum of gross domestic product and imports in relation to primary raw material input (RMI)



total raw material productivity**

Primary raw material input (RMI)**

Gross domestic product and imports (adjusted for price)

Target path according to German Sustainability Strategy***

* 2016 preliminary value
** RMI = Raw Material Input; there are no values available for the indicator from 2001 to 2007; the graph shown is based on an estimate of the missing values
*** Target according to "German Sustainability Strategy. Revision 2016": Desired growth in total raw material productivity per year between 2010 and 2030 corresponds to the average annual growth between 2000 and 2010 (approx. 1.6 %)

Source: Federal Statistical Office 2020, Table "Gesamtrohstoffproduktivität und ihre Komponenten, Index 2000=100", destatis.de (02.06.2020)

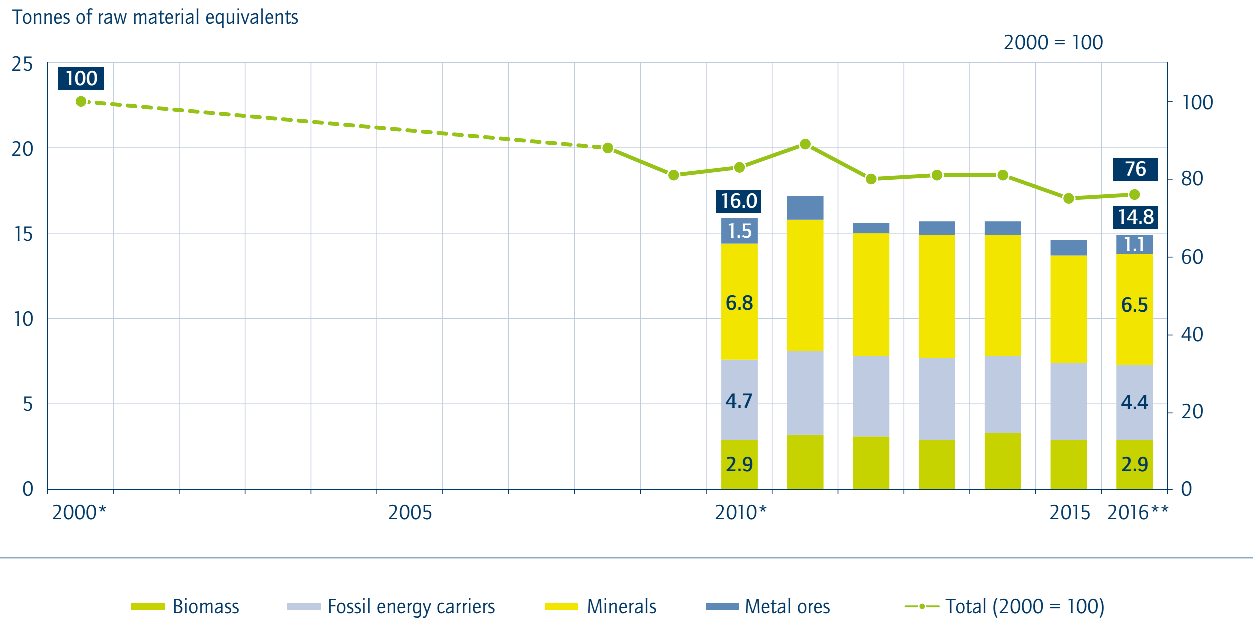
Figure 7: Development of total raw material productivity in Germany (Source: Umweltbundesamt 2020e)

2.3 Need for and potential of a systemic Circular Economy perspective

In contrast with resource productivity indicators, raw material consumption (RMC) merely reflects absolute resource consumption. In 2016, Germany's RMC was around 1.2 billion tonnes, which corresponds to a decline of 7 per cent relative to 2010. In comparison with the previous year, however, the RMC rose by just under 2 per cent. RMC per capita relates raw material consumption to population growth.[70] While the decline between 2000 and 2010 can mainly be attributed to lower construction investment,[71] no clear development trend can be discerned in particular since the global financial and economic crisis of 2008–2009 (see figure 8). To avoid over-stressing ecosystems, RMC per capita must be reduced significantly, however.[72] Neither Germany nor the EU has so far set a quantitative target for reducing raw material consumption. The strategies set out in Germany's Resource Efficiency Programme[73] can serve as initial guidance, but a long-term approach is now needed.[74]

Applying the principles of a Circular Economy systemically will contribute to reducing absolute consumption of resources and decoupling it from economic growth. Progress monitoring and the objectives of the German Circular Economy must therefore be extended and linked more closely together. This needs to

70 | See Statistisches Bundesamt 2020a.
71 | See Umweltbundesamt 2020b.
72 | See ibid.
73 | See Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit 2019.
74 | See Umweltbundesamt 2020b.



* Due to methodological reasons, absolute figures for raw material use can only be displayed for years 2010 and later. A presentation of figures starting in 2000 is possible only by means of an indexed value (2000 = 100).
RMC = Raw Material Consumption
** 2016: preliminary data

Source: Federal Statistical Office 2020, Umweltökonomische Gesamtrechnung. Aufkommen und Verwendung in Rohstoffäquivalenten. Berichtszeitraum 2000 bis 2016

Figure 8: Development of raw material use for domestic consumption and investments (RMC) per capita (Source: Umweltbundesamt 2020c)

include both absolute raw material consumption and indicators which take account of the transition to Circular Economy business models and Circular Economy principles as well as product and consumption systems.[75]

Raw material consumption is directly related to greenhouse gas emissions, since increasing consumption of new products generates carbon emissions along the value chain in terms of extraction, processing and transport of raw materials.[76] Scenario modelling by the Federal Environment Agency shows that in the medium term coordinated measures for reducing greenhouse gas (GHG) emissions and resource consumption help in achieving both objectives markedly more efficiently.[77]

Moving towards a fully Circular Economy, which extends beyond waste and recycling management, would also open up new possibilities for economic growth. Although much of Germany's potential for a systemically conceived Circular Economy has not hitherto been fully exploited, the economic indicators in the market segments technology for waste management, collection, transport and street cleaning, waste processing and evaluation and scrap material wholesale have clearly been moving in the right direction since 2010 (see table 1). The number of employees working in these sectors has risen by an average of 1.3 per cent. Turnover has likewise seen average annual growth of 2.3 per cent.[78] More targeted promotion of Circular Economy products and business models would give this development a clear boost.

75 | See Umweltbundesamt 2020c.
76 | See Lutter et al. 2018.
77 | See Purr et al. 2019.
78 | See Prognos et al. 2020a.

Figure 9: Development of Germany's raw material consumption (RMC) and carbon footprint, 1995–2012 (Source: Lutter et al. 2018)

Overview of the development of economic indicators of the Circular Economy							
	2010	2012	2015	2017	2019	Development (in %)	p.a.
Number of employees	277,300	288,480	289,770	295,360	310,470	12.0	1.3
Turnover (in 1,000 €)	71,499,000	79,664,800	76,094,400	84,084,200	–	17.6	2.3
Gross value added (in 1,000 €)	21,538,400	23,685,800	26,318,400	28,111,800	–	30.5	3.9
Companies	11,600	11,700	11,000	10,700	–	–7.8	–1.1

Table 1: Value added and jobs created by the Circular Economy in Germany [79] (Source: Prognos et al. 2020b)

2.4 Conclusion

It is therefore clear from an examination of the current situation regarding a Circular Economy in Germany that it has so far made only a limited contribution to protecting the climate and resources. The measures initiated thus far have not been sufficient to achieve the hoped-for effect. The vision of a greenhouse gas-neutral, resource-productive Circular Economy needs Germany to be far more ambitious than current efforts imply. In order to achieve these ambitious objectives and effectively reduce environmental impact, further measures are needed which provide systemic support to the Circular Economy. Circular Economy concepts may increase the productivity of the materials and products used, in particular by exploiting the potential of digitalisation, for example intelligent value chain networks. The service life of products and the materials used may by extended, among other things, by new business models and incentives to adopt them. In addition, recovery rates for materials can be increased, for example by applying Circular Economy principles to product design or to after-sales service processes and by better locating

79 | These figures relate to the market segments technology for waste management, collection, transport and street cleaning, waste processing and evaluation and scrap material wholesale and do not reflect all business sectors relevant in the context of a systemically conceived Circular Economy.

and comprehensively recording scrap products at end-of-life. Aspects of data availability and quality along the value chain can also contribute to further improvement in this respect. The development and rapid implementation of circular business models can significantly boost the already promising trend towards a Circular Economy in Germany, open up new value creation potential and contribute to securing raw material supply.

3 Vision for a Circular Economy in Germany

As long ago as 2015, the European Commission's Circular Economy Action Plan set out a broad vision of the transformation to a Circular Economy. In addition to adding environmental value through resource conservation, the Circular Economy is set to increase competitiveness, promote sustainable economic growth and create new jobs.[80, 81] Decoupling economic growth and human wellbeing from the consumption of resources is thus intended to contribute significantly to the European goal of greenhouse gas neutrality and the protection of ecosystems. This understanding of a broad vision is also reflected in the current Circular Economy definitions in academia and practice, according to which a Circular Economy should not only cut resource consumption and waste, but also contribute to renewable ecosystems and to ensuring prosperity and wellbeing.[82, 83] Building on these described environmental and socioeconomic effects of such a transformation, the vision for a Circular Economy in Germany in 2030 and 2050 was developed over the course of the *Circular Economy Initiative Deutschland*.

3.1 Procedure for developing the vision

When it comes to developing the vision, the focus is on concrete, operationalisable objectives by which both progress and regression can be measured and understood. These concrete objectives play a key role for governments since their focus on implementation can be used to motivate other stakeholders and to derive concrete measures for achieving the objectives and indicators for measuring progress.[84] It should be emphasised, however, that no sufficiently comprehensive set of indicators is available for some Circular Economy objectives. Accordingly, many activities are currently under way at national and international level to identify and select suitable indicators (e.g. Bellagio process, Circular Economy Monitoring Framework, Circular Economy Financing Expert Group; see also section 3.3). The objectives selected for the vision can therefore be described partly quantitatively and partly qualitatively. This approach is intended to emphasise that the transformation to a Circular Economy requires a broad understanding of the vision which goes beyond the existing set of indicators. There is accordingly a need to accelerate the development of appropriate indicators for monitoring the qualitatively described objectives.

The vision is being developed against the background of international and national agreements such as the Sustainable Development Goals and the Paris Agreement of the Framework Convention on Climate Change (UNFCCC) and Germany's Sustainability Strategy and Climate Action Plan 2050. The European Commission's Circular Economy Action Plan and Circular Economy Monitoring Framework, Germany's Resource Efficiency Programme (ProgRess III), the Federal Environment Agency's Guidelines for a Circular Economy, Germany's Raw Materials Strategy and the German Federal government's High-Tech Strategy 2025 were also analysed. The findings from this research were compared and combined with the proposals developed during *Circular Economy Initiative Deutschland* working group and task force meetings.

The first step of developing the vision involved the working groups and the task force identifying environmental, economic and social objectives. The second step, based on the first one, involved carrying out a thorough literature search and making a comparison with existing national and international agreements. The third step involved defining process goals and objectives for the impact of a Circular Economy which were adopted by the members of the *Circular Economy Initiative Deutschland*. The following section presents the articulated vision; an overview of the environmental, economic and social implementation goals as well as the targets for the impact of a Circular Economy are compiled in the Appendix.

From an environmental perspective, the Circular Economy is a process of transformation in which improved closed-loop management of materials, components and products brings about an overall reduction in the consumption of resources, greenhouse gas emissions and waste generation. As "umbrella concept", the Circular Economy brings together all "Resource Life-Extending Strategies" (RLES) and activities of relevance to resource management such as reduce, reuse, repair, recycling etc.[85] Ensuring the success of this transformation entails formulating **concrete process goals for implementation** of the circular

80 | See European Commission 2015.
81 | See European Commission 2019a.
82 | See Ellen MacArthur Foundation 2015.
83 | See Kirchherr et al. 2017.
84 | See Morseletto 2020.
85 | See Blomsma/Brennan 2017.

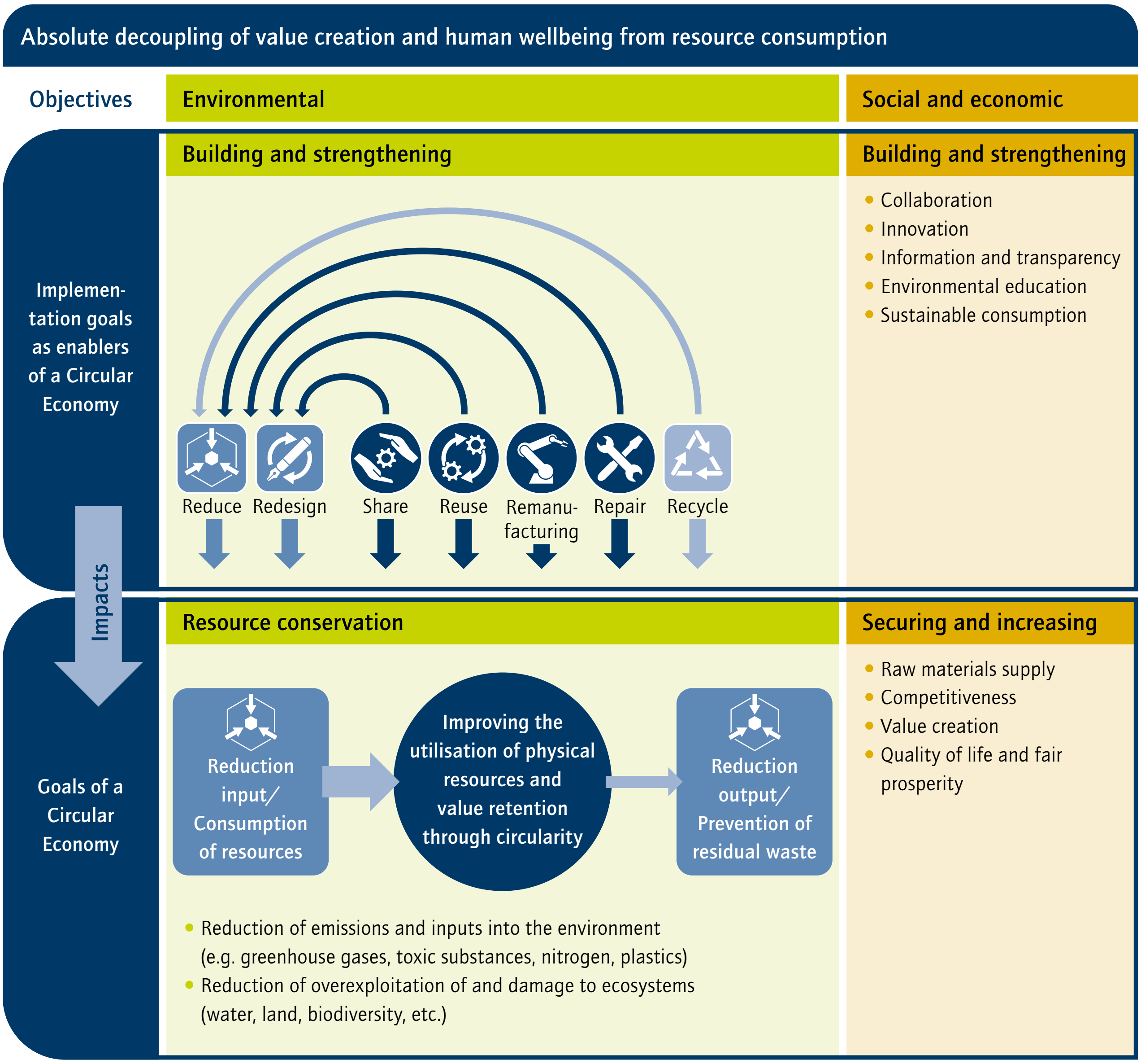


Figure 10: Reference framework for Circular Economy objectives at the national level (Source: own presentation, based on Koch/Coelho Megale 2020)

strategies. There is furthermore a need to draw up **concrete objectives for the impact** of these circular strategies in order to ensure that they achieve the desired **effect**, namely conserving resources, cutting (greenhouse gas) emissions and leakage and reducing ecosystem overexploitation and damage (see figure 10). Building on the reference framework of the Ministry of the Environment of the Netherlands[86], resource-related objectives are formulated as follows at the national level: a) minimise consumption of resources (inputs), b) maximise circularity and inventory management of physical resources (utilisation and value retention) and c) avoid waste (outputs, see figure 6). In this respect, the transformation to a Circular Economy is not viewed as an end in itself but instead as a means for avoiding the negative environmental impact associated with the previous linear approach to value creation.[87] Accordingly, a distinction is drawn between process-oriented objectives and their concrete

86 | See Koch/Coelho Megale 2020.
87 | See Weber/Stuchtey 2019.

effects when it comes to creating the vision of the Circular Economy and developing a corresponding monitoring framework.[88, 89]

In addition to the formulation of environmental objectives, the inclusion of social and economic factors was central to the success of the Circular Economy concept. *Circular Economy Initiative Deutschland* experts confirmed that the contribution they make to value creation, to ensuring competitiveness and the supply of raw materials, as well as to human wellbeing and fair prosperity is an important objective of a Circular Economy. As during the formulation of the environmental objectives, concrete process goals were also identified for social and economic areas (see figure 10). Using this approach, the *Circular Economy Initiative Deutschland's* reference framework for the vision provides a new basis both for deriving measures for shaping the transformation process and selecting suitable indicators for measuring progress (see section 3.3).

3.2 Germany 2030: Vision for the transformation to a Circular Economy

In 2030, Germany will be on its way to a prosperous Circular Economy, which will mean **value creation and human wellbeing can be absolutely decoupled from resource consumption.**

The basis for this success will be **the achievement of a wide range of environmental implementation goals** as enablers for a Circular Economy. In order to reduce the consumption of resources, comprehensive reduce and redesign strategies will be used in product development. Renewable energy sources will account for 65 per cent of gross power consumption and 30 per cent[90] of gross final energy consumption, while primary energy consumption will be 30 per cent[91] lower than in 2008. Innovative business models using share/repair/maintain/upgrade/remanufacture principles will have become established in order to intensify and prolong the use of materials and products. In addition, higher recycling rates combined with increased recycled material quality will lead to higher end-of-life resource recovery rates. Contaminants in materials and products will be avoided, so reducing waste generation (see figure 10 for an overview of the objectives).

The **impact of a Circular Economy** on resource conservation will be clearly apparent and will be reflected in an **absolute reduction in resource consumption.** The share and use of secondary materials will have risen distinctly. The **utilisation of physical resources** will have improved substantially, and **true circularity will have extended value retention** for products, components and materials. Accordingly, **(residual) waste volumes will have decreased distinctly**. Progress in resource conservation will be becoming apparent in a slow, but perceptible **recovery of damaged and overexploited ecosystems,** including outside Germany, and will be contributing to the preservation of biodiversity. In addition, a **comprehensive reduction in (toxic) emissions and inputs into the environment** will have been achieved, so reducing ecosystem eutrophication and plastics inputs and making a clear contribution to greenhouse gas neutrality. In this respect, the Circular Economy will have helped to reconcile economic activity with planetary boundaries.

Major social and economic objectives for the implementation of a Circular Economy will also have been achieved. The development of circular products, components and processes for the Circular Economy will be being comprehensively promoted, and the innovative capacity of German companies with regard to circular products, processes and business models will have significantly increased. Collaborative, intersectoral stakeholder alliances and access to common data platforms will have led to transparent, regional to global value creation networks in which human and workers' rights are respected (e.g. in the context of responsible sourcing and responsible recycling). The inclusion of external costs in economic accounting will have helped to develop circular business models and boost investment in Circular Economy strategies. This will have led to the emergence of new areas of value creation for companies, which will enable consistently sustainable business management.

The effects of these changes will be manifested in the contribution of a Circular Economy to **increased value creation and competitiveness**. In addition, **raw material supplies will have been secured**, by having reduced not only the risk of shortages but dependence on imports of (critical) raw materials.

88 | See Potting/Hanemaaijer 2018.

89 | See Ellen MacArthur Foundation 2020.

90 | This quantification corresponds to the assumptions of the Wuppertal Institute's modelling and is based on the objectives of Germany's sustainability strategy.

91 | This quantification corresponds to the assumptions of the Wuppertal Institute's modelling and is based on the objectives of the Federal Ministry for Economic Affairs and Energy's Efficiency Strategy 2050, 2019.

Societal and political support for the transition to a Circular Economy will have been achieved by the development of Circular Economy-relevant initial and in-service training provision and increased Circular Economy policy advice. This will have enabled across-the-board environmental education, including initial and in-service training, and created broad societal awareness of and know-how about sustainable value creation and resource efficiency. Social innovations such as repair initiatives, co-creative production methods such as FabLabs and prosumer models will have been enabled with the assistance of new forms of cooperation and participation in the value chain and in society. Previously written-off (skilled) occupations such as radio and television technicians will be experiencing a renaissance for the professional repair of terminal equipment. Finally, sustainable and sufficient consumption and use patterns will have developed and demand will predominantly be for Circular Economy products and services. Public procurement in particular will play an essential role in boosting demand for circular alternatives.

Ultimately, the transformation to a Circular Economy will have been found to bring about a **sustainable improvement in quality of life** and **to secure fair prosperity extending beyond Germany**. These positive effects will be attributable, for example, to the following changes: protection of human health by avoiding and eliminating toxic materials, the creation of new jobs as well as new approaches to collaboration and participation which will have increased citizens' involvement in value creation.

Building on the objectives described above, the vision for a Circular Economy for Germany can be summarised as follows:

> *"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 absolutely decoupled from resource consumption. It will ensure planetary limits are respected and sustainability goals achieved and help to enhance quality of life and ensure equitable prosperity through collaborative, inter-company value creation and innovation."*

3.3 Metrics for measuring the vision

Evaluating national progress on the way to a Circular Economy and controlling the process requires a control set of appropriate metrics. A European and national process which is intended to ensure that Circular Economy objectives are achieved should make use of macro-level metrics both for measuring outcomes and for tracking the transition to a Circular Economy. In line with the thinking behind the vision set out in section 3.1 (see also figure 10), the metrics are subdivided into measured variables for activities which enable the transition to or implementation of a Circular Economy and those which describe the actual effects of a Circular Economy. The effectiveness of a Circular Economy can be analysed and described on the basis of a systemic consideration of thermodynamic efficiency (enthalpy and entropy (exergy)). Many activities are currently under way at national and international level to identify and select suitable indicators (e.g. Bellagio process, Circular Economy Monitoring Framework, Circular Economy Financing Expert Group etc.).

The results of an analysis of existing Circular Economy metrics[92] are consistent with the findings in the literature that there are already many metrics in existence for measuring the results of a Circular Economy, in particular for the reduction of resource consumption and waste. These are based on calculation methods such as input-output modelling, where data are available for such calculations[93, 94] Metrics for circular strategies[95] are necessary in order to assess whether specific Circular Economy-related activities lead to the desired implementation outcomes of a Circular Economy. Tables 3 to 5 in the Appendix present the results of this analysis.

The analysis reveals, however, that at present only a few metrics, mainly for recycling and recovery, are proposed for evaluation at national level and in most cases even these are poorly suited to evaluating actual physical circularity. Furthermore, there is currently a lack both of calculation methods and of data for most of the proposed metrics related to the other circular strategies such as rethink/redesign, repair, reuse and remanufacturing. In addition, few metrics are proposed in the literature for evaluating the environmental, economic and social impacts of a Circular Economy. It is also doubtful whether the proposed metrics are capable of measuring the contribution of Circular Economy activities to

92 | Due to the rapid progress being made in developing Circular Economy indicators and in the absence of the specific focus of a dedicated working group on this area, it was not possible within the framework of the Circular Economy Initiative Deutschland to derive recommendations for a suitable set of indicators for measuring progress towards a Circular Economy. The results presented in the Appendix thus form a basis for further work on this topic.

93 | See Alaerts et al. 2019.

94 | See Potting/Hanemaaijer 2018.

95 | The Glossary provides a description of the various circular strategies.

any reduction in impact at the national level.[96, 97] This is problematic since metrics for measuring the success of measures (here described as "enablers") would help to make the effectiveness of implemented activities transparent and thus controllable. This is because the effects of Circular Economy activities only become visible later. In the meantime, many options for change might already have been missed if no other control measures are available.

However, while metrics are available for determining national resource inputs and outputs for the purposes of measuring progress, metrics for evaluating Circular Economy activities (circular strategies) and the associated socioeconomic impact and environmental effects would need to be further developed. It should be noted that there is currently a considerable need for research on the links between the implementation of Circular Economy strategies and their impact on society. This concerns not only what still remains inadequate empirical contextual knowledge, but also the ongoing lack of concepts and tools to enable observation and measurement of social impact, for example on quality of life or participation. There is a need here, on the one hand, for inter- and transdisciplinary development of target knowledge (("Which social and societal objectives are normatively desirable?") and, on the other hand, for further development of transformation knowledge ("How can processes be designed and evaluated so as to achieve normative objectives and avoid negative effects?").

3.4 Quantifying the vision

As explained in the previous section on Circular Economy metrics, it is not possible to make comparable statements for a similarly differentiated consideration of further Circular Economy levers such as reuse or repair, as there is still a lack of robust data. For instance, the legal bases intended to provide data on reuse to EU Member States from 2022 were still pending in January 2021.[98] Nevertheless, analyses for example from Material Economics[99] and the UN International Resources Panel[100, 101] suggest that in particular these further Circular Economy levers, which are directed towards ensuring higher-quality continued use of products, have great potential for decoupling prosperity from resource utilisation.

As described in section 3.2, saving resources and helping to reduce emissions in order to achieve greenhouse gas neutrality are central objectives of a Circular Economy. With regard to resource savings, the *Circular Economy Initiative Deutschland* has set out a vision of absolute decoupling of economic growth from the consumption of resources. On this basis, a quantitative target for the Circular Economy of halving the consumption of natural resources by 2050 has been defined. This is intended to help achieve the goal of greenhouse gas neutrality by 2050 as described in the Climate Action Plan. The Wuppertal Institute undertook a modelling exercise including interim targets for 2030 in order to describe the path towards achieving this target. This modelling is based on an ambitious reference scenario which already takes current climate policy impetus into account. A similarly ambitious, alternative Circular Economy scenario presents the potential of circularity levers for achieving the defined resource consumption and greenhouse gas reductions.

3.4.1 Reference scenario

Reference scenarios for Germany's future consumption of resources (developed on the basis of global, macroeconomic input-output models) show that the current climate policy impetus in Germany is capable of distinctly reducing carbon emissions (down by 77 per cent by 2050 in comparison with 1990).[102, 103] However, the consumption of resources (raw materials consumption (RMC), i.e. including the upstream chains necessary for individual products) would fall by only a very limited extent in such a business-as-usual scenario from the current 22 tonnes per capita to 18.5 tonnes due to incremental improvements in recycling rates. This would be a long way off from current estimates of a sustainable level of resource consumption, which is put at

96 | See Blum et al. 2020.
97 | See Helander et al. 2019.
98 | See European Union 2018.
99 | See Material Economics 2018.
100 | See International Resource Panel 2020.
101 | See International Resource Panel 2018.
102 | Using the GINFORS3 model, a "climate-active Germany" scenario was modelled for this purpose, this model taking account of the effects of energy policy transformation efforts, for a example a 100 per cent share of renewable energy in 2045 and an ETS CO_2 certificate price of 147 euro in 2050.
103 | See Distelkamp/Meyer 2018.

a possible target corridor of 5.6 to 10 tonnes.[104, 105, 106, 107] These results illustrate that the goal of dramatically reducing greenhouse gas emissions does not inevitably lead to the equally necessary reduction in resource consumption.

However, this reference scenario also falls well short of the goal of climate neutrality in 2050 in combination with a halving of total resource consumption. This would require a much more comprehensive transformation of production and consumption patterns in Germany and associated global value chains for many sectors, for which the transition to a Circular Economy must be one of the core strategies.

3.4.2 Circular Economy scenario

Statements regarding the central levers of a Circular Economy were derived from the RESCUE scenarios proposed by the Federal Environment Agency.[108] Figure 11 shows the reduction in greenhouse gas emissions (as an objective of the *Circular Economy Initiative Deutschland* vision) in the reference scenario (climate scenario) with existing climate policy impetus compared with an alternative scenario (GreenME) which is tightly focused on the transition to a Circular Economy.[109] This clearly shows that, without the use of Circular Economy levers, the radical reductions in greenhouse gas emissions needed to achieve a two-degree-compatible development pathway[110] would not be achievable at all.

The levers or circular strategies taken into account according to the definition of the Circular Economy used by the *Circular Economy Initiative Deutschland,* such as material savings through service life extensions due to repair, design or maintenance as well as intensification of use, are summarised under "savings" for the description of the results of the modelling. Concrete examples of circular approaches which are included are durable design and remanufacturing, for instance in the construction of renewable energy infrastructure, lightweight construction and resource efficiency in construction, and repairability in consumer goods.

The greenhouse gas savings achieved in the Circular Economy scenario to 2030 are distributed across a number of areas of activity (see figure 12). Around half the savings are obtained from changes in energy supply, while mobility, industrial production and agriculture are further major areas of activity. Circular Economy levers can accordingly be seen to make a significant contribution to greenhouse gas reduction in the Circular Economy scenario.

Viewing the resource consumption associated with the scenarios as the second dimension of the vision reveals even more significant differences between the reference and Circular Economy scenarios: figure 13 shows one possible development of raw materials consumption in Germany to 2050 in a Circular Economy scenario and the associated consumption of resources along global value chains. The resource savings compared to the reference scenario illustrate both the increasing significance of the use of secondary raw materials from recycling and the role of the other Circular Economy levers.

- Extensive application of Circular Economy levers for extending service life and intensifying use and distinctly higher levels of recycling (including greatly increased energy efficiency) would enable an overall reduction in primary raw material use of 68 per cent by 2050 compared to 2018 ("savings" plus secondary raw materials).[111]
- The provision of secondary materials through recycling accounts for just under 50 per cent of the achieved resource savings, the other half being achieved by savings generated by the other circular strategies.

104 | See Weber/Stuchtey 2019.
105 | See Schmidt-Bleek 1994.
106 | See Bringezu 2014.
107 | See Wuppertal Institut s.a.
108 | The results presented here are based substantially on the work carried out as part of the "Transformation process towards a greenhouse gas-neutral and resource-efficient Germany" research project (research ID 3715411150). A combination of a total of five models, which were supplemented with detailed sector- and industry-specific analyses, was used. Modelling in the transport sector is based on TREMOD (Transport Emission Model), in the space heating and cooling sector on GEMOD (Buildings Model) and in the agricultural sector on ALMOD (Agriculture and LULUCF Model). In combination with the industrial sector-specific analyses as well as the waste sector, the energy modelling was carried out with SCOPE (cross-sectoral deployment and expansion optimisation for analyses of the future energy supply system). Macroeconomic raw materials use and upstream emissions were modelled using the environmental economic raw material and GHG model (URMOD). A detailed description of how the models work can be found in Dittrich et al. (2020) .
109 | See Purr et al. 2019.
110 | See Prognos et al. 2020b.
111 | See Purr et al. 2019.

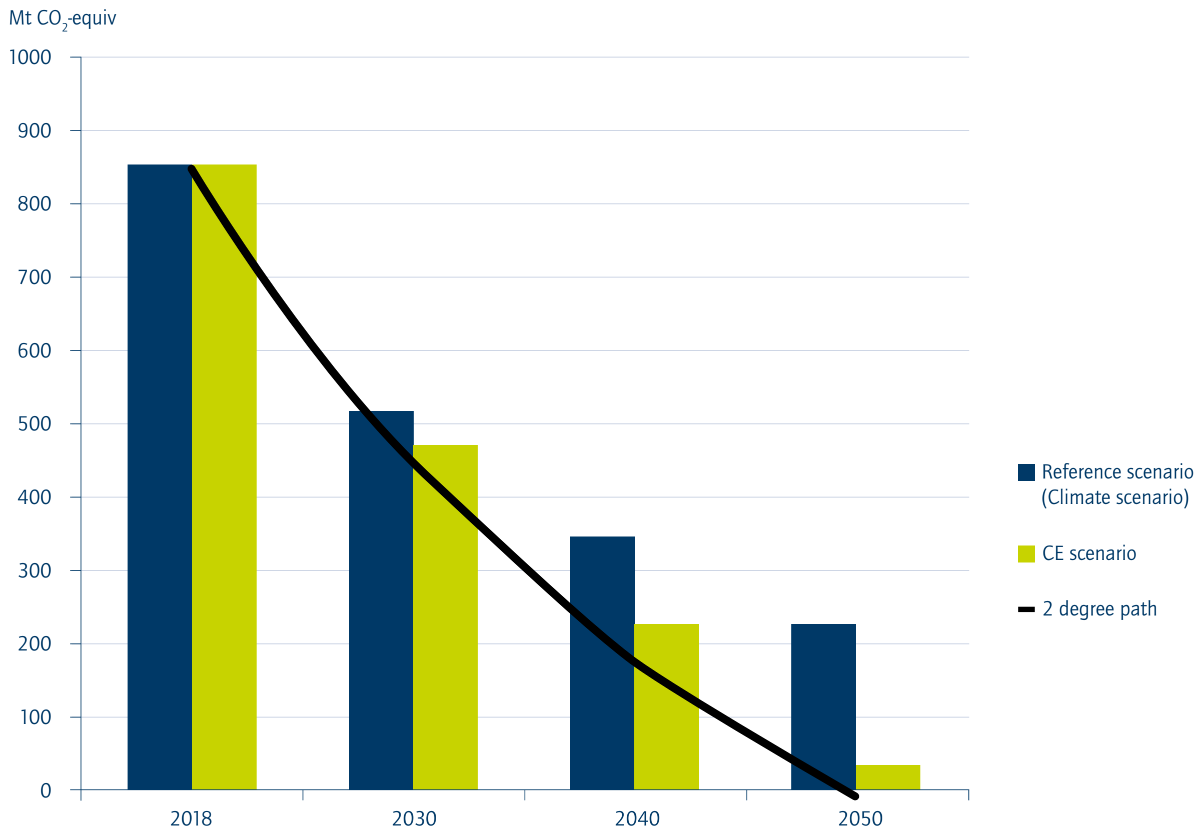


Figure 11: Greenhouse gas emissions in the ambitious climate policy reference scenario and a Circular Economy scenario in Germany, 2018–2050, in million tonnes of CO_2 equivalents
(Source: own presentation, based on Purr et al. 2019 and Lutter et al. 2018)

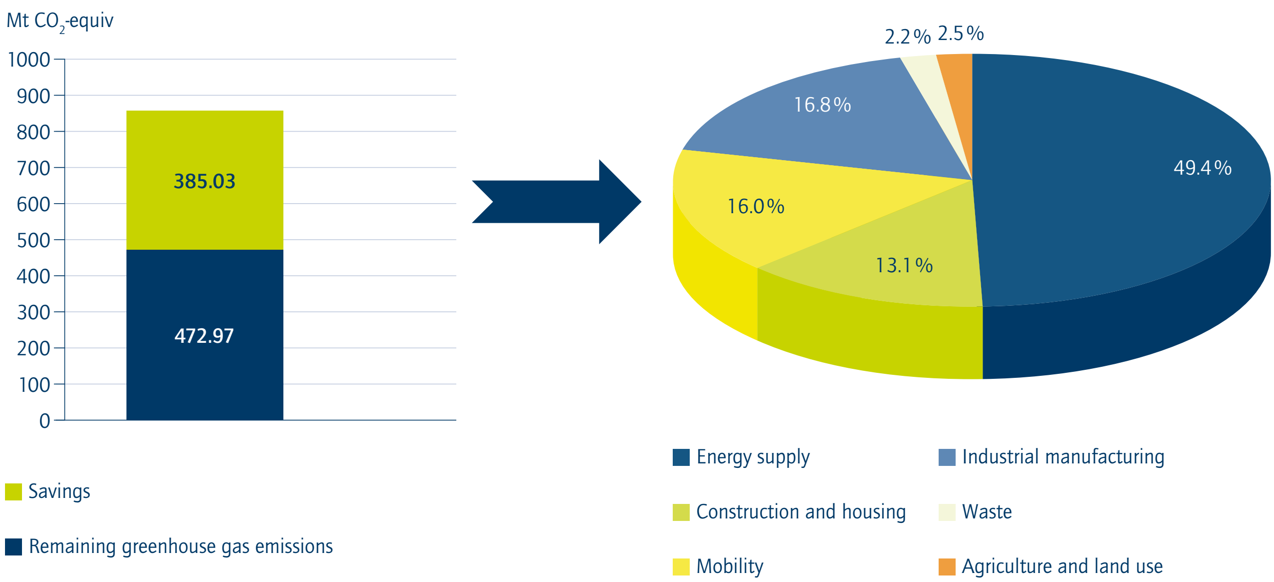


Figure 12: Shares of different areas of activity in the greenhouse gas reductions achieved in the Circular Economy scenario from 2018 to 2030 (in million tonnes of CO_2-equivalents) in per cent (Source: own calculation based on Purr et al. 2019)

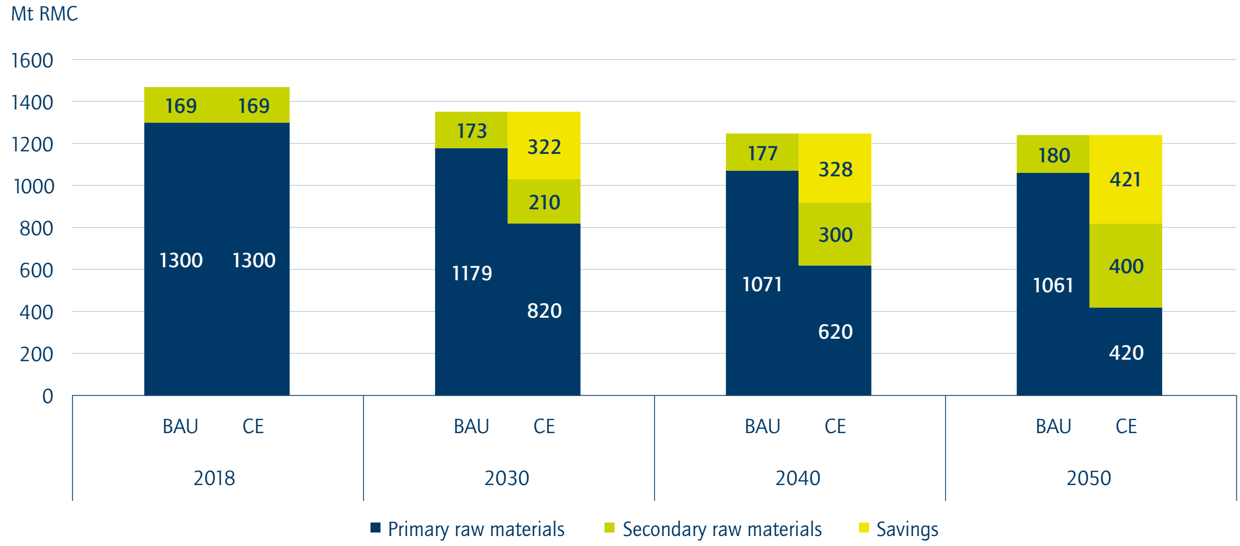


Figure 13: Germany's consumption of resources in the Circular Economy (CE) scenario in million tonnes of raw materials consumption (RMC) compared to the reference scenario (Bussiness-as-Usual, BAU) (Source: own calculation, based on Purr et al. 2019 and Lutter et al. 2018)

With regard to the distribution of resource consumption among the four main groups biomass, metals, non-metallic minerals (i.e. in particular building materials) and fossil energy sources to 2050, the complete abandonment of fossil energy sources and, in addition, the savings in building materials and metals achieved through circular levers are shown to be the main drivers in reducing per capita resource consumption (see figure 14).

In view of the complexity and uncertainties associated with the necessary transformation processes up to 2050, the evaluation of **overall economic effects** is challenging.[112] If we consider the direct effects of using secondary raw materials of comparable quality, the savings for 2018 amount to approximately 2.2 billion euro, of which some 1.7 billion euro are accounted for by the metals sector and around 500 million euro by the plastics sector.[113, 114] The cumulative effects up to 2030, assuming constant raw material prices and qualities, can be estimated at approximately 32 billion euro, a sum which could be increased still further by improving the quality of the recycling processes.

Significantly higher potential savings would be possible through Circular Economy levers applied earlier in the value chain. Total costs for raw material consumption in the manufacturing sector in Germany can be estimated at around 941 billion euro (as at 2018).[115] A reduction in resource consumption through savings of 33 per cent to 2030 by means of Circular Economy levers beyond recycling and the associated cost savings or economic productivity gains would thus be a factor of ten higher than the direct cost savings through recycling. In addition, the necessary expenditure, for example for repairs to extend the service life or personnel costs for the provision of services, would correspond to additional, less material- and cost-intensive, sales with corresponding effects on gross domestic product. At the same time, the new circular business models and innovative processes needed make quantification markedly more uncertain. However, case studies at least anecdotally reveal the market potential for example of continued use (Amazon: 26 per cent growth in turnover in the second-hand market between 2005 and 2010),[116] which can be backed up for selected sectors by UN International Resource Panel analyses.[117]

112 | In a meta-study on macroeconomic effects of a Circular Economy, the OECD refers to calculated increases in GDP of the order of 0 to 15 per cent, see McCarthy et al. 2018.
113 | Including steel, aluminium, copper, lead and zinc and PE HD, PE LD, PVC and PS.
114 | See Steger et al. 2019.
115 | See Statistisches Bundesamt 2019.
116 | See Ellen MacArthur Foundation 2013.
117 | See International Resource Panel 2018.

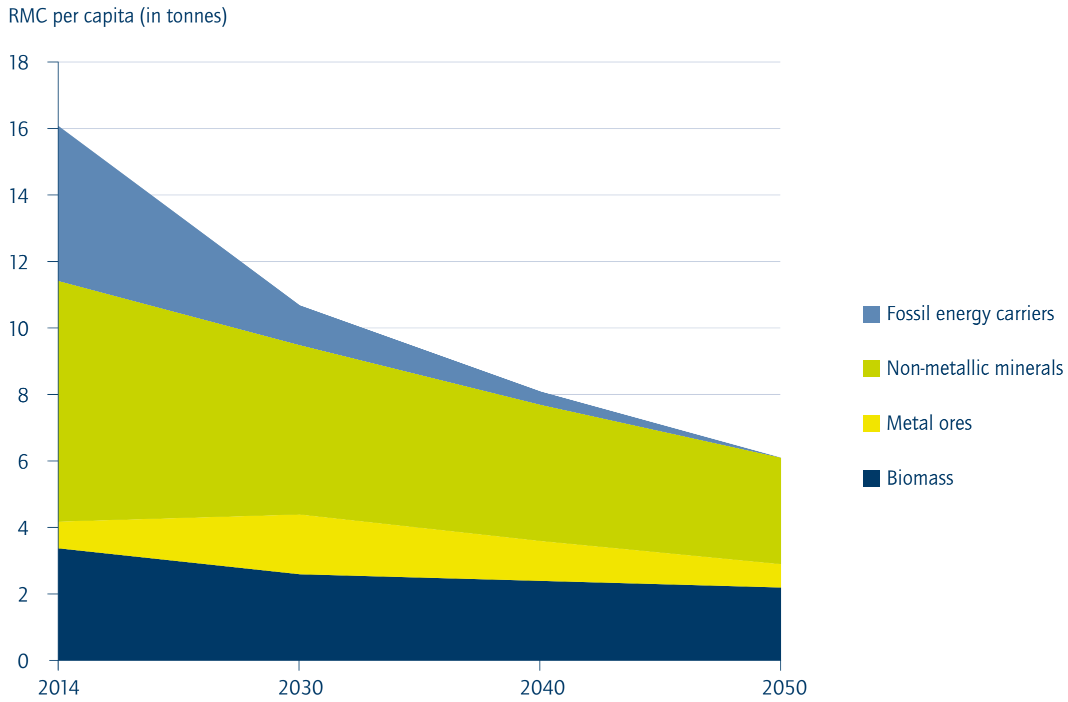


Figure 14: Development of per capita raw material consumption, differentiated by main material groups for Germany to 2050 in the Circular Economy scenario (Source: own presentation, based on Purr et al. 2019 and Lutter et al. 2018)

Achieving the vision of a future Circular Economy as described in section 3.2 will entail **huge investment** both in new recycling capacity and in circularly oriented production and management processes, the amount of which and, in particular, its distribution among specific stakeholders are still largely uncertain. In addition, the direct savings effects increase on the one hand due to optimised return (collection) and recycling rates, but on the other hand the total quantities available for recycling are reduced due to the decline in total resource consumption. For this reason, innovative circular business models, which are not geared to maximising resource throughput as in the linear economy but instead to optimising resource turnover, will have a central role to play in this transformation process.[118]

3.4.3 Conclusion

The resource perspective on a Circular Economy presented here makes it clear that the vision of a climate-neutral and simultaneously resource-productive Germany can only be achieved by a comprehensively transformational approach: climate neutrality cannot be achieved solely through the transition to a Circular Economy but at the same time, the Circular Economy is a key prerequisite for doing so. In addition to reducing resource demand through avoiding waste, remanufacturing and extending the useful life of products, closing material cycles also contributes around fifty per cent of the required primary resource consumption savings.

Incrementally optimising existing recycling technologies alone will not be enough by itself - among other things because the volume of waste will fall significantly and significantly more and higher quality secondary raw materials will then have to be obtained from less input material for recycling than is the case today. This would have to be countered by an improved collection rate, which would increase the availability of input material. There is an urgent need to combine any improvement in collection rate with other Circular Economy levers such as increased efficiency in the use of natural resources by extending the useful life and intensifying the use of products, also in the light of increasing Circular Economy requirements applicable to

118 | See Circular Economy Initiative Deutschland 2020a.

products in export markets that are important for German industry. In this context, the importance of use- and results-oriented business models should be emphasised due to their potential effectiveness in resource-decoupled value generation. At the same time, the expansion of renewable energies is a key prerequisite for a climate-neutral Circular Economy. In the light of global value chains and in particular the large proportion of possible resource savings in metal processing outside Germany, a global perspective on the Circular Economy is also imperative in order to avoid merely shifting effects abroad and, in line with the vision, actually to achieve positive effects with regard to respecting planetary boundaries and safeguarding quality of life.

4 Transformation to circular material and product management

Section 3 having discussed the development of a vision for transforming Germany into a Circular Economy, this section will look more closely at this transformation and its requirements. To find a way to strike a balance between the scope and complexity of the concept of a Circular Economy on the one hand and the generalisability of the findings relating to the more closely investigated topics on the other, the *Circular Economy Initiative Deutschland* has concentrated on circular business models in general and on selected products, namely packaging and traction batteries, in particular.

Key parameters for selecting the products were their value and service life, as these have a critical effect on product flow and thus on material and product management.[119, 120] As in Franco[121], extreme scenarios were used to arrive at generalisable statements about the transformation of various product categories into a Circular Economy: packaging materials and traction batteries were selected as examples of products respectively having low value and short service life and high value and long service life. Identified as priority sectors in the EU Circular Economy Action Plan[122], they are also areas in which significant action is needed and which are of strategic relevance from a transnational policy perspective. According to the EU, reasons for this include high levels of societal interest (environmental pollution due to packaging waste) and high economic criticality (dependency of the EU's automotive industry on battery (material) imports). The disposal of (plastic) packaging is also increasingly a major issue,[123] and traction batteries are likely over the coming years to become a central technology in the decarbonisation of road traffic and indeed the energy sector.[124]

The findings presented in sub-sections 4.1 to 4.3 have been brought together from the respective comprehensive reports from the working groups of the *Circular Economy Initiative Deutschland*: Circular Business Models, Packaging and Traction Batteries. The objective of such a synthesis was not to repeat in detail the insights compiled in these reports but rather to formulate the systemic aspects of transformation to a Circular Economy in line with the above-stated vision. The top-down perspectives of the Circular Business Models working group's findings and the bottom-up perspective of the product-specific insights from the other two working groups (Packaging and Traction Batteries) will be compared. For this purpose, the actual situation, the desired situation that it is hoped to achieve will be presented and potential solutions defined:

- Sub-section 4.1.3 presents the potential solutions from the Circular Business Models working group. These provide so to speak the overarching framework for the presentation of the other two working groups (top-down approach). Sub-sections 4.2.3 and 4.3.3 present the potential sector-specific solutions from the Packaging and Traction Batteries working groups within this framework (bottom-up approach).
- The findings of all the working groups are additionally subdivided for clarity's sake on the basis of a multilevel design model (MDM)[125]: i.e. from a social perspective, sociotechnical perspective, business model perspective and product perspective (see figure 15).

Section 4.4 compares the findings from sections 4.2 and 4.3 to gain generalisable insights for material and product management beyond these specific products.

119 | See Franco 2019.
120 | See Gobbi 2011.
121 | See Franco 2019.
122 | See European Commission 2020a.
123 | See Pew Charitable Trusts/SYSTEMIQ 2020.
124 | See Circular Economy Initiative Deutschland 2020b.
125 | See Joore/Brezet 2015.

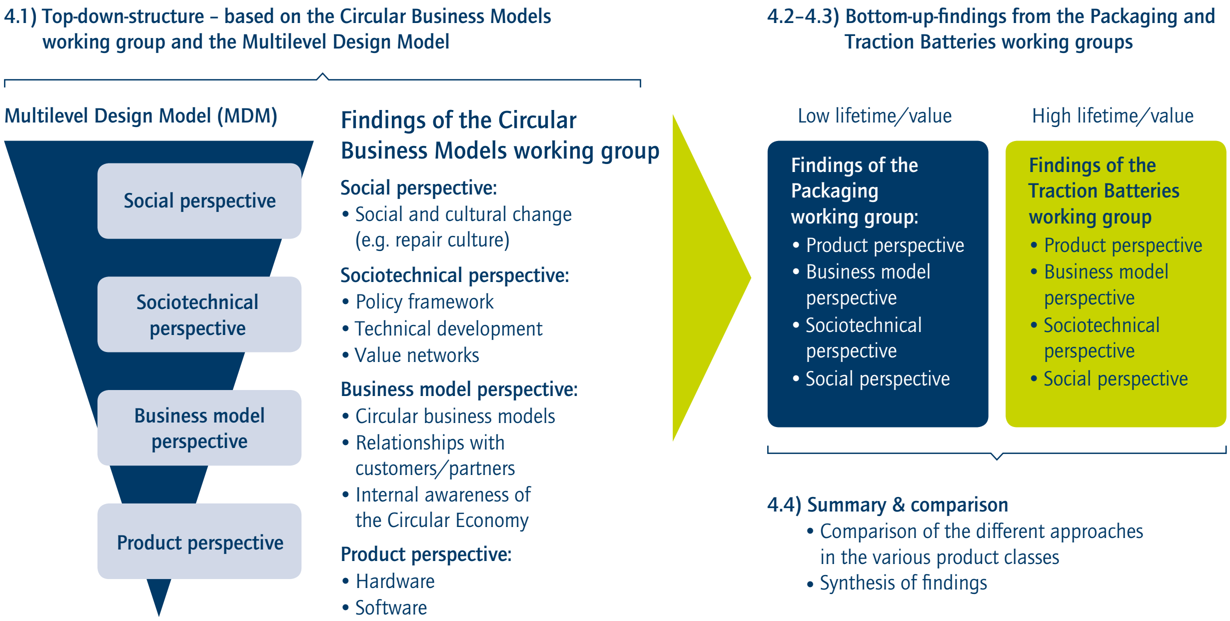


Figure 15: The findings of the Circular Economy Initiative Deutschland structured on the basis of the Circular Business Models working group's framework (Source: own presentation, based on Multilevel Design Model after Joore/Brezet 2015)

4.1 Findings of the Circular Business Models working group

This sub-section summarises the findings of the Circular Business Models working group,[126] with the aim of developing a conceptual framework for analysis. This framework is intended to provide a structure for the transformation to circular management of materials and products and to present the challenges and measures for the transformation to a Circular Economy from a cross-sectoral standpoint (see also figure 16). Detailed explanations and citations can be found in the working group's own final report.[127]

4.1.1 Actual situation: Current challenges for the transformation to a Circular Economy

The isolated optimisation and profit maximisation opportunities offered by individual actors' business models does not meet the requirements of a systemic transformation to a Circular Economy, since most economic activities are oriented towards maximisation of (material) turnover and, if anything, lead to rapid downcycling of the raw materials used. Circular ecosystem design therefore needs an integrated approach. Actor-specific challenges and difficulties and shifting role requirements within newly arising value networks complicate the process of making such a fundamental economic change. The actual implementation and dissemination of circular business models is still slow and is hindered by a multiplicity of **regulatory, financial, organisational, technical or consumption- or value chain-related barriers**.

Although Germany has a long tradition of waste legislation, there is **as yet no proper legal framework for a Circular Economy**, whether in Germany or the European Union. Rather, Circular Economy-related aspects are generally covered by waste prevention and management legislation, which is oriented more towards waste disposal than resource-productive material management (see also section 2). In addition, the relevant aspects

126 | In the course of its work, the Circular Business Models working group addressed the following central issues: a typology with 22 actor specific business model patterns, five integrated potential solutions for overcoming barriers (in line with the Circular Economy strategies defined by the Circular Business Models working group: maintenance & upgrade, repair, reuse, remanufacture, recycle), a "dashboard" indicating the potential of digital technologies when it comes to implementing intelligent Circular Economy strategies; 32 detailed policy recommendations, summarised as seven overarching key recommendations for further implementation, a circular product policy framework for targeted harmonisation of various policy instruments and a use case analysis (taking the television as an example) to illustrate existing barriers to and potential for circular business models.

127 | See Circular Economy Initiative Deutschland 2020a.

are scattered over various branches of the law. At the same time, existing policy instruments are also not as yet directed at promoting a circular, resource-productive economy; for example, ecodesign legislation remains very much focused on energy efficiency at an individual product level. Nonetheless, with the Sustainable Products Initiative, the European Commission did in 2020 begin a review of ecodesign legislation at EU level, which is intended to broaden this narrow focus to some extent. The possibilities offered by digitalisation – from digital technical support for circular product management strategies to fundamentally digital, dematerialised business models – are nowhere near being exhausted. Particular attention should thus be paid to promoting the introduction of suitable digital technologies into corporate practice and so improving the data and information exchange needed for a Circular Economy. Germany currently occupies only **12th place in the European digital competitiveness rankings**.[128] Circular business models are at present still based mainly on product-oriented services and are a concept which is often applied only after the product design phase, which limits their feasibility and profitability. Digitalisation may in this context be used in future, alongside product-oriented business models, to exploit to a greater extent the potential of use- and results-oriented business models.

4.1.2 Desired situation: Closed-loop systems as the new business paradigm

Successful implementation of a Circular Economy requires society as a whole to completely rethink itself as a Circular Society (see excursus "Circular Society", section 4.1.3). Implementation of a Circular Economy should enable Germany to deal with the growing climate and environmental crises, reduce overall dependency on raw materials imports, achieve domestic value creation through regional circular income flows and develop competitiveness through targeted technology and market leadership (see section 3.2 on the vision for a Circular Economy).

A crucial factor in the successful implementation of a Circular Economy will be whether economic incentives can be created through new circular business models. In this respect, value creation must in particular also include Circular Economy levers such as repair, reuse or remanufacturing. At material stream level (recycling), a rethink of downcycling is needed, with the focus moving to upcycling to achieve highly segregated, toxicologically safe materials of the highest possible quality, or at least to continuously closed loops where quality is maintained at the same level.

A comprehensive learning and rethinking process is essential for all actors, with this process extending from the development of circular business models with circular strategies as the core element to a circular redesign of products, requiring a consistent overhaul of all the subsequent business processes involved in value creation, delivery and return. In the context of this overhaul, core value creation processes and the associated understanding of their role within a company's value chain also require dynamic adaptation, whether with regard to product design, business model design, competitive standing within the value cycle or behaviour in relation to the surrounding value network.

It will in any event be important to ensure that all actors along a value chain are mobilised and ready to reconsider their business models and cooperate in "circular ecosystems".

Also crucial to the implementation of a Circular Economy is making the best possible use of the potential of digital technology, with environment- and climate-friendly technologies and processes being a particular priority. The provision of product lifecycle data can extend product service life, maintain maximum quality throughout this service life and ultimately close material and energy loops. These data may be provided, for example, in the form of material and product passports which create digital product histories, the comprehensive use of sensor systems and connectivity (Industry 4.0) and the fast-growing possibilities offered by machine learning.[129]

The criterion most crucial to successful implementation of a Circular Economy in Germany and Europe is an integrated policy framework which reduces waste by extending service life and increasing reuse and remanufacturing of products on the basis of circular requirements and standards for product design. This policy framework should include a shift in economic incentivisation for example by adjusting tax and duty systems to include social capital costs and costs to nature and reflect resource utilisation. Only then will it be possible to make it attractive for businesses to adopt circular business models which focus on value-maintaining circular strategies such as repair, reuse, remanufacture and finally high-quality recycling.

128 | See European Commission 2020b.
129 | See Glossary.

4.1.3 Potential solution: Achieving a Circular Economy through an integrated approach to value creation

Social perspective

Education and research are particularly significant in encouraging the "rethink" needed to move towards a "Circular Society" (see excursus "Circular Society" in this section) and in motivating different societal stakeholders to take an active role in shaping this Circular Society.

- **Education and research: New formats for participation and the promotion of individual initiatives and social innovation** are ways of increasing citizens' basic understanding and helping them to participate in and feel at home with circular value creation processes. Do-it-yourself and community repair initiatives (e.g. in the form of a repair café) are a first step in transforming passive "consumers" into circular prosumers[130]. Such participation initiatives should be supported by (standards-based) **product labelling and declarations** which provide higher levels of transparency about average product life and the repairability of products (i.e. their repairability index) and **detailed environmental labelling**.
  Education and training programmes in schools, vocational training centres (e.g. repair of home entertainment equipment) and universities (e.g. Master's degrees in the Circular Economy) remain the basis for building circular awareness. In addition, a national or European institution must be set up and funded with the aim of accelerating the **interdisciplinary consolidation of scientific insights, industrial practice and societal needs** within a Circular Economy.

Sociotechnical perspective

A distinction needs to be drawn here between the policy framework, technical development and value networks. Careful configuration of these action points will enable direct transformation from the pre-existing sociotechnical regime of a linear economy to circular industrial value creation.

- **Policy framework: Economic instruments** can help to incentivise the Circular Economy. This can be achieved on the one hand by raising the cost of using natural resources (e.g. higher carbon prices) and eliminating harmful subsidies (e.g. all types of tax exemption/relief associated with the use of fossil fuels). On the other hand, Circular Economy strategies can also be directly encouraged, for example by redirecting subsidies or decreasing the tax burden (e.g. VAT exemption for repair and maintenance services). Consumption of resources and carbon emissions outside Europe must also be taken into account.
  Regulatory instruments take the form of statutory regulations or ordinances which oblige manufacturers and consumers to take specific measures. These regulatory instruments include mandatory standards and strengthening of manufacturer/retailer responsibilities throughout a product's life cycle (e.g. compulsory take-back).
  Moreover, governments and authorities can use **public procurement processes** and used product management to boost demand for circular products and business models and so promote innovation (e.g. by introducing a minimum proportion of circular products or services).

- **Technical development:** Technical developments can lead to **various types of innovation** (from process and material innovation to innovative redesign of products and business models), which in turn contribute to successful implementation of a Circular Economy. **Voluntary standards** developed by industry and research and university institutions, as well as civil society, constitute one such potential instrument. Businesses adopt voluntary standards to demonstrate quality (e.g. development of a standard to cover remanufacturing quality). The development of such standards must of course be open to **(technological) innovations which benefit the environment**. A further technological lever is more intensive use of digital technologies, processes, services and applications, including the necessary IT infrastructure. This requires not just technological know-how but in particular also a willingness on the part of all actors concerned to change processes in order to create transparency along the entire value chain. Improved infrastructure and digital technologies can help in remedying the information deficits, for example, which currently hinder optimum implementation of circular strategies. A product passport (or more strictly a material passport) can provide all actors in the value chain with information about origin, location, composition (including substances of concern), repair and disassembly instructions and guidelines for managing the end of the life cycle. Information on the life cycle of specific products could likewise be recorded and stored in corresponding databases (e.g. by evaluating the service life of products and components with sensors to establish how much life they have left or whether or how they can be repaired or recycled).

130 | See Glossary.

A further example of technological levers is the further development of **process technologies for instance for the collection or (re)utilisation of used or discarded products** (e.g. recycling).
To assist in the development of customised digital Circular Economy strategies, the Circular Business Models working group is making a "**dashboard**" available to businesses as a guiding framework. Depending on the smart circular strategy selected by a business (from the six smart circular strategies[131] described by the Circular Business Models working group) and that business's degree of digital maturity, the dashboard can provide an overview of the possible benefits of the selected Circular Economy strategy and offer a decision-making aid and guidance for the business to develop its own tailored digital Circular Economy strategy.

Business model perspective

A description of the transformation from this standpoint is based on the three key dimensions of circular business models defined by the Circular Business Models working group.

- **Actors:** The transformation to a Circular Economy **changes the dynamics** within industry, with actors possibly moving beyond their previous roles: **positioning in the value cycle** changes when actors take on additional roles (e.g. producers do their own recycling or award controlled service contracts for it) or when completely new actors and roles are created. **Value networks** are closely linked with the actor dimension:[132] Since circular solutions cannot be provided by individual businesses alone, they have to work together in a circular ecosystem. The partners' business models have then to be brought into line, so that the collaboration brings benefit to each. To expand their business models with circular services such as repair and remanufacture and extend them to further **stages of the value cycle**, actors will preferably apply the strategies of **vertical integration** (Make) or **networking** (Ally) to their decision-making. In contrast to outsourcing (Buy), actors can thus identify weak points in products and business processes previously designed for a linear economy, feed back into the product development process to improve circular redesign and promote organisational learning. In addition to the business ecosystem established at the microlevel, which concentrates on partnerships between companies to provide circular solutions, the meso- and macro-level stakeholder ecosystem may include further relevant stakeholders from their respective communities, districts, nations and cultures and should be supported by setting up new institutional structures and coordinating mechanisms.
- **Circular Economy strategies:** Circular Economy strategies describe how actors implement the concept of circularity in their business models. On the basis of the identified Circular Economy strategies and further considerations regarding related approaches, the proposed **typology** includes the following key circular strategies: maintenance and upgrading or reconditioning, repair and reuse, remanufacture and recycling.
- **Service level:** This involves a change from product- to service-oriented business models. The rollout of **use-oriented** (e.g. leasing) or **results-oriented** (e.g. pay-per-performance) **business models** in both the B2B and B2C sectors is a measure which may potentially incentivise businesses to extend the service life of their products, to put them to the most intensive use possible and, once they have reached the end of their useful life, to make the best possible use of parts.[133]

By combining the three dimensions of actors, Circular Economy strategies and service, a typology of 22 business model types has been defined, each with three service levels, which can be adopted (with company-specific adaptations) by the various types of actor in the value cycle.

As already noted from the sociotechnical perspective, the development of **digital technologies** has the potential to play an absolutely crucial role in the implementability of circular business models. They not only further the circularity of manifold processes in the value chain of a product but also offer, depending on how they are applied – for instance internet of things (IoT), digital twin, digital product passport, online platforms, blockchain technology, big data, analysis and artificial intelligence – the potential to operationalise a Circular Economy. In particular, they reinforce, through the provision and efficient transfer of data and information, the value-generating function of actor business models in a service-, product-, component- and materials-based ecosystem. In addition, they may also be combined as building blocks, to enable a specific business case. Digital technologies are thus not an end in themselves but rather a driver for transforming previously linear business models into circular

131 | See Circular Economy Initiative Deutschland 2020a.

132 | According to the MDM framework, value networks may function at a sociotechnical level due to their inter-company nature. The Circular Business Models working group, however, approached them from a business model perspective and they are appear under that heading in this report.

133 | The increase in service-oriented business models can also raise customer expectations, and so increase the demands on manufacturers in terms of circularity.

business models. Furthermore, they may also help in breaking down the remaining barriers to the implementation of circular business models.

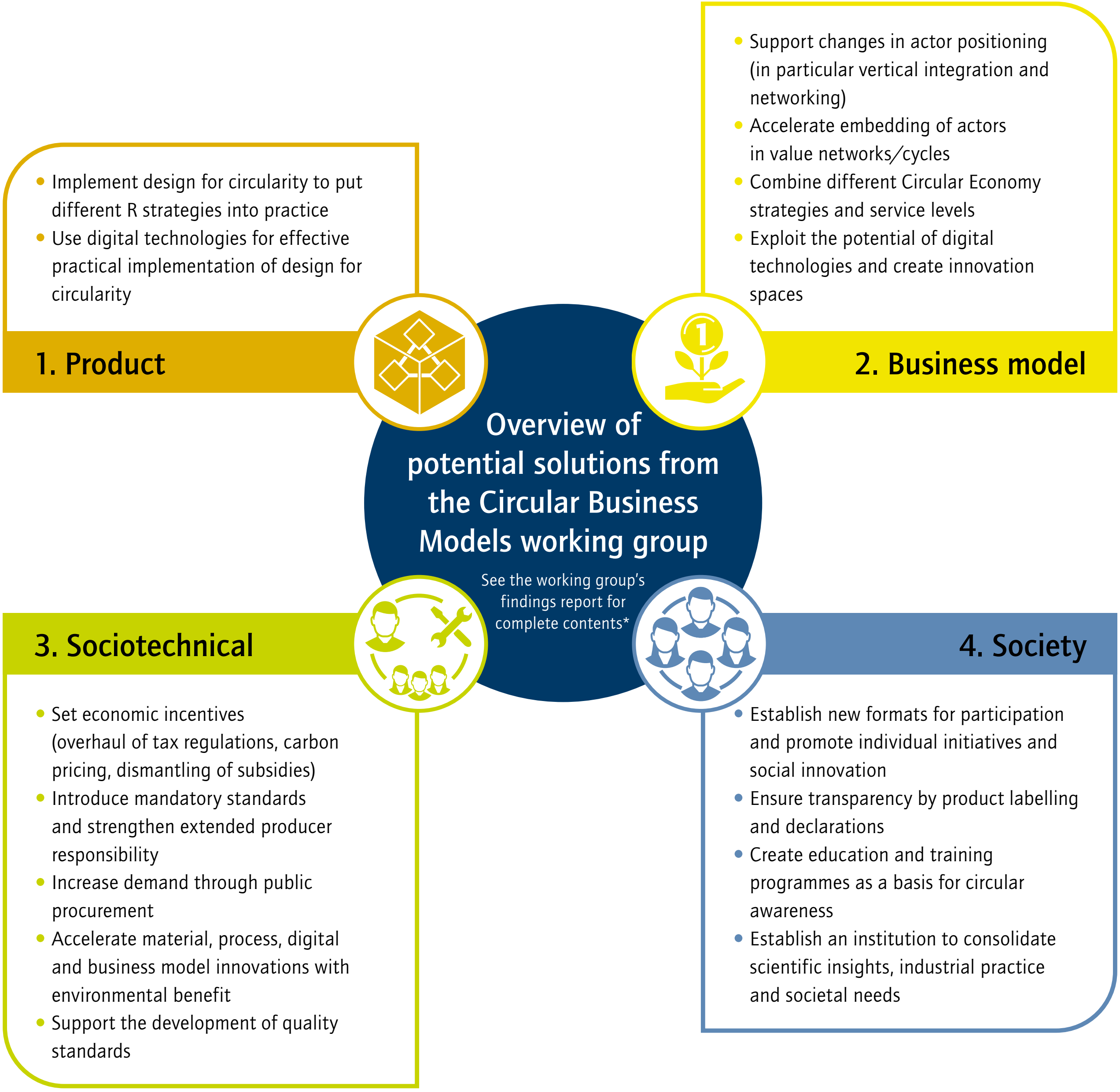
From these dimensions and the compiled findings, the Circular Business Models working group has identified the following essential task for businesses: in order to drive innovation forwards and accelerate the transformation to a Circular Economy, businesses must **approach the transition proactively**, reorienting their strategies and research and development objectives and generally investing more time and resources. In particular, to reshape their businesses to fit with a Circular Economy, they should establish **innovation spaces** (within or independently of core business areas) where traditional linear business models, previous product designs and associated value chains can be examined and, in particular, radical new service business models can be investigated.

Product perspective

As part of the value proposition, products lie at the heart of business models. In the Circular Economy context, product design is of particular significance. Both hardware and software components may constitute relevant building blocks integral to the transformation to a Circular Economy.

- **Hardware:** There are a number of **design for circularity** strategies which aim to maximise the Circular Economy potential of products. These strategies include design for longevity or durability, for upgrade, for maintenance and repairability, for remanufacture, for recycling or indeed the avoidance of hazardous substances (safe by design). The Circular Business Models working group has demonstrated, on the basis of their television use case, that there may also be limits to the immediate incorporation of circular design aspects: these days, hardly any TVs for the German market are produced in Germany or even in Europe, meaning that it is impossible directly to influence product design processes. A renaissance of European niche suppliers of smartphones (e.g. Fairphone) shows that a countertrend in the field of electronic products is nonetheless possible. Revolutionary changes and ever faster innovation cycles (such as the move from CRT to flat screen) may also limit the long-term potential for Circular Economy-oriented product design.
- **Software: Digital technologies** also play an important role in effective practical implementation of a design for circularity strategy. By way of example, products or machines (the television use case is a good example of the advantages of modularity) can be equipped with integrated sensors which allow data to be provided in real time about the current status, performance and state of the product or its constituent modules and such data to be used to derive appropriate circular strategies, for example preventive maintenance and repair.

The product perspective can be significantly influenced by establishing regulatory frameworks (such as the framework legislation for a circular product policy outlined in this final report).



* Circular Economy Initiative Deutschland 2020: *Circular Business Models: Overcoming barriers, unleashing potentials*, acatech/SYSTEMIQ, Munich/London 2020.

Figure 16: Overview of potential solutions proposed by the Circular Business Models working group (Source: own presentation)

Excursus: Circular Society

Recent criticism of the Circular Economy debate has highlighted, in particular, that issues relating to social and cultural sustainability and social change currently receive too little attention.[134, 135] Criticism is also levelled at the Circular Economy concept for being primarily an environmental modernisation project, which, moreover, is based on a capitalist interpretation of progress and economic growth.[136, 137] The term "Circular Society" (CS) is used by various stakeholders in research and industry to emphasise dialogue and approaches which go beyond technological and market-based solutions and view the transition to circularity as a root-and-branch socioecological transformation. One thing the different approaches to a CS do have in common is the notion that the change to a Circular Economy is impossible without the participation and commitment of society as a whole. The approaches differ in their degree of focus on social sustainability and social change and the question of restructuring society.[138] Those approaches which would like to see current Circular Economy strategies supplemented with sociopolitical measures enabling citizens to use circular products and services can be described as "Circular Economy Plus".[139] These approaches want to see measures, for example, to increase product transparency and accessibility, reduce costs or expand rights. "Economic restructuring" approaches take a step further and apply the principle of circularity also to the distribution of power and (im)material resources, stressing that, if sustainable, future-proof Circular Economy management is to be achieved, there must be a fairer distribution of prosperity, knowledge, technology and the means of production.[140] With its focus on new "wellbeing" narratives, the term Circular Society is linked to the idea of the "Good Life". This approach would like to see notions of the "Good Life" decoupled from the need for material prosperity and economic growth[141] and predominant definitions of the purpose of trade and commerce replaced by alternative narratives. Approaches which describe a circular consumption and production system based on participation and solidarity could be denoted a "transformative Circular Society".[142] This approach underlines the importance of bottom-up initiatives, social innovation and emancipatory movements to socioecological economic transformation. These, it is argued, should play a central role in political strategies in order, in the long term, to reconfigure production and consumption models to create stronger regional, participative value networks very much along the lines of E.F. Schumacher's "Small is Beautiful":[143]

The debate around a Circular Society is still in its early, dynamic days. Initial implications for designing the transformation can be derived from the various lines of argument and the practical examples considered: 1) Current definitions of economic value creation, with their focus on monetary and corporate value, must be broadened to focus on socioecological value creation as a sustainability objective. 2) Greater attention should be paid to strengthening sufficiency strategies: current Circular Economy debates concentrate mainly on efficiency and consistency strategies such as repair and recycling. Strategies and business models which encourage a "rethink or refuse" attitude and thus a culture of material sufficiency are still currently rare, and innovation in these areas should be given particular impetus. 3) Citizen participation in the Circular Economy should not just be limited to expanded consumer rights and more information possibilities, but rather new pathways and forms of participation in production processes should be opened up, for example via codecision-making procedures, human-centred design and open source initiatives. This should include enabling people to carry out repairs, do-it-yourself, upcycling and to form production and use communities.

134 | See Korhonen et al. 2018.
135 | See Hofmann 2019.
136 | See Hobson/Lynch 2016.
137 | See Valenzuela/Böhm 2017.
138 | See Calisto Friant et al. 2020.
139 | See Qiping 2011.
140 | See Schroeder/Anantharaman 2019.
141 | See Kothari et al. 2014.
142 | See Jaeger-Erben/Hofmann 2019.
143 | See Schumacher 2011.

4.2 Findings of the Packaging working group

This sub-section summarises the findings of the Packaging working group,[144] which looked into a Circular Economy for plastics packaging, describing the actual situation, the desired situation and potential solutions. The working group's aim was to apply the analysis structure presented in the introduction to section 4 to a product of low value and with a short service life, major challenges for systematic circularity and significant societal visibility – in this case plastics packaging. This bottom-up approach is why the description of potential solutions in section 4.2.3 begins at product level (see also figure 17). Detailed explanations and full citations can be found in the Packaging working group's own findings report.[145]

4.2.1 Actual situation: Increasing amounts of plastics packaging waste due to inadequate circularity

In 2018, Germany created 18.9 million tonnes of packaging waste – a new record. The particular focus is on plastics packaging, which constitutes a major challenge. Over the last 20 years the amount of plastics packaging placed on the market in Germany has doubled from 1.6 (1998) to 3.2 million tonnes (2018). Roughly two thirds of this takes the form of domestic plastics packaging and one third is transport and outer packaging.

Of the volumes of plastics processed in the packaging industry in 2019, just some 474.000 tonnes or 10.1 per cent were recycled materials, almost 90 per cent therefore being virgin material. The reason for this is both individual hiccups in the value chain (e.g. packaging design unsuitable for reuse or recycling, conflict between higher-quality sorting and quicker, more convenient sorting processes, collection misplacement rates) and a **lack of transparency and compatibility** throughout the value chain (for instance, the wide variety of packaging designs which are not tailored to the existing recycling landscape, a lack of guaranteed commercial demand for recycled material and transnational differences between national regulatory objectives).

4.2.2 Desired situation: Defossilised packaging industry with good material productivity

Through the use of defossilised materials, maximally closed resource loops and increased material productivity, the packaging industry can contribute to achieving a climate-neutral Circular Economy (see section 3.2 on the vision for a Circular Economy). Packaging will no longer be considered a disposable product. Potential solutions will be evaluated holistically and are accordingly subordinate to the Circular Economy hierarchy of the following major principles: 1) **Avoiding packaging** is the top priority, providing the overall environmental footprint (e.g. due to larger volumes of food waste if less/different packaging is used) does not increase as a result. 2) 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. 3) Material and product design will consistently **eliminate toxic effects** along the value chain and will ensure safe subsequent use. 4) Where reasonable and feasible, **secondary materials or alternatives to a fossil-based primary material** will be used. 5) All circularity levers are subject to an environmental footprint analysis (e.g. **life cycle assessment (LCA)**) so as to promote sustainable potential solutions.

Results from a model calculation, based on expert-verified assumptions, show that increasing the share of mechanical recycling to 40 per cent, the share of chemical recycling to 20 per cent and the share of packaging reuse to 20 per cent by 2050 would enable savings of on average some 4 million tonnes of CO_2 equivalents annually compared to a business-as-usual scenario. However, the modelling also shows that, in the absence of additional measures, there would still be a substantial shortfall even in 2050 in achieving both climate neutrality and true circularity.

144 | The Circular Economy Initiative Deutschland's Packaging working group developed a roadmap to 2030 which indicates how the plastics packaging industry can move towards a Climate Neutral Circular Economy. With this in mind, the group first analysed why the packaging industry has hitherto largely operated linear value chains. The analysis was carried out both at the level of the packaging industry system as a whole and looking at two concrete case studies. A common vision was also outlined which describes in greater detail the potential ways in which a Climate Neutral Circular Economy can be achieved for the packaging industry. A thought experiment was additionally considered, which describes the technological, economic and regulatory parameters of a climate-friendly Circular Plastics Economy. Building on this foundation, a total of 34 policy recommendations for policy makers, business, academia and civil society for transforming the packaging industry were drawn up and ranked by priority.

145 | See Circular Economy Initiative Deutschland 2021.

4.2.3 Potential solution: Maintaining quality and reducing material volumes by combining Circular Economy levers

Product perspective

- **Hardware:** The end-of-life or subsequent use of packaging or the materials used in it needs to be given greater consideration from the product design stage onwards. This means that all non-avoidable packaging should be usable, reusable and recyclable to a high quality for as long as possible. Packaging must be designed in such a way that it fits clearly into the collection, sorting and recycling structures available in practice, and is separable (design for sorting) and recyclable to a high quality (design for recycling). Of particularly importance is the use of monomaterials rather than composites. In addition, the numerous plastics variants used in the packaging market need to be reduced overall, to make sorting and recycling more economically viable. In other words, manufacturers and distributors of packaging should not all place their own unique packaging solutions on the market but rather EU-wide minimum standards are needed to reduce the number of fractions to be sorted and accordingly increase the volumes that are recycled. Not only should suitable base materials be selected (not forgetting the auxiliary substances and additives used), they may also possibly be replaced with another material if this has better overall performance (material substitution). Where it makes sense to do so, secondary material or alternative starting materials (e.g. bio-based plastics[146]) can also be used. Individual consideration must always take account of the specific field of application. It does not currently seem advisable to use biodegradable plastics in Germany, as there is no appropriate recycling infrastructure and such plastics are simply incinerated. It is thus doubtful just how environmentally useful it is to use biodegradable plastics. 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. Reuse or recycling is accordingly preferable to composting from an environmental standpoint.
- **Software:** Sorting technologies, marker-based technologies or technologies based on artificial intelligence (AI), ensure unambiguous technical detectability of packaging and so enable optimised sorting, including of mixed materials, by material, corresponding processing and colour. Markers on packaging, for example, can provide the necessary information for process control (sorting and recycling). AI-based systems, which manage without markers, are also already giving highly promising test results.

Business model perspective

- **Actors:** Closer cooperation within the value chain is required because changes in individual links of the chain (e.g. material selection, packaging design, recycling infrastructure) have an impact on the entire system. Establishing new solutions, for example innovative multi-use systems, will mean identifying new stakeholder alliances.
- **Circular Economy strategies:** 1) The **prevention** of packaging and packaging waste primarily means that unnecessary packaging and packaging components are dispensed with (e.g. zero-packaging shops). In addition, packaging material can be saved by reducing the size of packaging, for example by compressing the package contents or avoiding unnecessary empty volume. The long-established material efficiency approach also falls under this category. In the past, however, this approach has not led to circular packaging (e.g. multi-layer packaging). In the trade-off between material consumption and recyclability, less efficient but more recyclable packaging should always be preferred if it enables greater efficiency to be achieved at the level of material cycles. 2) The **reuse** lever begins with the usage and service life of the packaging. Examples of this include not only well-established multi-use systems (return on the go), for example for beverage bottles or pallets, but also refillable parent packaging (refill at home), consumers filling their own containers from large containers (refill on the go) or reusable transport packaging, which is collected from home (return from home). 3) The dominant **recycling process** is currently **mechanical recycling**. Mechanical recycling offers considerable potential for reusing packaging materials. However, physical 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

146 | Bio-based plastics only make sense as a replacement for fossil-based plastics if the biomass used as their raw material 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 can 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. 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 and the prevention of overuse of water resources.

be offset by virgin-grade plastics. **Chemically** recycled plastics[147] and **bio-based plastics** are better solutions than fossil virgin material if they are accompanied by corresponding environmental advantages over fossil virgin material. An **environmentally optimised and technically feasible defossilised material mix**[148] is dependent on quality requirements and overall environmental considerations. In Germany too, intensive research should therefore be carried out into alternatives to existing recycling methods and non-fossil sources.

Sociotechnical perspective

- **Policy framework:**
  - **Economic incentives** can make it more expensive to act in a way that does not conform with the aims of circularity or support particular efforts towards recyclability. Since crude oil is so inexpensive that recycled material cannot compete with virgin material on price, regulatory intervention is necessary. This may take place at various points in the value chain, one being at the product design stage through the bonus system for environmental packaging design already created under section 21 of the Packaging Act (VerpackG). 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. In order to allow this instrument to be used in practice despite competition from Germany's dual system recycling scheme, a funding mechanism and/or appropriate rules are needed as soon as possible. A general and ambitious carbon levy would on the other hand make fossil virgin material more expensive and so incentivise meaningful use of recycled material[149] and provide motivation to optimise recycling technologies with regard to their carbon footprint.
  - **Regulatory instruments** for supporting market-based instruments are also needed at various points in the value chain. For instance, an EU-wide minimum standard could contribute to the harmonisation of packaging materials, their components and auxiliary substances and additives. Harmonising and reducing the variety of different packaging materials in this way would simplify subsequent sorting and increase recycled material quality. EU-wide 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.
    To improve the quality of recycled material, recycling needs in future to focus not only on improving the recycling system input stream but also on output quality, i.e. recycling rates should be coupled with quality. The extent to which it makes sense to extend mandatory deposits to other product groups which generate significant streams of packaging waste merits investigation. Safety requirements and standards for recycled materials which are applicable across the EU should also be defined to promote the use of these materials. Finally, to provide the necessary boost to the demand for recycled materials, it makes sense to gradually roll out a fixed minimum proportion for the use of post-consumer recycled plastics[150] in products. At the same time, it must be ensured that sufficient volumes of the necessary quality are available and that such regulatory measures do not weaken existing circular systems suitable for foodstuffs by extracting recycled material for other packaging. In addition to improving the recycling loop, regulatory instruments can also contribute to the prevention of packaging and packaging waste, for example by compulsory usage rates for multi-use food, transport and shipping packaging, not just in the beverage sector, if environmentally advantageous systems have been designed for this purpose.
  - **Information instruments** are also an important pillar of the transformation. On the one hand, a generally accepted decision-making aid should be created for determining the environmentally best packaging alternative. Building on this foundation, information campaigns can

147 | The term "chemical recycling" covers numerous recycling methods. The Packaging working group defines the term as follows: 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. A detailed overview and explanation of the various methods can be found in the report of the Packaging working group.

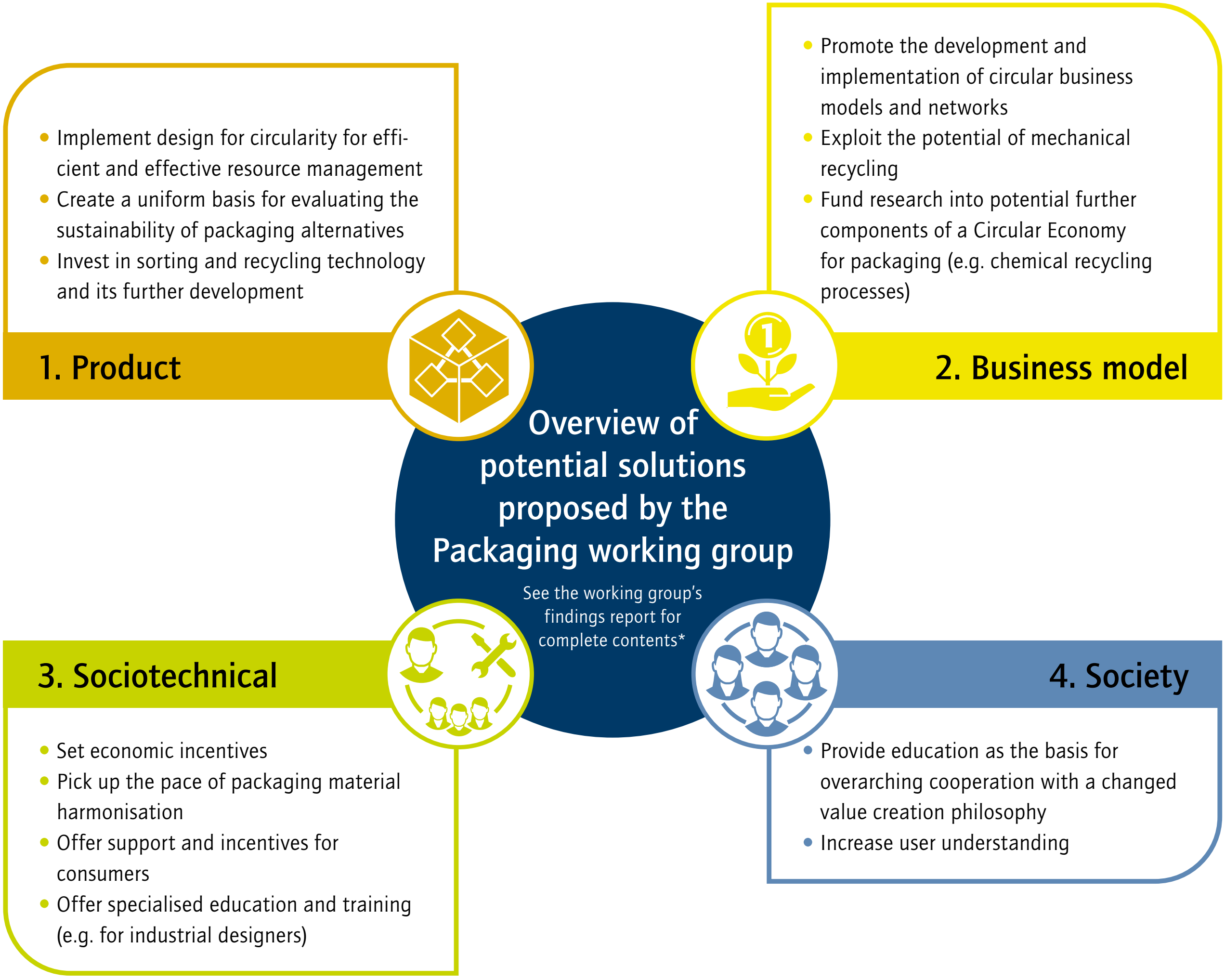
148 | The term "defossilised material" is used in this report as an umbrella term for bio-based virgin and recycled material and also mechanically and chemically recycled material. It thus covers all material alternatives to fossil-based virgin material. Despite the energy inputs involved in conversion, for which fossil energy sources are currently used, this term was selected in the light of electricity having to be 100 per cent generated from renewables when greenhouse gas neutrality is reached in 2050.

149 | See Glossary.

150 | See Glossary.

increase user demand, for example through suitable labelling. Moreover, during the changeover in the plastics industry from chemical processes for purely fossil-based natural resources to completely defossilised raw materials, a certified mass balance procedure is definitely going to be needed for over a decade. This procedure needs to define how the quantity of input defossilised material may be apportioned to the finished products and what may be marketed as "recycled".

- **Technical development:** Technical development for packaging is focused primarily on **process innovation**. To achieve high-quality mechanical recycling, overfilling should be avoided right from the sorting process and uniform material stream management attained, so as to improve sorting quality. The incorporation of multistage sorting processes also enables a further improvement in the technical efficiency of modern sorting plants.
Furthermore, upgrading sorting and washing technologies and introducing deinking or delamination processes (even with separate collection) can make a significant contribution to decontamination and so improve the quality and output of recycled materials. Re-sorting residual waste would increase the volume of material that can be sent for recycling.



* Circular Economy Initiative Deutschland 2021: *Plastics Packaging in a Closed Loop – Potentials, Conditions, Challenges*, Munich/London: acatech/SYSTEMIQ 2021.

Figure 17: Overview of potential solutions proposed by the Packaging working group (Source: own presentation)

This approach may make sense where separate collection of packaging is problematic.
A further technical option for increasing the quality of waste stream sorting is the use of (digital) marker-based systems. These are still at the developmental stage, however, and establishing them on the market will entail collaboration between manufacturers, who will have to use them, and recyclers, who will have to install appropriate sorting systems on their premises. Highly promising research results have however also been obtained for modern sorting technologies without markers, such as AI-based technologies.
With regard to the development of recycling technologies, it is important to understand whether, the purposes for which and volumes in which chemically recycled and bio-based virgin materials are required and what an environmentally optimised and technically feasible defossilised material mix might look like. There is also a need for further research into minimising the carbon footprints of all recycling technologies and into obtaining bio-based virgin material from biological waste streams.

- **Value networks:**
  - Cooperation is important both across actor groups as well as within the value chain. There is a need for a common, unified direction and **objectives** in order to set the appropriate course and create investment certainty.
  - Implementing circular approaches 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. This can only be achieved jointly by the triad of policy makers, industry and civil society working together.
  - Designing and establishing environmentally advantageous reuse systems needs new stakeholder alliances. Since this involves, among other things, making changes to business models and creating new infrastructure, it is more difficult to establish such a new system than to optimise the recycling loop. Funding is accordingly needed for corresponding platforms, initiatives and start-ups attempting to develop scalable reuse systems.
  - High-quality recycling of packaging materials also requires cooperation throughout the value chain: packaging design and recycling infrastructure need to be coordinated. The more standardised the packaging design (material, auxiliary substances and additives), the leaner the sorting and reprocessing process can be, even when producing high-quality recycled material. The toxicity aspect must always be taken into account in this context, in addition to circularity aspects. Consequently, the more complex the reprocessing and recycling process, the more expensive the recycled material. These chains of cause and effect are part of the reason that sorting and recycling capacity is still insufficient to produce high-quality recycled material on a large scale. Recyclers do not consider their position sufficiently secure to make such investment, nor are the returns sufficiently reliable. However, optimised packaging design alone is inadequate – it is essential to expand the recycling landscape if a Circular Economy for packaging materials is to be made a reality. These conflicting factors make it clear that a closed loop can only be successfully established across value chains.
  - Support is needed in the form of labelling or incentive systems (e.g. deposit systems), and barriers to correct disposal should 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.

Social perspective

- **Education and research:** Educational institutions, from schools through vocational schools to universities, 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**. If design for circularity and sustainability aspects are to be taken into account in the long term, for example, core Circular Economy ideas must be embedded in curricula and corresponding specific **training content** must be provided, for example for early-career industrial designers or material developers.

4.3 Findings of the Traction Batteries working group

This sub-section summarises the findings of the Traction Batteries working group.[151] The objective is to apply the analytical structure presented in the introduction to section 4 to a product of high value and with a long service life – in this case traction batteries. This bottom-up approach is why the description of potential solutions in section 4.3.3 begins at product level (see also figure 18). Detailed explanations and full citations can be found in the Traction Batteries working group's own findings report.[152]

4.3.1 Actual situation: Material footprint as a challenge for new, climate-friendly mobility

The transport sector is currently responsible for approximately 24 per cent of all carbon emissions worldwide, and 19 per cent of Germany's. Timely decarbonisation of the transport sector is essential to achieving the Paris climate targets. Rapid scaling of the number of battery electric vehicles for private transport is crucial to the achievement of this objective. Germany's target – according to scenarios from the National Platform Future of Mobility – is for around 7 to 10 million electric vehicles to be on Germany's roads by 2030; battery electric vehicles, i.e. vehicles with traction batteries, are likely in the long term to account for the vast majority of private cars.

For battery-powered and plug-in hybrid vehicles to achieve this **expected rapid growth** in market share, the **annual production of lithium-ion (traction) batteries** is predicted to rise sharply in the coming decade. On the one hand, this market expansion promises significant potential for creating new economic value and wealth. On the other hand, there is a need from the outset to minimise ecosocial challenges such as environmental impact and issues of occupational safety and human rights abuses which can arise along the supply chain from raw material extraction to recycling.

The current regulatory framework and measures (e.g. low recovery rates which are undifferentiated by material) are not suited to supporting productive use and effective circular management of important battery materials and need to be adjusted. Examples of aspects that need such adjustment are the generally incomplete nature of the data needed for efficient, reliable and high-quality continued use and recycling of traction batteries, the as yet insufficiently developed value networks for circular business models, including after-use options, and the inadequate incentives provided by the regulatory framework for establishing a level playing field, making circular management worthwhile. Comprehensive use of digital technologies is also necessary if circular traction battery management including the necessary data transparency is to be achieved: consistent use of such technologies could ensure sustainable battery production, optimise battery service life, repair and recycling and enable resource-productive business models and efficient regulation. The draft revised EU Batteries Directive under discussion by the EU Commission[153] at the time of drawing up this report in early 2021 takes a highly promising approach, but if the hoped-for positive effects are to be achieved, the ambitious objectives it sets out will have to be transposed into law. The recommendations[154] formulated by the working group, for example with regard to individual recycling targets for the key battery materials, definitions and system boundaries and with regard to creating powerful digital data infrastructures for instance in the form of a "battery passport" should be applied.

4.3.2 Desired situation: Life cycle material management helps electromobility to an environmentally friendly breakthrough

Circular Economy measures further improve the environmental and economic benefits of electric vehicles and can also create extra added value such as cost savings, safeguarding of jobs and increased economic resilience. Closing the loop can thus contribute significantly to achieving the Paris climate goals and to decoupling resource utilisation from value creation and human wellbeing (see section 3.2 on the vision for a Circular Economy). For traction batteries, a Circular Economy in particular increases productivity through repeated use, extends service life (repair and reconditioning) and ensures effective and efficient recycling

151 | The Circular Economy Initiative Deutschland's Traction Batteries working group has developed a common vision for the Circular Economy for traction batteries. This describes what a German Circular Economy for batteries might look like in 2030 with regard to the five dimensions of regulatory framework, material streams, technical development, value networks and in-company implementation. Through its work on three pilot profiles, the Traction Batteries working group has identified issues of central importance and outlined possible steps for practical implementation in order to accelerate the transformation process. By developing policy recommendations for policy makers, business and academia and creating a schedule for their implementation, the Circular Economy Initiative Deutschland has created a roadmap for achieving its vision.

152 | See Circular Economy Initiative Deutschland 2020b.

153 | See European Commission 2020c.

154 | See Circular Economy Initiative Deutschland 2020b.

with the aim of high-quality recovery of all important battery materials – subject to compliance with high standards in terms of environmental and social effects.

A Circular Economy is not an end in itself, but rather is intended to improve progress towards other sustainability goals. By bringing together the needs of various interest groups and generating value by conserving resources, a Circular Economy may simultaneously improve various sustainability dimensions. Finally, to achieve the above-stated goals, mobility needs an integrative rethink and the roles of various modes of transport must be critically assessed. A Circular Economy offers an opportunity in this regard, for instance by focusing on accelerating innovation cycles and greater intensity of product use and utilisation, on expanding knowledge- and labour-intensive remanufacture and recycling operations and systemically improving productivity through business models for repeated and continued use of batteries (second-life applications).

Results from a model calculation based on expert-verified assumptions[155] show that, by 2030, a total of 8,100 tonnes of lithium, 27,800 tonnes of cobalt and 25,700 tonnes of nickel will be recovered from vehicles placed on the market in Germany. For lithium, for example, approximately 13 per cent of demand could be met in this way by 2030. By 2050, a total of 109,000 tonnes of lithium, 180,000 tonnes of cobalt and 576,000 tonnes of nickel could be recovered. At current raw material prices, this would correspond to an economic value of 1.2 billion euro by 2030 or 13.8 billion euro by 2050. Carbon emission reductions could thus amount to approximately 36 million tonnes by 2030. By 2050, refurbishment could even generate savings of around 5.3 billion euro and 282 petajoules of energy demand (corresponding to 31.4 million tonnes of CO_2-equivalents), while, under optimistic assumptions, second-life applications will bring about cumulative energy requirement (CER) savings of 655 petajoules (73 million tonnes of CO_2 equivalents).

4.3.3 Potential solution: A data-driven Circular Economy maximises battery productivity

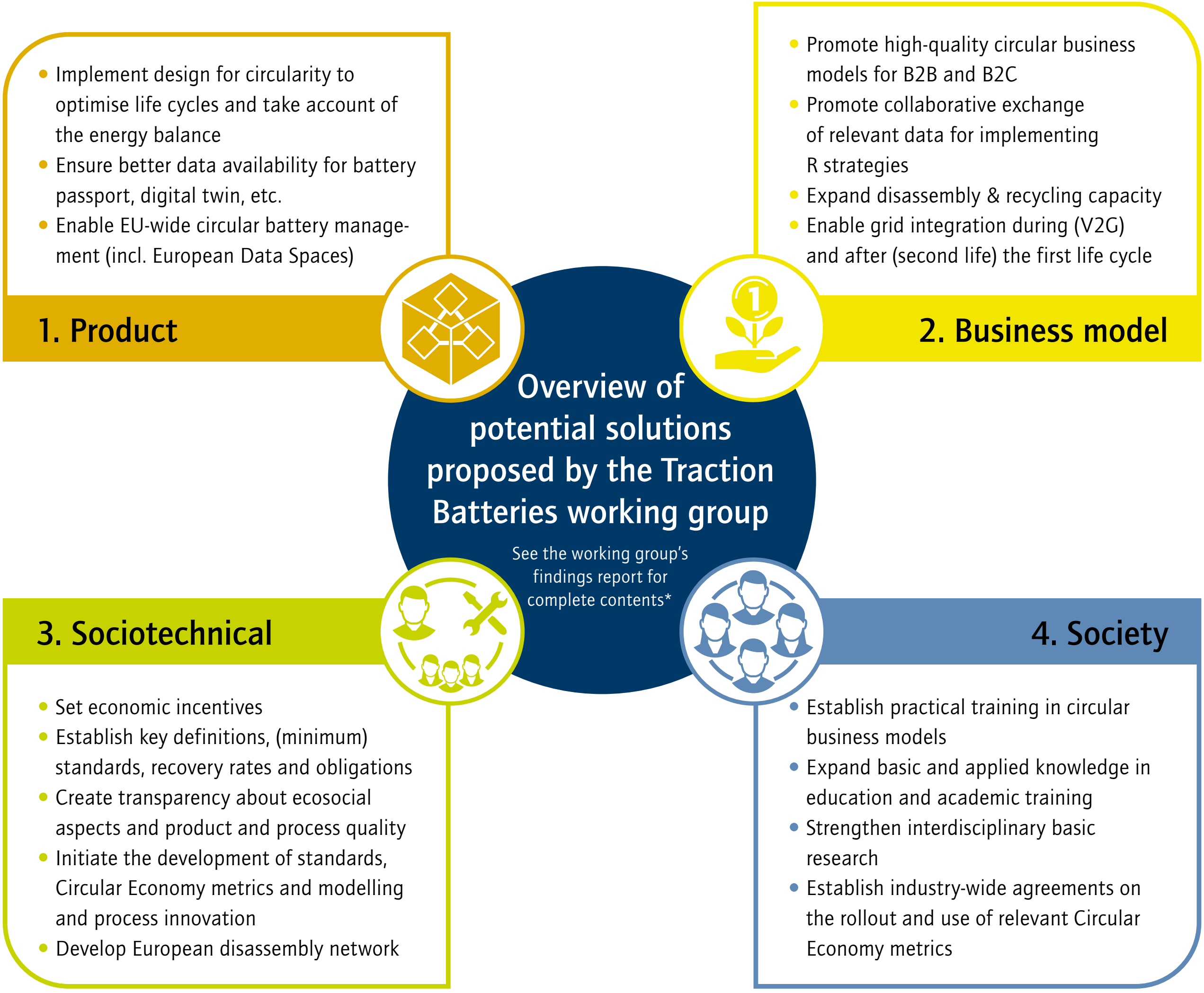
The working group's recommendations for achieving the transformation to a Circular Economy for traction batteries can be summarised as follows:

Product perspective

- **Hardware**: There is a need to consider both constructive (design for repair) and destructive (design for recycling) design principles and to review the role which greater modularity can play. This encompasses both the design of the battery housing itself and vehicle design for ease of battery removal, in order to reduce logistics, repair and disassembly risks and costs. Science also has a contribution to make, in optimising material composition, in particular also with regard to the material purities achievable by recycling and taking account of the systemic energy balance.
  Looking ahead, further development of battery technology in the direction of solid-state batteries and other new battery generations (e.g. lithium-sulfur batteries) should include consideration of effective circular management of the materials right from the outset. For instance, battery design processes should also consider optimisation of the environmental impact of the active and passive materials used over the entire life cycle, from production to recycling and reuse of the secondary raw materials.
- **Software**: Standards for providing relevant data must be technically feasible and agreed upon industry-wide if efficient circular management is to succeed. They are necessary, for example, to enable the battery's condition and location to be efficiently determined. Material or rather product (battery) passports deserve particular mention as a solution here. These should in future store and provide information about the origin, durability, composition, reuse, repair and disassembly options for a material (material passport) or a product (product passport) as well as usage data/SoH and so enable locating and handling of the material/product at the end of its life.
  Embedding in the planned European Data Spaces is important if public sector and industry-wide data usage is to be possible. The specific data need to be defined inter alia in accordance with regulatory requirements. Legislators have to this end to define the framework with appropriate regulations (see in particular pilot project I of the Traction Batteries working group in the corresponding findings report).[156]

155 | See the Traction Batteries working group's report for the underlying assumptions; however, due to the significant uncertainties regarding the forecast development of technologies and markets, the values should only be regarded as indicative.

156 | See Circular Economy Initiative Deutschland 2020b.



* Circular Economy Initiative Deutschland 2020: *Resource-Efficient Battery Life Cycles – Driving Electric Mobility with the Circular Economy*, Munich/London: acatech/SYSTEMIQ 2020.

Figure 18: Overview of potential solutions proposed by the Traction Batteries working group (Source: own presentation)

Business model perspective

- **Actors**: Circular product and material management of traction batteries is dependent on multiple actors such as suppliers, logistics companies, vehicle manufacturers, users, repairers and recyclers and operators of stationary storage sites. To make effective use of any data and information generated, economic actors need to make it available and encourage **collaborative exchange**. This needs incentives for the respective actor groups to motivate them to take part in line with their interests and business models. Business decision-making should increasingly take account of systemic economic efficiency and resource and energy efficiency (entropy increment/residual exergy). Service approaches with a longer term focus will consequently gain in importance.
- **Circular Economy strategies**: **Return and disassembly**: Across-the-board application of digital technologies for locating traction batteries at decision points (change of owner), in particular end-of-life (EoL), and the expansion of necessary disassembly and logistics capacities are needed. **Repair and reconditioning** or repurposing of batteries

can extend their service life. The reuse of traction batteries after the end of their first useful "life" in a **second life** in less demanding applications (e.g. stationary power storage systems), optionally after remanufacture, could under certain circumstances (creation of suitable structures) open up significant potential. Collection of spent batteries needs to be as comprehensive as possible, as does transfer to appropriately skilled second-life or professional recycling organisations. Take-back and testing processes and transfer to second-life applications or recycling could for example be carried out compulsorily under Extended Producer Responsibility systems (EPR systems). Ultimately, at the end of their life all batteries – and of course also production scrap – must be **recycled to a high quality**.

- **Service level:** A whole series of potential B2B/B2C business models, for example **deposit models** (B2C) or **leasing models** (B2B), are available for improving recirculation, continued use and recovery, including recycling, of batteries. One aspect not looked at by the working group but nonetheless of potential significance is **ride and car sharing for (electric) vehicles**. These concepts increase the productivity of the traction batteries used by achieving greater vehicle utilisation (more person-kilometres per kilowatt-hour of capacity). **Smart charging, vehicle-to-grid and vehicle-to-X (V1G/V2G/V2X)** are potentially the strongest levers for increasing productivity through additional revenue generation by various network services, higher product utilisation and cost savings in the expansion of grid infrastructure.

Sociotechnical perspective

- **Policy framework:** The working group emphasised the importance of the implementation of appropriate and effective **economic incentives**, such as deposit systems[157], for achieving higher rates of product return. Moreover, the application of further-reaching economic incentive systems if recycling targets are achieved or missed (e.g. bonus/penalty systems) should be considered. A balance has to be struck here between effectiveness and efficiency. The **regulatory instruments** mentioned include the determination of key definitions (e.g. legal definitions of vehicle batteries, standardisation of the calculation of carbon footprints and recycling rates) and of minimum standards (e.g. safeguarding of data protection, occupational safety, compulsory recovery rates).

  The members of the Traction Batteries working group recommend ambitious recovery rates which are nonetheless realistic under real-world conditions.[158] The definitions, system boundaries and explanations specified in the Traction Batteries findings report form the basis for these recommendations. To make second-life applications feasible, the transfer of responsibility (EPR, damages and product liability) between initial producers and possible second-life vendors must be uniformly clarified and appropriate incentivisation ensured.

  Reporting obligations (e.g. about origin, environmental effects and impact on human rights of the battery materials and substances used, safety-relevant data and battery end-of-life fate) must be defined and liability and warranty rules and return and take-back obligations clarified.

  To level the playing field, harmonisation of national and transnational regulatory frameworks is advisable (in particular at EU level). And last but not least, the battery-relevant regulatory framework must be harmonised with associated legislation, for instance energy market, infrastructure, product and mobility regulation, taking account of lifecycle effects.

  Information instruments can help in increasing consumer transparency, for example by introducing battery environmental performance labelling or by creating certification options for high-quality products and processes. A further measure is knowledge transfer in the context of international cooperation and development so as to promote a Circular Economy for traction batteries in less developed economies too.
- **Technical development: Data platforms and standards**, in particular also for the storage of data during the use phase, need to be developed so as to enable transparent material streams. Industry can make full use of synergistic potential at different levels by collaboratively initiating **voluntary (minimum) standards** (e.g. design for circularity). Individual actors as well as industry associations and standardisation bodies can all play a part here.

157 | Given the very long service life of traction batteries and the multiple changes of owner they undergo, it is not possible directly to compare and transfer deposit toolkits from sectors involving products with a short service life (for instance the packaging sector). Deposit systems for traction batteries could mean an increase in vehicle price, which could have a negative effect on purchasing decisions to the detriment of electromobility. To avoid an unreasonable cost burden on electric vehicles, the effects or possible configurations of a deposit system on traction batteries need to be reviewed objectively, with a view to achieving the desired return rates and ramping up the electromobility market.

158 | See Table 2 in Circular Economy Initiative Deutschland 2020b.

Process innovations are also important. These include the development of automated disassembly systems, the provision of efficient and reliable tests for the second-life suitability of batteries, the development of safe discharging technologies, the optimisation of existing and development of new recycling processes focusing on efficient recycling chains as well as the development of robust material synthesis processes.

The **development of Circular Economy-relevant modelling, simulation and tools** is also key. Greater use of simulation and big-data analyses for improving decision-making is recommended: a model-based decision-making platform (see pilot profile II[159] in the Traction Batteries findings report) has therefore been designed to contribute to optimised decision-making (second life or the various recycling routes) for dealing with spent traction batteries. There is also a need for accepted metrics to be developed, for instance for determining circularity, carbon footprint and material and energy efficiency. Last but not least, further research and empirical experience is required, to enable reliable assessment of the actual potential of second-life batteries and of vehicle-to-X applications and solution-oriented further development.

- **Value networks:** Targeted economic and scientific support for the Circular Economy is recommended, in particular to ensure that small and medium-sized enterprises develop the necessary knowledge. Industry can make full use of synergistic potential at different impact levels by collaboratively initiating common (minimum) standards and systemic design for circularity.

  The establishment of a **pan-European network of efficient disassembly plants** for traction batteries is essential for the success of the entire reuse chain. It is critical to the success of implementation for investment decisions regarding new disassembly plants to be made on the basis of valid data, so that the recycling infrastructure can be appropriately improved and made scalable at a European level. Pilot profile III in the Traction Batteries findings report contains the regulatory framework for developing the disassembly network for traction batteries.[160] Not only does such a disassembly network need to be developed, but **charging infrastructure and mobility systems also need to be expanded**, so that vehicle-to-X (V2X) and car- and ridesharing concepts can be implemented to ensure maximally productive use of traction batteries during their first lifetime.

  The **participation of public funding options, international capital markets and cross-financing** through incentive systems (e.g. deposit systems) is essential if investment in the development, commercialisation and scaling of necessary technologies and business models is to be encouraged.

Social perspective

- **Education and research**: To embed the Circular Economy within society, it is important to develop sound **basic and applied knowledge** by integrating it into relevant courses of study, for example by means of lectures on the Circular Economy, Circular Economy-related Master's degrees and in-depth courses of study. This includes educating the general population and professionals on the basic principles of the Circular Economy (e.g. on resource conservation and climate protection with the aim of changing usage behaviour and achieving acceptance of not only different product and business models but also economic and business skills), and further developing and opening up skilled occupations (e.g. manufacturing technology) for the Circular Economy. Finally, **interdisciplinary basic research** needs to be strengthened and embedded in institutions, for example by setting up professorships/university departments.
- **Technical development:** There is a need for industry-wide agreements which specify the **operational and macroeconomic indicators which can be used to measure circularity** and how these indicators relate to one another.

4.4 Summary and comparison of the Packaging and Traction Batteries functional systems

This sub-section will compare and contrast the findings of the Packaging and Traction Battery working groups so as to gain generalisable insights for systemic circular material and product management beyond these functional systems. Table 2 summarises and compares the findings of the Packaging and Traction Batteries working groups from sections 4.2 and 4.3.

159 | See Circular Economy Initiative Deutschland 2020b.
160 | See ibid.

Packaging (low value, short service life)	Traction batteries (high value, long service life)	Comparison and synthesis
Product perspective		
• Reduce: Avoidance (higher material efficiency, doing without). In the trade-off between material consumption and recyclability, less efficient but more recyclable packaging should always be preferred if it enables greater efficiency to be achieved at the level of material cycles. • Substitution with other (renewable) materials, recycled materials or bio-based plastics	• Potential of batteries for higher-quality repeated, additional and after-use • Design to simplify repair, reconditioning, repurposing and recycling • Further development of battery technology to enable the substitution of critical materials or materials of concern merely as a potential future lever	• **Common feature:** Optimum recycling must be considered as early as at the product design stage, to achieve the highest possible yield and high-quality recycled materials • **Difference:** More end-of-life options with traction batteries, since they are more complex products (repair, disassembly, measures to increase productivity and enable integrated energy systems (e.g. smart charging)) • **Difference:** Limited reduce and substitution options for traction batteries due to design for high performance • **Difference:** Non-toxicity in batteries only possible in the long term due to power requirement • **Difference:** Substitution simpler with packaging, but potential for traction batteries through further technological development
• Marker systems, such as digital watermarks on the packaging, provide information (for example, material composition, type of packaging)	• Product and material passports are necessary for safe and productive handling, as is analysis to determine condition and residual value. Data required: State of health, condition and safety information, disassembly instructions, location and recycling status	• **Common feature:** Collection and storage of product information essential in both cases, to ensure circular management • **Difference:** Scope of acquired data very much greater with complex products, as products and decision-making after the first life cycle are very much more complex and data availability is of acute safety relevance (possibly relevant to packaging, however, with regard to human toxicity)
Synthesis: With increasing product complexity, value and service life, product-related condition information and analysis becomes more important, as these allow not just safe handling but also service life- and productivity-enhancing measures. At the same time, the potential for material substitution and the possibility of reducing toxicity is limited due to more complex technical demands on the materials used. One challenge with lower quality products is poor differentiability and concomitant small margins which severely restrict the financial latitude for Circular Economy measures. For productive continued use of higher-value, longer-lasting products, therefore, measures should concentrate in particular on digital data collection and analysis with regard to product condition, safety-relevant measures and production in suitable ecosystems. For lower-value products with shorter service lives, on the other hand, the aim should be to modify the materials used or to avoid product use per se.		
Business model perspective		
• User behaviour plays a major role. If the quantity and quality of valuable material streams are to be ensured, users need to be spurred into action. • Greater cooperation within the value chain over the entire product life cycle is needed (e.g. material selection, packaging design)	• The use of data and information about battery life cycles is crucial to the implementation of inter-company and cross-supply chain collaboration. • Collaborative decision-making for the treatment of used traction batteries (e.g. through decision support and incentivisation for stakeholders)	• **Common feature:** In both cases the focus is on collaborative value creation • **Difference:** Achieving high levels of return and collection is easier for traction batteries due to their size, material value and hazard potential; at the same time, the costs and risks are also greater

Packaging (low value, short service life)	Traction batteries (high value, long service life)	Comparison and synthesis
• Reuse: There are various models for enabling reuse (refill on the go, refill at home, return on the go, return from home) • Recycling: Making full use of mechanical recycling potential and establishing carbon-saving chemical recycling and bio-based raw material extraction to obtain high-quality defossilised materials	• Repair, reconditioning, repurposing: can extend service life • Second life: Reuse of traction batteries in a less demanding application (e.g. stationary power storage systems) • Recycling: Further process innovation needed due to size, complexity, energy content and toxicity of batteries	• More options for productive and continued use of batteries due to longevity and value • Greater "horizontal linkage" of value chains through traction battery second life
• Novel solutions such as "packaging as a service" should be mentioned, but require further development • Some multi-use systems still need further development to make them suitable for large-scale application (e.g. reCUP)	• Leasing models could increase return or collection rates, simplify data collection and possibly clarify insurance liability issues, given that the battery remains the property of the operator. (Design) incentives for longevity, repairability and recyclability are also in train	• **Common feature:** Business model innovation is needed in particular to enable higher-quality circularity • **Difference:** Service-oriented business models (e.g. leasing) are more suited to traction batteries than to packaging because of their value • **Difference:** Capital requirements and uncertain profitability due to longer battery service life (not the case with packaging)
Synthesis: Both functional systems require an overhaul of business models. Increasing product complexity, value and service life are accompanied by additional options for reuse and remanufacture, leading to more complex value networks. Challenges with higher-value products are coordinating complex value networks and optimising decision-making with regard to used products. Service-oriented business models are also more suitable for products of high complexity, value and service life and in particular for business-to-business applications. Business models for increasing the circularity of shorter-lifetime products, on the other hand, primarily concentrate on the end user segment and are dependent on changing usage behaviour to increase return and/or collection rates, for example. Incentive systems, such as deposit systems, are particularly important here, and will be looked at below under the sociotechnical heading. Business model-oriented measures should therefore be aimed at supporting companies in the rollout and scaling of new business models.		
Sociotechnical perspective		
• Incentives (deposit or reward systems, fees) are important for spurring users into action • The current diversity of packaging needs to be standardised and harmonised, to create volume streams which make high-quality recycling economic • Binding rates (e.g. use of recycled materials) • Product labelling to inform users	• Incentives (e.g. deposit systems may act as an incentive for return) • Relevant standard and definitions must be developed to level the playing field • Setting of recycling targets • Labels and certification schemes are important ways of communicating ecosocial performance and quality	• **Common feature:** In both cases incentives (e.g. deposit systems) are highlighted as important ways of ensuring the return of products, primarily in B2C markets • **Common feature:** In both cases minimum standards in product design are defined by industry to reduce product diversity. Policy makers, in contrast, define standards in terms of end-of-life treatment, to ensure market functionality (e.g. for recycled materials) • **Common feature:** Labels are mentioned in both functional systems as transparency levers, for example for communicating overall ecosocial product ratings. These must be easily comprehensible and plausible irrespective of the product

Packaging (low value, short service life)	Traction batteries (high value, long service life)	Comparison and synthesis
• Process innovation: Technical development for simplifying end-of-life treatment and logistics (e.g. re-sorting of residual waste, upgrading of sorting and washing technology)	• Transparent material streams: Development of data platforms and (voluntary and compulsory) standards to ensure transparent material streams • Process innovation: Expansion of collaborative business projects and more efficient (digital) market structures which link supply and demand and lower transaction costs • Modelling and tools: Focus on support for decision-making	• **Difference:** In the case of traction batteries, a greater focus on improving post-use phase, since it may be possible to add additional value in further life cycles (second life). In the case of packaging, however, the focus is on process optimisation to improve end-of-life sorting.
• Importance of structure and further development of recycling infrastructure (e.g. building appropriate processing capacity)	• Establishment of a pan-European network of efficient disassembly plants • Funding requirement due to high capital and warranty risks for manufacturing companies	• **Common feature:** In both cases there is a shortage of the necessary disassembly and recycling networks • **Difference:** Significant funding need for traction batteries due to long service life, product value, complexity of necessary infrastructure
• Specialised education and training on the Circular Economy (e.g. for industrial designers)	• Specialised education and training on the Circular Economy	• **Common feature:** Both functional systems highlighted the significance of education and training, on the one hand to inform users and on the other hand to provide the specialists needed for a Circular Economy
Synthesis: Although the contexts of the two selected functional systems are very different, the comparison shows that they make similar demands of the sociotechnical regulatory framework. In both cases the importance of economic incentives was highlighted (e.g. deposit systems), primarily to spur users into action. In addition, regulatory frameworks make an important contribution to the creation of a level playing field, for example by defining standards. The importance of information instruments in increasing transparency was also underlined in both functional systems. As far as technical development is concerned, increasing product complexity, value and service life lead above all to a need for technologies which enable greater material stream transparency. With less complex, lower quality and longer-lasting products, it is very important to developing recycling technologies further. Moreover, it was highlighted for both functional systems that the networks and infrastructure needed for end-of-life product processing (e.g. disassembly or recycling) is currently lacking.		
Social perspective		
• Importance of education as the basis for overarching cooperation with a changed value creation philosophy • Importance of user understanding	• Importance of substantive basic research and business model research • Importance of development of relevant Circular Economy indicators • Importance of user readiness to adopt new business models (leasing, sharing etc.)	• **Common feature:** Education was deemed important in both cases, but with different priorities • **Difference:** (1) User understanding (more important for packaging than traction batteries, since "every day" behaviour needs to change in order to improve packaging circularity). (2) "Substantive research/basic research" (needed in both cases, but fundamentally different, for example development of chemical recycling versus new battery composition)

Packaging (low value, short service life)	Traction batteries (high value, long service life)	Comparison and synthesis
Synthesis: The analysis and comparison of the two product systems shows that a fundamental societal shift is needed to achieve transformation to a Circular Economy. This extends over all social systems and stakeholders and requires a new understanding of value creation and value retention. This is particularly relevant for functional systems on B2C markets, which are oriented to a significant degree towards supporting consumers and spurring them into action so as to enable value retention and the closing of resource loops. Educational policy plays a key role in supporting this transition to widespread awareness across society of the Circular Economy. It may contribute on the one hand to increasing awareness and on the other hand to developing the skills needed for the Circular Economy. The Circular Economy also needs to become embedded in policy making institutions, business and academia.		

Table 2: Summary and comparison of the findings of the Packaging and Traction Batteries working groups (Source: own presentation)

The comparison thus shows that short-lived, lower-value products and longer-lasting, higher-value products have some similar and some fundamentally different requirements when it comes to circular product and material management at sociotechnical and societal level. The following should be stated in terms of the Circular Economy principles[161] defined by the Ellen MacArthur Foundation:

For short-lived products such as packaging, the focus of the solution adopted is on putting products optimised for circularity into circulation ("designing out waste and pollution") and making use of them for as long as possible in the highest possible quality applications ("keeping products and materials in use"). One challenge for implementation is the extremely fragmented structure of the industry, which complicates both harmonising material streams and developing and setting up technologies and infrastructure. In addition, circular solutions are often not economically viable since it is cheaper to use virgin material than to carry out high-quality recycling. In the case of traction batteries, on the other hand, the focus is primarily on using products as productively as possible and keeping them in circulation for a long time in high-quality applications ("keeping products and materials in use"). Traction batteries being very much more complex, higher-value, longer-lasting products, the differences are clear in terms of possible levers and potential solutions; this is clear primarily from a product and business model perspective. At the same time, the long service life (on average over ten years) is also associated with challenges: there is major uncertainty about future requirements for higher-quality continued use of the products (e.g. in the context of stationary storage applications), future demand and the corresponding material values of the recoverable recycled materials.

It is clear overall that, looking at the issues from the point of view of the two specific sectors, on the one hand there are **specific needs** when it comes to reshaping the respective value chains into circularity-oriented value networks for a Circular Economy. The need for case-specific examination is underlined by the analysis of the Circular Economy strategies and different business model typologies carried out by the Circular Business Models working group. On the other hand, there are numerous universal principles which are reflected equally in the approaches of the sector-specific working groups and the overarching Circular Business Models working group. These include, for example, the need to establish uniform terminology and definitions as well as industry standards of relevance to the Circular Economy, to correct misguided subsidies or to promote comprehensive application of digital technologies and business models for resource-productive management. The common policy recommendations resulting from the three working groups are presented in section 5.

161 | See Ellen MacArthur Foundation 2017.

5 Policy recommendations for a Circular Economy

The working groups' analyses reveal overarching needs for action for achieving the vision set out in section 3. These accordingly make it possible to address resource conservation and climate protection targets as well as industrial policy intentions at the same time. The Circular Economy thus offers Germany an overarching narrative which can bring together economic and environmental policy and so make a significant contribution to achieving the objectives of the European Green Deal (in particular climate neutrality by 2050).

The Wuppertal Institute's calculations illustrate that achieving the cross-sectoral objective of greenhouse gas neutrality will entail not only focusing on fossil resource utilisation but also addressing overall resource consumption (see section 3.4). As an internationally renowned manufacturing base, Germany's starting position is favourable and it is in a better position than just about any other country to secure its future as a location for industry with not only digital (Industry 4.0) but also circular (Circular Economy) products, while increasing competitiveness, raw material productivity and local value added and creating high-quality jobs. Policy makers can use their COVID-19 stimulus packages to accelerate this change significantly.

The advantages of a successful transformation towards a Circular Economy are obvious:

1. It creates a new value proposition which puts Germany forward as a political and economic partner, moving from "Made in Germany" to "Made with Germany" as a symbol of reliable, collaborative cooperation with German companies for resource-productive, high-quality circular product solutions.
2. It repositions German industry internationally as the world's leading exporter of profitable Circular Economy solutions.
3. It enables a rebranding of German industry with a focus on circular business models via X-as-a-service and design for recycling/reuse/remanufacturing etc.

The work of the *Circular Economy Initiative Deutschland* shows that a Circular Economy can be shaped by a clearly definable set of measures, many elements of which have an impact across sectors and into other policy areas. By way of example, higher-level regulatory measures such as carbon pricing and resource utilisation support both climate protection and the development of Industry 4.0-inspired innovative digital business models. It has also become clear that the conditions for achieving a Circular Economy are in many instances already present and merely have to be implemented and combined in a meaningful way.

The policy recommendations set out below can provide guidance (in various degrees of detail) for decision makers in politics, business and academia.

- Sub-section 5.1 defines ten overarching action points (see figure 19). These arise from the results of the three working groups and the quantitative modelling from section 3 (see sub-section 3.4) and indicate the necessary thrust of this action.
- Building on this foundation, sub-sections 5.2 to 5.4 set out policy recommendations for policy makers, business and academia and present them along a timeline (2021 to 2030).

The target audience for the present recommendations are decision makers from the realms of policy makers, business and academia. For the first of these categories, it is important to make use, in both the European and the national context, of the full range of policy instruments (i.e. economic, regulatory and informational instruments as well as education and research) in order to accelerate the transformation towards a Circular Economy. As central stakeholders, Germany's legislators are called upon both to act courageously within a national context and to impart an ambitious impetus to the process in Europe.

5.1 Ten action points for achieving transformation

The results from the working groups in section 4 and the quantitative modelling from section 3 give rise to action points for the transformation to a Circular Economy.

1. **Circular business models:** Business needs to build on the successful model of Industry 4.0 to develop a resource-productive, data-driven circular economic model. The objective should in particular be to develop and scale **data-driven use- and results-oriented service business models** based on circular strategies, in line with the narrative envisaged in the European Green Deal. To promote the development of such business models, economic actors need to create **new innovation spaces** and initiate **lighthouse projects** both within their organisations and in partnership with others,

for instance in suitable industrial alliances. Economic actors also need to push ahead with setting up long-term collaborative efforts and cross-sectoral value networks as well as consistent design for circularity policies.

2. **Standardisation**: Policy makers need to define key Circular Economy objectives, for which businesses can **work on corresponding norms and standards within established national and international committees**. Responsibilities and procedures for developing these norms and standards will vary depending on the product systems in question. The aim of such initiatives is to exploit synergistic potential at various impact levels. These initiatives include the development of standards in order to classify the status of used or remanufactured products, the development of quality standards for remanufactured products and recycled materials and their deployment processes (e.g. audited remanufacturing processes), specifications for recycled material content and the development and adaptation of measured business variables (e.g. Circular Economy metrics, key performance indicators (KPI), incentivisation systems, accounting processes). In addition, basic principles need to be defined for open data formats and media, such as product and material passports.[162]

3. **Transparency:** Policy makers need to develop measures which **make Circular Economy-relevant information**[163] **commercially available**. To this end, they need to ensure data protection and security and call upon or oblige economic actors to make specific (standards-based) data and information available. Economic actors need to **encourage a collaborative exchange of relevant information and data**, for example using new digital systems such as distributed ledger technologies and product passports. There is furthermore a need to optimise transparency, accessibility and comprehensibility of information in order to encourage purchasing decisions in favour of sustainable products and business models. This needs to be supported by the consistent rollout of meaningful sustainability reporting.

4. **Regulatory instruments: Policy makers both on a national level and at European Union level should define** a **coherent product policy framework for the Circular Economy**, to enable product value retention. This should cover, among other things, the need for 1) clear and compulsory specifications to be defined for producing products according to design for circularity principles, 2) product features to be made easily accessible by a digital product ID (see also point 3 "Transparency"), 3) liability and warranty rules and return and take-back obligations throughout the whole product life cycle to be clearly defined, 4) the burden of proof to be reversed from the existing end-of-waste status to an end-of-life status, with the aim of using products for as long as possible, 5) longer statutory and/or commercial product service life guarantees to be established and 6) qualitative recycling rates (in addition to quantitative rates) to be introduced. Implementation should in particular proceed within the framework of the EU Commission's Sustainable Product Policy[164] and Sustainable Products Initiative.[165]

5. **Economic incentives:** Policy makers at both national and European Union level need to **set financial incentives in such a way as to encourage climate- and resource-optimal business decision-making**. This is because, in principle, targeted expansion of circular business models can contribute to strengthening a business's market position. In addition to **direct financial assistance** (inter alia for pilot projects or research) or the **promotion of new business models** (e.g. deposit systems and repair schemes), a more in-depth **overhaul of tax rules** is also needed. This should pursue the aim of making Circular Economy-relevant products and services proportionally more attractive than the carbon-intensive use of primary raw materials by a **targeted redistribution of the tax burden**. This aim could be achieved, on the one hand for example **by levying higher duties on resources and emissions** and **by dismantling environmentally harmful subsidies**. The resultant increase in tax take could, on the other hand, be used to **reduce the tax burden for businesses** (e.g. by lowering staff social security costs, tax benefits for taking on new staff members and investment in Circular Economy-relevant sectors) and consumers (e.g. by reducing VAT on

162 | The DIN/DKE advisory board currently being established represents an important step in this direction.

163 | Such as the raw materials contained in a product and their origin and environmental footprints, proportion of recycled material, corresponding repair instructions etc.

164 | See European Commission s.a.

165 | See European Commission 2020d.

specific Circular Economy services such as repair and maintenance).[166] The stated measures also need to be applied outside the European Union and the European Economic Area (EEA), if a global level playing field is to be achieved.

6. **Infrastructure for reuse, continued use and recycling:** Policy makers and business need to accelerate the **expansion and development of infrastructure for reuse, continued use and recycling**. Only in this way is it possible to ensure the necessary networks and capacity so that, at the end of their first life cycle, products can be effectively and efficiently collected, handled and properly evaluated with regard to their suitability for further use or indeed a change of use and a correct assessment made with regard to high-quality material recycling in line with a Circular Economy.[167] **Digital technologies must also become more widespread** to improve material identification and sorting as a basis for high-quality circular management including recycling.

7. **Technical development and research:** Policy makers, businesses and academia need to promote **technology-neutral development of relevant material, product and process innovations with an environmental benefit, digital technologies for producing transparency and methods and tools** for implementing the Circular Economy. These include the development of metrics (at product, business and macroeconomic level) for evaluating Circular Economy strategies and measures, the development of model-based decision-making platforms for the circular after-use of products, the development of digital technologies for the Circular Economy (e.g. digital market platforms or artificial intelligence) and the continuing development of product and material technologies. Policy makers should also be providing targeted economic and scientific support for the Circular Economy. This encompasses support for concrete projects for (further) development of Circular Economy-relevant technologies and business models by the provision of the necessary financial resources (inter alia through start-up support) and suitable (interorganisational) infrastructure (e.g. by building "innovation spaces" designed specifically to support radical innovation and business models). The wide-ranging issues around the implications of a Circular Economy for society must also be addressed under this action point.

8. **Public procurement:** Policy makers need to boost demand for circular products and business models by setting strategic objectives and binding targets for used, remanufactured and recycled products using a practical, science-based decision-making aid.[168] The development of (minimum) targets and rates should become part of budgetary planning at the various levels of the public sector.

9. **Institutional embedding:** Policy makers need to provide a **central institutional body** with the aim of ensuring Germany's transformation to a Circular Economy. This body should explore the topic of the necessary transformation in Germany in greater depth across legislative periods, identify innovative potential, create new connections and thus embed the Circular Economy more widely and set it in a European context. The institutional body could support the activities of political, economic and civil society stakeholders and, in the long term, bring them into line with one another. Support for knowledge sharing and the creation of technically sound Circular Economy-related product requirements can also make a contribution.

10. **Education and knowledge transfer:** Policy makers, businesses and academia must provide **Circular Economy-relevant education and training** to raise public awareness of the Circular Economy and develop skills. This can be achieved, for example, by including the Circular Economy in curricula, establishing in-depth Circular Economy-related courses of study, degree programmes and professorships, creating learning factories, collaborative research and appropriate

166 | See The Ex'tax Project 2016.

167 | Especially in the case of plastics packaging, mechanical recycling offers significant and as yet far from exhausted potential for making renewed use of packaging materials. However, permanently closed-loop management of packaging materials for the same applications cannot be achieved by mechanical recycling alone. In a closed Circular Economy model, there is a need to offset material and quality losses in mechanical recycling with virgin-grade defossilised plastics. It is therefore necessary to define an environmentally optimal and technically feasible defossilised material mix of mechanically and chemically recycled material together with bio-based plastics.

168 | It is important that such a decision-making aid not only makes an evaluation at product level, but also allows or deliberately promotes the sustainability potential of services linked to products and product-substituting service business models (e.g. by estimating the system-transforming impact of rental models).

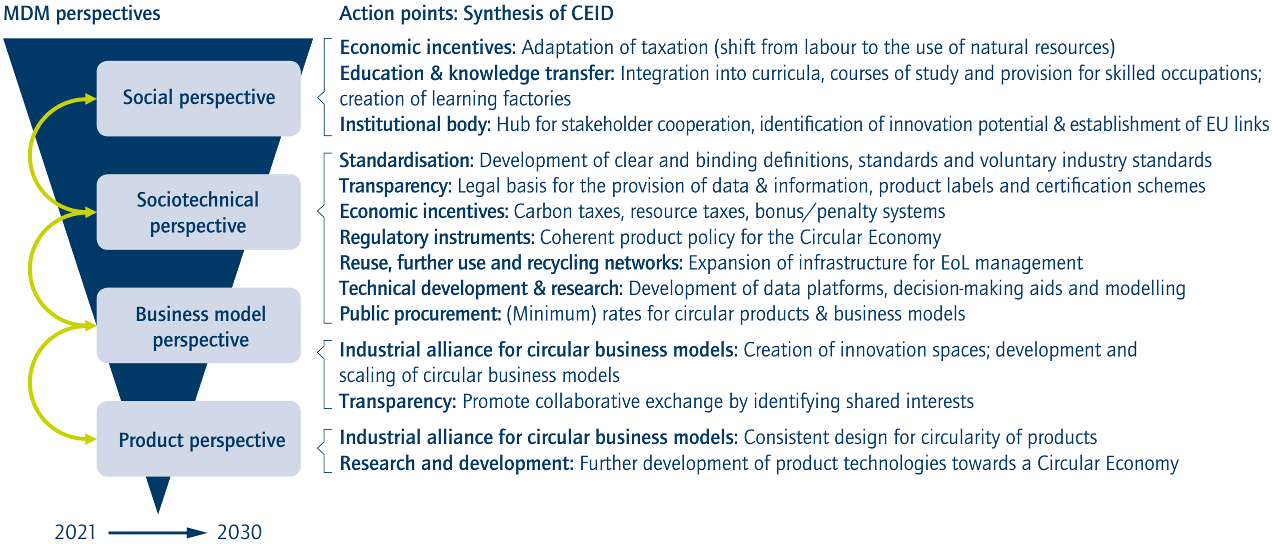


Figure 19: Effect of the action points along the Multilevel Design Model (MDM) perspectives
(Source: own presentation, based on Multilevel Design Model after Joore/Brezet 2015)

training provision for skilled occupations. A holistic educational package also includes the promotion of transformative learning in the context of Circular Economy-related bottom-up activities and social innovations such as repair initiatives, open workshops, prosumer initiatives and consumer citizenship networks. The **measures should also be transferred globally**, for instance in the context of international collaboration and development cooperation.

5.2 Policy recommendations for policy makers

The policy recommendations for policy makers are derived from the results of the three working groups, Circular Business Models, Packaging and Traction Batteries. They have been located along a timeline (2021 to 2030) and assigned to the action points defined in section 5.1 (see figure 20).

Up to 2024: Short term, "laying the foundations"

Standardisation:

1. **Clear and binding definitions and standards** are necessary to establish a "level playing field". Legislators should initiate and support activities through established standardisation committees. This is associated with the following aspects:
   - Creating central definitions, for example by clear legal definitions of products as opposed to waste (end-of-life/end-of-waste status), such that an owner "getting rid" of a substance or product becomes the exception and waste generation is accordingly avoided.
   - Introducing minimum standards which should include both enabling and protective parameters (in particular, safeguarding of data protection and occupational safety, mandatory recovery rates).
   - Promoting the development of secure standards for open data formats (e.g. product passports).
   - Supporting the development of new and/or harmonising existing quality standards for secondary materials.
   - Developing specifications for recycled material contents in finished products which take account of the origin, quality and quantity of the recycled material and of the specific use case.
   - Establishing a scoring system for product repairability including physical and digital components (i.e. upgradability) and an associated (mandatory) product labelling system.
   - Initiating the development of a generally accepted and practical decision-making basis or aid for evaluating the sustainability of different Circular Economy alternatives.
   - Promoting industry standards in consultation with industry and taking account of data and IP security and innovation effects.
     Cutting-edge technologies such as blockchain and end-to-end encrypted data transfer and databases should be used for this purpose.

   These points need to be shaped at the EU level in cooperation with other Member States and to be supported and implemented nationwide by the national legislators.

Economic incentives:

2. National legislators should introduce appropriate and effective **incentives (e.g. deposit systems, support for multi-use systems) and targeted financial support** (including for pilot projects) to support the implementation of Circular Economy business models and relevant research and development. Legislators should also focus on eliminating existing barriers to a transition to Circular Economy-related product-as-a-service business models (e.g. all-inclusive leasing) covering maintenance, repair and product take-back for remanufacturing and recycling.
3. National legislators need to **create a basis for overhauling financial incentives, in particular in the tax system,** in order to shift the tax burden from labour to the use of natural resources and negative externalities and so create incentives for a transformation to a Circular Economy. These points need to be coordinated with other Member States at EU level.
4. **Development of a waste prevention plan** with concrete targets, measures, smart economic incentive systems and defined timelines.

Regulatory instruments:

5. **Support for the reform of the EU Ecodesign Directive** with regard to the introduction of criteria relevant to a Circular Economy (e.g. longevity, reusability). These points need to be shaped at the EU level in cooperation with other Member States and to be supported and implemented nationwide by national legislators.
6. Legislators need to clearly define the **rights and obligations of relevant actors** within value networks, inter alia by defining reporting obligations and gradually developing sanction mechanisms to ensure that measures are efficiently implemented. These points need to be shaped at the EU level in cooperation with other Member States and to be supported and implemented nationwide by national legislators.
7. **Extension of statutory and/or commercial guarantees** for planned technical service life to three years for all products or to five years for selected products as an incentive to use service business models.

By 2024	By 2027	By 2030
Standardisation: • Clear and binding definitions and standards **Economic incentives:** • Incentives and targeted financial support for implementing Circular Economy business models and relevant R&D • Basis for overhauling financial incentives in particular in the tax system • Development of a waste prevention plan **Regulatory instruments:** • Support for the reform of the EU Ecodesign Directive • Clear definition of the rights and obligations of relevant actors within value networks • Extension of statutory and/or commercial product guarantees **Infrastructure for reuse, continued use and recycling:** • Development of a binding EU-wide common approach to expanding and optimising Circular Economy infrastructure • Investment support for setting up and operating reuse, further use and recycling networks **Technical development and research:** • Strengthening and expansion of R&D in material, product and process innovation, digital technologies, decision-making aids and relevant metrics • Targeted promotion of radical innovation and business models **Public procurement:** • Development and reinforcement of (minimum) targets and (minimum) rates for circular products and business models **Institutionalisation:** • Creation of an institutional body to oversee the transformation to a Circular Economy **Education and knowledge transfer:** • Initial and in-service training and rapid application of basic and applied knowledge • Creation of experimental spaces and support of bottom-up activities and social innovation	**Standardisation:** • Increasing transparency for actors in value networks **Economic incentives:** • Overhaul of pricing and taxation regulations relating to resource use **Regulatory instruments:** • Circular Economy criteria as a prerequisite for market access • Adjustment of EPR regulations for take-back of consumer durables • Revision of waste legislation (Circular Economy Act (KrWG)) • Harmonisation of national and transnational regulatory framework • Transition to “safe by design chemicals” where technically feasible • Introduction of recycling rates differentiated by individual materials including definition of quality levels for materials and processes • Setting a minimum content of recycled components in products **Technical development and research:** • Targeted economic and scientific support for technologies, business models and knowledge building, in particular in SMEs	**Economic incentives:** • Further development of appropriate incentive systems within the framework of tax law • Application of further-reaching economic incentive systems to achieve recycling targets **Regulatory instruments:** • Further increase in recycling rates in conjunction with requirements of quality levels for materials and processes **Education and knowledge transfer:** • Transfer of measures into a global context for leading markets (“race to the top”) and for development cooperation

Figure 20: Overview of short-, medium- and long-term policy recommendations for policy makers (Source: own presentation)

Infrastructure for reuse, continued use and recycling:

8. **Development of a binding EU-wide common approach to expanding and optimising collection, sorting, continued use and recycling technologies** so that economies of scale can be cost-effectively exploited and the advantages of the EU internal market fully utilised.
9. **Investment support for setting up and operating reuse, further use and recycling networks,** in order to reduce (capital) costs and risks for individual actors and thus support the development of a Circular Economy industry.

Technical development and research:

10. **Strengthening and expanding Circular Economy research and development,** in particular including Circular Economy-related, technology-neutral research funding with environmental benefits in the area of material, product and process innovation and digital technologies, expanding research infrastructure, providing funding to implement research, establishing an expert advisory board to develop and advise on funding concepts and measures, creating decision-making aids for business and policy makers including the development of operational and macroeconomic circularity indicators, and setting up the necessary database. This needs to be shaped both at the European Union level and by national legislators and, in Germany, at the federal and state levels.
11. **Targeted promotion of radical innovation and business models** by supporting pilot projects by companies and the provision of necessary financial resources (including start-up funding) and a suitable (interorganisational) infrastructure (e.g. by setting up "innovation spaces"). This needs to be shaped both at the European Union level and by national legislators and, in Germany, at the federal and state levels.

Public procurement:

12. **Development and gradual escalation of (minimum) targets and binding rates for circular products and business models** (preference for contracts within the framework of the product-as-a-service business model) in public procurement by means of a practical, science-based decision-making aid.[169] The development of (minimum) targets and rates should become part of budgetary planning at every level of the public sector.

Institutionalisation:

13. **Creation of central institutional body for the Circular Economy transformation** which should carry out continuous monitoring, identify innovation potential, consolidate perspectives from policy makers, business and society and carry out programmes, pilots and training. The creation of a corresponding body at European Level should also be considered.

Education and knowledge transfer:

14. Development of **initial and in-service training provision and rapid application of basic and applied knowledge** which enable scaling of a Circular Economy in cooperation between policy makers, business and academia. This includes integrating the Circular Economy into (early childhood) education and curricula, taking account of the Circular Economy in relevant skilled occupations (e.g. repair technicians), establishing in-depth Circular Economy-related courses of study, degree programmes and professorships, creating learning factories for the Circular Economy, creating experimental spaces and vigorously supporting Circular Economy-relevant bottom-up activities and social innovations, in which citizens as prosumers drive transformative learning processes for the Circular Economy on their own initiative and promote important circular skills and practices.

Up to 2027: Medium term, "creating structure"

Standardisation:

15. **Increasing transparency for actors in value networks:** for consumers, for example, through the (mandatory) introduction of product labels (e.g. repairability or average service life), for economic actors through the definition of mandatory data reporting and digital provision of relevant information through the legally binding description of material or product passports and through the creation of certification options for high-quality products (e.g. remanufactured products) and processes (e.g. recycling).

169 | It is important that such a decision-making aid not only makes an evaluation at product level, but also allows or deliberately promotes the sustainability potential of services linked to products and product-substituting service business models (e.g. by estimating the system-transforming impact of rental models).

Economic incentives:

16. **Design of the necessary overhaul of tax and duty rules to ensure climate- and resource-optimised economic decisions.** The precise configuration of such a market framework is yet to be fleshed out, but should pursue the fundamental goal of making Circular Economy-relevant products and services relatively more attractive than the carbon-intensive use of primary raw materials by a targeted redistribution of the tax burden. This aim could be achieved on the one hand for example by levying higher duties on resources and emissions and by dismantling environmentally harmful subsidies. The resultant increase in tax take could, on the other hand, be used to reduce the tax burden for businesses, for example by lowering staff social security costs, tax benefits for taking on new staff members and investment in Circular Economy-relevant sectors, and for consumers, for example by reducing VAT in the case of specific Circular Economy services such as repair and maintenance.[170] Appropriate bonus/penalty systems that encourage manufacturers to comply with ecodesign principles and close material cycles could also contribute to the necessary expansion of financial incentive systems.

Regulatory instruments:

17. **Evaluation of Circular Economy criteria (e.g. repairability, recyclability) in the EU product register** (Conformité Européenne/CE-Marking) as a prerequisite for market access to establish a level playing field.
18. **General obligation on producers to take back consumer durables** (combined with Extended Producer Responsibility (EPR)) to ensure products avoid waste status for as long as possible. It should be made possible to transfer EPR obligations from manufacturers to secondary users (in particular for second-life options). In addition, there is a need for clearer regulation regarding the transfer of liability and warranty between manufacturers and secondary users.
19. **Revision of waste legislation (Circular Economy Act (KrWG))** to prevent used but reusable, repairable or refurbishable products from being assigned waste status in the first place. This includes explicit integration of Circular Economy-relevant definitions and standards (both for remanufacture/repair and for recycling) into waste legislation to prevent export for reuse or recycling being used as a loophole for low-grade recovery, regulation of international trade to prevent returned (end-of-life) products/components ("cores") being assigned waste status provided shipment to certified recovery facilities can be proven, and harmonisation at international level to eliminate trade barriers.
20. **Harmonisation of the national and transnational regulatory framework**, including processes and requirements for cross-border shipment of end-of-life (EoL) products and materials, definitions of key terms and system boundaries for determining recovery success, product protection, disclosure obligations and accreditation options for key metrics.
21. Where technically feasible, make the transition to "**safe by design chemicals**", progressively substituting hazardous substances, a process which needs to be handled at the interface of REACH, ecodesign/product and waste legislation.
22. **Introduction of recycling rates**[171] which set ambitious targets which are implementable under real-world conditions for each type of material. Over and above quantitative targets, there is in particular a need to specify requirements for the quality of the processes and the resultant recycled materials and to provide uniform and clear definitions of key terminology throughout the EU.
23. Setting a **minimum content of recycled components in products**, where this is technically feasible, makes environmental sense and is economically viable (e.g. as already decided by the EU Commission for PET beverage bottles). Key factors in ensuring that the introduction of recycled material usage rates makes environmental sense are the availability of the required quantities and qualities of recycled materials and the possibility of providing proof and a precise definition of a recycled material's origin, for example taking into account that recycled material must not be removed from higher-quality material cycles and that only post-consumer recycled materials count towards the rate.

Technical development and research:

24. **Targeted economic and scientific support** for the Circular Economy: This firstly encompasses support for concrete projects for (further) development of Circular Economy-relevant technologies and business models by the provision of the necessary financial resources (inter alia through start-up support) and suitable (interorganisational) infrastructure

170 | The stated measures are based on proposals from the Ex'tax Project.
171 | See Glossary.

(e.g. by building "innovation spaces" designed specifically to support radical innovation and business models). Secondly, it is necessary to ensure that small and medium-sized enterprises develop the necessary knowledge and that, in the academic environment, funding initiatives with a view to successfully implementing the Circular Economy are continued and expanded (see point 10 in "Short-term measures"). In particular when it comes to funding applied research projects, Circular Economy requirements should be included in the bidding criteria as standard because they must be borne in mind for all new technologies. In addition, social science research approaches should be considered to accompany the development of the Circular Economy.

Up to 2030: Long term, "breaking through"

Economic incentives:

25. **Further development of appropriate incentive systems within the framework of tax law** to ensure that all kinds of taxation, such as income or consumption taxes, promote Circular Economy principles. A balance has to be struck here between effectiveness and efficiency.
26. **The application of further-reaching economic incentive systems** if recycling targets are (over)achieved or missed (e.g. bonus/penalty systems) should be considered.

Regulatory instruments:

27. **Long-term increase in recycling rates – differentiated by individual materials**, combined with clear definitions of the terminology which is key to determining the success of recovery, such as system boundaries or recycled materials and minimum quality levels for materials and processes. To this end, efforts should be made to ensure uniform regulations across the EU.

Education and knowledge transfer:

28. **Transfer of measures into a global context** for leading markets on the one hand ("race to the top") and for developing economies on the other by harmonising the regulatory framework, networking governments and other relevant stakeholders from third countries outside the European Union as well as knowledge transfer and cooperation within the context of international collaborative efforts and development cooperation.

5.3 Policy recommendations for business

The policy recommendations for business are derived from the results of the three working groups, Circular Business Models, Packaging and Traction Batteries. They have been located along a timeline (2021 to 2030) and assigned to the action points defined in section 5.1 (see figure 21).

Up to 2024: Short term, "laying the foundations"

Circular business models:

1. **Establishing design for circularity** in product development to enhance product longevity and recyclability. The objective is to ensure that products are used for as long as possible thanks to circular strategies and that end-of-life status is avoided. End-of-life should be consistently taken into account right from the design stage, including take-back logistics, reuse, continued use and high-quality recycling. Cooperation spanning value networks and networks based on this need to be established and used.
2. **Development and scaling of circular (business model) innovation**, in particular innovation going beyond recycling or the use of recycled materials and using higher-quality circular strategies such as maintenance and upgrade, repair, remanufacture or reuse.
3. Both within organisations and in partnership across companies, economic actors should **create new innovation spaces** and initiate **lighthouse projects** which offer companies an opportunity to develop new use- and results-oriented service business models around circular strategies. Possibilities in particular include sharing and pay-per-performance models. Ideally, inter-company coalitions can also be tested and established here.
4. Businesses should accelerate **digitalisation** as an essential tool for establishing circular business models. The objective is to **provide relevant data** which enable location tracking and tracing of products, components and materials. The intention is to enable the highest possible quality of continued use and material recovery after the end-of-life, to avoid the occurrence of toxic effects along the value chain and to have no negative impact on subsequent use.

By 2024	By 2027	By 2030
Circular business models: • Establishing design for circularity to maximise product longevity • Development and scaling of circular (business model) innovation • Creation of innovation spaces and lighthouse projects to develop new use- and results-oriented business models • Acceleration of digitalisation for the provision of product, component and material data **Standardisation:** • Collaborative initiation of common (minimum) standards and systemic design for circularity at material, product, process and system levels • Industry-wide agreements for operational and macroeconomic measurement of circularity **Transparency:** • Provision of relevant data and offerings to support circular business models • Active communication and provision of information to encourage customer decisions in favour of Circular Economy offerings • Expansion of sustainability reporting with regard to consistent and Circular Economy-relevant aspects **Education and knowledge transfer:** • Development and implementation of basic knowledge, education, initial (and technical) training to enable scaling of the Circular Economy	**Circular business models:** • Further and new development as well as scaling of circular use- and results-oriented business models • Formulation of requirements for promoting new Circular Economy business models • Acceleration of digitalisation for the trustworthy exchange of data for evaluating the condition of products, components and materials **Transparency:** • Greater investment in collaborative commercialisation and scaling of technologies and tools for creating transparency of material flows • Creation of metrics and evaluation rationales for defining and achieving Circular Economy targets **Infrastructure for reuse, continued use and recycling:** • EU-wide coordinated expansion of pan-European infrastructure for reuse, continued use and recycling • Demonstration and dissemination of digital technologies to improve material identification and sorting **Technical development and research:** • Greater investment in the collaborative development of necessary technologies for the Circular Economy (e.g. collection, sorting and recycling technologies)	**Circular business models:** • Use of integrated decision-making processes taking account of systemic resource, energy, environmental and social effects throughout the value cycle • Comprehensive application of service-oriented business models • Widespread dissemination of collaborative business activities and value networks **Standardisation:** • Broad adoption of technologies and technical standards for the provision and exchange of digital data with relevance to R strategies **Transparency:** • Embedding recognised metrics for sustainable circular business practices in a comprehensive incentive and control system

Figure 21: Overview of short-, medium- and long-term policy recommendations for business (Source: own presentation)

Standardisation:

5. Industry can make use of synergistic potential at different impact levels by **collaboratively initiating** not only **common (minimum) standards** and corresponding certification options but also systemic design for circularity. Individual actors as well as industry associations and standardisation bodies can all play a part here, in particular:

- At the material level: On the one hand, setting standardised quality levels for input materials (e.g. packaging waste) could improve economies of scale and the resulting cost reductions in recycling plants and could also lead to higher input material purity and thus more successful recycling. On the other hand, specifying ambitious recovery rates according to the defined recycled material quality levels for specific materials would provide a major incentive for the production of high-quality recycled materials.

- At the product level: This requires a focus on designing products for circularity (e.g. design for remanufacturing, reuse or recycling). There is moreover a need to develop standards in order to allow better statements to be made about the state of reused or remanufactured products/components and recycled materials on the basis of traceable data (e.g. with product history tracking, product passports) and so increase market participants' trust in used products. Where reasonable, the diversity of product types (e.g. traction batteries) should also be harmonised.
- At the corporate level: Product lifecycle data should be put to greater use, not only in corporate management and administration programmes but also for developing and adjusting key tax-related business metrics (KPIs and incentive systems based on them) and for adjusting accounting principles so that different circular strategies are consistently evaluated and incentivised.
- At the process level: This may include, for example, the initiation of refurbishment, remanufacturing and recycling standards as well as minimum standards for recyclability.
- At the system level: Products and processes should be embedded in resource-decoupled, sustainable process chains and along the value chain, for example by the development of new platform-based business models. These chains will generally transcend national borders and should therefore be embedded in a pan-European system, in which German policy makers and German companies should play pioneering roles.

6. There is a need for **industry-wide agreements** which specify the operational indicators which can be used to measure circularity and how these indicators relate to one another and to macroeconomic metrics. In particular, agreement must be reached through industry cooperation and relevant technical committees regarding:
   - Distinguishing between economic (e.g. ROI on service business models), environmental (e.g. recovery rates) and social (e.g. job creation) metrics and taking possible interactions into account.
   - Providing the data required for this purpose can be of benefit both for external reporting and for internal monitoring to support internal decision-making (e.g. for forecasting return volumes). This also includes the definition of depreciation rules which facilitate the evaluation of Circular Economy measures in companies.
   - In this field, the development of digital material and product passports is of central importance as they are capable of efficient, secure and user-related provision of data about lifetime and material content which are not only static (material footprint, serial numbers, manufacturing information, etc.) but also dynamic (owners, maintenance measures, state of health (SoH)). The specific data need to be defined inter alia in accordance with regulatory requirements.

Transparency:

7. Economic actors should **provide relevant information and data** in line with regulatory requirements and beyond and **promote collaborative exchange** which supports business models that enhance resource productivity. To avoid any conflict with data protection, manufacturers should only collect and share data that is relevant for this purpose. This requires a positive-sum game mindset[172] and identifying shared interests to encourage disclosure of usable information and transparent information sharing.
8. Active **communication and marketing** of Circular Economy issues and the background and context of new offers and business models. This means **optimising the transparency, accessibility and comprehensibility** of information (e.g. true costs, life cycle assessment and the impact of purchasing decisions), if necessary also with the participation of citizens, in order to promote decisions in favour of sustainable, circular products and services.
9. Consistent **rollout of meaningful sustainability reporting** with regard to Circular Economy metrics and content in accordance with international standards (e.g. UN Global Compact, Global Reporting Initiative (GRI)) in order to reveal the effects of measures transparently.

Education and knowledge transfer:

10. The **development and implementation of basic knowledge, (initial) training and (technical) training courses**, which enable scaling of the Circular Economy, must be tackled in cooperation with policy makers and academia. This involves:

172 | A cooperative mindset of market actors with the aim of achieving common advantages or "win-wins".

- Collaborative basic and applied research with universities and other institutions, not least including transferable social science research, inter alia with regard to customer behaviour and the communication of Circular Economy products and practices.
- Technical training courses, in particular to ensure occupational health and safety when handling end-of-life (EoL) batteries and the availability of trained personnel.
- Further development and opening up of skilled occupations (e.g. manufacturing technology) for the Circular Economy.
- Educating the general population and professionals on the basic principles of the Circular Economy (e.g. on resource conservation and climate protection as well as economic and business skills).
- Boosting funding for children's and young people's education, for example to promote an understanding of waste prevention, circular products and business models and the impact of purchasing decisions.

Up to 2027: Medium term, "creating structure"

Circular business models:

11. Use of the insights from the first lighthouse projects and innovation spaces to ensure that **circular, in particular use- and results-oriented business models are consistently further or re-developed and scaled** while ensuring their effectiveness in terms of resource conservation, climate protection and inclusivity. However, new business models such as leasing or sharing sometimes presuppose new ownership relationships which need to be negotiated transparently in dialogue with all stakeholders and the impact of which on, for example, value allocation and liability must be clarified. Negotiating concrete requirements and guidelines or codes of practice for long-term cooperation should provide an incentive for all relevant stakeholders.
12. **In the context of for example industry alliances,** there is a need to define **requirements for policy makers** in order to break down barriers to Circular Economy business models and to promote those models which encourage full producer responsibility over the product life cycle until end-of-life. **Use- and results-oriented business models** such as sharing or pay-per-performance models may be a consistent starting point or means of implementation.
13. **Digitalisation** should be accelerated by **trustworthy exchange of data** about products, components and materials with the assistance of new digital systems such as distributed ledger technologies and product passports. The pace of development of digital tools such as machine learning for **evaluating the state** of products, components and materials on the basis of the exchanged data should be stepped up.

Transparency:

14. **There is a need to improve the transparency of complex value networks and material streams by increasing investment in collaborative commercialisation and scaling of relevant technologies and tools.** More digital technologies should be introduced and used for this purpose. Product passports, machine learning algorithms or the internet of things can be mentioned as examples since they enable product, component and material traceability around the value cycle.
15. Creation of **metrics and evaluation rationales for defining and achieving Circular Economy targets** such as increasing product longevity, reusing components and high-quality recycling.

Infrastructure for reuse, continued use and recycling:

16. EU-wide coordinated **expansion of pan-European infrastructure for reuse, continued use and recycling** and scaling of capacity in Germany and across the EU.
17. Support for the **demonstration and dissemination of digital technologies (e.g. artificial intelligence) in the recycling sector** in order to improve material identification and sorting as a prerequisite for high-quality circular management including recycling.

Technical development and research:

18. **Intensification of investment in individual and collaborative development of necessary technologies** for the Circular Economy (e.g. collection, sorting and recycling technologies) which should take account of recognised standards (in particular the EU's taxonomy for sustainable investment) and further Circular Economy-specific recommendations.

Up to 2030: Long term, "breaking through"

Circular business models:

19. **Economic stakeholders should use integrated decision-making processes** which take systematic account of

impacts on the value cycle and associated effects on resources, energy (or exergy), the environment and social implications at the level of the overall system. These decision-making processes should be based on scientific principles or findings, take account of societal interests within and outside Germany and prioritise collaborative business practices within circular value networks.

20. **Comprehensive application of service-oriented business models** both by individual companies and by collaborative business activities and value creation networks.

Standardisation:

21. **Broad adoption of technologies and technical standards** for the provision and exchange of digital data with relevance to circular strategies.

Transparency:

22. **Embedding recognised metrics for a sustainable Circular Economy in a comprehensive incentive and control system.** This is intended to internalise resource externalities in the economy on a polluter-pays basis and provide optimum support for new Circular Economy business models.

5.4 Policy recommendations for academia

The policy recommendations for academia are derived from the results of the three working groups, Circular Business Models, Packaging and Traction Batteries. They have been located along a timeline (2021 to 2030) and assigned to the action points defined in section 5.1 (see figure 22).

Up to 2024: Short term, "laying the foundations"

Technical development and research:

1. A holistic view of economic, environmental and social objectives and of measurement and evaluation methods should enable academia to establish a **decision-making basis for evaluating possible trade-offs** and indicate options for resolving them. For the two functional systems of plastics packaging and traction batteries, the emphasis was on the significance of an evaluation and decision-making basis for increasing product sustainability and evaluating potential measures while taking account of overall systemic effects. Academia, in close consultation with policy makers and business, should help to develop and validate **operational and macroeconomic circularity indicators** and support the creation of the necessary database.
2. Academia can support the successful implementation of a Circular Economy on various levels through **application-oriented interdisciplinary research and development.** In particular, there is a need to pick up the pace in the (further) development of technical interdisciplinary solutions in order to optimise overall systemic effects at the material, product and process levels, for instance by (further) developing circular materials, data platforms and automated process technologies, models for the Circular Economy, for example for (more accurately) forecasting product lifetimes, or also through economic analyses of path dependencies and transaction costs.
3. Development of a long-term **inter- and transdisciplinary research strategy for addressing overarching issues relating to the societal implications** of a Circular Economy ("Circular Society"): in addition to insights from the social sciences into usage patterns or the use of circular products and business models, there is above all also a need to investigate empirical interrelationships and develop the necessary concepts and measuring instruments. In addition, knowledge must be built up about the social and societal goals being pursued so that the necessary transformative processes can be shaped.

Education and knowledge transfer:

4. The development of sound basic and applied knowledge among future social stakeholders should be supported by **integrating the Circular Economy into various courses of study.** This includes not only the provision of appropriate training content (e.g. circular product design) but also the establishment of Circular Economy-related Master's degrees and in-depth courses of study. However, in addition to the introduction of new professorships, courses of study, specialisations and classes, integration into existing classical subjects in the curricula should also be promoted (e.g. by awarding prizes, funding for teaching integration etc.), so that classical teaching (e.g. business administration) is not in conflict with new principles of circularity. In the medium term, Circular Economy-relevant study and training content should become standard in educational institutions.
5. Academia should accelerate the further development of the Circular Economy by **enhanced** basic and **interdisciplinary**

By 2024

Technical development and research:
- Provision of a decision-making basis for evaluating possible trade-offs
- Co-development of operational and macroeconomic circularity indicators
- (Further) development of application-oriented, interdisciplinary (digital) solutions for optimising overall systemic effects at the material, product and process levels
- Development of a long-term inter- and transdisciplinary research strategy on the societal implications of a Circular Economy

Education and knowledge transfer:
- Integration of the Circular Economy into various courses of study
- Establishment of professorships/university departments, targeted support of transdisciplinary research partnerships and real-world laboratories and further development of research infrastructure in dialogue with policy makers

By 2027

Technical development and research:
- Development and provision of Circular-Economy-relevant modelling, simulations and (digital) tools

By 2030

Technical development and research:
- Ongoing development of materials and process technologies

Figure 22: Overview of short-, medium- and long-term policy recommendations for academia (Source: own presentation)

application research. Possible measures include specially established **professorships and chairs, transdisciplinary research partnerships with targeted funding and real-world laboratories** as well as research infrastructure which is further developed in dialogue with policy makers.

Up to 2027: Medium term, "creating structure"

Technical development and research:

6. Academia is also a highly significant player in **Circular Economy-relevant modelling, simulations and tools**. In particular, this involves providing practically applicable models and forecasting tools for estimating physical material flows (e.g. for reducing material volumes and increasing systemic energy efficiency), the anticipated service life of products as well as trends in demand and optimising decision-making in reuse. A digital twin needs to be built on the basis of validated models. In addition, there is a need to develop an associated, if possible web-based, simulation platform to allow robust predictions to be made about material cycles. New methods need to be developed and validated for robust and valid measurement of, for example, recycling and energy efficiency. On this basis, there is a need to design potential market-oriented solutions for the overall system as well as to map out and ultimately oversee their gradual implementation.

Up to 2030: Long term, "breaking through"

Technical development and research:

7. **There is a need for ongoing development of materials and process technologies,** including, on the one hand, the ability to recycle substances at high recycling rates and material purity without loss of quality and, on the other, the development of economically and environmentally forward-looking materials and processes.

6 Outlook

In summary, the importance of the Circular Economy to decision makers in politics, business and academia can be described as follows:

Over and above existing measures, the Circular Economy is an important approach to achieving Germany's climate, resource and development goals. It is a critical prerequisite for market acceptance in some industries (packaging), while in others (traction batteries) it is also a critical competitive advantage. A concrete market model for greater circularity can only be developed collaboratively by policy makers and business. The Circular Economy should therefore become a central pillar for Germany's future viability in the policy debate across all parties. New business models for a more Circular Economy and greater resource decoupling provide a framework for Germany's digitalisation, for which the *Circular Economy Initiative Deutschland* has laid the foundation.

To become a leading nation for circular industrial development, Germany must set itself measurable Circular Economy targets. Germany should to this end become a driving force behind a Circular Economy within the European Union. Businesses should explicitly support such an industrial and environmental policy direction and in turn actively work to enable the implementation of the Circular Economy by product and business model innovations (in particular digitally assisted).

A start should in the near future be made on implementing the roadmap developed here in order to make the potential of the Circular Economy a reality and, so, on the one hand, achieve Germany's climate, resource and sustainability goals and, on the other, maintain and enhance the international competitiveness of the country's economy. This includes in particular:

1. Embedding the recommendations of the *Circular Economy Initiative Deutschland* in an integrated, comprehensive Circular Economy strategy for Germany, including concrete, complementary targets among other things for waste prevention, recycling and overall resource consumption,
2. Establishing interdepartmental coordination of the implementation of measures at the highest possible level overseen by a high-calibre and transdisciplinary expert advisory board,
3. Implementing effective real-world pilot projects, for example the project outlines developed by the Traction Batteries working group ("knowledge of battery life", "model-based decision-making platform" and "disassembly network"),
4. Exploring, piloting and scaling concrete business models which bring higher-quality circular strategies and use- and results-oriented business models to fruition,
5. Optimising the quantification of Circular Economy measures at the macroeconomic and operational level with regard to their environmental, economic and social impact and analysing the effect of carbon pricing and an overhaul of tax rules to support climate- and resource-optimised economic decision-making,
6. Intensifying the networking with other European initiatives, science academies and research networks initiated in the course of the *Circular Economy Initiative Deutschland* and
7. Carrying out further leading projects similar to the *Circular Economy Initiative Deutschland*, in order to generate in-depth insights into further functional areas (such as buildings and infrastructure, foodstuffs, agriculture and forestry, textiles and clothing, electrical appliances) in close cooperation with other (also European) initiatives.

The members of the *Circular Economy Initiative Deutschland* hope that their work which is presented here has contributed to the Circular Economy transformation and are ready and willing to support the above initiatives.

Appendix

A Glossary

The following terms are sorted thematically:

Term	Definition	Comment
Circular Economy	The aim of a Circular Economy is to ensure maximum value retention of the raw materials used by adopting a systems perspective, for instance by using digital technologies, redesigning products and reconfiguring value chains. It thus emphasises the importance of higher resource productivity and ultimately the decoupling of value creation and consistently follows the waste hierarchy, in which waste prevention comes first and incineration and landfill last. This is intended not least to avoid negative environmental effects (e.g. carbon emissions and ecotoxicity). In particular, it should be emphasised that a Circular Economy differs from the "closed-cycle management" concept used in Germany, which has to date been more of a recycling-oriented waste management system.[173]	See *Circular Economy Initiative Deutschland* (CEID) preliminary study.[174]
(Resource) decoupling	Decoupling economic performance and wellbeing from resource utilisation and externalities. A distinction is drawn between relative and absolute decoupling. Relative decoupling occurs if economic growth rises faster than the associated environmental and social consequences. Absolute decoupling does not occur until resource use and externalities remain constant or decrease while economic growth continues.	See International Resource Panel.[175]
Life cycle	"The consecutive and interlinked stages of a product from raw material use to final disposal."[176]	
End-of-life	The end-of-life phase in the life cycle begins when the product under consideration and its packaging are disposed of by the user and ends when the product is returned to nature or enters the life cycle of another product (e.g. as a recycled input).[177]	
Waste	"Any substance or object as defined in Annex I of Directive 2006/12/EC which the holder discards or intends or is required to discard."[178]	
Design for circularity	Overarching consideration of CE principles in product design. Design for circularity strategies aim to enhance product longevity and recyclability and include inter alia:[179] 1) Design for reliability and durability, 2) Design for ease of maintenance and repair, 3) Design for upgradability and adaptability, 4) Design for standardisation, 5) Design for dis- and reassembly, 6) Design for refurbishment/remanufacturing, 7) Design for recycling, 8) Safe by design, i.e. the avoidance of toxic or hazardous substances.	
Reuse	"Any operation by which a product or its components, having reached the end of their first use, are used for the same purpose for which they were conceived, including the continued use of a product which is returned to a collection point, distributor, recycler or manufacturer, as well as reuse of a product following refurbishment."[180]	
Maintenance	Combination of all technical and management actions intended to retain an item in, or restore it to, a state in which it can perform as required.[181]	

173 | See Sachverständigenrat für Umweltfragen 2020b.
174 | See Weber/Stuchtey 2019.
175 | See International Resource Panel 2019.
176 | See European Parliament/Council of the European Union 2009.
177 | See Zampori/Pant 2019.
178 | See European Parliament/Council of the European Union 2009.
179 | See Bocken et al. 2016.
180 | See European Parliament/Council of the European Union 2009.
181 | See International Organization for Standardization 2020a.

Term	Definition	Comment
Repair	Process of returning a faulty product to a condition where it can fulfil its intended use.[182]	
Upgrade	Process of enhancing the functionality, performance, capacity or aesthetics of a product.[183]	
Refurbishment	Functional or aesthetical maintenance or repair of an item to restore it to its original, or upgraded or other, predetermined form and functionality.[184]	
Remanufacturing	Industrial process in which a previously used or non-functional product or component is restored to a "like-new" or "better-than-new" state.[185]	
Recycling	The reprocessing in a production process of waste materials for the original purpose or for other purposes but excluding energy recovery.[186]	
Closed-loop/ open-loop recycling	Closed-loop recycling means the reuse of recycled materials in the same application from which the input materials originate. In open-loop recycling, in contrast, the recycled materials are also used in other applications.	Open-loop recycling enables a broader range of applications for recycled materials, which means a larger market and thus possibly higher demand but also entails the risk of greater quality losses in recycling. A closed loop in terms of one hundred percent permanent recycling of all materials is physically impossible and approximating this becomes increasingly thermodynamically suboptimal. This ideal is therefore not desirable.
Upcycling	A process of converting materials into new materials of higher quality and increased functionality.[187]	
Downcycling	A process of converting materials into new materials of lesser quality and reduced functionality.[188]	
Mechanical recycling	An umbrella term for all purely mechanical and physical treatment processes for used plastics. Mechanical recycling retains the molecular structure of the polymer molecule.	See Packaging working group[189]
Chemical recycling	An umbrella term for all processes which use more than just mechanical or physical processes to treat the starting material but do not lead to complete chemical conversion (combustion) with atmospheric oxygen.	See Packaging working group[190]
Post-consumer material	Material generated by households or by commercial, industrial and institutional facilities in their role as end-users of the product which can no longer be used for its intended purpose[191, 192]	
Post-industrial material	Material diverted from the waste stream during a manufacturing process, excluding reutilisation of materials such as rework, regrind or scrap generated in a process and capable of being reclaimed within the same process that generated it.[193]	

182 | See International Organization for Standardization 2020a.
183 | See ibid.
184 | See ibid.
185 | See Thierry et al. 1995.
186 | See European Parliament/Council of the European Union 2009.
187 | See Ellen MacArthur Foundation 2013.
188 | See ibid.
189 | See Circular Economy Initiative Deutschland 2021.
190 | See ibid.
191 | See International Organization for Standardization 2020a.
192 | See International Organization for Standardization 2020b.
193 | See ibid.

Term	Definition	Comment
Recycled material	Material which has been reprocessed by a manufacturing process from recovered (remanufactured) material and made into a finished product or 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.	The decision to focus exclusively on post-consumer recycled materials is justified by the fact that the focus of closing resource loops in a Circular Economy is thus on circulation between post-consumer and manufacturing.[194]
Recycling rate = recovery rate (RR)	The RR is the quotient of the mass of the physically reusable recycled material and the mass of the input into the overall recycling process and is to be averaged over a financial year for an operating unit (recycling site or business unit). In multistage recycling processes, the losses of each individual stage must be taken into account, i.e. the total RR/yield is the product of the yields/efficiencies of each individual step.	Recycling rates for the purposes of the physical Circular Economy are subject to more stringent requirements than the current RR set in waste legislation. The latter do not generally relate to the reusable output streams of the overall process, but instead mostly to the input streams into the final process stage.
Circular business model	A circular business model (CBM) is a business model, in which the conceptual basis for value creation is the exploitation of the economic value retained in used products for the production of new offerings.[195]	Consequently, a circular business model implies a flow back from the users to the producer, there possibly being intermediaries between the two parties. The term circular business model (CBM) therefore overlaps with the concept of closed-loop supply chains and always involves recycling, remanufacture, reuse or a similar process (e.g. reprocessing, renovation or repair). Reuse and remanufacture are always preferable to recycling for economic reasons, since a large proportion of the added value remains with the components. The circularity of the business model is determined by the proportion of new products which originate from used products.
Circular ecosystem	A circular ecosystem is defined by the business models of various complementary actors for creating sustainable value propositions with closed resource loops, which in turn are based on coordinated product design. On this basis, a Circular Economy may be viewed as the interplay of complementary business models around a circular ecosystem.[196]	
Use-oriented business models	Service business models in which the product remains the property of the provider and is made available to the user by the provider and in some cases shared by a number of users.[197]	These may include, for example, leasing or sharing models such as car sharing or bike sharing.
Results-oriented business models	Service business models in which the customer and provider agree in principle on a result rather than a predetermined product.[198]	These may include, for example, pay-per-performance business models.
Collaboration	Voluntary exchange of information, modification of activities, sharing of resources and a willingness to improve another party's skills for mutual benefit and a common purpose.[199] In the context of a CE, collaborative business management for example involves the provision of data and information about the condition, status and use of products. On the basis of such data, it will increasingly become possible to take account of systemic economic efficiency and resource and energy efficiency (entropy increment/residual exergy) in business decision-making. Closer cooperation within the value chain is required because changes in individual links (e.g. material selection, product design, recycling infrastructure) have an impact on the entire system.	

194 | See Bocken et al. 2016.
195 | See Linder/Williander 2017.
196 | See Takacs et al. 2020.
197 | See Tukker 2004.
198 | See ibid.
199 | See Himmelman 2001.

Term	Definition	Comment
Positive-sum game mindset	In game theory, a positive-sum game is the name for a game in which all players obtain advantages.[200] A positive-sum game mindset therefore describes a cooperative mindset of market actors with the aim of achieving common advantages or "win-wins".	
Digital twin	A digital twin is a virtual counterpart to a product. It can be used to run simulations of how the product works.[201, 202]	
Machine learning	Machine learning and deep learning are approaches which enable machines to perform tasks involving recurring patterns and inference without specific human instructions.[203]	
Material or product passport (specifically, battery passport)	A digital tool for storing and providing information about the origin, durability, composition, reuse, repair and disassembly options for a material (material passport) or a product (product passport) as well as usage data/SoH and locating and handling the material/product at end-of-life.	See EU Commission Strategy for Data.[204]
Consumer citizenship	The term "consumer citizen" is a predominantly normative construct and denotes both the moral responsibility of citizens for their decisions and actions in a society increasingly shaped by consumption and the rights they must be granted in order to fulfil this responsibility.[205] The Consumer Citizenship Network (CCN) identifies the following obligations of consumer citizens: they should consider ethical, social, economic and environmental issues in order to take an active decision on the basis of these considerations. Basic rights such as the right to security, the right to comprehensive information, and the right to appeal and to represent one's interests must be in place so that free and moral decisions can be made in the first place.	
Prosumers	The term "prosumer" was coined as long ago as the 1980s by Alvin Toffler[206], primarily to criticise the common disconnect between the sphere of production and the sphere of consumption as artificial and to highlight that consumers always also have a certain share in the production of a good or service (e.g. assembling purchased furniture themselves, preparing food from fresh ingredients). Interest in this term has grown strongly over the past decade thanks to technological and social changes such as digitalisation (especially Web 2.0) and greater interest in social innovation, for example in relation to a do-it-yourself approach and collaborative production (such as community-supported agriculture, open workshops, FabLabs).[207] Prosumption is also increasingly used to describe activities in which citizens themselves create offerings and, for example, contribute to the creation of platforms such as Wikipedia or navigation aids such as Google Maps via "crowdsourcing", i.e. compiling numerous participants' contributions.[208]	
EU Ecodesign Directive	The EU Ecodesign Directive provides the European legal framework for defining environmentally responsible ecodesign requirements for energy-related products. The Energy-related Products Act (EVPG) transposes this directive into German law. Previous regulations primarily focused on energy efficiency. Very little use has yet been made of the Directive's potential to address wider environmental impact over a product's entire life cycle. Within the framework of the Circular Economy Action Plan (CEAP), the EU Commission now intends in 2021 to submit a legislative proposal for a Sustainable Products Initiative to remedy some of these shortcomings.	

200 | See Nielsen 1988.
201 | See Gabor et al. 2016.
202 | See Negri et al. 2017.
203 | See Kristoffersen et al. 2020.
204 | See European Commission 2020e.
205 | See Schrader 2007.
206 | See Toffler 1980.
207 | See Blättel-Mink/Hellmann 2010.
208 | See Tapscott/Williams 2007.

Term	Definition	Comment
Sustainable Products Initiative	The aim of the Sustainable Products Initiative, which involves revision of the Ecodesign Directive and may propose additional legislative measures, is to make products placed on the EU market more sustainable.[209] It will also address the presence of harmful chemicals in products such as electronics and ICT equipment, textiles, furniture, steel, cement and chemicals.	

209 | See European Commission 2020d.

Circular Economy Initiative Deutschland

B List of figures

C List of tables

D Metrics for the Circular Economy

Table 3 shows an overview of environmental implementation goals as enablers of a Circular Economy (light green rows) and objectives for the impact of a Circular Economy (green rows; see figure 10 in section 3.1). The results of a literature search on possible indicators are also shown; these indicators are not *Circular Economy Initiative Deutschland* recommendations. The second column from the right indicates the availability of the respective indicators ("available") or the need to develop them for measuring Circular Economy progress ("needed").

Implementation goals for measures		**Indicators**	**Available/ needed**	**Level**
Building and strengthening	Increasing the share of renewable energies	Share of gross final energy consumption (30 % by 2030),[210] share of gross power consumption (65 % by 2030)[211]	+/+	Macro
	Reducing primary energy consumption	Cutting primary energy consumption by 30 % by 2030 compared to 2008,[212] cumulative energy consumption[213]	+/+	Macro
	Qualitative waste prevention (reduction of pollutant content in materials and products)	Hazardous substances in production[214]	-	Micro
	Intensifying use by sharing	Car sharing – frequency of car sharing by type of trip and age[215]	+	Macro
	Extending use by repair, maintenance and upgrading	Household expenditure on repair and maintenance of products,[216] longevity indicator[217]	+/+	Macro; product
	Extending use by reuse	Reuse potential indicator[218]	+	Product
	Extending use by remanufacturing	Share of remanufacturing business in manufacturing industry[219]	-	Macro
	Increasing recycling rates	Recycling rate,[220] all-waste recycling rate (excluding large mineral waste),[221] value-based recycling index,[222] end-of-life recycling input rate[223]	+/+/+/+	Macro
	Increasing recycled material quality	Material quality indicator,[224] Substitution rate[225]	+/+	Product
	Increasing recovery rates	Efficiency rate of the recycling process[226]	+	Micro

210 | See European Commission 2014.
211 | See Bundesregierung 2018.
212 | See Bundesministerium für Wirtschaft und Energie 2019.
213 | See Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit 2016.
214 | See European Environment Agency 2016.
215 | See Magnier et al. 2017.
216 | See ibid.
217 | See Franklin-Johnson et al. 2016.
218 | See Park/Chertow 2014.
219 | See European Environment Agency 2016.
220 | See Graedel et al. 2011.
221 | See European Commission 2018.
222 | See Reuter et al. 2018.
223 | See Graedel et al. 2011.
224 | See Steinmann et al. 2019.
225 | See Ressourcenkommission am Umweltbundesamt.
226 | See Graedel et al. 2011.

Targets for impact		Indicators	Available/ needed	Level
Resource conservation				
Absolute reduction of resource consumption (input)	Reducing raw material/resource/ material consumption by reduce and redesign strategies	Value-based resource efficiency indicator,[227] Total material demand[228] Total raw material productivity[229]	+/+/+	Macro
	Increasing share of secondary materials	DERec/DIERec[230], substitution rate[231]	+/+	Macro
Improving the utilisation of physical resources and value retention through circularity		Per capita raw material consumption,[232] consumption-related material productivity,[233] circular material use rate[234]	+/+/+	Macro
Reducing waste (output)	Quantitative waste prevention	Waste generation by businesses and households kg/year/capita; waste/GDP[235]	+/+/+	Macro
Reducing overexploitation of and damage to ecosystems	Preserving biodiversity	Increase to index value 100 by 2030[236]	+	Macro
	Reducing use of soil/land and water	Land use,[237] land footprint; water exploitation index,[238] water consumption per capita	+/+/+/+	Macro; individual
Reducing emissions and inputs into the environment	Contribution to greenhouse gas neutrality	Greenhouse gas emissions in Germany (reduction by 55 % by 2030 compared to 1990),[239] carbon footprint of materials/products	+/+	Macro; product
	Reducing inputs of plastics into the environment	-		
	Reducing ecosystem eutrophication	SDG 15 – terrestrial ecosystems: nitrate – 35 per cent reduction by 2030 compared to 2005	+	Macro
		SDG 6 – water: phosphorus – compliance, or better than compliance, with typical guideline values for bodies of water at all measurement points by 2030; nitrate – compliance with "50 mg/l" nitrate threshold value in groundwater by 2030	+/+	Macro
		SDG 12 – compliance with good status according to the Surface Water Ordinance (annual mean values for total nitrogen should not exceed 2.6 mg/l in rivers flowing into the Baltic Sea or 2.8 mg/l in those flowing into the North Sea).	+/+	Macro

Table 3: Overview of environmental implementation goals as enablers of a Circular Economy (Source: own presentation)

227 | See Di Maio et al. 2017.
228 | See Mayer et al. 2019.
229 | See Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit 2016.
230 | See ibid.
231 | See Ressourcenkommission am Umweltbundesamt.
232 | See Haas et al. 2015.
233 | See European Commission 2014.
234 | See Eurostat s.a.
235 | See Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit 2019.
236 | See Bundesregierung 2018.
237 | See ibid.
238 | See European Commission 2014.
239 | See Bundesregierung 2018.

Table 4 shows an overview of economic implementation goals as enablers of a Circular Economy (light blue rows) and objectives for the impact of a Circular Economy (blue rows; see figure 10 in section 3.1). The results of a literature search on possible indicators are also shown; these indicators are not *Circular Economy Initiative Deutschland* recommendations. The second column from the right indicates the availability of the respective indicators ("available") or the need to develop them for measuring Circular Economy progress ("needed").

Implementation goals for measures		Indicators	Available/ needed	Level
Strengthening innovation	Promoting technical innovation for the Circular Economy	Share of Circular Economy-relevant funding in R&D budget; number of Circular Economy-relevant publications and patents	-/+	Macro
	Increasing Circular Economy innovation in companies	Eco-innovation index,[240] share of products with "circularity label"; 34 % market share of products with government/independently certified ecolabels by 2030,[241] Circular Business Models working group:[242] share of Circular Economy-related innovation projects in the overall innovation portfolio	+/-/+/-	Macro; micro
Strengthening inter-company collaboration	Building transparent value networks/data transparency	Share of products with product passport	-	Macro
	Expansion of collaborative and intersectoral stakeholder alliances	Participation of companies in CE networks[243]	-	Meso
	Responsible value networks (compliance with human and workers' rights)	s-LCA (social LCA) for specific material and product groups; members of the Partnership for Responsible Textiles	+/+	Product
	Development of circular business models	Sales of new maintenance/repair service packages; number of "total care" contracts	-/-	Micro
	Increasing investment in Circular Economy strategies	Share of Circular Economy expenditure; full-time employees in CE-relevant fields[244]	+/+	Micro
	Sustainable management	Number of companies with a zero-waste programme[245]	-	Macro
Targets for impact		**Indicators**	**Available/ needed**	**Level**
Raw materials supply				
Dependency on imported raw materials		Security of supply of resources within the EU[246, 247]	+	Macro
Increasing value creation and competitiveness		Contribution of the Circular Economy to value creation[248]	-	Macro

Table 4: Overview of economic implementation goals as enablers of a Circular Economy (Source: own presentation)

240 | See Smol et al. 2017.
241 | See Bundesregierung 2018.
242 | See Circular Economy Initiative Deutschland 2020a.
243 | See Smol et al. 2017.
244 | See Ellen MacArthur Foundation 2020.
245 | See Smol et al. 2017.
246 | See Potting/Hanemaaijer 2018.
247 | See European Commission 2017.
248 | See Potting/Hanemaaijer 2018.

Table 5 shows an overview of social implementation goals as enablers of a Circular Economy (light orange rows) and objectives for the impact of a Circular Economy (orange rows; see figure 10 in section 3.1). The results of a literature search on possible indicators are also shown; these indicators are not *Circular Economy Initiative Deutschland* recommendations. The second column from the right indicates the availability of the respective indicators ("available") or the need to develop them for measuring Circular Economy progress ("needed").

Implementation goals for measures		**Indicators**	**Available/ needed**	**Level**
Establishing nationwide, environment-specific initial and in-service training	Development of Circular Economy-relevant initial and in-service training provision	Number of Circular Economy courses; environmental education expenditure[249]	-/-	Macro
	Strengthening Circular Economy policy advice	Number of Circular Economy advisers[250]	-	Macro
	Sustainable consumption through substitution – increasing demand for more environmentally/socially sound alternatives	Environmentally friendly public procurement;[251] share of Blue Angel ecolabel paper in direct federal administration's total paper consumption[252]	+/+	Macro
Increase in participation and innovation	Social innovation through new forms of cooperation in value creation (co-creation/prosumers/ repair cafés etc.)	Number of repair cafés/exchange platforms; increasing turnover of the platforms, resale[253]	+/+	Macro
Targets for impact		**Indicators**	**Available/ needed**	**Level**
Securing quality of life				
Jobs		Employees working in repair, reuse and recycling[254]	+	Macro

Table 5: Overview of social implementation goals as enablers of a Circular Economy (Source: own presentation)

249 | See Potting/Hanemaaijer 2018.
250 | See ibid.
251 | See European Commission 2018.
252 | See Bundesregierung 2018.
253 | See Magnier et al. 2017.
254 | See Eurostat s.a.

E Description of the methodology for quantifying the Circular Economy

The explanations presented in section 3.4 for quantifying a vision of a resource-efficient and (maximally) climate-neutral Circular Economy are based on a series of models and assumptions, which are set out below. The approach followed here builds on various established models which estimate both current and future resource use in Germany.

The reference scenario is based on the "climate-active Germany" scenario developed with the GINFORS3 model which was developed as part of the research project "Long-term scenarios and potential for resource efficiency in German in a global context"[255] and takes account of various effects of energy policy transformation efforts, for example a 100 per cent share of renewable energy in 2045 and an ETS CO_2 certificate price of 147 euro in 2050.[256]

The alternative scenario uses basic principles from the "Transformation process towards a greenhouse gas-neutral and resource-efficient Germany" project commissioned by the Federal Environment Agency[257], which were analysed from the specific perspective of the transition to a Circular Economy. A combination of a total of five models, which were supplemented with detailed sector- and industry-specific analyses, was used here. Modelling in the transport sector is based on TREMOD (Transport Emission Model), in the space heating and cooling sector on GEMOD (Buildings Model) and in the agricultural sector on ALMOD (Agriculture and LULUCF Model). In combination with the industrial sector-specific analyses as well as the waste sector, the energy modelling was carried out with SCOPE (cross-sectoral deployment and expansion optimisation for analyses of the future energy supply system). Macroeconomic raw materials use and upstream emissions were modelled using the environmental economic raw material and greenhouse gas model (URMOD).[258] Data from the "Climate neutral 2050" scenario developed by Prognos, Öko-Institut and Wuppertal Institute (2020) were used for comparison with a two-degree path.[259]

The basis for quantifying the resource and climate effects of the Circular Economy was the "Resource conservation through a material flow-oriented secondary raw materials economy"[260] research project coordinated by the Wuppertal Institute. The primary focus of this project was to estimate material flows for Germany and use these estimates to determine the quantity of primary raw materials which can be substituted by recovering the most important secondary raw materials and secondary products. The indicators DIERec (Direct and Indirect Effects of Recovery) and DERec (Direct Effects of Recovery) were designed to allow this potential for substitution and its impact at the cumulative raw material input level to be estimated. Using these two indicators, it is possible to compare the raw material and energy impacts of secondary raw material recycling processes with those of the corresponding processes for the substituted primary materials and so model the actual contribution of the secondary raw materials industry to resource conservation for each (raw) material.

255 | See Distelkamp/Meyer 2018.
256 | See Distelkamp/Meyer 2018 for methodological details.
257 | See Dittrich et al. 2020.
258 | A detailed description of how the models work can be found in Dittrich et al. 2020.
259 | See Prognos et al. 2020b.
260 | See Steger et al. 2019.

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