acatech IMPULSE

Innovations for a European Green Deal

Martin Brudermüller, Reiner Hoffmann, Henning Kagermann, Reimund Neugebauer, Günther Schuh (Eds.)

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The acatech IMPULSE series

This series comprises contributions to debates and thought-provoking papers on strategic engineering and technology policy issues. IMPULSE publications discuss policy options and are aimed at decision-makers in government, science and industry, as well as interested members of the general public. Responsibility for the contents of IMPULSE publications lies with their authors.

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Foreword

"Act always so as to increase the number of choices." This ethical imperative formulated by the philosopher and physicist Heinz von Foerster should guide Europe's efforts to tackle the triple challenge to its freedom and agency posed by climate change, the pandemic, and growing international trade disputes.

In practice, this means that the measures to help the economy recover from the impacts of the pandemic must be clearly focused on forging viable and robust pathways for transitioning to a sustainable industrialised economy in Europe. Accordingly, it is imperative to keep following the blueprint provided by the European Green Deal.

At a time of growing budget constraints, and in view of the fact that a transition to a sustainable economy will affect every part of society, maintaining widespread support among the public and the business community will be particularly critical to the Green Deal's successful implementation. Key to this is a broad definition of sustainability that encompasses the environmental, economic and social dimensions. In addition to climate action and the protection of biodiversity, policy goals should also include the strengthening of Europe's global competitiveness and the implementation of structural change across different industries and regions in a manner that includes workers and offers them new opportunities.

This acatech IMPULSE highlights the fact that Europe has many brilliant minds with groundbreaking ideas who are primed to tackle this once-in-a-generation challenge. It is now up to government to activate these drivers by providing clear targets and a reliable framework (for example with regard to carbon pricing), and by engaging in joint initiatives with science and industry in order to make Europe an attractive location for investment in sustainability.

Europe should not limit its ambition to becoming the first climate-neutral continent – it should also aim to supply sustainable technology to the entire world. Instead of putting innovation policy on hold because of the current crisis, now more than ever it is vital for policymakers to make a well-founded and passionate case for pioneering European projects and the mobilisation of the necessary public and private investment.

This study is a revised version of a paper that was discussed with members of the German government in summer 2020.

acatech and the editors would like to thank everyone involved for their enthusiastic engagement in its production.

Dr. Martin Brudermüller
Chairman of the Board of Executive Directors of BASF SE

Reiner Hoffmann
President of the German Trade Union Confederation

Prof. Dr. Henning Kagermann
Chairman of the acatech Board of Trustees

Prof. Dr.-Ing. Reimund Neugebauer
President of the Fraunhofer-Gesellschaft

Prof. Dr.-Ing. Günther Schuh
Chair of Production Engineering at RWTH Aachen University

Executive Summary

The economic shock triggered by the SARS-CoV-2 pandemic has prompted calls to postpone the implementation of the European Green Deal that forms the central project of the European Commission under Ursula von der Leyen. The experts consulted for this IMPULSE publication unanimously and emphatically reject these calls. Instead, they recommend that the German government should work towards a **sustainable and resilient recovery**, especially since this will strengthen the numerous transformation initiatives that had already commenced before the crisis.

The current crisis cannot stop or delay efforts to bring about the **necessary transition** to a sustainable economy that will **secure long-term value creation and employment** in Europe. The SARS-CoV-2 pandemic must not result in **innovation policy being put on hold**.

The following **ten key messages** summarise the main outcomes of the discussions and analysis carried out for this publication. As well as providing a strategic framework for shaping an effective, **sustainable, long-term recovery and prospective strengthening** of Europe based on the lessons learnt from the pandemic, they also set out the most promising **innovation policy drivers and initiatives** for achieving this goal.

1. **Innovation** must be **at the forefront** of a sustainable **reboot** of the German and European economies, with a focus on **technological, social and business model innovations** across all sectors.
2. Equal weight should be given to the **environmental, economic and social** dimensions of **sustainability**. Manageable paths to the transformation of business models and the proactive management of social transitions are every bit as important as the systematic pursuit of climate goals. Any potential conflicts of goals must be identified and addressed as soon as possible.
3. The aim should be to create a sustainable, more **resilient social market economy** that is both **internationally competitive** and capable of responding to unexpected shocks in a more flexible, more stable and technologically sovereign manner.
4. The **Green Deal's goals** should remain an integral part of the **design and concrete implementation of the medium- and long-term economic programmes**. Once they have been appropriately adapted, the parts relating to innovation and investment can play a particularly important role in this context.
5. **Hydrogen** and renewables-based **electrification**, the **digital and biological transformations**, and the **circular economy** are all promising **drivers** of a sustainable **transformation of industry**. In addition, there is the potential to build on the **strong research base** that already exists in these areas in Germany and Europe.
6. The necessary **private investment** will only come about in a regulatory environment that supports innovation and if policymakers are able to build **confidence** in the predictability of measures that is currently lacking, especially with regard to **carbon pricing**. This investment would give Germany the opportunity to become a leading **global supplier** of sustainable, climate-friendly technology.
7. The example of the **plastics industry** serves to illustrate that sustainability is achieved through the comprehensive **transformation of value networks** rather than through the piecemeal replacement of individual products. Government can facilitate this by supporting pre-competitive collaboration between the relevant actors, for example in **regulatory sandboxes** – an approach that can also provide policy makers with input for **proactive, enabling regulation**.
8. **Transparent and comparable reporting** of sustainability indicators must be developed in order to provide a **robust basis for decisions** taken by businesses, investors, and government regulators.
9. **Germany** must maintain its position as a pioneer in the field of **sustainable finance** but must **avoid going it alone**. Instead, it must promote standardisation throughout Europe and ensure that companies' roadmaps for the transformation towards climate neutrality are taken into account, rather than focusing exclusively on their current status.
10. **Funding for first-class research without restrictions regarding topics** must be maintained even during these times of crisis in order to avoid jeopardising the basis of future innovations. Funding should be complemented by **improved transfer and innovation programmes**, for example under the auspices of the **European Innovation Council** (EIC). These programmes can be closely coordinated with national funding instruments such as the Bundesagentur für Sprunginnovationen (Federal Agency for Disruptive Innovation).

These **strategic decisions** must be taken sooner rather than later. It will be necessary to **prioritise the key innovation projects**, not least because the crisis has substantially curtailed the financial resources that governments and businesses have at their disposal. The projects should be designed to contribute to the recovery while at the same time driving a successful, sustainability-based **transformation of key industries and sectors** that is socially **acceptable** and proactively manages the social transitions for the affected **workers**.

Accordingly, this IMPULSE publication begins by presenting a series of **proposals for initiatives** that can be used strategically by Germany and the EU to implement the identified transformation drivers (see Chapter 2). Their deployment can also contribute to increasing resilience of the economy (see Chapter 2.5). The initiatives should be implemented through **learning, adaptive strategies** capable of adjusting to dynamic developments in the economy and the relevant technology fields.

The proposals include the ambitious development of **infrastructure** for a **European hydrogen economy** (see Chapter 2.1). Germany would benefit from secure, environmentally and climate-friendly **energy imports** and from **systems technology exports**. Meanwhile, southern EU member states could gain opportunities to create value locally, also with the support of German investment. If implemented rapidly, this proposal would ensure that Europe was well placed to **compete in the global market** for this critical emerging technology while also pursuing an **innovation-led cohesion policy**.

While the pandemic has starkly exposed some of the shortcomings with regard to the **digital transformation**, it has also prompted an increase in the use of digital technology that should be used as a springboard to ensure that these **shortcomings are swiftly addressed** (see Chapter 2.2). As well as providing infrastructure for a common **European data space** and quantum computing hardware, the experts interviewed for this publication felt that the principal role of the State should be to set an example by drawing up an ambitious roadmap for the digital transformation of its own structures, particularly **government services** and **schools and universities**.

On top of technological innovations, implementation of a **circular economy** (see Chapter 2.3) will be heavily dependent on **new business models** and the **transformation of value networks**. In addition to better information and networking of the relevant actors, significant momentum can be generated through the introduction of **digital product passports** and through regulatory incentives based on **life cycle assessments** and the lessons learnt from regulatory sandboxes and living labs.

In conjunction with digital solutions, the **biological transformation** (see Chapter 2.4) can provide new innovation opportunities in several different industries. The combination of biotechnology and bioinformatics has already revolutionised medical design and production (see Box 5). Initiatives such as **regulatory sandboxes for a materials transformation** (see Box 6) could stimulate similar developments in other industries and sectors that are key to a sustainable transformation of the economy. The **agenda "From Biology to Innovation"** should send out a strong policy message in support of this approach.

The example of the **plastics industry** (see Chapter 3) shows that the **transformation of industries** towards a circular economy model cannot be achieved simply through the piecemeal replacement of individual products. Instead, **systemic solutions** are required, coupled with policy measures to **address conflicts** that do not have a technological solution.

One way of going about this in the plastics industry would be to establish a **regulatory sandbox for chemical recycling** (see Box 7) that brings together all the relevant actors in the resource cycle. This approach could also provide a knowledge base for innovation-friendly regulation, for example with regard to the synergistic **combination of new and established recycling processes** to facilitate more widespread use of recycled plastic.

Implementing all of these initiatives and harnessing the drivers of the transformation will call for high levels of public investment and in particular the **mobilisation of private capital**. Consequently, the second focus of this study is on policy approaches to creating **transparent and user-friendly instruments** for evaluating sustainability (see Chapter 4). Together with **key market signals** such as carbon pricing, the experts identified this as a key requirement for generating the necessary investment.

The plethora of different methods currently used both to calculate financial product **ESG ratings** and for corporate **sustainability reporting** has created a **confusing landscape** and a lack of comparability in the markets. Consequently, policymakers should use the development of the EU Taxonomy (see Chapter 4.1), Germany's sustainable finance strategy (Chapter 4.2) and sustainability-based reporting standards (see Chapter 4.4) to work towards the establishment of standardised, **comparable key indicators** that can provide a robust **basis for both policymaking and corporate decision-making**. It will be important to ensure that these reporting obligations do not overburden businesses, especially SMEs, and that Germany does not damage the European Single Market by going it alone.

Securing the **European Research Area's** existing **strengths** over the long term is just one of the reasons why the experts interviewed for this publication recommend close cooperation within Europe (see Chapter 5). Instruments like **IPCEIs** (e.g. for hydrogen), institutions such as the **European Investment Bank**, and European experiences with regional innovation and transformation strategies can also provide a basis for sustainability initiatives with far-reaching appeal. Clear market signals can also be sent through **sustainable public procurement** practices, especially as part of stimulus packages and economic programmes.

Ambitious initiatives and a **convincing sustainability narrative** will be key to raising awareness of the **opportunities for sustainable value creation and sustainable prosperity** among industry, the workforce and the general public, thereby **empowering** them to successfully **undertake the necessary transformations**.

Interviewees

Acknowledgements

In addition to carrying out a review of the specialist literature and other studies, the acatech Secretariat conducted exploratory interviews with 75 experts from science, industry, government and civil society. The aim was to gain an overview of current opinion about how best to pursue sustainability goals and identify promising approaches to help industry successfully carry out and finance the necessary transformation.

Telephone or face-to-face interviews with an average duration of one hour were conducted between March and May 2020. An open-ended discussion format was chosen to support the exploratory nature of the interviews and capture the "undertones" of the responses. This study presents an overview of the key views expressed in the interviews. However, individual interviewees may have had different opinions on some of the questions.

The positions listed below were held by the respective interviewees at the time of their interviews. The text is interspersed with anonymous quotes taken from the interviews in order to illustrate some of the interviewees' key views.

On behalf of acatech's Executive Board, the acatech Secretariat would like to thank everyone involved for agreeing to take part in the interviews.

Dr.-Ing. Reinhold Achatz	Thyssen Krupp AG *Chief Technical Officer – Head of Corporate Function Technology, Innovation & Sustainability*
Prof. Dr.-Ing. Thomas Bauernhansl	Fraunhofer Institute for Manufacturing Engineering and Automation IPA *Director*
Bernd Biervert	European Commission Directorate-General for Research and Innovation *Head of Unit Ecological and Social Transitions*
Dr. Urs Bitterling	Allianz SE *Head of Corporate Responsibility*
Jocelyn Blériot	Ellen MacArthur Foundation *Executive Lead, Institutions, Governments & Cities*
Götz Brandau	Lidl Stiftung & Co. KG *Public Affairs – Head of Brussels Office*
Dr. Philipp-Bastian Brutscher	European Investment Bank *Advisor to the President*
Ralph Büchele	Roland Berger GmbH *Partner*
Dr. Christine Bunte	BASF SE *Senior Manager Industry Advocacy*
Dr. Peter Dröll	European Commission Directorate-General for Research and Innovation *Acting Director, Prosperity*

Prof. Dr.-Ing. Welf-Guntram Drossel	Fraunhofer Institute for Machine Tools and Forming Technology IWU *Director*
Prof. Dr. Sebastian Dullien	Hans Böckler Foundation Macroeconomic Policy Institute *Research Director*
	Hochschule Technik und Wirtschaft Berlin – University of Applied Sciences *Professor of International Economics*
Prof. Dr. Ottmar Edenhofer	Potsdam Institute for Climate Impact Research *Director*
Ramona Eitzenhöffer	GreenCycle Umweltmanagement GmbH *Communication*
Kathrin Falk	ExxonMobil Central Europe Holding GmbH *Head of Berlin Office*
Prof. Dr.-Ing. Manfred Fischedick	Wuppertal Institute *Scientific Managing Director*
Prof. Dr. Magnus Fröhling	Technical University of Munich *Chair for Circular Economy*
Dr. Marion Früchtl	Fraunhofer Institute for Casting, Composite and Processing Technology IGCV *Head of Central Unit of Biological Transformation*
Michael Funcke-Bartz	Gesellschaft für Internationale Zusammenarbeit (GIZ) *Senior Advisor, Centre of Competence "Environment"*
Dr. Lena Grimm	Fraunhofer-Gesellschaft Headquarters *Research Coordinator "Materials, Life Sciences"*
Dr. Jens Hamprecht	BASF SE *Head of Market Development Biopolymers*
Prof. Dr. Gerald Haug	Deutsche Akademie der Naturforscher Leopoldina – German National Academy of Sciences *President*
Christian Heller	value balancing alliance e. V. *Chief Executive Officer*
Dr. Patrick Herhold	Boston Consulting Group GmbH *Managing Director & Partner*

Prof. Dr.-Ing. Christoph Herrmann	Technische Universität Braunschweig Institute of Machine Tools and Production Technology (IWF) *Head of Institute/Sustainable Manufacturing & Life Cycle Engineering* Fraunhofer Institute for Surface Engineering and Thin Films IST *Director*
Christoph Heuer	Goldman Sachs International *Managing Director | Investment Banking Division | Head of Equity Capital Markets Germany & Austria*
Alexander Holst	Accenture Strategy *Managing Director – Sustainability & Utility Strategy*
Christian Holzleitner	European Commission Directorate-General for Climate Action *Head of Unit for Land Use and Finance for Innovation*
Dr. Werner Hoyer	European Investment Bank *President*
Brigitte Irsfeld	Permanent Representation of the Federal Republic of Germany to the European Union *Counsellor for Economic Affairs*
Dr. Marion Jung	ChromoTek GmbH *Chief Executive Officer*
Prof. Dr. Henning Kagermann	acatech – National Academy of Science and Engineering *Chairman of the acatech Board of Trustees/member of the acatech Senate*
Dr. Gernot Kalkoffen	ExxonMobil Central Europe Holding GmbH *Chairman of the Supervisory Board*
Dr. Andreas Kicherer	BASF SE *Senior Expert Sustainability*
Frederike Krebs	Mechanical Engineering Industry Association (VDMA) European Office in Brussels *Adviser Technical, Environmental and Sustainability Affairs*
Prof. Dr. Klaus Kümmerer	Leuphana University Lüneburg *Professor of Sustainable Chemistry and Material Resources*
Thomas Kyriakis	Schwarz Gruppe GmbH *Member of the Board of Schwarz Zentrale Dienste KG*

Christian Lach	BASF SE *Project Lead ChemCycling*
Peter Lacy	Accenture Strategy *Senior Managing Director – European Strategy Lead & Global Sustainability Lead*
Ulrike Linnig	EIT Climate-KIC *Innovation Lead Germany*
Gernot Löschenkohl	Munich Re AG *Head of Alternative Investments*
Dr. Michael Menhart	Munich Re AG *Global Chief Economist*
Dr. Gunnar Muent	European Investment Bank *Deputy Director General, Projects Directorate*
Prof. Karsten Neuhoff, Ph. D.	German Institute for Economic Research (DIW) *Head of Climate Policy Department* Technische Universität Berlin *Professor at the Institute of Economics and Law*
Lars Oestling	European Investment Bank *Head of Institutional Strategy*
Dr. Thomas Ogilvie	Deutsche Post AG *Member of the Board of Management for Human Resources*
Dr. Stefan Oschmann	Merck KGaA *Chief Executive Officer*
Jean-Eric Paquet	European Commission Directorate-General for Research and Innovation *Director-General*
Prof. Dr. Karen Pittel	ifo Institute – Leibniz Institute for Economic Research at the University of Munich *Director of the ifo Center for Energy, Climate and Resources* LMU Munich *Professor of Economics specialising in Energy, Climate and Exhaustible Natural Resources*
Dr. Gerald Podobnik	Deutsche Bank AG *Chief Financial Officer Corporate Bank*

Dr. Carsten Polenz	SAP SE *Sherpa Office Executive Board*
Harriet V. Poulter	Accenture Strategy *Strategy Analyst*
Ernst Rauch	Munich Re AG *Global Head Climate & Public Sector Business Development*
Aldo Romani	European Investment Bank *Team Leader and Senior Expert, Sustainability Funding*
Dr. Artur Runge-Metzger	European Commission Directorate-General for Climate Action *Director for Climate Strategy, Governance and Emissions from Non-Trading Sectors*
Jim Hageman Snabe	Siemens AG *Chairman of the Supervisory Board*
Christian Schiller	Cirplus GmbH *Chief Executive Officer*
Dr. Katharina Schlegel	BASF SE *Market Development Manager Biopolymers*
Prof. Dr. Robert Schlögl	Fritz Haber Institute of the Max Planck Society *Director*
Prof. Dr. Christoph M. Schmidt	RWI – Leibniz Institute for Economic Research *President*
Sabine Schlüter-Mayr	Munich Re AG *Project Manager Climate & Public Sector Business Development*
Dr. Norbert Schultes	Permanent Representation of the Federal Republic of Germany to the European Union *Head of Economic Affairs and Energy*
Wesley Spindler	Accenture Strategy *Business Strategy & Sustainability Senior Manager*
Dr. Markus Steilemann	Covestro AG *Chief Executive Officer*
Kurt Vandenberghe	European Commission President von der Leyen’s Team *European Green Deal Adviser*

Michael Vassiliadis	IG BCE Industriegewerkschaft Bergbau, Chemie, Energie (mining, chemicals and energy union) *President*
Stefaan Vergote	European Commission Directorate-General for Climate Action *Adviser for Emission Reduction Strategies, Research & Innovation*
Michael Vorländer	Permanent Representation of the Federal Republic of Germany to the European Union *Head of Unit, Education and Research*
Prof. Dr.-Ing. Thomas Weber	acatech – National Academy of Science and Engineering *Vice-President* Circular Economy Initiative Deutschland *Chair of the Steering Committee*
Prof. Dr.-Ing. Dieter Wegener	Siemens AG *Head of Department of Corporate Technology*
Dr. Joachim Wenning	Munich Re AG *Chairman of the Board of Management of* Münchener Rück AG
Dr. Petra Wicklandt	Merck KGaA *Head of Corporate Affairs, Senior Vice President*
Dr. Markus Wolperdinger	Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB *Director*
Dr. Georg Zachmann	Bruegel *Senior Fellow*
Oliver Zühlke	Bayer AG *Chairman of the Central Works Council | Vice Chairman of the Supervisory Board*

Contributors

Overall supervision

- Prof. Dr. Henning Kagermann, Chairman of the acatech Board of Trustees

Content collaboration

- Dr. Martin Brudermüller, BASF SE
- Reiner Hoffman, German Trade Union Confederation
- Prof. Dr.-Ing. Reimund Neugebauer, Fraunhofer-Gesellschaft
- Prof. Dr.-Ing. Günther Schuh, RWTH Aachen University

Content support and review

- Prof. Dr. Dr. Andreas Barner, Stifterverband für die Deutsche Wissenschaft
- Gabi Grützner, micro resist technology GmbH
- Prof. Dr. Jörg Hacker, German National Academy of Sciences Leopoldina
- Prof. Dietmar Harhoff, Ph. D., Max Planck Institute for Innovation and Competition
- Dr. Marion Jung, ChromoTek GmbH
- Prof. Dr.-Ing. Anke Kaysser-Pyzalla, German Aerospace Center
- Prof. Dr. Renate Köcher, Allensbach Institute
- Dr.-Ing. Reinhard Ploss, Infineon Technologies AG
- Prof. Dr. Martin Stratmann, Max Planck Society
- Stefan Vilsmeier, Brainlab AG
- Dr.-Ing. Anna-Katharina Wittenstein, Wittenstein SE
- Oliver Zipse, BMW AG

Editorial collaboration

- Simin Chelopaz Amini, BASF SE
- Susanne Finkenzeller, Fraunhofer-Gesellschaft
- Thomas Fischer, German Trade Union Confederation
- Dr. Carolin Kranz, BASF SE
- Dr. Kai Lindemann, German Trade Union Confederation
- Dr.-Ing. Jan-Philipp Prote, e.Go REX GmbH
- Christian Schubert, BASF SE

Concept, text and interviews

- Florian Süssenguth, acatech Secretariat
- Dr. Jorg Körner, acatech Secretariat
- Dr. Annka Liepold, acatech Secretariat

Assisted by

- Louisa Everett, acatech Secretariat
- Stefan John, acatech Secretariat
- Silke Liebscher, acatech Secretariat
- Elisabeth Paul, acatech Secretariat

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1 The challenge: a rapid and sustainable reboot of Europe's economy

In essence, the **European Green Deal** launched by Ursula von der Leyen at the end of 2019 aims to transform our economy by decoupling growth and prosperity from the consumption of finite resources. Conceived as Europe's **response** to the global challenge of **climate change**, it seeks to create a framework for Europe to achieve climate neutrality by 2050, while at the same time proactively managing the **social transitions** for workers in the industries and sectors affected by the transformation and maintaining Europe's **global competitiveness**.

The economic crisis triggered by the **SARS-CoV-2 pandemic** has led to singular calls for the Green Deal to be shelved on the grounds that it constitutes an additional burden for the economy. The experts consulted for this publication unanimously and emphatically reject these calls. The pandemic cannot result in **innovation policy being put on hold**.

It is vital to maintain and develop Europe's innovative capacity in order to secure its competitiveness and technological sovereignty as well as successfully accomplish a sustainable, long-term **reboot of the European social market economy**.[1] Achieving this goal will require **learning, adaptive strategies** that are regularly adjusted to reflect new developments in both the economy and the relevant technology fields.

The experts regard the **Green Deal's objectives and individual elements** as **a valuable blueprint that lays the foundations** for the corresponding stimulus packages and economic programmes. They reject the critics' calls for the Green Deal to be shelved, arguing that it in fact provides a particularly suitable basis for the relevant programmes because it focuses primarily on **driving growth through investment and innovation** rather than on rollbacks and bans.

Accordingly, the best way forward is to align the **stimulus packages and economic programmes** adopted in response to the pandemic with the Green Deal's objectives, instruments and timelines.[2] According to the experts, failure to take sustainability aspects into account would send out the wrong signal, especially since many industries have already started the transition to a sustainable model.

The environmental, economic and social dimensions of sustainability

The Green Deal's concept of sustainability can provide valuable guidance for efforts to bring about the transition. In the Green Deal, sustainability means striking a balance between the **environmental, economic and social dimensions**. It recommends an approach that **avoids focusing exclusively on any one** of these three dimensions to the detriment of the other two. Transformation strategies that achieve a balance between the different dimensions are attracting more and more attention in general, and can provide a useful framework in this context.[3]

Consequently, as well as focusing on the relevant **climate targets,** efforts to bring about the transformation should also facilitate economically **viable business model transitions** and the restructuring of value networks. This includes both supporting the emergence and **growth of powerful new competitors** and the proactive **management and financing of social transitions** coupled with continuous training and professional development of the workforce.

This is sometimes easier said than done. Any **potential conflicts must therefore be identified and addressed as soon as possible** through close cooperation between businesses, employees, academia, policymakers and the public. This will be even more important in the wake of the pandemic, when hard-pressed government and corporate budgets will have less scope to resolve conflicts by increasing spending.

The experts believe that current **public opinion** provides a favourable **climate** for achieving the desired balance between the different dimensions of sustainability. **Awareness of climate issues is high** and there is widespread support for the relevant climate targets.[4] It is also becoming apparent that employees and the general public see **no fundamental contradiction** or conflict between **measures to alleviate the economic crisis** and sustainable value creation.

1 | See acatech 2020.
2 | See Leopoldina 2020.
3 | See Raworth 2017.
4 | See Hoevermann/Fulda 2020.

Recent surveys have found that the SARS-CoV-2 pandemic and resulting economic crisis **have not pushed climate action down** the public's policy agenda. Moreover, most people do not think that there is a **fundamental conflict** between measures to mitigate the **economic crisis** and a stronger **focus on sustainable value creation**. However, if any conflicts between Europe's economic recovery and climate action programmes were to arise, the vast majority strongly believe that the economic recovery should be prioritised, at least in the short term. This highlights the importance of **pursuing the two goals in tandem**, both at the decision-making stage and in the development and implementation of the relevant programmes.

Innovation can play an important role in **mitigating any conflicts**. In many cases, social, technological and business model innovations can even create **win-win situations** among former competitors.

In **manufacturing industry**, it is possible to avoid zero-sum games that pit the cessation or reduction of carbon-intensive steel production against the protection of steel industry jobs, for example. Instead, modern, **climate-friendly technologies** (such as Carbon Direct Avoidance in the production of green steel, see Box 2) can deliver long-term solutions that – taking account of the climate damage they prevent – address the social dimensions of sustainability as well as the environmental and economic aspects. However, these **welfare gains** will require the **creation of the relevant infrastructure**.

This will also be necessary to **fully harness the potential of digital solutions**. The **shortcomings** in this area that have been so starkly exposed by the pandemic are not confined to the healthcare system. The key digital systems that make it possible to keep the economy going while still protecting public health are only now starting to be modernised. The **experience currently being gained** with working from home, remote maintenance and initiatives such as the creation of platforms providing real-time information on the number of free intensive care beds must be used as a **springboard** to accelerate the digital transformation.

Windows of opportunity currently exist **at European level** to set the relevant **priorities** and establish **flagship projects** that can act as major drivers of a sustainable transition throughout Europe. It is vital to adopt this approach, **rather than** pouring large amounts of money into the artificial **preservation of antiquated structures** and allowing path dependencies to hold back efforts to modernise industry for decades to come.

Resilience: an additional requirement for the new structures being created

The direct impacts of the shutdown of large parts of Europe's economy due to the pandemic have provided a stark reminder that any transformation of Europe's economic engine can only be undertaken while it is still running if it is to be accomplished without causing a dramatic downturn. The disruption has highlighted weaknesses and **vulnerabilities** in existing **economic structures and business models**, meaning that it is no longer possible simply to return to pre-pandemic business as usual.

Consequently, the transformation of industrial and economic structures must be geared towards increasing their **resilience** as well as their sustainability. Here too, any potential conflicts must be identified and addressed as soon as possible.[5] **Resilience** is the ability to factor in potential adverse events of all kinds and to prepare for them, avert them if possible, cope with them if and when they occur and recover from them, thereby creating a new normal that is better adapted to the current circumstances (see also Chapter 2.5).[6]

It also means that government, science, industry and civil society must learn to **think in terms of multiple future scenarios** and ensure that there is enough **flexibility** to allow agile adaptation. Once immediate solutions have been found to address the acute impacts of the crisis, it will be necessary to engage in a **period of joint reflection** in which the lessons learnt from the pandemic are analysed and translated into **concrete measures** to increase the resilience of the economy and other areas of society. This can be facilitated through prompt funding for research projects that systematically identify the impacts of the crisis and the strategies developed to address them.

Main focus of the IMPULSE publication

This IMPULSE publication focuses on **two main priorities** that derive from Germany's position as a highly industrialised member of the EU. It is from this perspective that ideas and solutions are formulated so that they can be put forward by Germany at European level, where they will need to be weighed up against the interests and perspectives of member states with different economic priorities and structures.

5 | See FAZ 2020b.
6 | See acatech 2014.

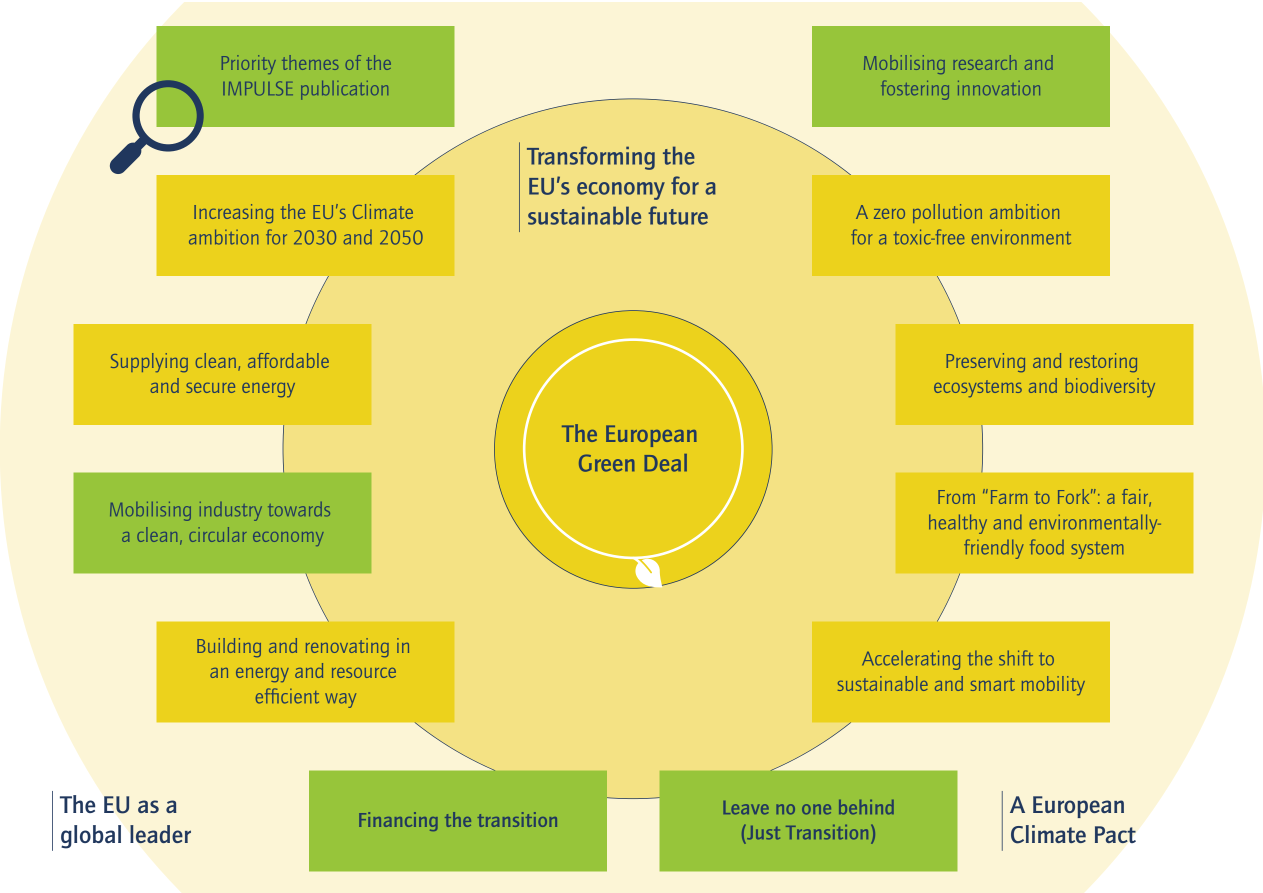


Figure 1: The European Union's Green Deal (focus areas of IMPULSE publication in green, source: authors' own illustration based on EU COM 2019d)

The first priority concerns the **transition to sustainable industrial production**, while the second relates to the instruments and conditions needed to mobilise capital for the required **investment**. This covers some, but not all, of the main priority areas identified in the Green Deal (see also Figure 1).

This focus in no way implies that the elements of the Green Deal not addressed in this publication are any less important to the successful reboot of the European economy and its long-term transition to a sustainable model. For example, almost all the industrial transformation pathways outlined in this report are reliant on **a significant increase in the availability of renewable electricity**. **Box 1** provides a brief **overview of other key fields** that are not examined in detail in this publication.

Structure of the IMPULSE publication

The first focus is the **transition** to environmentally, economically and socially **sustainable industrial production**. The interviewed representatives from industry estimated that optimisation of existing manufacturing technologies and value networks will only be enough to meeting roughly half of the relevant climate targets. The more challenging second half will call for **innovations** that go beyond the physical production process, including innovations in behaviour, a supportive regulatory framework and new business models **across the entire value and usage chain**.[7]

Chapter 2 presents the **main drivers** for delivering the desired transformation of industrial production:

7 | See WEF/BCG 2020.

- The use of **hydrogen** and hydrogen-based synthetic energy sources, coupled with the **electrification** of processes that currently use fossil resources.
- The **digital transformation** as an enabler of the other drivers and of sustainable business models.
- A **circular economy** approach that provides a conceptual framework for new technological solutions and business model innovations to close resource loops.
- A **biological transformation** offering a holistic approach to resource-efficient manufacturing techniques and processes throughout the product life cycle, from design to recycling.

Chapter 3 illustrates the existing potential for greater sustainability through **the example** of the **plastics industry value cycle**. It shows how a transformation of the overall system cannot be accomplished through the piecemeal replacement of individual products by environmentally-friendlier alternatives. Instead, science, industry and government must work together to bring about a fundamental transformation, creating industrial value networks and business models that are sustainable but still globally competitive.

These changes will call for high levels of investment that cannot be covered by the State or the corporate sector on their own. It will therefore be necessary to mobilise **private capital for sustainability** initiatives. **Chapter 4** discusses various instruments that can help to increase transparency and comparability in the fields of **sustainable finance** and corporate sustainability **reporting**. Germany has the opportunity to promote common, user-friendly European standards that attach equal weight to the environmental, social and economic dimensions.

Chapter 5 discusses institutions and instruments that could be used or strengthened as part of a **coordinated European approach** to achieving **sustainability through innovation**. These include everything from the European Investment Bank to specific regional initiatives to support the transition, the establishment of a level playing field in relation to producers in markets with lower climate and sustainability standards, and a focus on sustainability in the important public procurement sector. The forthcoming European Research Framework Programme must support basic research that is not limited to specific topics and supplement it with new transfer and innovation initiatives such as the European Innovation Council.

Box 1: Other priority areas for achieving sustainability goals

The experts interviewed for this publication were unanimous in the view that intelligent, cross-sectoral planning is essential if sustainability measures are to succeed as a whole. Accordingly, some of the areas that overlap significantly with the two main topics of finance and industry are briefly outlined below and referred to at the appropriate points in the text, but are not addressed in detail in this report.

This IMPULSE publication regards the climate targets that have been committed to by Germany as set.

Energy transition

The availability of an **adequate supply of renewable energy** is fundamental prerequisite to meeting the climate targets. The electrification of industrial processes will lead to a **rise in demand for electricity**.[8] Energy in the form of electricity and heat is a **fundamental requirement for industrial production** in most sectors.

While Germany has already made big strides, the energy transition must not stall now.[9] The current **renewable energy targets will need to be met** or even **increased** if the measures proposed in the following chapters are to be implemented and the desired sustainability goals achieved throughout industry by 2050.

Since most renewable energy in Germany comes from volatile sources such as wind and solar, the **systematic expansion** of the country's smart grid **infrastructure** is absolutely vital. The energy system of the future must be able to smartly **couple and distribute** energy that has been produced in a decentralised manner.[10] Implementation of the energy transition is thus inextricably linked to digitalisation. Recommendations and guidelines for the energy sector have been produced in Germany by the ESYS working group "Energy Transition 2030" and are also being formulated at European level by Science Advice for Policy by European Academies (SAPEA).[11]

8 | See DECHEMA/FutureCamp Climate GmbH 2019.
9 | See EWI 2020a; 2020b.
10 | See ESYS 2020.
11 | See Leopoldina et al. 2020.

Mobility

Mobility in Germany is in transition and is currently facing major challenges. **Transport** is the **fourth biggest** greenhouse gas **emitter** in Germany, after the energy, industrial and heating sectors. By 2030, Germany aims to reduce its emissions by 42 per cent compared to the baseline year of 1990. The six working groups of the **National Platform Future of Mobility (NPM)** are formulating concrete, cross-modal recommendations that address the environmental, social and economic dimensions of the future of mobility.

A key focus of the NPM's work is on **reducing CO_2 emissions** without compromising mobility. Specific **priority areas** include alternative drives for passenger cars and HGVs, more efficient vehicles, increasing the use of alternative fuels, promoting rail and bus passenger transport, cycling and walking, strengthening rail freight transport and inland navigation, and leveraging the benefits of digitalisation. In particular, there is a **technology-neutral** focus on alternative drives and fuels such as electric mobility, fuel cells and hydrogen, and electricity and biofuels.[12]

The **European hydrogen economy** described in Chapter 2.1 as one of the drivers of the transformation is thus directly **relevant** to the transport sector and to **Germany's automotive industry**.

Forestry and agriculture

The **forestry, agriculture** and food sectors can play a significant part in achieving the sustainability goals and realising bioeconomy models.[13] Forestry and agriculture are sectors that can actively help to **sequester emissions** in the soil and **protect natural resources**. This can be supported through afforestation, changes in cultivation methods and innovations in seed, breeding and plant protection products.[14]

Agriculture is also the largest single recipient of **direct EU subsidies**. This means that the European Commission can directly utilise the **criteria and conditions for awarding subsidies** as a powerful **driver** of the transformation. Once again, however, it is important to reflect the three dimensions of sustainability. Realisation of the **ecological opportunities** must be **compatible** with **socially and economically** sustainable solutions for the people who work in the agricultural sector.[15]

In the **food industry**, innovative solutions such as lab-grown meat could help to **reduce food-related emissions** while also contributing to the protection of natural resources in a scenario where land is no longer needed to produce feed.[16] Promising approaches to **preventing** the high levels of **food waste** that currently occur include more efficient use of food, better monitoring of distribution channels and consumer education.[17]

Construction

In general, the experts agree that the construction industry has a key role to play, both in achieving climate targets and in the stimulus packages and economic programmes for tackling the economic consequences of the pandemic. This study takes a closer look at the important contribution of techniques for the production of **green steel** (see Box 2) and **climate-friendly cement** (see Box 4). However, it does not address the remaining **life cycle** of these products in the construction industry or the potentially major contribution of energy-efficient retrofits of existing buildings.

12 | See NPM 2019a; 2019b.
13 | See SAPEA 2020.
14 | See BCG 2019b; BMEL 2019; BMU 2016.
15 | See acatech 2019a; BReg 2019c; EU COM 2020d.
16 | See McKinsey & Company 2019c.
17 | See EU COM 2016; FUSIONS 2016.

2 Solutions for a more sustainable industrial sector

The sustainability targets and the objectives of the Green Deal cannot be achieved without a transformation of industry. A number of technologically mature solutions already exist that can be used to transform value networks across different industries and sectors. Hydrogen and electrification are driving the decarbonisation of industrial processes. Together with the digital and biological transformation, overarching concepts like the circular economy provide the basis for protecting resources and adding value through new business models.

The recovery and rebound of Europe's economy in the wake of the SARS-CoV-2 pandemic must support the **objectives of the Green Deal and the Digital Europe Programme**. Accordingly, the approaches to transforming value networks outlined in this chapter should occupy a **key place** in the design and implementation of the **recovery measures**.

In most cases, the creation of sustainable value networks will be an incremental process that takes several years. This is particularly true of the Germany economy, with its strong **industrial sector** and very **long investment cycles**. Consequently, the **first or next steps** in the transition towards a sustainable German and European economy **must be taken without delay**, in order to ensure that the **climate and sustainability goals** are delivered in the long run.

A **twin transition** where the transition to a sustainable economy goes hand in hand with the digital transformation is key to long-term **prosperity, value creation** and **global competitiveness** in Germany and Europe. This symbiotic approach is already anchored in the combined content of the **European Industrial Strategy, Green Deal** and **Digital Europe Programme**. Now it must be fleshed out in order to enable the transition to business models that are both sustainable and robust.[18]

"Carbon pricing is the key innovation driver. It also provides the most economically efficient means of transforming the economy and is thus a more effective alternative to piecemeal individual measures."

According to **the overwhelming majority of the experts interviewed**, the extension of effective **carbon pricing** to additional sectors should form the basis of the economic transformation. This is **key to the economic viability** of many of the cross-sectoral **drivers** identified in this publication and will accelerate their large-scale market introduction. The experts call for an **approach that is effective throughout Europe** and recommend that the desired **long-term price increases** should be determined strategically.

However, it is also important to ensure **mitigation of the social impacts** of carbon pricing.[19] Moreover, accompanying measures will be required to create **a level playing field** between European providers and providers from markets with lower climate and sustainability standards. This is vital in order to strengthen the European economy and **prevent both an exodus of manufacturing industry and carbon leakage** (e.g. through a Carbon Border Adjustment mechanism, see Chapter 5.1).

This approach would help to address the huge uncertainty that, according to the experts, is currently preventing businesses and investors from pushing ahead with a comprehensive transformation. A **reliable basis for long-term planning** is essential if the necessary large-scale investments, for instance in more climate-friendly production facilities, are even to be contemplated. It would also significantly **reduce the time needed to make more sustainable business models economically viable and competitive.**[20]

"The only chance is to spend the money we have now wisely. We can only spend it once."

Almost all the experts agreed on two key points: investing **to transform value chains** is expensive and **requires policy support across all industries** in the shape of a favourable framework. Nevertheless, the cost of making the relevant investments now **will be significantly lower** than the **cost of mitigating** the future impacts of climate change. The interviewees also believe that an innovative climate-friendly and sustainable manufacturing

18 | See EU COM 2019b; 2020b; 2020h.
19 | See DGB 2019.
20 | See HBS 2019; ifo Institut 2019; Leopoldina 2019; MCC/PIK 2019.

industry will give Germany and Europe the **opportunity** to maintain their position **as leading global competitors**.

Individual businesses will need to identify the exact places where **transforming their manufacturing processes**, replacing materials and **changing their business models** can lead to a more sustainable way of doing business and in particular to the prevention of greenhouse gas emissions. According to the experts, however, this cannot be achieved solely by optimising existing structures. Instead, it will call for **a diverse innovation portfolio across the entire value chain**. The experts repeatedly identified the following, often mutually complementary solutions as **the key drivers** for delivering the Green Deal's objectives:

- Hydrogen/electrification
- Digital transformation
- Circular economy
- Biological transformation
- Carbon Capture and Utilisation/Carbon Capture and Storage (CCU/CCS)

In the case of particularly carbon-intensive industrial processes, **CCU/CCS** technology that enables the reuse and storage of carbon can help to achieve carbon neutrality. However, since CCS technology will only become a viable solution in the medium term, it is not examined directly in this chapter. Instead, it is addressed in Appendix B.

Advanced technology already exists for all the other **solutions** referred to above, often thanks to first-class research in Germany and Europe. The following sections describe **the priority steps and measures** identified by the experts, together with the **concrete goals** that should be achieved **in the next five to ten years**. They also outline possible **ways of providing policy support** for the introduction of the relevant solutions and further research projects to optimise the technologies in question.

2.1 Electrification and hydrogen – the sustainable energy sources of the future

In the future, the energy required by industry must come from renewable sources. Carbon-neutral hydrogen and the electrification of manufacturing processes can provide the basis for this shift. The necessary infrastructure must be built now so that businesses can start transforming their processes and implementing sustainable business models.

> *"There is no sign of any alternative to hydrogen on the horizon."*

The highly industrialised nature of Germany's economy means that there is huge potential to reduce greenhouse gas emissions in industrial value chains. The **transformation of industry** can therefore make a **major contribution to achieving Germany's climate and sustainability targets**. The **decarbonisation of manufacturing processes** has a key role to play in this context. The use of hydrogen and the electrification of production processes are two key solutions that can help to reduce manufacturing industry's dependence on fossil fuels.

Innovative solutions for reducing industrial CO_2 emissions are also necessary because Germany and Europe have very **little capacity to create natural carbon sinks**, for example through afforestation. According to several different experts, the global figure for the amount of CO_2 that could potentially be sequestered from the atmosphere through afforestation is over 200 billion tonnes. However, most of the land identified as suitable for afforestation is found in Russia and North America.[21]

Hydrogen: a versatile fuel for sustainable, climate-friendly industry

Hydrogen can be **used throughout industry** and provides the basis for innovative **Power-to-X solutions**.[22] The goal should be to obtain hydrogen from carbon-neutral sources in order to maximise its contribution to meeting climate targets in industry and in the heating and mobility sectors.

The **market ramp-up must begin as soon as possible**, even if it is not initially possible to produce all the hydrogen carbon-neutrally. **Viable transformation pathways** must be identified across the whole of industry. There was some disagreement among the experts regarding how efforts to achieve a green hydrogen economy can strike the optimal balance between cost-effectiveness, readiness for large-scale industrial deployment and carbon intensity.

21 | See Bastin et al. 2019; IPCC 2018.
22 | See ESYS 2017.

Germany is a leader in hydrogen-related technologies. It must **take advantage of** and strengthen **this world-leading expertise in the relevant research fields and industries**. Particular emphasis should be placed on promoting hydrogen technologies **across the entire value chain**, from production (electrolysers), storage and compression to liquefaction and transport.

Hydrogen's current applications fall a long way short of its potential. To fully tap into this potential, **a systemic approach to the expansion of the necessary infrastructure should be pursued at European level**. The Industrial Strategy for Europe published in March 2020 already contains the goal of a trans-European infrastructure for carbon-neutral hydrogen.

The necessary technology for producing hydrogen by electrolysis is already functionally mature. However, further support is required to make it ready for commercial applications and to **generate the economies of scale** needed to bring down the currently very high cost of purchasing this technology.[23]

The **German and European hydrogen strategies** called for by most of the **experts** interviewed have now been launched, marking an **important step** towards the realisation of a European hydrogen economy.[24]

The recently founded **European Clean Hydrogen Alliance** brings together investors and representatives of industry and government with the aim of **identifying and adapting** the necessary **regulatory conditions**, initiating concrete research projects and developing the relevant technologies.[25]

"Europe must win the race for Power-to-X and the hydrogen economy. And I believe we can."

The Fuel Cells and Hydrogen Joint Undertaking (FCH) has initiated the Hydrogen Valleys (H2Vs) **platform** to provide an overview of **current research projects** at European level and facilitate a **dialogue** between the actors. The platform is still currently under development and is scheduled to go fully live in December 2020.[26]

In addition, the European industry association Hydrogen Europe is already working with partners from industry such as BMW, DB Schenker and Siemens, as well as regional organisations and research institutes, to develop concrete **plans for possible projects under the planned hydrogen IPCEI**.[27]

The experts welcome the plans for a **hydrogen IPCEI** to drive R&D into hydrogen technology and its initial industrial introduction at European level. They also hope that, in addition to those member states that are already interested, such as Austria, Denmark and Germany, it will encourage other nations to get involved in the project to create a European hydrogen infrastructure.

The interviewees believe that a hydrogen IPCEI can help to **overcome** the current **shortfall in the investment** needed to develop and scale up hydrogen technology. They underline the importance of building a pan-European hydrogen infrastructure in order to ensure an adequate supply of hydrogen in all the regions where demand exists.

In Europe, hydrogen production is primarily of interest to the **southern European member states** that can harness their extensive solar energy resources to power the energy-intensive electrolysis process used to produce green hydrogen. Countries such as Spain and Portugal have a particular **opportunity to develop sustainable local industries**. This should be supported by Central European countries such as Germany that need the hydrogen produced in southern Europe for their domestic industry. The production of hydrogen in Germany can also be supported by lowering ancillary electricity charges and removing regulatory barriers, as well as through the ambitious implementation of the EU's Renewable Energy Directive (RED II).

"We have to recognise that Germany remains a net energy importer."

Most of the experts interviewed said that in addition to promoting hydrogen production and the infrastructure required to transport it within Europe, a **concrete import strategy is also vital**, since Europe will not be able to produce enough renewable hydrogen to meet demand from industry. Ultimately, only **hydrogen that has been produced carbon-neutrally** can help to meet the relevant climate targets in industries such as steel manufacturing (see Box 2).

23 | See FNB Gas et al. 2020; NPM 2020.
24 | See BMBF 2019a.
25 | See EU COM 2020b.
26 | See FCH/MI 2020.
27 | See HydrogenEurope 2020.

Box 2: "Green steel" – towards sustainable heavy industry

The **steel industry** is extremely important to the economies of both Germany and Europe as a whole. While current steel manufacturing processes are very **carbon-intensive**, innovative **hydrogen-based** production methods promise to make them much more climate-friendly. The German Environment Agency has calculated that the use of hydrogen in the iron and steel industry could **cut CO_2 emissions by approximately 38 million tonnes a year**.[28]

The European Commission also recognises that steel has a key part to play. It is seeking to explicitly promote climate-neutral steel through its **industrial strategy** in order to bring forward the point at which it can compete in the market.[29] The use of **renewable hydrogen** is **key** to the production of **green steel**.

At present, there are two different approaches to making greener steel. The first involves the **direct avoidance of carbon by using hydrogen instead (Carbon Direct Avoidance**, CDA). This process, in which hydrogen replaces coking coal in existing blast furnaces, has the potential to **reduce CO_2 emissions** by somewhere between **20% and 30%**.[30] The experts see this as an important **transitional technology** that can be deployed immediately in existing blast furnaces while facilities for more climate-friendly alternatives are being built.

Ways of achieving an even **higher level of Carbon Direct Avoidance** in the manufacturing process are currently being investigated in initiatives such as **SALCOS, a research project** led by Salzgitter AG in collaboration with the Fraunhofer-Gesellschaft and systems engineering company Tenova.[31]

The second approach involves capturing the carbon produced during the manufacturing process so that it can be **utilised in other industries (Carbon Capture and Utilisation**, CCU). The Federal Ministry of Education and Research-funded joint project Carbon2Chem has already successfully demonstrated that the carbon generated during steel production can be **captured from the steel mill gases** and used as a **base chemical** in the chemical industry, for example to produce fertiliser or plastics. The hydrogen needed to convert the carbon into base chemicals is produced by companies that have surplus renewable electricity.[32]

According to the experts, **producing green steel** is the **only way** that Germany and Europe can **remain globally competitive** in this industry, especially in view of the reductions in CO_2 emissions required to meet the sectoral targets. In the future, conventional steel made in Europe will no longer be able to compete in the global market.

Since the **costs of producing green steel are currently still high, policymakers must create a framework** that **promotes its manufacture** so that it can eventually become competitive. This will require them to work closely with the steel industry to support its transformation. It is important to bear in mind that blast furnaces take between 5 and 10 years to convert and will then remain in service for approximately 30 years. It will also be necessary to ensure the long-term **availability of** sufficient quantities of **green hydrogen** to provide companies with the reliable planning basis that they need in order to make the required investments.

The prioritisation of green steel in **public procurement** can also serve as a useful instrument for scaling up the technology in Germany and Europe. The use of **Carbon Contracts for Difference** as an incentive should also be investigated.

The long-term objective should be to create a **level playing field in the global market** through **effective global carbon pricing**. At present, however, this goal remains a long way off, since the climate targets in other parts of the world that compete with Europe are in some cases far less ambitious than the European targets. **Carbon leakage protection** (for instance through a Carbon Border Adjustment mechanism, see Chapter 5.1) should therefore be considered as an alternative solution.

28 | See UBA 2019b.
29 | See EU COM 2020b.
30 | See Westdeutsche Zeitung 2019.
31 | See IHK 2019.
32 | See Thyssenkrupp 2020.

As well as its major areas of application in (heavy) industry, hydrogen also has multiple applications in the transport sector. The first production models of hydrogen-powered road and rail vehicles are already available. Hydrogen's high energy density makes it particularly suitable for vehicles used for long-distance travel. At present, however, there are hardly any hydrogen fuel cell models on the market. As a result, hydrogen-powered vehicles are still rarely seen on our roads and railways. However, the market for **hydrogen-based drive technologies for road and rail is projected to grow** in the medium to long term.[33] The key to this will be an **extensive network of hydrogen filling stations throughout Europe** that can deliver an adequate supply of ideally low-carbon hydrogen for cars and HGVs.

In the long term, **green hydrogen** will therefore **play a key role throughout industry** as a storage medium, energy source and chemical reactant, and as a fuel in the transport sector.[34] Accordingly, in order to address both the sustainability and value creation dimensions, it will be necessary to adopt a strategy of importing hydrogen and exporting electrolysis technology and fuel cell systems and vehicles.

Electrification: sustainable industrial production using electricity

The **electrification of industrial processes** that currently rely on fossil fuels is a very promising means of reducing emissions in manufacturing industry. However, it is important to bear in mind that the electrification of industrial processes will also cause a **significant rise in electricity demand**. If the electrification of manufacturing is to be sustainable, the electricity used must be **renewable**. A projection produced by DECHEMA on behalf of the German chemical industry association (Verband der Chemischen Industrie, VCI) shows just how dramatic the increase in electricity demand would be in the chemical industry alone, if it were to switch its production processes and become largely climate-neutral by 2050 (see Figure 2).[35]

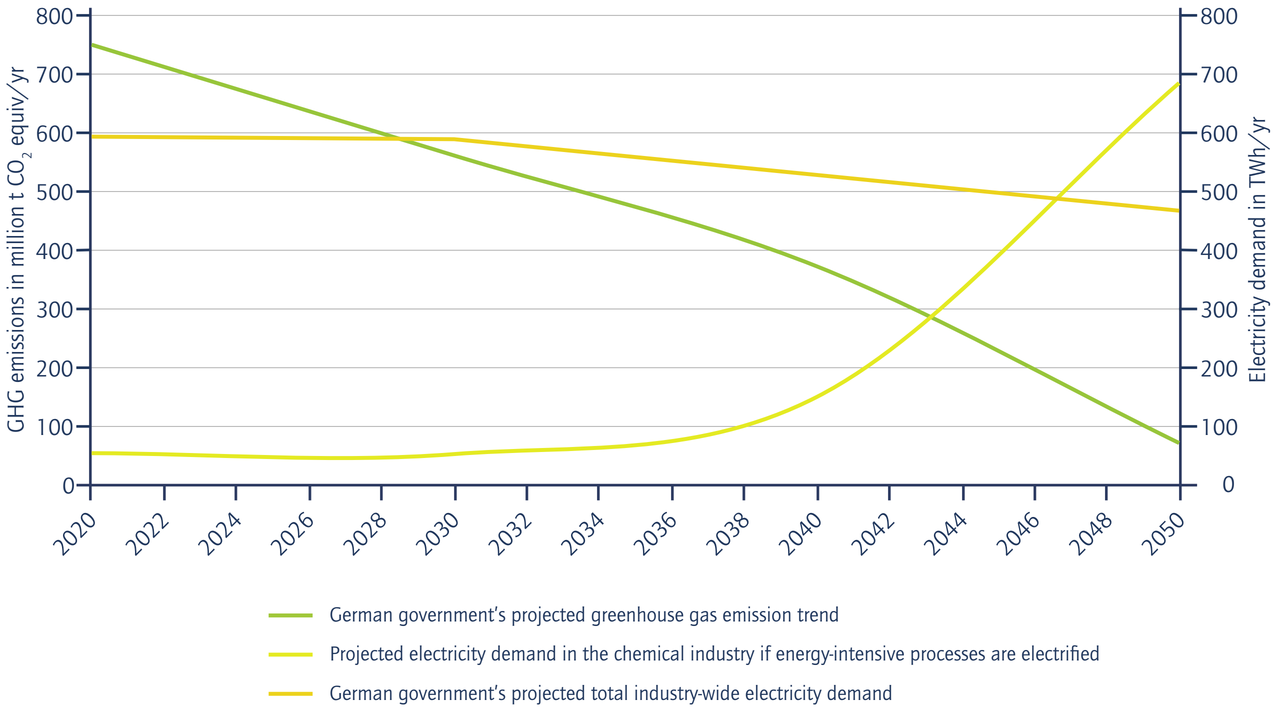


Figure 2: Germany's projected electricity demand based on reductions in greenhouse gas emissions up to 2050 (source: authors' own illustration based on Bundesnetzagentur 2019; DECHEMA/FutureCamp Climate GmbH 2019; UBA 2010)

33 | See Hydrogen Council 2017.
34 | See NPM 2019b; 2020.
35 | See DECHEMA/FutureCamp Climate GmbH 2019.

The **supply of renewable energy** must be regularly **compared against industrial demand** and **adjusted** accordingly. Unless there is an adequate supply of renewable energy, it will often be impossible to ensure climate-neutral implementation of the measures proposed in the following chapters, meaning that they will no longer be effective. The **German government's total electricity demand projections**, especially post-2030, are at present significantly lower than the **demand projected by certain individual industries**.[36] According to the experts, **major technological transformations** will be required in many industries, particularly to **achieve the last 10%-15% of the desired emission reductions**. Among other things, this will result in high electricity demand.

The European Commission has recognised the need to expand renewables and is calling for a **strategic increase in renewable energy production**.[37] The experts recommend that **electrification** should be promoted **in parallel with this expansion of renewables**. Even if some of the electricity does not initially come from renewable sources, it is important to start introducing and developing the technology now so that it is more efficient and competitive in the long run.

The expansion of renewables and a smart combination of **centralised and decentralised elements** are vital to successful electrification and to the **energy system of the future**.[38] At European level, the planned **European data space** could support the intelligent coupling of renewably produced energy in **smart grids**.[39]

Proposed measures

- **Development of a concrete, pan-European hydrogen infrastructure strategy**: This will require identification of appropriate locations for hydrogen production in Europe and planning of the physical infrastructure needed to transport the hydrogen from where it is produced – most likely in sunny southern European locations or windy coastal regions – to the industrial manufacturing facilities where it is needed. Strategies for transporting hydrogen from other parts of the world will also be necessary.
- **Conclusion of strategic partnerships to import hydrogen**: In order to meet projected demand, Europe will need to supplement its own hydrogen production with imports. It should therefore seek to conclude strategic partnerships with reliable international partners who produce sustainable hydrogen, for example Australia and the sunny MENA region. This could also have the positive side effect of supporting the regions in question by creating jobs and developing alternative industries in markets that are currently heavily focused on fossil fuels.
- **Comprehensive analysis of electricity demand trends**: If the electrification of industrial processes is to be sustainable, the electricity used must be renewable. In order to ensure an adequate supply of renewable energy, a detailed analysis of projected electricity demand should be carried out at European level, or at the very least in Germany. Although existing processes are expected to become more efficient, the electrification of mobility and industrial processes will still cause electricity demand to rise across the whole of industry. Future expansion of renewables should be based on the outcomes of this analysis.

2.2 The digital transformation – virtual optimisation of value chains

By supporting the transition to a sustainable economy, the digital transformation is paving the way for the future competitiveness of Germany and Europe. Digital solutions can deliver production efficiency gains and enable completely new business models throughout the whole of industry. Policymakers must create the necessary framework and infrastructure to support the continued digital transformation of the economy – especially the SME sector – and of everyday life.

It is vital to adopt a systematic, joined-up approach to the **digital transformation** and sustainable development, since in the future, digital technology will play a key role in every sector of industry. Digital applications often provide the **basis** for implementing the **other drivers identified above** and the **accompanying business models**. A future-proof digital infrastructure is thus a key enabler.

Framework and opportunities for a digital transformation of the economy

In order to ensure that the German and European economies remain competitive, a **twin transition** will be required, in which

36 | See Bundesnetzagentur 2019; DECHEMA/FutureCamp Climate GmbH 2019; UBA 2010.
37 | See EU COM 2020b.
38 | See ESYS 2020.
39 | See EU COM 2020b.

the objectives of the Green Deal are pursued in tandem with the systematic implementation of the Digital Europe Programme and the Shaping Europe's Digital Future strategy.[40] A European data strategy and AI strategy were presented as part of this programme in spring 2020.[41]

The **goal of a digital transformation** of European industry is also **firmly anchored** in the **new European Industrial Strategy**.[42] Building on the Digital Agenda 2014–2017, the German government's 2019 Shaping Digitalization strategy sets out the basis for the ongoing implementation of Germany's digital transformation.[43] The next step is to create the required framework at German and European level and ensure that the planned projects are realised swiftly and systematically.

> *"Digitalisation is a key enabler of Germany's and Europe's future success."*

Industrie 4.0 will help companies to become more sustainable by enabling even more precise monitoring of the production process through the digitalisation and interconnection of (additional) process operations. This can support **more efficient and resource-efficient** manufacturing, and also fits well with the profile of German industry as a leading producer of **green tech**.[44] The overview in Figure 3 provides examples of how digitalisation instruments can be used to achieve a sustainable transformation of industrial processes.

The use of **digital twins** can **cut companies' development times by up to 75%** and reduce their costs by over 30% per part.[45] According to the experts, it also makes it possible to incorporate enhanced **refitting** and **remanufacturing** into the design right from the planning phase and to optimise the efficiency of the system as a whole. Digital twins can also help to **digitalise supply chains**. In many areas, problems such as a lack of common standards or media disruption such as paper consignment notes currently prevent a transparent, end-to-end **overview of goods**

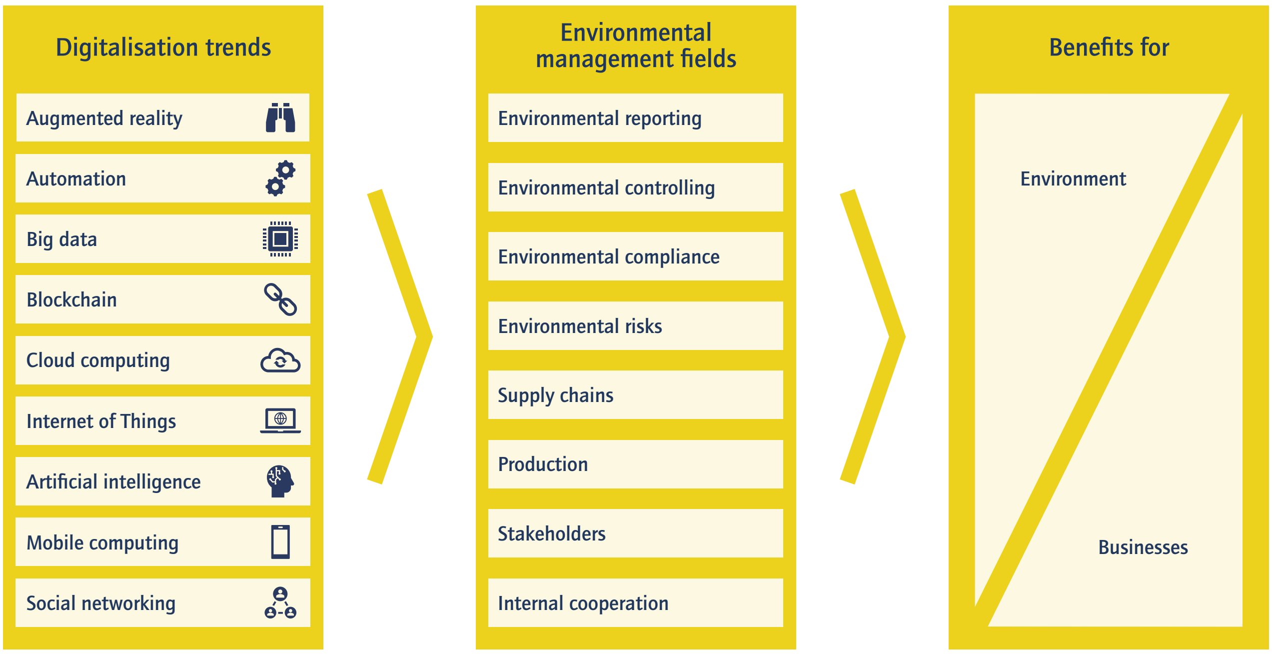


Figure 3: Potential benefits generated by the use of digitalisation instruments in environmental management (source: authors' own illustration based on UBA 2019b)

40 | See EU COM 2019b; 2020f.
41 | See EU COM 2020a; 2020k.
42 | See EU COM 2020b.
43 | See BReg 2014; 2019a.
44 | See BMU 2018.
45 | See ZVEI/Wegener 2020.

flows in real time. This also makes it harder to plan restarts after a break in production. Especially in the energy-intensive chemical sector, it is hoped that the digital transformation and circularity will combine to create "**Chemicals 4.0**" – an industry that uses resources more sustainably and emits significantly less CO_2.[46] Digital **tracking of material streams** and components is also essential for **circular economy** strategies.

Digital applications that are expected to play a major role in achieving sustainability targets – for example **artificial intelligence, big data and cloud services** – are **extremely energy-intensive** in their own right.[47] In view of the large amount of electricity consumed by data centres[48], it is **essential to keep improving** the **efficiency** of the relevant technologies. As a result, the field of **green IT** is gaining fresh impetus in the context of the digital transformation's environmental footprint.

R&D into **disruptive, low-energy storage media** is thus also extremely important in terms of providing an alternative that can help to significantly **reduce the energy demand of data storage systems** (see also Box 3).

However, it is important to take a **life cycle approach** to digital products and applications. One aspect that does not always get the attention it deserves is that, as well as consuming energy, **digital applications** also make a major contribution to **saving energy and optimising resource utilisation** in downstream processes. These savings are often several times greater than the amount of energy consumed by the application.[49] Smart meters and precision agriculture are just two examples of how digital solutions are already helping to meet climate and sustainability targets today.

According to the experts, **integrated digital industrial solutions** that, for example, help to measure the carbon intensity of a manufacturing operation in real time and, if necessary, intervene to manage it, have huge **value creation potential for German businesses** operating in the Industrie 4.0 sector.

Enabling value creation and flexibility through digital solutions

Value creation based on digital business models is becoming increasingly common throughout industry. Moreover, digital applications are fundamentally changing how and where value creation can occur in value networks.[50] The digital transformation **can open up new markets**, particularly for smaller, specialised businesses.

Smart, digital solutions are enabling the growth of **service-based business models** throughout industry, encompassing everything from the energy supply to improved grocery shopping transparency for consumers.[51]

According to the experts interviewed for this publication, the digital transformation enabled by Industrie 4.0 and automation could allow certain manufacturing processes to be carried out competitively in Germany and Europe again. This would require value networks to be analysed in order to **assess whether reshoring of production could be competitive** in certain instances. Reshoring would also result in shorter supply chains, which could in turn strengthen value network resilience.

Shortcomings of Germany's digital transformation

The current **SARS-CoV-2 pandemic** is **providing a huge boost to the digital transformation**. However, it is also **starkly exposing** the **current shortcomings** of the transformation in public administration, the healthcare system, schools, universities and businesses.[52] Nevertheless, it has been possible to create digital alternatives to analogue structures in a very short timeframe, for instance home working and remote maintenance solutions and digital retail platforms.

The success of the German government's **#WirVsVirus (Us vs. the Virus) hackathon** can also be seen as a demonstration of the digital transformation's potential to enable greater agility.[53] It will be important to **learn from and build on** the digital structures that are currently being created in order to keep companies and institutions open for business.

46 | See Deloitte/VCI 2017.
47 | See WBGU 2019.
48 | See Borderstep Institute 2015.
49 | See DIGITALEUROPE 2015.
50 | See McKinsey Global Institute 2019; Roland Berger 2017.
51 | See BMBF 2019b.
52 | See EFI 2020; Handelsblatt 2020.
53 | See BReg 2020a.

Box 3: Alternative digital storage solutions: skyrmions and synthetic DNA

In the long run, technological innovations that enable a **new form of low-energy data storage** will be necessary in order to create an alternative to today's energy-intensive data centres. Two solutions at different stages in their development are described below.

Skyrmion configurations could potentially be used as a **storage medium in the medium term**. Their extremely high potential storage density makes them an attractive computer memory solution, for example. This technology is based on established basic magnetic data storage principles. Skyrmions are stable magnetic whirls in fields, that behave like particles.[54] Skyrmion configurations are **highly stable**, even at room temperature, and can be used in liquid crystals. Tightly packed skyrmion configurations known as **"skyrmion bags" significantly increase storage potential** compared to linear arrangements in the form of chains.[55]

The concept of storing data on **synthetic DNA** is an exciting but even more distant **prospect for space-saving long-term data storage**. It is also an example of the **biological transformation of digital technology**. Hundreds of thousands of terabytes can be stored on a single gram of DNA. In theory, this means that the entire Internet could be stored in a DNA container the size of a shoebox. This extremely high data density would make it possible to create space- and energy-saving alternatives to or expansions of existing data centres, which currently consume very large amounts of energy. DNA molecules are also **extremely stable**.[56] For example, we can still retrieve information from mammoth DNA that is thousands of years old. This could open up a **new long-term dimension** for data storage.

The technique for storing data on DNA can be broadly described as follows: a software application **converts** the digital data's **binary code to DNA code** which is then stored **on synthetic DNA strands**; a sequencer can subsequently be used to retrieve the code and translate it back into information that can be used by a computer.

The practical proof that digital data can be encoded in DNA, stored in the DNA and subsequently retrieved was provided by a team of scientists in the US as long ago as 2012.[57] **In 2019**, a team at Microsoft Research took a major step towards scaling up the technology when it delivered **proof of concept** in the laboratory **of fully automated** DNA storage, including every stage from encoding and storage to retrieval.[58] This is a significant advance, since it eliminates the laborious manual processes that were previously necessary.

The automated **process is currently still very slow** – in the Microsoft Research experiment, it took around 21 hours to store and retrieve the word "HELLO". Moreover, the **production of synthetic DNA** is **a significant cost factor** and the **error correction** during decoding does not yet function perfectly. Nevertheless, the technology is so promising that the **first start-ups** have already been founded. Some, like Catalog in the USA, specialise directly in storing data on DNA, while others, like Kilobaser in Austria, are making the enabling technologies for key steps in the process.

"Our digital infrastructure is not good enough for an economy like Germany's."

The current pandemic is demonstrating just how **indispensable** a functioning **digital infrastructure** is for businesses, since it allows them to respond **flexibly and resiliently** to challenges and continue operating, even during **times of crisis** (see also Chapter 2.5).[59] Companies are reporting that they have **significantly accelerated** their **digitalisation activities** across all parts of their business and all steps in the value creation process during the SARS-CoV-2 pandemic.[60] **Pronounced differences exist between different industries** in terms of their requirements, their ability to implement digital initiatives and their existing expertise in this area.[61]

54 | See Spektrum.de 2017.
55 | See Foster et al. 2019.
56 | See Erlich/Zielinski 2017.
57 | See Church et al. 2012.
58 | See Golem.de 2019; Takahashi et al. 2019.
59 | See acatech 2020.
60 | See McKinsey & Company 2020a.
61 | See McKinsey & Company 2020b.

The same applies to educational institutions, prompting the experts to call for a rapid **digital transformation** in **schools and universities** over the next few years. The basis for this transformation could be provided by the "Offensive Digitale Schultransformation" (Digital Transformation of Schools Campaign), which was launched by the "Gesellschaft für Informatik" in response to the SARS-CoV-2 pandemic and is supported by a broad network of stakeholders from science, civil society and industry.[62] Digital classrooms could also be trialled. The goals for the digitalisation of schools that were established at the **education summits** in summer 2020 – for example the expansion of Wi-Fi networks and the provision of laptops – must now be followed up with **concrete measures**.

Digital working solutions such as **virtual meetings, working from home and digital services** contribute to the social and **environmental dimensions** of sustainability both at work and in people's everyday lives. A 6% increase in working from home in Germany (compared to 2015 levels) could reduce CO_2 emissions by up to 1.7 million tonnes.[63] Surveys have also revealed that employees think **the number of days they work from home will increase permanently** after the SARS-CoV-2 pandemic. Moreover, they see working from home as a good way of improving their work-life balance.[64]

In addition, systems based on digital technology, such as assistance systems and **human-machine collaboration** systems, can help to create a healthier working environment that also promotes learning. Moreover, some experts believe that, in the context of **demographic change**, human-machine collaboration could be used to **support older people** both in the workplace and with healthcare, for example.

Proposed measures

- **Development of a roadmap for the digital transformation of everyday life:** The development of a roadmap with clearly defined milestones and targets can accelerate the digital transformation of everyday life and enable flexible use of digital services by the public in the not too distant future. The goals should include digital access to all government services and the creation of online learning and teaching platforms to enable full digital participation in lessons at schools and universities within the next 5 to 10 years.
- **Creation of common European data spaces:** In order to further develop digital applications, especially those that use big data and AI, businesses must have secure access to data and data infrastructures. If implemented rapidly, a platform that conforms with the European General Data Protection Regulation could guarantee the secure exchange of anonymised enterprise data and support Europe's digital sovereignty.
- **Further digitalisation of supply chains:** In order to make global supply chains more flexible and resilient, industry must continue to drive their digitalisation, especially with a view to eliminating disruption, for example by introducing digital versions of paper consignment notes, and ensuring their scalability. Government can support these initiatives where the public authorities are actively involved in supply chains and through efforts to achieve common global standards.

2.3 The Circular Economy – decoupling economic growth from resource consumption and emissions

To ensure future value creation and prosperity in Germany and Europe, the economy must switch to circular business models wherever possible. As well as saving resources, this will also optimise applications for customers, for instance through "as-a-service" offerings. Regulatory frameworks should be adapted to make circular economy solutions economically competitive, for example by pricing in externalities. The circular economy has major synergies and overlaps with the bioeconomy and biological transformation.

The basic principle of the circular economy is to replace linear ways of doing business with a **circular approach**. Alongside several other advantages, this approach makes it possible to **minimise** both the **amount of virgin materials used** in value chains and the associated **damage to the climate and environment**.[65]

The circular economy **is much more than** a slightly **expanded recycling system** – 75% of its value creation potential lies in

62 | See GI 2020.
63 | See NPM 2019b.
64 | See bidt 2020.
65 | See Circular Economy Initiative Deutschland 2019.

business models outside of the recycling sector.[66] The circular economy addresses **three levels**:

1. Prioritising the use of **high-performance**, reusable **raw materials**
2. Maximising **products' useful life**
3. Preventing or reclaiming **by-products and waste products**

Figure 4 illustrates what these basic principles mean for the individual process stages, from new input, design, production, distribution and use to collection and recycling.

"We must reduce resource consumption, or it will never work. The circular economy and green tech are the right solutions for this."

The transition to this circular economy model will call for **technological and social innovations** and **new business models** across entire value networks. As well as reducing CO_2 emissions, a circular economy can also help to decrease resource dependence, make first movers more competitive and **open up new markets** for them, **create jobs**, and **strengthen resilience** (see also Chapter 2.5).[67] The circular economy has major synergies

Figure 4: Basic principles of the circular economy (source: authors' own illustration based on wbcsd/BCG 2018)

66 | See Lacy et al. 2020.
67 | See Ellen MacArthur Foundation et al. 2015; Ellen MacArthur Foundation 2019a; Green Alliance 2015; Material Economics 2018b; PwC 2019; wbcsd/BCG 2018.

and overlaps with the bioeconomy and biological transformation (see Chapter 2.4).[68]

Initiatives in Germany and Europe

The concept of a **circular economy is well established in Germany**, although it is still mostly understood in the **narrow sense of recycling**, which is in turn often taken to include the production of energy from waste.[69] Despite its familiarity with the concept, Germany remains one of the world's leading consumers of resources like paper and plastic.[70]

Commissioned by the Federal Ministry of Education and Research (BMBF) and coordinated by acatech since 2019, the **Circular Economy Initiative Deutschland (CEID)** brings together key **actors from science and industry** with the goal of promoting the transition to a more circular economy and drawing up a concrete **roadmap for Germany**.[71]

A **Circular Economy Action Plan** has been pursued at **European level** since 2015. The plan encompasses a range of measures to promote a circular economy in the EU and has been added to on several occasions.[72] Most recently, it was fundamentally **expanded and deepened in March 2020**.[73] The Action Plan is a pillar of the transformation of Europe's economy envisaged by the Green Deal .[74] The European **Industrial Strategy** calls for Europe to take a **leading role** in the **creation and implementation of circular business models**.[75]

Last but not least, a **partnership of European promotional banks** including the EIB and KfW has committed to make **EUR 10 billion** available to support initiatives to implement a circular economy.[76]

Box 4: Using pure oxygen to produce climate-friendly cement

Construction is a **growth industry** around the world, and steel and cement are indispensable for new buildings and infrastructure. Like steel, however, **cement is very carbon-intensive to produce** and is difficult to incorporate into circular economy models.[77] Since cement is usually produced near to where it is used, cement production within the EU will remain important in years to come.

Production process innovations will therefore be key to climate-friendlier cement production. **Public procurement** can **actively promote** the further development, **scaling and competitiveness of "green" cement production methods**. One promising approach is the **CCU-based oxyfuel process** (see Appendix B). Conventional cement is produced in rotary kilns. Air is used in the combustion process and CO_2 is released into the atmosphere. In contrast, the oxyfuel process **burns almost pure oxygen**, making it possible to achieve a much higher flame temperature. The flue gas from the combustion process is fed back into the combustion chamber and recirculated, thereby increasing the percentage of CO_2 in the flue gas.

This makes it easier to subsequently sequester (i.e. separate out) the CO_2 that has accumulated during the cement production process.[78] One of the challenges currently facing this technique is how to secure a sufficiently large supply of pure oxygen. The oxyfuel process **can also be used to produce steel**.[79] Instead of being released into the atmosphere, the **recovered CO_2** can be used as a feedstock in other industries, for instance in fuel production.

68 | See SCAR 2017.
69 | See RNE et al. 2017.
70 | See Heinrich Böll Stiftung/Break Free From Plastic 2019.
71 | See Circular Economy Initiative Deutschland 2019.
72 | See EU COM 2019c.
73 | See EU COM 2020c.
74 | See EU COM 2019d.
75 | See EU COM 2020b.
76 | See EIB 2019c; KfW 2019b.
77 | See Ellen MacArthur Foundation 2019a.
78 | See HeidelbergCement 2020.
79 | See Thyssenkrupp 2020.

Opportunities and challenges on the journey towards a circular economy

In its initial preliminary study, the Circular Economy Initiative Deutschland **identified areas where action is required to address the barriers** to a more circular economy in Germany and Europe.[80]

At a **technological level**, for example, products must be designed to last longer and be easier to reuse, recycle and repair. This is a particular challenge for complex, high-tech products such as smartphones. It can also be difficult to incorporate basic construction materials such as cement into circular economy models. In these instances, greater sustainability can be achieved through process innovations (see Box 4).

Statutory regulations and standards must either require circularity or at least promote it instead of impeding it. The experts believe that **life cycle assessments** should be carried out both for individual **products and for production facilities** and systems, in order to identify the most sustainable materials and circular systems for each product and its manufacturing process.

> *"Policymakers throughout Europe have fundamentally underestimated the opportunities of a circular economy."*

Fiscal incentives are a further possibility, for example shifting (not increasing) the tax burden from labour to resource consumption, or introducing and harmonising regulations and standards.[81] The **Industrial Strategy** discusses further **tax harmonisation within the EU** as a means of facilitating cross-border business models.[82] The experts believe that harmonising tax rules would also help to significantly strengthen circular business models.

The circular economy can also help to **strengthen employment in the skilled trades**, since product **repair and maintenance** and waste management are key components of circular models. According to the experts, more **specialists** will also be needed to **research and develop new materials and systems** and to develop the accompanying software for databases and process operations. The European Commission estimates that up to **700,000 new jobs will be created by 2030**, mainly in maintenance and waste management.[83]

In order to ensure that there are enough people qualified to do these jobs, it will be necessary to introduce the relevant **content** into **university and vocational training courses**. It will also be necessary to **promote interdisciplinary research** in areas relevant to the circular economy, such as product design and engineering. Inter- and transdisciplinary research projects can also make an important contribution by developing measuring techniques and instruments that can be widely used and are commercially scalable.

The benefits of overcoming the barriers to circularity are twofold. Studies have shown that implementing circular economy principles could reduce **greenhouse gas emissions** in the **production of cement, steel, plastic and aluminium by as much as 40%** by 2050, and by up to 49% in food production.[84]

Furthermore, if circular economy principles are systematically implemented in the three sectors of mobility, the built environment and food systems, the potential **economic benefits** derived from increased resource productivity are estimated at **over EUR 1 trillion** for Europe alone.[85] In practice, however, the **high** short-term **costs associated with the transition** are often a barrier to realising these future economic benefits for many businesses.

> *"A circular business model can be a point of difference in the market."*

Consequently, the experts maintain that **the level of investment in circular economy models is not yet high enough** to achieve a widespread transition to circular business models. One **problem** has to do with the **risk assessment** of new circular business models – investors are generally more comfortable with known risks as opposed to new, unknown risks. The experts therefore call on investors to build greater expertise with regard to circular economy business models.

80 | See Circular Economy Initiative Deutschland 2019.
81 | See Circular Economy Initiative Deutschland 2019; Kirchherr et al. 2018.
82 | See EU COM 2020b.
83 | See EU COM 2018d.
84 | See Ellen MacArthur Foundation 2019a.
85 | See Ellen MacArthur Foundation et al. 2015.

New business models and restructuring existing value networks

"We need more modular products that can be easily dismantled into their individual parts."

In a circular economy, **value is created** in networks rather than in linear production chains. This means **rethinking how roles are distributed among the relevant actors**.[86] It is important to ensure that circular economy value networks are **designed to be as flexible as possible**. This will strengthen their resilience by avoiding overdependency on individual partners.

According to the experts, **new business models and services** harbour the greatest potential for driving progress towards a circular economy. For example, **as-a-service offerings** allow producers to also become service providers. **Repairing** products and **recycling** materials at every point in the value network can also generate new business models for the relevant actors.

The **digital transformation** has a key role in two different respects. Firstly, solutions such as digital twins open up completely **new opportunities for planning and developing** processes and products, particularly in the design and concept phases. And secondly, the digital transformation supports direct contact between individual suppliers and their customers, allowing them to provide **customised solutions** in the form of as-a-service or sharing offerings, for example.

Digital solutions can also help to **increase transparency** regarding the inputs and components used to make products, thereby making them **easier to repair, remanufacture, reuse and recycle**. This is illustrated by the "Battery Passport" proposed by the WEF's Global Battery Alliance, **primarily for electric vehicle batteries**.[87]

The experts point out that **concrete projects** to promote circularity and resource efficiency are **often initiated by a company's employees**. After all, it is they who are most familiar with the specific processes in a value creation system and who thus know where there is significant potential for optimisation.[88]

In order to realise a circular economy, it will also be necessary to introduce **social innovations** aimed at promoting product **sharing** and raising awareness among consumers and decision-makers in industry.[89]

More can also be done to promote circular economy concepts among **SMEs**. According to the experts, there is **great potential** for the successful implementation of circular economy solutions in this sector. **Circular economy business models** often focus on the **regional level**. Since SMEs are particularly strongly represented at this level, they could potentially make better use of these structures going forward.[90]

Some of the experts interviewed attribute the low number of circular business models to a **lack of communication between the relevant actors,** and call for **better** opportunities to **network** with partners from the same value networks at regional and especially supra-regional level. This is something that could be enabled by digital platforms. Networking is also key to **encouraging other actors** to analyse their processes and adopt circular solutions.

Circular business models rely on networking sites and **production systems comprising units that are small, modular, flexible and scalable**. The experts recommend bringing actors from the relevant value networks together in order to develop and test new production systems. Platforms such as the CEID can facilitate and support networking among these actors. Regional circular value creation can also enable **shorter logistics chains** and **strengthen value network resilience through resource provider diversification**. The SARS-CoV-2 pandemic has exposed the vulnerability of linear logistics and supply chains that rely on a single provider (see also Chapter 2.5).

In addition, **Germany is extremely well placed** in many of the research fields and industrial sectors that are key to a circular economy, such as materials science.[91] If Germany and Europe take ambitious action to promote a more circular economy, they will be able to establish a **lead market** for the relevant products and solutions. This can **serve as a model for the rest of the world** and secure **value creation for German and European companies.**

86 | See Lacy et al. 2015.
87 | See WEF 2020a.
88 | See HBS 2020.
89 | See Circular Economy Initiative Deutschland 2019; Ellen MacArthur Foundation et al. 2015; Kirchherr et al. 2018.
90 | See Seidel/Meyer 2016.
91 | See BMU 2018; Circular Economy Initiative Deutschland 2019.

Proposed measures

- **Establishment of a European platform for tracking value streams:** Value stream tracking requires universal instruments that can be accessed by manufacturers, downstream industries and recycling actors. A European platform could support life cycle sustainability assessment by enabling cross-border material flow tracking. User-friendly digital access to the data and the ability to securely share potentially sensitive commercial information are key to widespread participation among businesses.
- **Promotion of interdisciplinary research:** The development of products and processes for sustainable and resilient circular value creation models will require knowledge drawn from several different disciplines. This will call for inter- and transdisciplinary research projects, for example to prepare the ground for the introduction of digital product passports. Among other things, it is important to guarantee that the data cannot be forged, that the relevant dynamic data (e.g. transfers of ownership) is generated throughout the product's lifetime, and that the data is transferred across to subsequent life cycles. It will also be necessary to develop measuring techniques and instruments that can be widely used and are commercially scalable, so that the circularity of products and processes can be accurately evaluated using life cycle assessments. This will also help to ensure more science-based policy and business decisions in connection with circular business models.

2.4 The biological transformation – bioinspired sustainability in industry

Bioinspired insights can support more sustainable design and implementation of materials, processes and production systems. In the context of the biological transformation, it is vital to build on Germany's already strong bioeconomy to enable the development of industries in Germany and Europe that are highly competitive in the global market.

Biotechnology, and more generally the increased **use of biological principles and processes**, have the potential to **revolutionise industry and the economy** on a scale comparable to the digital transformation, and are key pillars of the **industrial bioeconomy**.[92]

Biological principles can be systematically transferred and applied to manufacturing industry, both in the form of integrated process steps such as microbial cell factories, and as a means of enabling the overall **optimisation of products and production systems**.[93] Biology can be a model and nature's resilience a yardstick for transforming unsustainable, linear value chains into value networks, for example in the shape of material loops and reuse cascades. **In this way, the biological transformation can pave the way for the circular economy**. Restructuring or redesigning processes along these lines makes it possible to reduce demand for materials and cut energy consumption, for example.

"There are major synergies between the objectives of the Green Deal and the goal of increasing the resilience of our value networks. These can be leveraged through the principles of the biological transformation."

It is possible to distinguish between **three development modes of the biological transformation**: bioinspired value creation, biointegrated value creation and biointelligent value creation (see also Figure 5). The biological transformation enables the necessary **diversification of the raw material base** for an industrial bioeconomy.

The industrial use of biological organisms and processes can also make it possible to employ a wide variety of raw and residual materials in energy-saving, low-emission processes, facilitating the development of **innovative products with modified properties**.

The experts point out that in many existing value networks, for example in the chemical industry, the **potential to integrate biological process steps** has **by no means been fully leveraged**. In order to tap into this potential, it will be necessary to expand the current knowledge base. Students of (interdisciplinary) **university, advanced training and continuing professional development courses** will need to be taught **interdisciplinary approaches** and **learn** how to combine technology, biology and sustainability requirements.

There are many places where the biological transformation **overlaps directly with the digital transformation**. Intelligent machines and **smart materials management** help to save additional resources and enable the **decentralised, modular production** of goods that are precisely tailored to consumers' needs.[94] In the

92 | See acatech 2017.
93 | See FhG 2019.
94 | See FhG 2019.

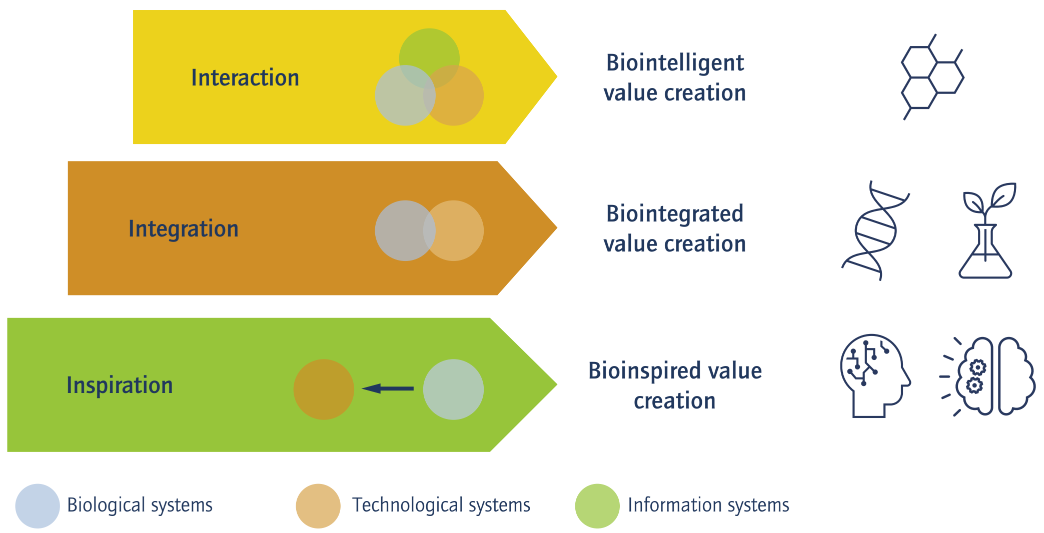


Figure 5: Development modes of the biological transformation (source: authors' own illustration based on Miehe et al. 2019)

materials sector, the biological transformation spans everything from the replacement of conventional, petroleum-based materials with bio-based materials to classical bionics (e.g. lightweight design) and even the fusion of biological and technological systems, for example organs-on-chips. The boundaries hereby are fluid. Digitalised applications and processes from the biological transformation, **bioeconomy** and **bioinformatics** are **driving innovation** (see also Box 3).

The experts also make the point that the biological transformation will promote **greater decentralisation** and a focus on using **local resources** in production and value creation systems. This could help to reduce dependencies and **significantly increase the resilience of the relevant systems** (see Box 5). The biological transformation can help to replace fossil feedstocks with renewable resources, thereby substantially reducing emissions from manufacturing.[95]

Policy strategies to promote the biological transformation

Published in **2014**, the Federal Government's **"Bioeconomy in Germany" agenda** laid an important foundation for the biological transformation and the development of a bioeconomy industry.[96] This was subsequently built on with the publication of the **"National Bioeconomy Strategy"** (NBÖS) in **January 2020**.[97] Once the new Bioeconomy Council (III) is up and running, the German government will once again be able to consult a scientific advisory body on questions relating to the bioeconomy. In order to raise the bioeconomy's profile among the general public, it was also chosen as the theme of Germany's **Science Year 2020**.[98]

Cross-disciplinary cooperation will be vital to the development of the **new business models** that will be key drivers of the biological transformation. According to the experts, government-funded **transdisciplinary research programmes** that also support **collaborative research** with actors from industry will be necessary in order to bridge any financial gaps in the innovation process.

The German government is also currently drawing up the **interdepartmental agenda "From Biology to Innovation"** (led by the Federal Ministry of Education and Research and the Federal Ministry for Economic Affairs and Energy), which aims to set out guidelines for the use of biotechnology in German society.[99] This **soon to be published agenda** should be systematically pursued in order to promote the biological transformation. The experts believe that it can **make an important contribution to the development of industries that are highly competitive in the global market**.

95 | See acatech 2019a.
96 | See BMBF/BMEL 2014.
97 | See BReg 2020b.
98 | See Wissenschaftsjahr 2020.
99 | See BIO Deutschland 2018; BReg 2020b.

Box 5: The biological transformation in practice: biotech innovations in the field of medicine

Modern biotechnology is playing a pivotal role in the **current SARS-CoV-2 pandemic** by enabling the development of the effective drugs, first and foremost a **vaccine,** needed to **save lives** and enable a **return to normality both at work and in everyday life**. Worldwide, there are now over 170 clinical trials aiming to develop active vaccines. New technologies and the lessons learnt from previous projects to develop vaccines against related viruses have hugely accelerated the development process – the first vaccine candidates are already being tested on volunteers, with many more to come in the near future. The fact that **innovative genome-based (DNA and mRNA) vaccines are being trialled** alongside more conventional approaches is **extremely important for the future** of vaccine development.[100] The development of vaccines often goes hand in hand with the development of better methods of testing for the virus or its antibodies. Biotechnology thus plays an **important role in preventing and overcoming public health crises**, and therefore in preventing or mitigating their economic and social impacts.

Until an effective vaccine is available, **researchers in Germany and Europe** will continue to work around the clock on ways of **stopping or dramatically slowing down the spread of the virus**. The approaches being investigated range from plans to introduce an early warning system for regional outbreak clusters to discussions about carrying out mass personalised genome sequencing in conjunction with smart contact tracing.[101]

Biotechnology is thus one of the **key technologies of the 21st century** – a biological transformation of science, industry and civil society offers **huge potential for sustainable value creation and for strengthening the resilience** of modern industrialised societies.[102] Biotech in medicine, agriculture and industry should therefore be a key innovation funding priority for the European Industrial Strategy and European Green Deal. Biotechnology **has already been making a substantial contribution to improving people's lives for several decades**. For example, biological treatments have been revolutionising patient outcomes for a range of fatal and chronic diseases for more than 30 years. The material basis of a sustainable society will depend on chemical products and processes that are designed following principles that make them conducive to life. **New systems thinking and design** must therefore begin **at the molecular level** in order to take the inherent properties of molecules into account from the earliest stage.[103]

Germany and some other parts of Europe are extremely well positioned in the field of life sciences and biotechnology research. It will be necessary to ensure that the associated **economic potential** is realised throughout the EU as part of the transition to a sustainable European economy. This will require a **common European innovation policy drive**, since the **capital requirements** and **investment risks** are higher for biotechnology than for other technology fields.[104] A **clear commitment from the European Commission** to making Europe a world-leading biotech location would generate **significant momentum**. Existing initiatives to promote biotechnology should be strengthened. The German government's agenda **"From Biology to Innovation"** should also aim to provide **extensive support for R&D projects** focused on implementation of the biological transformation and the bioeconomy in German industry.

The biological transformation should **be accompanied** by supporting **digital transformation** measures. The **highly data-driven methods** used to study complex living systems mean that significant advances and the acceleration of R&D in the field of biotechnology can only be achieved if **bioinformatic skills and digital research infrastructures** are developed throughout Europe.[105]

100 | See WHO 2020.
101 | See FAZ 2020c; FhG et al. 2020.
102 | See acatech 2017.
103 | See Zimmerman et al. 2020.
104 | See BCG/vfa 2019; EY 2020; McKinsey & Company 2019a.
105 | See acatech 2017.

Proposed measures

- **Strengthen interdisciplinary skills:** A successful biological transformation of the economy will require an adequate supply of qualified workers. This will call for appropriate knowledge transfer formats for teaching the necessary interdisciplinary skills. The bioeconomy industry would also benefit from a broader knowledge base in disciplines that intersect it.
- **Regulatory sandboxes for a materials transformation:** The establishment of regulatory sandboxes for a materials transformation would provide a framework to enable the further development of innovative technologies for the development and production of new materials from renewable primary products on an industrial scale and under real-life conditions, together with the necessary certification procedures, test criteria and standards. This would make it easier to bring new materials to market (see also Box 6).

2.5 Outlook: creating resilient value networks

The current **SARS-CoV-2 pandemic** has starkly exposed just how **vulnerable global value networks are to disruption**. Many companies depend on just-in-time delivery from **global supply chains** for the smooth operation of their manufacturing processes. Businesses and some government bodies are also reliant on **single-source suppliers**.

During the early stages of the SARS-CoV-2 pandemic, some **manufacturing processes** in Germany and Europe **were brought to a standstill** when the supply of the necessary parts and components dried up. There were also **shortages** of drugs and personal protective equipment for which **production capacity no longer exists** in Germany and Europe.

Moreover, it is not just pandemics that can cut off the European economy's supply of individual products, raw materials or key components – **trade disputes, wars and natural disasters** can all have a similar impact. This has led to **calls** – both in the public debate and from the experts interviewed for this publication – for the **resilience of value networks** in Germany and Europe to be **strengthened** so that they are better able to cope with future shocks.

Resilience is the ability to factor in potential adverse events of all kinds and to prepare for and avert them if possible, as well as to cope with and recover from shocks when they occur, thereby creating a new normal that is better adapted to the current circumstances.[106] In particular, this means that government, science, industry and civil society must learn to **think in terms of multiple future scenarios** and ensure that there is enough **flexibility** to allow agile adaptation.

However, the complete reshoring of the **value networks** for all the products and services of a modern, affluent society is **neither possible nor desirable**, especially if one considers the potential foreign, trade and security policy implications.

Instead, **strategic decisions** must be taken about which industries should receive support to **increase regional production capacity** or otherwise **transform and diversify** their value networks in order to guarantee the supply of basic social necessities and services (for instance in the healthcare sector) or the **ability of key industries to keep producing** (for example the automotive and mechanical engineering industries). The question of resilience is thus linked to that of **technology sovereignty**.

An intensive, structured dialogue between the German government, science, industry and civil society is key to ensuring that the topic of resilience is addressed in as nuanced a manner as possible. In particular, it would help to translate the **lessons, experiences and conclusions** of the crisis into **widely viable concepts and initiatives**.

Any increase in production capacity (or at least a return to former levels) will need to be closely **coordinated at European level**. In this context, it might be possible to explore the extent to which increases in production capacity could be tied in with aspects of **European cohesion policy**.

In general terms, stronger local or regional connections among value networks would help to prevent companies from shopping all over the globe for their parts, thereby **reducing the distance that intermediate products are transported** as well as the associated **CO_2 emissions**.

> *"The pandemic will ramp up the pressure to move towards a circular economy and resilient production structures."*

The previously cited drivers of a sustainable transformation, and in particular of the circular economy and the digital and

106 | See acatech 2014.

biological transformation, will also be key to creating a more resilient economy:

- **Strengthening the biological transformation and bioeconomy:** Biotechnological manufacturing processes can be used to sustainably produce feedstock for complex materials or even directly make products with novel properties by converting locally sourced biomass. A biointelligent value creation system applies self-organisation principles from nature to industrial production processes in order to resolve the conflict between efficiency and flexibility. Production is decentralised and modular, enabling adjustment to current and/or regional demand, rapid switchovers to the manufacture of different products, and short-term increases in output and throughput in order to optimise capacity utilisation. This also helps to reduce the production systems' vulnerability to disruption and crises,[107] allowing companies to make a faster return to the market when they occur. Improvements in the modelling and simulation of these complex systems should form a key part of future R&D so that this approach can be applied to different value networks as soon and as effectively as possible.
- **Circular economy:** In essence, the circular economy aims to decouple value creation from additional resource consumption wherever possible. Extending products' useful life, increased reuse and repair, and a move towards sharing and as-a-service business models can help to decouple value creation and prosperity from direct production and reduce dependency on raw material imports.[108] The value networks in a circular economy must be as flexible as possible in order to prevent overdependency on individual partners and thus make them more resilient.
- **Accelerating the digital transformation:** Solutions from the fields of Industrie 4.0, artificial intelligence and big data – for example predictive maintenance using digital twins – enable improved identification of potential disruption to production processes and thus allow organisations to include possible solutions in their advance planning. Similarly, digitalisation of supply chains can enable more transparent and flexible goods flows. If digitalisation is to contribute to a more resilient economy, it will be necessary to build a powerful digital infrastructure, including an expanded broadband and mobile communications infrastructure providing full coverage throughout Germany. It will also be necessary to develop the digital skills of businesses, the public authorities and the general public. One example of additive manufacturing's potential to strengthen resilience is the rapid, autonomous and decentralised establishment of capacity for making face shields with 3D printers during the SARS-CoV-2 pandemic.

107 | See FhG 2018; 2019; Fraunhofer IPA 2018.
108 | See BReg 2020c; Ellen MacArthur Foundation et al. 2015; Material Economics 2018b.

3 Making basic materials industries more sustainable: the example of the plastics industry

The transition to sustainable industrial production poses a major challenge, especially for energy-intensive basic materials industries. Innovations are needed at every level (products, processes, business models) and across all the elements of the relevant value networks. It will only be possible to successfully realise the necessary transformation if the appropriate policy framework and social conditions are established to make it economically viable. The plastics industry provides an illustration of the relevant challenges, transformation pathways and conflicts.

The first part of this chapter provides a brief introduction to the particular requirements for making **energy-intensive basic materials industries** more sustainable (Chapter 3.1). Moving on to the concrete **example of the plastics industry**, a **scenario** is described outlining how plastics could be used sustainably (Chapter 3.2). Chapter 3.3 discusses examples of pathways to realising the **necessary changes and innovations** across an entire value network, while Chapter 3.4 identifies a number of **areas where policy action is required**. Finally, the Appendix includes a more **in-depth analysis** of the challenges and opportunities associated with the transformation of the plastics industry, providing a more detailed discussion of the issues addressed in this chapter.

3.1 The industrial value networks at the heart of the German economy

The German economy relies on the products supplied by its strong basic materials industries. The transformation of these value networks is particularly challenging due to their energy-intensive production processes. Nevertheless, it is achievable if favourable conditions are created, if the high levels of investment required are delivered in good time, and if the major transformation drivers identified in this publication are harnessed systematically.

A significant proportion of the **wealth** and **value creation** in the German economy derives from its strong industrial base, which is in turn dependent on an adequate **supply of basic industrial materials**.

Globally the production, use and disposal of **steel, plastics, ammonia and cement** is responsible for around 20% of CO_2 emissions (14% in the EU).[109] Due to the **high carbon intensity** of these sectors, even ambitious strategies based on incremental efficiency gains will not be enough to achieve the target of climate neutrality by 2050.[110] What is required instead is a fundamental **transformation of value networks**, with a long-term focus. Solutions and concepts that are successful in the basic materials industries can subsequently be transferred to other industries once they have been adapted to their specific characteristics.

> *"We are already well set to complete the first half of the journey towards carbon neutrality. Thereafter, however, we are going to need a major transformation of value networks, coupled with fundamental product, process and business model innovations."*

The transformation calls for **technological innovations, behavioural innovations** and new **business models**. These can also provide a basis for **exporting sustainable solutions** to the rest of the world and thus for sustainable value creation in Europe. The policy **framework** and social conditions needed to make this happen extend far beyond the boundaries of any individual industry or policy area (for instance industrial, climate or energy policy) and thus require a **coordinated approach**.[111]

A wide-ranging, two-part study carried out on behalf of the European Climate Foundation identifies potential **pathways and systemic barriers** (for the latter, see Figure 6) for the transition to climate-neutral steel, plastics, ammonia and cement industries.[112]

109 | See Material Economics 2019.
110 | See BCG/Prognos AG 2018; Material Economics 2019.
111 | See BCG/Prognos AG 2018; Wyns et al. 2019.
112 | See Material Economics 2019; Wyns et al. 2019.

The study concludes that

- the necessary changes will require **investment** in these industries to **increase** by an average of **76%-107%** between now and 2050,
- **production costs** in these basic materials industries will **rise** significantly (by 25%-115%),
- but this will only lead to a **slight increase in end-user costs** of around 1%.

The study confirms the importance of the cross-sectoral and cross-industry strategies outlined in the previous chapter, namely the use of hydrogen and electrification, the digital and biological transformation, and the circular economy. In addition to the **closure of material cycles**, it identifies an adequate supply of **renewable biomass and electricity** as vital to the successful transformation of basic materials industries.[113]

Figure 6: Barriers to the transformation of energy-intensive basic materials industries (source: authors' own illustration based on Wyns et al. 2019)

113 | See BCG/Prognos AG 2018; Material Economics 2019; Wyns et al. 2019.

3.2 Scenario: how plastic could form part of a sustainable future

Peter is on his lunch break. Like almost every other day, he buys a meal from one of the many fast food outlets in the area. The meal comes in practical, **reusable plastic packaging**. He can return the packaging at several different outlets that all participate in a common return and reuse scheme.

Peter also shops sustainably on his trips to the **supermarket**. There is less plastic packaging in general than there was in 2020, especially multi-packs. However, plastic packaging is still widely used due to its unique properties. **Clear and consistent labelling** allows Peter to pick out the most sustainable products. A quick scan with his smartphone provides him with further information about the packaging, for example the percentage of recycled content or bio-based plastics.

Peter's neighbour Katharina is a production engineer at a **bio-based plastics** company. The biomass feedstock used at the plant is mostly organic waste. **Online commodity exchanges** allow Katharina to transparently monitor the current supply and demand trends for bio-based and recycled plastic.

She is able to flexibly adjust the bioreactor's output to current demand using a biointelligent control system. The overall **market for bio-based polymers and secondary feedstocks** has grown significantly, since primary feedstocks like oil and natural gas are hardly used to make plastics anymore. This trend is supported by an approach to **product design** that focuses on recyclability across multiple life cycles and now forms part of the standard curriculum on the relevant study courses.

There has been a fundamental change in society's attitude towards **waste**, which is now seen as a **valuable resource**. User-friendly plastic collection systems make things easier for consumers, while the **sorting and recycling** of plastic waste has become a **burgeoning high-tech industry**. A combination of modern sensors, product tags and machine learning allows plastic waste to be routed to the **most sustainable recycling pathway**.

Technological innovations have made mechanical recycling much more efficient, while various chemical and enzymatic techniques offer additional options for recycling plastic waste. This means that even **high-grade products** can now be made from **recycled plastic**.

3.3 Transformation pathways for plastic value networks

The plastics industry already has access to an extensive portfolio of product, process and business model innovations to support the transition to a more sustainable value network. These must now be utilised and expanded even further. In some cases, policy decisions may be required to resolve conflicts between individual solutions. These should be based on a comprehensive life cycle assessment of the relevant products.

Overcoming the complex challenges involved in the transition to a sustainable plastics industry will call for a broad **spectrum of innovative solutions** across different links in the value chain (see Figure 7), in order to leverage the full development potential.

The experts stress that in order to achieve a successful transformation it will be essential to **avoid isolated solutions** and ensure coordination of **innovations** at the different levels so that they can be combined to create synergies. This will require **networking** of the different actors **in the value network**, together with a favourable policy framework based on the **circular economy principles** outlined in Chapter 2.3.

Product innovations

Plastic products perform a variety of **important functions** such as helping to guarantee food hygiene and safety. However, they are also responsible for significant levels of **resource consumption and CO_2 emissions**, in part due to the fact that some products are **only used for a very short time** and have very short life cycles. Packaging in particular currently tends to be thrown away after a single use.

Sustainable product innovations must therefore begin with a **design** that takes their **entire life cycle** into account rather than focusing solely on product features (see also Appendix E). In particular, the experts believe that **design for circularity** (for example component separability and standardisation or mono-material solutions) combined with efficient collection and sorting has considerable potential to **increase** reuse and **recycling rates** and **improve the quality** of the resulting **recycled materials**.[114]

Benign by design and **green chemistry** are two further approaches that can help to make plastics easier to recycle and

114 | See Lacy et al. 2020; WEF et al. 2016; WEF/Ellen MacArthur Foundation 2017.

Figure 7: Transition to a sustainable plastics value chain (source: authors' own illustration based on Material Economics 2019)

prevent other negative environmental impacts. **Essentially**, they begin by analysing and testing the intended **application** to establish whether it requires the use of specific materials. If it does, then every effort should be made to ensure that the materials' design is tailored **as precisely as possible to the relevant requirements**. The **molecular composition** of the materials should be as simple as possible, and they should **break down easily and completely** after use or be fully recoverable.[115]

Benign by design was developed as a new design concept for persistent **pharmaceuticals** that do not break down in the environment after use. However, its goals can also be **applied to plastics**.[116]

On the other hand, some experts warn that **focusing solely on recyclability** at the product design stage could compromise the performance of the plastics in question. In specific applications, this could have **negative impacts on their sustainability** (e.g. their weight or their ability to keep food fresh).

> *"It's not about making existing products 'slightly less bad', it's about designing products to be sustainable from the outset."*

According to the experts, it will **not always be possible to fully resolve these conflicts** by researching and developing new materials and processes, even though this field is a core competency of the German research landscape. Policymakers will also have to intervene.

In order to ensure that **design choices are as sustainable as possible**, it is necessary to carry out a precise analysis of what a plastic (product) will be used for, which product characteristics are necessary for this purpose, and what impact different choices have on the product's **sustainability footprint**. The latter calls for detailed **life cycle assessments**. However, these can often be difficult to carry out – the necessary **data may not be available**, and the cost can also be prohibitive. The relevant methodologies should therefore be **refined and standardised**.

Greater **use of secondary feedstocks made from recycled material** should be a **top priority** in the transformation of plastics production. It will only be possible to meet the relevant sustainability goals in the plastics industry if a significantly higher percentage of end-of-life plastics are recycled as fully as possible and reused **for products of equivalent or higher value** (see also section below on "Process innovations"). Nevertheless, even in optimistic scenarios, factors such as the unavoidable process losses that occur during recycling mean that in the future **it will still not be possible** to meet **more than 60%-70% of demand for plastics with secondary feedstocks**.[117]

However, plastics made using **biomass as an alternative primary feedstock source** can help to decouple plastics production as fully as possible from fossil fuel inputs (for an explanation of the difference between bio-based plastics and bioplastics and a more in-depth discussion, see Appendix F.2).[118]

Many common plastic polymers are already produced **in biotechnological plants**.[119] These can be operated as **decentralised** facilities located near to biomass sources, and can provide an opportunity for sustainable value creation, particularly in **structurally weaker regions**.

> *"A lot of progress has already been made with regard to the development of bio-based plastics, and many products are market-ready. The real problem is whether there is enough demand for them and whether they are commercially viable."*

The fact that the negative environmental and climate impacts of **fossil fuel-derived plastics** are not factored into their price means that they currently enjoy a **competitive advantage** over secondary feedstocks comprising **recycled material** and over **biomass-based** primary feedstocks.[120] Low oil prices due to the economic crisis triggered by the SARS-CoV-2 pandemic have put **secondary and biomass feedstocks at an even greater** competitive disadvantage.

Growing **biomass demand** in the plastics industry could lead to **competition** with agriculture and forestry, land restoration projects geared towards climate and biodiversity protection, or biomass demand **for other purposes (such as fuel production)**.[121]

115 | See Deutsche Welle 2016; Kümmerer 2017; Kümmerer et al. 2020; Zimmerman et al. 2020.
116 | See Deutsche Welle 2016; FAZ 2018; Kümmerer et al. 2020.
117 | See Material Economics 2019.
118 | See DECHEMA/FutureCamp Climate GmbH 2019; Material Economics 2019; WEF/Ellen MacArthur Foundation 2017.
119 | See European Bioplastics 2016.
120 | See VCI 2019b.
121 | See acatech et al. 2019.

Some studies conclude that the use of **biomass to make plastics is more energy-efficient** and therefore more sustainable than its use for fuel or to generate electricity.[122]

The use by the plastics industry of individual biomass or **waste stream** components such as chitin, lignin and terpenes has particular potential in terms of avoiding conflicts with primary biomass uses.

Box 6: Regulatory sandboxes for a materials transformation

Background

Innovative new **materials** can make an important **contribution to sustainability**, especially if they are made from renewable resources or possess **enhanced product characteristics** such as improved recyclability, more flexible applications or lower weight. For some applications, however, new materials must comply with strict **criteria and regulations** before they are approved for market. For instance, materials that come into contact with food (e.g. packaging materials or food processing machinery parts) must be tested for **conformity** with the relevant **food safety regulations**. However, the current testing procedures are designed for established, petroleum-based plastics and sometimes also establish stricter requirements for **bio-based plastics**. They therefore constitute a **barrier to the latter's commercial rollout**.

This has deterred some businesses from increasing their R&D investment in this area. Similar challenges exist with regard to the **approval of new classes of materials** in other industries such as the construction trade. By providing optimised infrastructure and logistics, and bringing together the competencies required to study structural and property interactions in one place, **regulatory sandboxes for a materials transformation** would make it possible to **develop and commercialise new materials** faster and more cheaply, giving a **major boost** to the realisation of a **bioeconomy**. Below, a regulatory sandbox for bio-based plastics is described by way of example.

The regulatory sandbox in practice/participating actors

The aim of the regulatory sandbox is to create a close network encompassing the different **actors in the value network** as well as an appropriate **testing facility and authority**. As far as possible, these should all be in close proximity to each other. In the specific case of bio-based plastics for the food industry, the sandbox would include **research institutions, materials manufacturers** (e.g. SMEs), **suppliers and processors** (e.g. packaging manufacturers), testing facilities and authorities, and the **users** of the products at the end of the value chain, in this case food producers.

The different stages involved in developing a marketable product are of course already being driven by a variety of different actors:

- materials engineering at universities and/or non-university research institutions,
- upscaling, material production by suppliers (requires material testing by authorities or certified testing facility),
- material processing and subsequent market rollout, e.g. by large corporations (requires component testing, possibly by authorities or certified testing facility).

However, **there is currently a lack of close cooperation on the key points** between the different actors in the value chain. This is where regulatory sandboxes come in.

Benefits of regulatory sandboxes

As well as facilitating the development of sustainable materials and **viable business models** right from the outset, one particular benefit of regulatory sandboxes is their focus on the necessary **regulatory learning** with regard to testing and approval procedures and the corresponding norms and standards.

Modified, **simplified and faster approval procedures** that bring forward the use of new materials without compromising their safety can help to **overcome market barriers**, even in sensitive areas such as food packaging. This can in turn drive further innovation, encouraging businesses to invest more in developing new materials.

The lessons learnt from the regulatory sandboxes could be applied to **other materials**, for example in the construction industry. They could also serve as best practices for **harmonising regulations throughout the EU**.

122 | See BCG/prognos AG 2018; Material Economics 2018b; 2019.

This type of approach is addressed by Germany's National Bioeconomy Strategy. Moreover, initiatives such as the Fraunhofer Cluster of Excellence for Circular Plastics Economy are researching how bio-based plastics can best form part of a **sustainable, circular plastics economy**.[123] The experts stressed the importance of finding ways to **bring innovative products and processes to market** as safely and **rapidly** as possible. **"Regulatory sandboxes for a materials transformation"** are one possible solution (see Box 6).

Process innovations

At present, a substantial proportion of end-of-life plastics in Europe (approximately 43% in 2018) and Germany (approximately 60% in 2018) are incinerated in order to **produce energy**, releasing **large amounts of CO_2** into the atmosphere.[124]

Existing legislation coupled with the EU plastics landfill ban currently under discussion could create **incentives** to **burn** an even higher proportion of plastic waste. The experts are concerned by this possibility and call for changes to the regulatory framework in order to maximise the amount of plastic that is recycled (see also Appendix I).

> *"If the incentives for waste-to-energy get too big, no-one will bother recycling anymore."*

Regardless of the process used, **making plastics from secondary feedstocks** has a significantly **smaller carbon footprint** than using primary feedstocks (see Figure 8). The experts believe that there is still considerable **untapped potential for innovations** to improve the throughput volumes and recycled plastic quality of **mechanical recycling** processes. Current mechanical recycling methods are often unable to produce high-grade plastics and can therefore result in downcycling. Many of the necessary technologies are already available, for example **more accurate sensors** or greater use of **machine learning and AI** for sorting waste streams.[125] However, low demand for high-grade recycled plastics coupled with the competitive advantages of fossil fuel-derived primary feedstocks means that **investing** in improved sorting and recycling facilities **does not make financial sense** at this point in time.

> *"There is still plenty of potential to optimise mechanical recycling, but investing in innovations doesn't make financial sense at the moment."*

If the market conditions change, the forecast increase in global plastics production coupled with a focus on sustainability targets could also generate **export opportunities**, allowing **German green tech companies** to consolidate their **strong position** in the global recycling and waste management market.[126]

Not all waste streams are suitable for mechanical recycling. One of the potential benefits of **chemical recycling** is that it could be used for mixed or contaminated waste streams. Chemical recycling refers to processes in which plastics are **broken down into their chemical constituents**, which are then used to **make new plastics**.

Chemical recycling techniques include pyrolysis, catalytic cracking, gasification, depolymerisation and solvolysis.[127] However, some experts caution that the actual **purity and quality requirements** of the waste input for the individual techniques have yet to be tested in an industrial setting (see also Appendix I.2).

The **main criticism** of chemical recycling processes is that they are **extremely energy-intensive**. The higher the **percentage of fossil fuels** in the energy/electricity mix used for the chemical recycling process, the **worse** its **environmental footprint**.

Another promising approach that is still at a much **earlier stage in its development** is **enzymatic recycling**, which uses biotechnological methods to recycle plastic polymers.[128]

> *"It will be impossible to close the plastic loop without at least some chemical recycling."*

123 | See Fraunhofer CCPE 2019; BMBF/BMEL 2020.
124 | See Material Economics 2019; PlasticsEurope 2019a.
125 | See Material Economics 2019; Wilts et al. 2020.
126 | See BMU 2018.
127 | See Bauer et al. 2018; DECHEMA/FutureCamp Climate GmbH 2019; Solis/Silveira 2020.
128 | See Tournier et al. 2020.

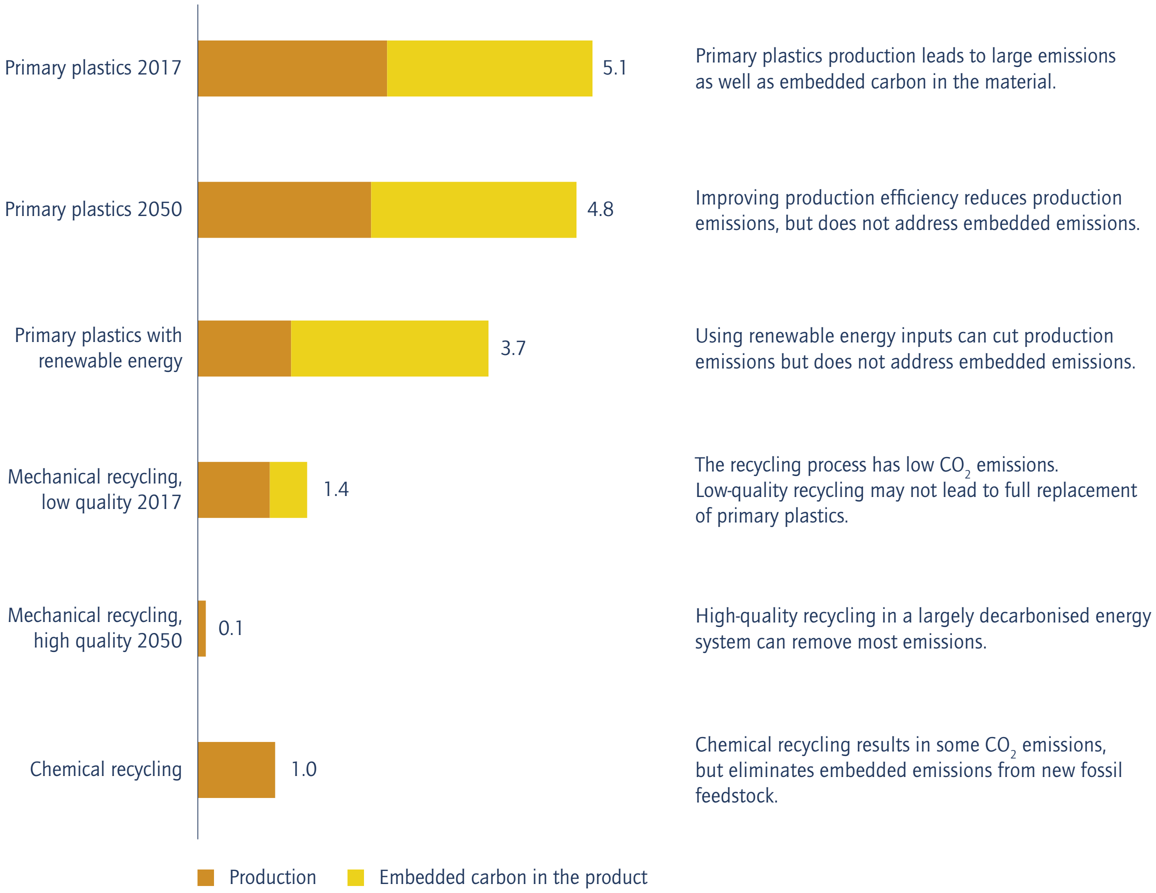


Figure 8: CO_2 emissions for different plastics production pathways (source: authors' own illustration based on Material Economics 2018b)

The goal should be to develop a **holistic plastic reuse and recycling strategy** that routes plastics to the **most sustainable recycling pathway** and leverages **synergies** between different methods (see Figure 9). A **regulatory sandbox** for testing **chemical recycling** and carrying out the corresponding life cycle assessments could make an important contribution to achieving this goal (see Box 7).

The cracking and subsequent polymerisation of the feedstock during plastics production are particularly **energy-intensive processes** that are currently powered mainly by **fossil fuels**. **Electric cracking technology** is almost ready for **industrial applications** (TRL7), and offers one possible solution for making this part of the plastics production process more environmentally sustainable. However, the goal of completely eliminating greenhouse gas emissions from this production stage will only be achieved if the electricity used is derived entirely from renewable sources.[129]

According to the experts, the potential of **Industrie 4.0** to make plastics production and in particular the plastic processing industry more sustainable has **yet to be fully harnessed** (see also Chapter 2.2 and Appendix G). Solutions from the **biological transformation** of manufacturing industry and the **bioeconomy** can also help to meet the relevant sustainability targets (see also Chapter 2.4 and Appendix G).[130]

One example from the plastics industry involves the **production of biopolymers for bio-based plastics. Biorefineries** could produce **different types of polymers** and flexibly adjust production volumes in line with demand and customer requirements. These **flexible, modular production processes** are enabled by a combination of biotechnological processes (bioconversion by microorganisms), digital processes (artificial intelligence, IoT, big data) and hybrid processes (biosensors).

129 | See Axelson et al. 2018; DECHEMA 2017; Material Economics 2019.
130 | See BMBF/BMEL 2020; FhG 2018; 2019.

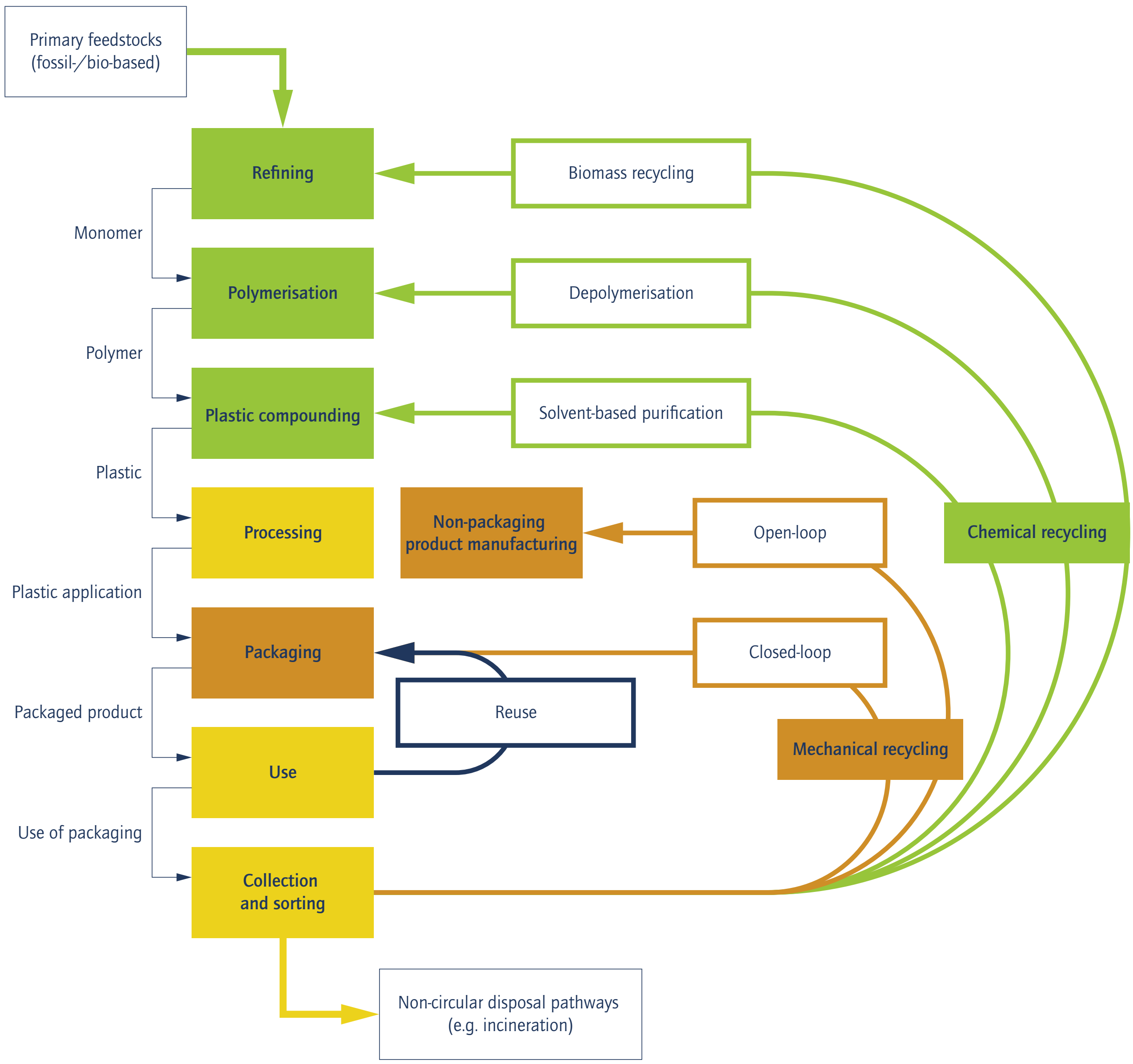


Figure 9: Value chain for plastic packaging and recycling pathways (source: authors' own illustration based on EU COM 2019a; WEF et al. 2016)

By **optimising capacity utilisation, these biointelligent plants would be able to save resources and cut emissions**. This way of organising production can help to make the plastics industry more sustainable and resilient (see also Chapter 2.5). In the **industrial symbiosis** concept, waste products (material waste, emissions, heat, water) from one stage in the manufacturing process are reused in other stages as feedstocks for new industrial processes.

It is estimated that symbiotic industrial parks such as Kalundborg Eco-industrial Park in Denmark (see Appendix G), the Pomacle-Bazancourt biorefinery complex in France and BASF's Verbund site concept have the **potential to reduce greenhouse gas emissions** by up to **10%**.[131] **Plastic manufacturers** could, for example, cooperate **more closely with paper mills** in order to source organic waste for the production of bio-based primary feedstocks.[132]

131 | See EU COM 2020g; OECD 2018.
132 | See Material Economics 2019.

Box 7: A regulatory sandbox for chemical recycling – optimised and innovative recycling processes for plastic packaging

Background

Chemical recycling (see also Appendix I.2) is an innovative solution that can increase the percentage of plastic waste that is recycled instead of burnt, and is almost ready for large-scale industrial use. However, the **statutory regulations** for chemical recycling **vary across the EU**, and plastic packaging feedstock that has been produced by chemical recycling is **not currently classified as a recycled material under German law**.

In order to develop **the most sustainable overall solution** for packaging recycling and create an appropriate legal framework to enable it, policy decisions should be based on product and process **life cycle assessments that are as precise as possible**.

A **regulatory sandbox** for plastic packaging recycling would offer an ideal opportunity to combine and optimise **established and innovative processes on an industrial scale**, thereby harnessing their potential to support a circular economy.

Participating actors

A regulatory sandbox would need to be **government-led** in order to achieve the necessary **networking of actors** from across the entire value network. The actors should include:

- chemical companies,
- pyrolysis plant operators,
- where relevant, operators of other innovative recycling facilities,
- mechanical recyclers,
- waste disposal companies,
- operators of waste sorting facilities,
- the Dual System,
- regional/testing authorities,
- universities and/or non-university research institutions and,
- where relevant, NGOs.

The European dimension

There are multiple **advantages** to establishing the **regulatory sandbox at European level** and including partners from several different member states. For example, some countries such as Spain and Denmark are already operating **plastic pyrolysis plants** or plan to do so in the near future, while others such as the Netherlands have adopted plastic recycling **action plans**. These countries could share their experience and **expertise**.

The regulatory sandbox would facilitate direct sharing of **regulatory best practices** and provide a space for initiating **harmonisation of the relevant regulations** at European level. This would also contribute to the establishment of a **single European market for secondary feedstocks**. The regulatory sandbox could also be used to test whether and how the European Commission's planned European **data space for smart circular applications** could help to establish this single market. The establishment of a regulatory sandbox is also supported by the fact that the EU's Circular Economy Action Plan highlights the potential of chemical recycling for a modern circular economy.

Benefits of the regulatory sandbox

The practical industrial setting offered by a regulatory sandbox is essential for producing realistic and **meaningful life cycle assessments** and refining their methodology. These life cycle assessments can then provide the basis for creating a **regulatory framework** and an infrastructure for recycling plastic packaging that ensure that waste is routed to the most sustainable recycling pathway, as well as leveraging **synergies** between mechanical and chemical recycling and potentially also with production processes. This will also include optimisation of the collection, sorting and decontamination of plastic waste, which could help to bring down **waste management costs**.

The incorporation of chemical recycling processes into established recycling structures has the potential to **widen the range of plastic waste types that can be recycled**. This would offer particular **benefits** for established producers of high-grade plastic packaging that cannot be recycled using conventional methods. These are mostly **small and medium-sized enterprises** that specialise in particular types of packaging (e.g. for cheese or sausages).

It may also be possible to **transfer** the **learnings** about the potential regulatory, systemic and process-inherent barriers and the relevant optimisation strategies from packaging to other plastics applications. These learnings could also help to **optimise product designs**.

One of the **challenges** associated with projects of this type is to ensure that short-term fluctuations or interruptions in one partner's output do not directly **compromise** another partner's **production operations**. It is thus important to strike a **balance** between **maximising synergies** and **diversification of feedstock sourcing**.

Business model innovations

New business models that are also important for implementing **circular economy models** in other industries have a number of concrete applications in the plastics sector.

Digital platforms for secondary feedstocks are one solution for providing transparency **about the availability of recycled plastic** while also bringing producers and suppliers together.[133] The German start-up Cirplus, which is supported by EIT Climate KIC, is one of several actors already using this type of business model.

The experts suggest that biointelligent value creation solutions could be used to build **modular production capacity** in an **as-a-service model**. Intelligently controlled and connected production systems could be provided by a third party, allowing companies to hire the systems that they require on demand. This would be particularly **beneficial for SMEs and start-ups**, since it would provide them with access to efficient, modern production architectures that can be tailored to their requirements, without the need to finance major direct investments in infrastructure or maintain unused production capacity.

As-a-service models could also play a role in the **distribution of plastics**, for example in the packaging and logistics business. Instead of supplying plastic packaging, businesses could provide a service guaranteeing that the product will be safely delivered in a defined condition. This would serve to **decouple value added from the volume of packaging**, giving companies an economic incentive to reuse packaging as much as possible and to **minimise the amount of materials used**. Customers would also benefit from the supplier's expertise regarding the most effective use of different packaging types. Other parts of the chemical industry are already trialling similar models involving **"chemical leasing"** of solvents and disinfectants.[134]

Reusable products are another way of reducing demand for plastics. This approach is particularly promising in the **B2B market**, where standardised, reusable packaging could be used in logistics, for example, provided that all the actors in the value network are **properly coordinated**. It is easier to implement packaging tracking in this market, where business models can be **scaled up more easily** and be **less fragmented**.

As well as **simplifying reverse logistics**, IoT solutions such as RFID tags, sensors and **digital product passports** make it possible to **grow business models** and **optimise** processes by providing packaging with additional functionality.[135] In the **consumer market**, too, there are more and more examples of business models based on **reusable or refillable packaging**, for instance for cleaning or personal care products and food delivery services.[136]

3.4 Areas requiring policy action

Market forces alone will not be enough to drive the necessary transformation of plastics industry value networks – policy support will also be vital. Areas that must be addressed by policymakers include the creation of a level playing field for sustainable plastic products, the amendment of the regulatory framework, funding for R&D, training and professional development, and consumer empowerment.

The **policy framework** plays a key role in determining whether the innovations needed for a sustainable transformation are **implemented in practice** and whether any **market barriers** are overcome. The following sections address policy areas that are particularly important for the transformation of the plastics industry, but which in many cases are also **of cross-sectoral significance**.

A level playing field for sustainable plastic products

Fiscal instruments can help to create a **level playing field for sustainable products and services**, for example allowing plastics made from secondary feedstocks to compete with plastics made from fossil fuel-derived primary feedstocks. A standard **carbon price** set at an effective level is the most frequently cited instrument in this context.

133 | See Berg/Wilts 2019.
134 | See Kümmerer et al. 2020; Schülke & Mayr GmbH 2012.
135 | See Ellen MacArthur Foundation 2019c; EPC 2020..
136 | See Ellen MacArthur Foundation 2019c.

The experts also called for a fundamental remodelling of the tax system that would involve a (revenue-neutral) **tax shift** away from labour and income and **towards resource consumption** (e.g. a tax on extracted raw materials).[137]

Instruments like this could help to **internalise the costs of damage to the climate and environment** resulting from activities such as the extraction of primary fossil resources, thereby creating a **level playing field** for sustainable products and services and labour-intensive circular economy business models.

"Even with access to the full range of technologies, a circular economy for plastics is not economically viable at this point in time."

Some of the experts suggested the alternative approach of an **extended producer responsibility fee** that would be paid directly into a fund for improving the recycling infrastructure or for R&D in this area. In addition, the **public sector** can directly grow the recycled plastic market by stipulating recycled content requirements in its **sustainable procurement rules**, for example.

A regulatory framework that promotes sustainability

In principle, the experts considered a continued focus of the **EU's Ecodesign Directive** on sustainability criteria to be an **appropriate instrument** for the relevant regulatory action. However, they also stressed that it is necessary to **strike a balance**, since overly detailed definitions could potentially inhibit innovation and confuse or overburden producers. Regulatory design should be **underpinned** by a holistic **approach to the entire life cycle**.

In order to encourage more businesses to engage in innovation, the **approval procedures** for new materials and products should be **simplified, accelerated and aligned with new developments**. The lessons learnt from the regulatory sandbox for a materials transformation could support this process (see Box 6).

"Someone has to cut the Gordian knot of plastic recycling."

The introduction of a **recycled content requirement** (see also Appendix I.5) would provide the most **direct incentive** to use a higher percentage of recycled plastic. It would have the **advantage** of supporting the use of recycled plastic in the **higher-grade plastics** made in Europe, as well as making it less attractive to **downcycle** plastic waste or remove it from the value cycle by using it to **produce energy**. A recycled content requirement is already mentioned as a possible policy instrument in the EU's Circular Economy Action Plan.[138]

Some of the experts interviewed for this publication advised a cautious approach to recycled content requirements, since **the recycling capacity needed to achieve high percentages will not be available in the short term**. However, they believe that a long-term strategy to gradually increase the recycled content requirement can be a valuable instrument that provides companies with a **reliable basis for planning investments** to expand recycling capacity and improve recycled plastic quality.

"There are serious limits on what a circular economy can achieve with 27 different waste management systems."

A lack of regulatory harmonisation with regard to waste management and the circular economy is hampering the development of sustainable, transnational value networks.[139] It is therefore important to create **platforms at European level** where member states can coordinate their actions and discuss their experiences with different types of regulation. According to the experts, the **European Plastics Strategy** and the **Circular Economy Action Plan** already set out an appropriate pan-European vision in this regard.[140] However, they stress that this vision must now be **rigorously implemented** by the member states.

Hardly any economic incentives exist for prolonging the useful life of plastics by **reusing, remanufacturing and repairing** products with plastic components. Solutions such as **deposit return schemes** could make a contribution in this area.[141] However, the experts warn against creating **too many parallel** structures.

137 | See The Ex'tax Project 2016.
138 | See EU COM 2020c.
139 | See acatech 2019c.
140 | See EU COM 2018c; 2019a; 2020c.
141 | See PwC 2011.

An ecosystem for a sustainable plastics industry

Individual actors, especially SMEs, often lack the **information** they need to drive forward a holistic, sustainable transformation of the fragmented plastics value network. Figure 10 provides an overview of the relevant actors.

Platforms that enable **pre-competitive collaboration between different links in the value chain** are thus an important instrument for developing and coordinating sustainable products and services. The regulatory sandboxes proposed in this publication can play a valuable role in this context (see Boxes 6 and 7).

A **European data infrastructure** or a **central open data hub** could provide the plastics industry with data relevant to the circular economy. This would facilitate circular business models and improve **transparency with regard to value streams** and **access to secondary feedstocks**.

Overall, the experts rate the research funding landscape positively, identifying several relevant programmes, especially in Germany. However, some criticised the **lack of funding opportunities for explicitly interdisciplinary research projects**. They also felt that greater emphasis could be placed on teaching **university** students **interdisciplinary collaboration skills**.

"We mustn't overlook capacity building in our discussions about access to capital, pilot projects or technology funding. People need the skills to actually put things into practice."

Consumer behaviour can also influence the **use, consumption and recycling** of plastics. Accordingly, children should be **taught** responsible attitudes towards waste and learn about its importance as a potential raw material from an early age. The "Plastic Pirates" initiative of the Federal Ministry of Education and Research is one good example of how this can be done.[142]

Greater demand for **recycled plastic and reusable products** can also act as an **incentive** for industry, even though it should also be **increasing the supply** of these products of its own accord.

The experts have **mixed feelings** about the role that **labelling** can play in helping consumers **to shop sustainably**. They feel that the introduction of a **simple, harmonised labelling system (similar to the EU organic logo)** is key to the success of this approach. This would address their concerns about consumers becoming confused if there are too many different labels.

Better **labelling of product recyclability**, including information about the relevant waste collection and sorting **infrastructure**, could also help to **improve material streams**.[143] However, it is important not to confuse consumers with overly complex instructions for sorting waste.

142 | See BMBF 2020a.
143 | See EPC 2020.

Using secondary and renewable feedstocks – decoupling plastics production from fossil resources

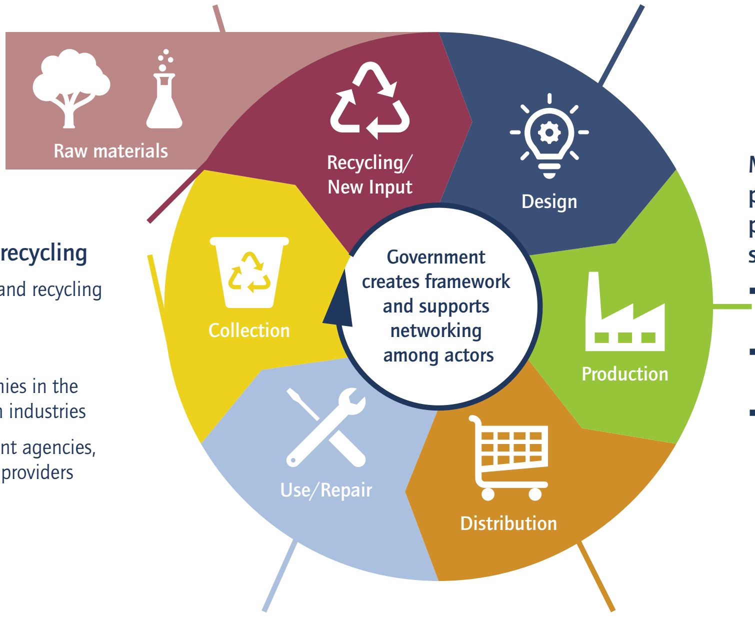
- Companies in the chemical, biotech, waste management and recycling industries
- Biomass producers

Designing for circularity and avoiding harmful characteristics – improving plastics design

- Universities and non-university research institutions
- Companies in the chemical and biotech industries

Closing the loop – increasing plastics recycling

- Waste management and recycling companies
- Dual System
- Retailers and companies in the chemical and biotech industries
- Potentially government agencies, as public data space providers



More efficient, modular production – producing and processing plastics more sustainably

- Companies in the chemical and biotech industries
- Companies in the plastic processing industry
- Universities and non-university research institutions

Extending useful life and increasing resource productivity – reusing plastics

- Suppliers of plastic-based products
- Retailers, restaurants and reusable system suppliers
- Consumers
- Potentially government agencies, as public data space providers

Figure 10: Key actors in the plastics value network (source: authors' own illustration based on wbcsd/BCG 2018)

4 Instruments for promoting more sustainable investment and corporate policy

As well as government funding, financing the necessary but costly transformation of the economy will also require the mobilisation of sufficient levels of private investment. In order to promote investment in sustainable business models, investors should have access to transparent instruments for evaluating companies' efforts to become more sustainable. These should also reflect the transformation strategies that they intend to implement in the future. The EU Taxonomy, financial product labels, rating agencies and corporate reporting can all serve as points of reference. The fragmented and often confusing current reporting system should be harmonised and should focus on measurable indicators. Furthermore, the reporting process for businesses should be as unbureaucratic as possible.

If the objectives of the Green Deal and the German government's sustainability targets are to be achieved, **sustainability** must become an **integral part of corporate policy** and **investment decisions**. This will require **climate and sustainability goals** to be anchored **in the corporate strategy** of individual businesses, while progress towards these goals will need to be measurable at an operational level.

> *"The Green Deal is the biggest revolution in the finance sector since the Second World War."*

However, financing the **transition towards sustainable, resilient value chains** involves a **long-term commitment** that is not always easy to reconcile with shareholder expectations of short-term profit. On the other hand, there are currently some signs of a **trend towards a values-based way of doing business** that – as long as the right framework is created – could give corporate leaders more leeway to make decisions focused on long-term sustainability.[144]

In order to encourage this transformation, the experts believe that it is **especially important** for companies' sustainability and climate strategies to be **auditable and comparable**. As well as technological innovations within businesses, this will also call for **social innovations** in the field of **sustainable finance and reporting**. It will only be possible to transform society as a whole if the changes in the different subsystems such as investment, production, legislation and consumption mutually reinforce each other, thereby ensuring that the overall trend is clearly in the desired direction.

The following sections look at some of the instruments for mobilising private capital in order to pursue sustainability goals. They combine the twin objectives of **directly increasing investment in sustainable activities** and making sustainable investments **more transparent**, thereby indirectly increasing the level of such investments by making them more visible and attractive. In addition, the incentive instruments described below are aimed at **encouraging companies to switch to sustainable business models** and making it financially viable for them to do so**.**

4.1 EU Taxonomy

The EU Taxonomy is the central instrument underpinning the European Commission's sustainable finance strategy. As a classification system for assessing the sustainability of almost every economic activity, it provides an overall framework for the public and private finance sectors. The current version assesses climate and environmental criteria and could already be used in the development and implementation of economic recovery measures. It is intended that future versions of the Taxonomy should also address social and governance criteria.

The EU Taxonomy forms the **basis of the EU's sustainable finance strategy**.[145] According to the experts, the Taxonomy is **well advanced** in its development and could to some extent already be used to establish climate and environmental **principles** for the implementation of the **economic recovery packages**. However, the EU Taxonomy cannot yet be used to shape the social and governance dimensions of these packages, since it does not currently include the relevant criteria. Some of the experts

144 | See BCG 2020; Bloomberg Green 2020.
145 | See Deutsche Bundesbank 2019; EU COM 2018b.

express concerns about the risks of employing the EU Taxonomy for this purpose, due to the lack of experience with its practical application.

The **EU Taxonomy** was **adopted** by the European Commission **in June 2020** on the basis of the final report of the Technical Expert Group (TEG), published in March 2020. The Taxonomy is **mandatory**, and **came into force in July 2020**,[146] earlier than originally planned.

The aim is to use the Taxonomy as a **classification system in different areas** such as

- standards,
- labels,
- a green-supporting factor that would reduce the capital reserve requirements of banks and other financial institutions for investments in green financial products,
- and sustainability benchmarks.[147]

This **sustainability assessment** approach will be used to evaluate **economic activities** and determine whether they are sustainable according to the EU Taxonomy's definition.[148] The EU Taxonomy can be used both at EU level and at the member state level.

The introduction of an **EU Taxonomy** is the **central measure** of the **EU Action Plan on Financing Sustainable Growth**.[149] The Taxonomy is based on the final report of the specially appointed TEG, which was published in March 2020 following a two-year consultation process.[150]

The EU Taxonomy **aims** to create **transparency and comparability through a standardised classification system** that applies both to the economic activities of businesses and governments and to providers of ESG financial products.[151] In future, it will be a requirement to disclose the extent to which financial products are aligned with the EU Taxonomy (expressed as a percentage). This will make it possible to classify investments as sustainable or not sustainable according to the European Commission's criteria.

It is hoped that making it easier to compare financial products will promote targeted **investment in sustainable options**. More specifically, mobilising investment in "green financial products" should support initiatives that **help to deliver the objectives of the Green Deal**.[152] Furthermore, using the EU Taxonomy to compare financial products should help to **prevent greenwashing**, since financial products will now be assessed on the basis of a standard classification system that will flag up inadequate sustainability standards.[153]

Plans to **incorporate** social and governance criteria **into the EU Taxonomy** are scheduled to be adopted in December 2021 and **enter into force in December 2022**.[154]

How the EU Taxonomy works

Initially, the TEG defined **climate-related aspects as the basis for the** EU Taxonomy **assessments**. The aim was to determine which financial products can contribute to achieving the European Commission's climate goals by 2050.[155]

However, the current version of the EU Taxonomy **does not include criteria for assessing social and corporate governance sustainability**. Since the inclusion of these dimensions would allow for a more comprehensive assessment of financial product sustainability, it is planned to incorporate them in the next version. A **consultation process** is currently being carried out in order to identify the best criteria for measuring social sustainability. The aim is to develop the rules for these criteria by the end of 2021.

In order for a **financial product** to be classified as sustainable, it must have **a substantial positive impact on at least one** of the **criteria listed below**, while avoiding any negative impacts on the other criteria, in accordance with the **do no harm principle**. **Minimum social safeguards** must also be guaranteed.[156] The criteria are as follows:

- climate change mitigation
- climate change adaptation

146 | See EC 2019; EU COM 2020i; 2020l.
147 | See TEG 2020b.
148 | See Deutsche Bundesbank 2019.
149 | See EU COM 2018b; HLEG 2018.
150 | See TEG 2020a; 2020b.
151 | See FNG 2019.
152 | See Deutsche Bundesbank 2019; HLEG 2018.
153 | See Deutsche Bundesbank 2019; PRI 2020b.
154 | See EC 2019.
155 | See TEG 2020b.
156 | See Ibid.

- sustainable use and protection of water and marine resources
- transition to a circular economy/bio-based economy/bioeconomy; waste prevention and recycling
- pollution prevention and control
- protection of healthy ecosystems

The TEG drew on existing **reporting standards that are widely used throughout the industry as the basis for assessing alignment with the criteria listed above**.[157] This has the advantage of making reporting easier for companies, since they are already familiar with these standards.

Evaluation of the EU Taxonomy

Most of the experts broadly **welcome the introduction of the EU Taxonomy**. However, the fact that it has only been in force for a short time means that it is too early to say whether it will achieve the desired mobilisation of investment in more climate-friendly financial products.

There are some **differences of opinion** regarding the extent of the **EU Taxonomy's impact** on the financial markets. Some of the experts believe that **financial products classified as sustainable** according to the Taxonomy **will be much more attractive** to investors, and that companies' desire to obtain a positive rating will lead them to make proactive efforts to fulfil the criteria.

However, other experts **fear** that although the Taxonomy is **a useful niche market tool** for evaluating financial products, it will be unable to mobilise large volumes of capital for sustainable investment.

> *"Companies' long-term transformation plans are critical – it is not just about assessing the status quo."*

Some of the experts feel that the **scope of the criteria considered by the EU Taxonomy is inadequate**. For example, it only **assesses** companies' **status quo** and does not consider their long-term **environmental and sustainability strategies** for achieving the relevant climate goals by 2030 or 2050. This means that carbon-intensive companies tend to fare particularly badly, even if they have already committed to an ambitious transition to a more sustainable business.

Some of the experts also express **concern** that the **extensive list of assessment criteria** could **overburden** SMEs in particular and significantly increase the cost and effort of reporting. Customised reporting software solutions could help to address this issue. However, some financial experts point out that the EU Taxonomy's reporting criteria are based on reporting standards that are widely used throughout the industry. Consequently, there may be no additional costs and effort for businesses at all, and even if there are, they should be manageable.

Another drawback identified by the experts is that the use of separate assessment criteria for different industries will make it difficult to make overall comparisons, and the **assessment rules are extremely extensive**. Despite the fact that an expansion of the EU Taxonomy is already planned, some are also critical of the fact that the **current version focuses exclusively on the climate dimension**.[158]

4.2 The German government's sustainable finance strategy

Germany is already actively pursuing a sustainable finance strategy, and is thus one of the pioneers in this area within Europe. Germany must avoid going it alone – it must ensure that further efforts to develop its sustainable finance industry remain aligned with the EU framework.

In 2019, the **German government** adopted a resolution to make "Germany a leading location for sustainable finance". It also appointed a **committee** to develop a **sustainable finance strategy** for Germany.[159] In order to ensure a **balance of different interests**, the Sustainable Finance Committee includes members from the financial sector, science, industry and civil society.[160] It should be stressed that sustainable finance is **nothing new** for the German government, which has been taking sustainable finance criteria into account in its **public procurement** processes for several years.[161]

The Sustainable Finance Committee is of the opinion that the **financial sector** will play a **key role** in **financing the planned transformation** and promoting climate-friendly technology. By

157 | See TEG 2020c.
158 | See FNG 2019b.
159 | See BReg 2019e; Sustainable Finance Beirat der Bundesregierung 2019.
160 | See Deutsche Bundesbank 2019.
161 | See BMWi 2020a.

fostering innovative, climate-friendly and sustainable technologies, sustainable finance can make an important contribution to **strengthening Germany's competitiveness**. In the medium to long term, a stronger green tech sector will help to secure both prosperity and value creation in German industry.[162]

In its interim report published in March 2020, the Sustainable Finance Committee made the following three **key recommendations** to the German government:

- the introduction of an **effective carbon price**,
- implementation of the government's own **climate goals** in **budgetary allocations** and in the design of its **funding programmes**,
- and **active participation in shaping the European Green Deal and the EU Action Plan on Financing Sustainable Growth**, and in particular in the implementation of the EU Taxonomy.[163]

The interim report provides the basis for the ongoing development of the German government's consultation. A **communication strategy** is currently being drawn up in order to **increase the visibility** and understanding of sustainable finance among consumers and in the financial industry.[164] In addition, the government-owned development bank **Kreditanstalt für Wiederaufbau (KfW)** is to be given a stronger role in the context of the climate package, with the aim of turning it into a **sustainable development bank that supports the transition** of industry and the financial markets to a greenhouse gas neutral future.[165]

Evaluation of the Sustainable Finance Committee

The experts broadly **welcome the German government's engagement** with the topic of sustainable finance and its appointment of an advisory committee. They also believe that the committee's **ambitious goals** are an important step towards strengthening sustainable finance within the German financial sector.

However, some of the experts are **concerned that** because some of the goals set by the Sustainable Finance Committee are so ambitious, **Germany** could end up developing measures that **go much further than the EU targets** and actually make it harder to establish common European standards in the long run. The experts unequivocally **call for a solution that is ambitious, but common to the whole of the EU.** There is no reason why this should be at odds with Germany's stated ambition of becoming a leading sustainable finance provider – it is perfectly possible for Germany to lead the way without going it alone.

The experts believe that **Germany** should use its strong position in the field of sustainable finance to **bring other EU member states on board** and convince them of the importance of this issue. In this way, matters that are important to Germany would also have a prominent place in the measures implemented at European level. Some of the experts also criticise the extremely **detailed provisions** in the committee's recommendations, arguing that these could cause **a lot of extra bureaucracy, especially for SMEs**, but would only have a limited impact.

4.3 Transparent assessment of financial product sustainability

Sustainable financial investments are a growth market. Transparency encourages investment in sustainable financial products, and this contributes to the necessary transformation of industry. However, the criteria currently used to assess financial product sustainability are often extremely heterogeneous. Policy action is required to support the goal of harmonising ESG assessment criteria.

In order to achieve the relevant climate and sustainability goals, it will be vital to channel investment in the right direction. The extent to which this is currently happening is insufficient, not least due to the **lack of a standard definition** of green or sustainable investments. A **multitude of different assessment systems** used by different institutions are currently found in the financial markets. At least some of these **lack transparency** or only enable **very limited comparisons** of the financial products offered by different providers. This means that there can be a risk of greenwashing in the case of some individual investments.

Improved transparency could help to ensure a greater focus on sustainability, for instance by giving investors a clearer picture of environmental risks.

162 | See BMU 2018; Sustainable Finance Beirat der Bundesregierung 2019.
163 | See Sustainable Finance-Beirat der Bundesregierung 2020.
164 | See BMF 2019.
165 | See BReg 2019b.

> *"I'm not sure companies really take sustainability reporting that seriously. It feels like a lot of what they currently do is just window dressing."*

In the opinion of the financial experts, **not enough attention is currently paid to climate change risks** in the valuation of listed companies and financial products.[166] The experts also advocate **assessing the scale** of potential **climate or sustainability effects** in order to ensure the most efficient allocation of capital.

The aim should be to channel **investments primarily towards technologies and initiatives** that make a particularly **strong contribution to achieving climate and sustainability goals**. Moreover, the focus should not be exclusively on the short term – it is also necessary to support technologies that have a long-term future and can help to **increase the overall resilience** of value networks (see also Chapter 2.5).

Finally, **greater transparency** is also needed with regard to the environmental footprint of individual **products and services**. This is key to allowing consumers to make **informed purchasing and investment decisions** so that they too can contribute to the transition towards a climate-neutral society.

The EU Taxonomy that is currently being developed should also help to channel **capital towards investments** that are compatible with the **goals of the Green Deal**, thereby making the EU a leading provider of sustainable finance.[167] Further information about the EU Taxonomy is provided in Chapter 4.1.

ESG criteria

Financial product **sustainability** is usually **assessed** using the **ESG criteria**. The acronym ESG refers to the three fundamental assessment categories: **environment (E), social (S) and governance (G)**. Figure 11 provides an overview of the individual factors that affect a company's rating in each of these three categories.

As well as being required to **prove** that they have adequately **fulfilled the positive criteria**, companies also usually have to demonstrate that they are not guilty of any of the **exclusions**, such as forced or child labour or the manufacture and trading of controversial arms.[168] In other words, the underlying strategy takes a two-pronged approach: on the one hand, it aims to promote targeted investment in sustainable products, while on the other, it aims to prevent investment in unsustainable options in an equally targeted manner (often referred to as **divestment**).

Some of the experts call for the **strengthening of company-level employee participation to be included as a positive criterion** for assessing **governance**. According to some international corporate governance assessment systems, the employee representatives who currently sit on companies' supervisory boards are not independent enough and should therefore receive a negative rating.[169] However, company-level and board-level employee participation structures strengthen the pursuit of sustainability goals and collective bargaining coverage within companies. Moreover, studies have shown that **companies with stronger employee participation structures are likelier to have innovation-driven corporate strategies**. Especially in an age characterised by digitalisation and

Environment	Social	Governance
▪ Climate change strategy	▪ Equal opportunities	▪ Business ethics
▪ Environmental management	▪ Freedom of association	▪ Compliance
▪ Environmental impact of product portfolio	▪ Health and safety	▪ Supervisory board independence
▪ Eco-efficiency: CO_2, waste, water, energy	▪ Human rights	▪ Remuneration
▪ Energy management	▪ Product responsibility	▪ Shareholder democracy
▪ Water risks and impact	▪ Social impacts of product portfolio	▪ Shareholder structure
	▪ Supply chain management	▪ Taxes

Figure 11: ESG criteria for businesses (source: authors' own illustration based on KfW 2019)

166 | See BlackRock 2020a; 2020b; McKinsey Global Institute 2020.
167 | See TEG 2020b.
168 | See KfW 2019a.
169 | See Höpner 2003.

demographic change, such strategies are considered to have better overall future prospects and to enable more sustainable value creation.[170] Consequently, Germany should lobby at European level to prevent employee participation in companies' supervisory boards from being rated negatively in sustainability assessments.

The **classification system** for sustainable investments in the EU was drawn up by the High-Level Expert Group on Sustainable Finance (HLEG) appointed by the European Commission.[171] Based on this, the **European Sustainable Investment Forum (Eurosif)** has formulated seven strategies for responsible investment in Europe:[172]

1. Best-in-Class
2. Engagement and Voting
3. ESG Integration
4. Exclusions
5. Impact Investing
6. Norms-based Screening
7. Sustainability-Themed

At present, although the **classification systems used by different financial service providers and institutions** for evaluating financial products' ESG criteria **are often broadly similar, they nevertheless differ on some individual points**. These systems are partly based on principles that they have formulated themselves or on the recommendations of different international institutions such as the Global Sustainable Investment Alliance (GSIA), the Principles for Responsible Investment (PRI) and the European Funds and Asset Management Association (EFAMA).[173]

It is thus important to pursue the **goal** of **standardising the criteria for assessing ESG financial products**. This will create transparency for investors, thereby helping to channel capital towards investments that contribute to the accomplishment of sustainability and climate goals. A **standardised taxonomy or labelling system** could play a key role in this regard. In order to prevent a negative impact on global competitiveness, the experts believe that the **ESG criteria should be framed as an incentive** rather than a constraint.

ESG investment: a growth market

Rather than focusing solely on maximising their returns, a growing number of investors are also taking sustainability standards into account when choosing where to invest their money. **ESG investment is up 68% since 2014** and now **tops $30 trillion in total**.[174] Despite these clear signs of a strong trend towards sustainable investment, however, the Bundesbank estimated that **sustainable investments accounted for just 3% of the total investment market** in Germany in 2018.[175]

Although the trend towards investing in sustainable financial products and/or divestment is particularly strong among younger investors, the **growth** in sustainable investment is **being driven** mainly **by institutional investors** (with an annual growth rate of around 35%). The current growth in ESG investment among institutional investors is being propelled first and foremost by religious and charitable organisations.[176] On the other hand, sustainable investment by private investors is only growing by around 8% a year (see Figure 12).[177]

170 | See IMU 2019; 2020.
171 | See EU COM 2018b.
172 | See EUROSIF 2020.
173 | See EFAMA 2020; GSIA 2020; PRI 2020a.
174 | See McKinsey & Company 2019b.
175 | See Deutsche Bundesbank 2019.
176 | See FNG 2019a.
177 | See Deutsche Bundesbank 2019; FNG 2019a.

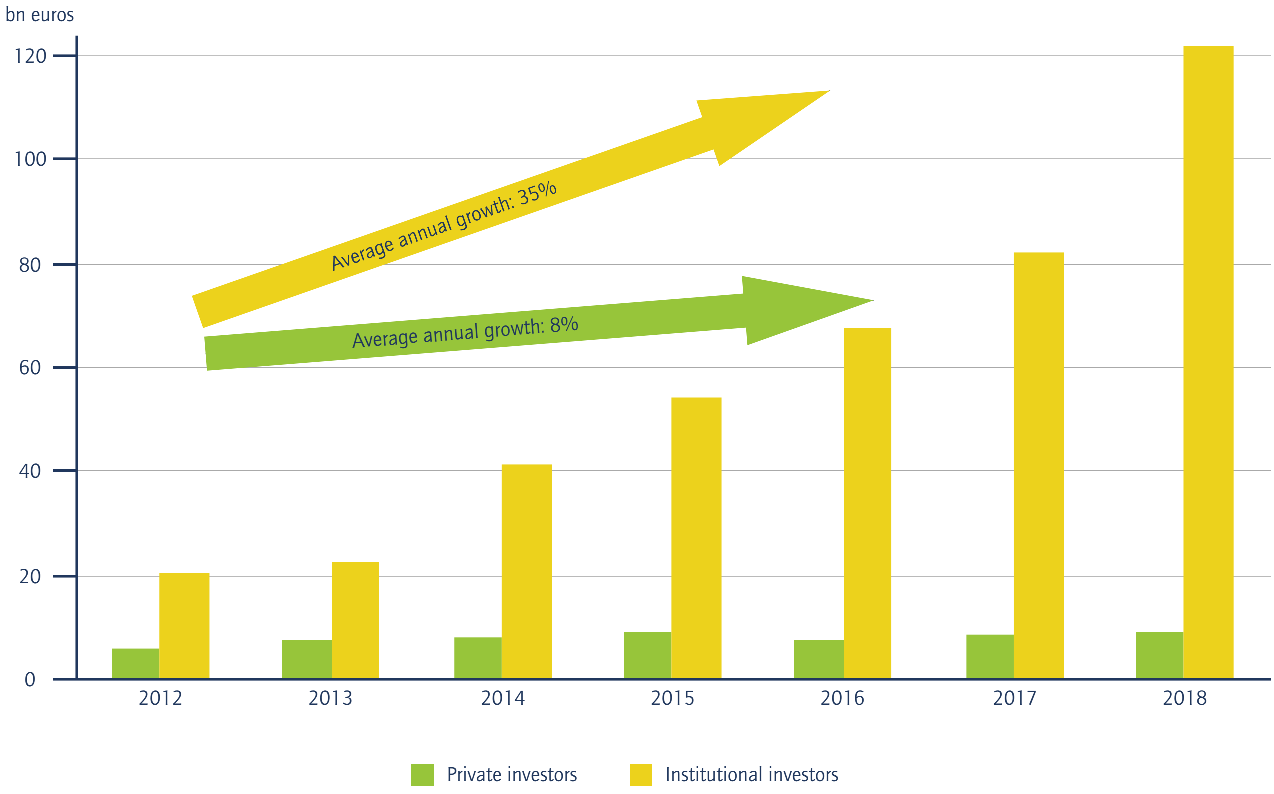


Figure 12: Overview of sustainable investment in Germany by investor type (source: authors' own illustration based on FNG 2019a)

Despite this trend, the experts interviewed for this publication report that there has **so far been very little change in the investment strategies** of larger companies and financial institutions. They believe that this is partly due to the fact that, outside of NGOs, there is currently very little pressure for organisations to change their portfolios. The experts also point out that there are **not** currently **enough sufficiently large-scale sustainable investment options** for all major investors. This means that, at this point in time, companies simply are not able to reinvest all of their capital more sustainably.

Nevertheless, more and more companies and finance and asset managers are **recognising the long-term need to change their investment strategies**. The industry is seeing a rise in voluntary commitments to progressively work towards sustainability goals through **voluntary bodies** such as the Net-Zero Asset Owner Alliance. The fact that major asset managers such as BlackRock have clearly stated that investments should pay greater attention to environmental sustainability could further accelerate the growth of this market.[178] However, some experts are already starting to warn of a **bubble**.[179]

Labels

Labels are one solution that would allow investors to tell at a glance whether or not a particular financial product is sustainable. The German government's Sustainable Finance Committee also supports the use of labels to ensure that **products complying with the relevant transformation goals** are clearly identifiable and **as easy as possible** for customers **to invest in**.[180] Labelling can also benefit financial providers by **increasing the visibility of their financial products**.

Start-ups often have particular difficulty in obtaining the venture and growth capital that they require on the European market, and this problem has been exacerbated by the SARS-CoV-2

178 | See BlackRock 2020a; 2020b.
179 | See Handelsblatt 2019a.
180 | See Sustainable Finance-Beirat der Bundesregierung 2019.

pandemic.[181] A sustainability label could increase the visibility of **green start-ups** and thus make it easier for them to gain **access to capital**.

A number of **established labels** for rating ESG financial products already exist in Germany and Europe. These include the FNG Label, the Greenfin label, the Nordic Swan Ecolabel and the Novethic SRI Label.[182] According to the experts, **there are significant differences between these labels** in terms of how much they tell investors about a product's contribution to achieving climate and sustainability goals and in terms of their **selection and exclusion criteria**. This makes it very **difficult to compare** different labels. The experts also highlight the danger of financial product greenwashing in cases where financial service providers create their own labels based on very weak criteria.

Although the experts believe that well-designed labels can make it easier to decide which sustainable financial products to invest in, they also stress the **importance of avoiding** a confusing **proliferation of labels**. The European Union's plans to extend the **EU Ecolabel** to **financial products** could offer one possible solution. The intention is to use the EU Taxonomy as the basis for determining whether a financial product should be awarded the EU Ecolabel.[183]

4.4 Reporting standards

Businesses produce both mandatory and voluntary reports publicising their current sustainability initiatives and planned future transformations. However, the reporting standards used often provide only limited meaningful information, or only allow limited comparisons to be drawn. Policymakers should promote meaningful, harmonised reporting standards that can provide a robust basis for corporate and policy actions.

The multitude of ESG criteria that can be used to measure a company's sustainability is directly reflected in the **large number of different reporting standards** that currently exist side by side. **Efforts to harmonise reporting standards** are thus of paramount importance. The aim should be to create a global standard, or at the very least **a common European standard**. This is absolutely key to increasing transparency in relation to corporate sustainability, which is in turn essential to providing a robust basis for corporate and policy actions.

It will be important to ensure that the **results are as meaningful and easy to compare as possible**, but that the reporting burden for companies is kept within manageable proportions. The EU Taxonomy can provide a useful basis for a European standard (see also Chapter 4.1).

> *"We need to harmonise reporting standards, but we can't do it with a bottom-up approach."*

In most cases, the reporting standards are used as a **basis** for drafting corporate **sustainability reports**. However, **some initiatives** go a step further, aiming to help companies use transparent reporting to work towards **achieving certain climate or sustainability goals**. Some of the most important reporting standard initiatives are presented below. Appendix J contains an overview of the following **other initiatives**: Global Reporting Initiative (GRI), Task Force on Climate-Related Financial Disclosures (TCFD), Carbon Disclosure Project (CDP) and Net-Zero Asset Owner Alliance.

Non-Financial Reporting Directive (NFRD)

The vast majority of corporate reporting standards are voluntary in nature. However, the Non-Financial Reporting Directive (NFRD) is an exception to this rule. This **EU directive** requires listed **companies with over 500 employees** to disclose their non-financial information.

Companies must report on the **environmental and social impacts** of their activities and on how their business is implementing the social goals anchored in the SDGs (e.g. anti-corruption policy, equal opportunities). The directive, which was **last updated** in 2016, **is currently being reviewed**.[184] A public consultation on the review of the Directive concluded in mid-June 2020.[185] The experts hope that the review will address its **current weaknesses** such as the **lack of quantitative evidence** to back up the claims made in the reports and the **lack of a standardised reporting format**. The goal of achieving harmonised reporting standards is addressed by the two initiatives described below.

181 | See acatech 2020.
182 | See FNG 2020; Nachhaltiges Investment 2020; Nordic Swan Ecolabel 2020; novethic 2020.
183 | See EU COM 2018b; TEG 2020b.
184 | See EU 2014.
185 | See EU COM 2020e.

WEF Common Metrics

The first draft of a common metrics system for reporting ESG standards was presented at the **World Economic Forum (WEF)** in Davos in **January 2020**. The common metrics were developed by the International Business Council (IBC) in collaboration with Deloitte, EY, KPMG and PwC, in a process lasting just under one year. The **goal** of this initiative is to **align** the metrics **used by different industries and countries for reporting ESG criteria** ("alignment process").[186]

The IBC is made up of 120 selected chief executives from all industries. As a result, the metrics developed in this process enjoy industry-wide support. Wherever possible, they are based on **existing principles**, in order to ensure that the **additional reporting burden** for companies is **as manageable as possible**.

The reporting standard comprises four pillars: principles of governance, planet, people and prosperity (see also Figure 13). There are **22 mandatory core metrics** and a number of additional **expanded metrics**, some of which address industry-specific issues.[187] The **goal** of the initiative is to work towards a **common global reporting standard** and to harmonise existing standards as far as possible.

Value Balancing Alliance

The Value Balancing Alliance was founded in 2019 with the **vision** of developing a single, generally accepted standard for the **measurement and monetary valuation** of companies' **environmental and social impacts** and the assessment of companies' contributions to society from an environmental, social and economic perspective.[188]

Together with its project partners, the Alliance aims to develop a **binding standard** within the next three years. It is hoped that this standard will play a decisive role in determining future corporate investment decisions, thereby supporting the Alliance's vision of encouraging a shift **away from an exclusive focus on maximising returns and towards a focus on optimising value.**[189] In order to ensure better comparability and transparency, the assessment of a company's positive and negative impacts on society and the environment – and of the value contributed by the company itself – will be based on uniform, standardised data. To ensure that this data is **auditable**, it must be **incorporated into the financial reporting system**.

The Alliance's members include both **German and international companies** such as BASF, Bosch, Deutsche Bank, LafargeHolcim,

Principles of governance	Planet	People	Prosperity
The definition of governance is evolving as organisations are increasingly expected to define and embed their purpose at the centre of their business. But the principles of agency, accountability and stewardship continue to be vital for truly "good governance".	An ambition to protect the planet from degradation, including through sustainable consumption and production, sustainably managing its natural resources and taking urgent action on climate change, so that it can support the needs of the present and future generations.	An ambition to end poverty and hunger, in all their forms and dimensions, and to ensure that all human beings can fulfil their potential in dignity and equality and in a healthy environment.	An ambition to ensure that all human beings can enjoy prosperous and fulfilling lives and that economic, social and technological progress occurs in harmony with nature.

Figure 13: The four pillars of the Common Metrics (source: authors' own illustration based on WEF 2020b)

186 | See WEF 2020b.
187 | See Ibid.
188 | See Value Balancing Alliance 2020b.
189 | See FAZ 2020a.

Mitsubishi Chemicals, Novartis, Porsche-Volkswagen, SAP and SK Holdings. Moreover, the Alliance is **supported** by the **EU**, the **OECD**, the **World Bank** and the big four **accounting organisations** Deloitte, EY, KPMG and PwC.[190] It is also partnering with **several universities** to develop the relevant methodologies. The EU also has an interest in the development of green accounting principles and is supporting the Alliance's work.

The Value Balancing Alliance's **medium-term vision** is for its standard to become **a global accounting industry standard** that incorporates all three (environmental, social and economic) dimensions of sustainability.

Rating agencies

Some rating agencies specialise in evaluating sustainability criteria, for example imug rating, ISS, MSCI ESG and Sustainalytics.[191]

Moreover, the established rating agencies such as **Fitch, Moody's and Standard & Poor's,** also offer **assessments based on ESG criteria** as part of their **credit assessments** of companies and financial products.[192]

> *"We don't even have a common standard for measuring carbon footprints."*

There are some **differences of opinion** among the experts **about the need for a European rating agency** focused specifically on the assessment of climate and sustainability goals. Some see an **opportunity to plug a gap** in the financial market and create an **alternative to the Anglo-Saxon rating agencies**. With a market share of around 95%, the big three US rating agencies mentioned above currently form an oligopoly, and some of the experts felt that a European alternative is urgently necessary.[193]

Trade union representatives also support an independent European rating agency, arguing that the current rating landscape lacks transparency and that the dominance of the Anglo-Saxon agencies distorts competition. However, other experts express **concerns** that the establishment of a European sustainability rating agency could result in the current reporting system **becoming even more fragmented**.

Evaluation of the current reporting standards landscape

The European Financial Reporting Advisory Group (EFRAG) has found that **companies** are good at reporting the climate-related policies that they have in place, but **less good at disclosing** how successful or unsuccessful they are at achieving the **targets they set themselves**.[194] One general criticism of systems that assess companies based on their own reporting is that **it is difficult for third parties to audit their self-reported data**, since this data usually relates to internal processes, value chains and cash flows.

Although the **logistics** of carrying out **external audits** of self-reported data are **extremely complicated**, the experts suggest that **digital solutions could provide invaluable support**. For instance, sensors could be used to automatically measure and digitise reporting data such as waste gas emissions or fresh water consumption.[195]

The experts regard **digital assessment platforms** such as Arabesque, which are **based on big data and AI-enabled swarm intelligence**, as promising examples of new digital business models for the bottom-up assessment of financial products.[196]

Some of the experts are also **concerned** that policymakers might prefer to **impose additional reporting requirements** on businesses **instead of implementing** concrete and **far-reaching** but controversial policy **measures** such as a higher carbon price. Business representatives clearly signal their readiness to carry out reporting, since it can also help them to analyse their own internal processes. However, they call for policymakers to keep reporting requirements within manageable proportions.

190 | See Value Balancing Alliance 2020a.
191 | See imug 2020; ISS ESG 2020; MSCI ESG 2020; Sustainalytics 2020.
192 | See Fitch Ratings 2020; Moody's 2020; SP 2020.
193 | See Siebert 2014.
194 | See European Reporting Lab/EFRAG 2020.
195 | See Bloomberg Green 2020.
196 | See Arabesque 2020.

5 A coordinated European approach to sustainability through innovation

Germany should promote the coordination of European initiatives aimed at fostering sustainability through innovation. It can do this through existing institutions for financing innovative projects such as the European Investment Bank, through measures to support structural change at regional level, and through IPCEIs, a targeted instrument for addressing market failure in strategic areas. Europe's strength in research must be consolidated on a long-term basis through the next Framework Programme for Research and Innovation, supplemented by closely coordinated transfer and innovation programmes that could be bundled under the new European Innovation Council, for example.

The **Green Deal** was conceived as a conceptual framework for the work programme of the new European Commission (see Appendix A for an overview of the original version of the Green Deal and its central investment programme, InvestEU). The experts highlight two aspects of the Green Deal that they believe should be included in all future sustainability initiatives.

Firstly, the Green Deal seeks to **systematically connect different policy areas** such as environmental, social, industrial, competition, economic and innovation policy. This is to be welcomed, since contradictory developments in the individual policy areas have often hampered innovation in the past.

"If we are now able to make big steps in political concepts and projects in Europe, that can be a door opener."

Secondly, it aims to **coordinate European efforts to promote sustainability**, in order to minimise inefficiencies and generate cross-border **synergies**. Some experts argue that a coordinated European approach – both in this area and also for the economic stimulus and recovery programmes in the wake of the SARS-CoV-2 pandemic – is not only necessary to **add value** beyond the individual projects, but also to **prevent the single market from being compromised** by different member states implementing different packages of measures.

Accordingly, the following sections look at a variety of **European instruments and institutions** that, in the opinion of the experts, could either be used directly or be strengthened in order to **finance** European sustainability-related **innovation projects** (Chapter 5.1) and translate Europe's strong **research base into commercially viable innovations** that support sustainability (Chapter 5.2).

5.1 European instruments and institutions for financing innovative projects

The European Union already has a variety of instruments and institutions that focus on sustainability goals. For instance, the EIB can play an important role as a complementary partner to private investors in the forthcoming recovery programmes. Lessons learnt from the smart transition concept can be applied to programmes for strengthening regions that have been hard hit by the pandemic and are also more generally under pressure to transform. Sustainable public procurement and contracts for difference can encourage innovative businesses to risk bringing sustainable processes, goods and services to market, even during an economic downturn.

The European Investment Bank – complementing rather than competing with private investors

The **European Investment Bank** (EIB) plays an important institutional role in financing sustainable initiatives. Even before the Green Deal was adopted, the EIB had reviewed its **internal objectives** and, as part of its new Energy Lending Policy, announced that it will increase the share of its **financing dedicated to climate action** from 25% to **50%**.[197] The bank will aim to support EUR 1 trillion of investments in climate action and environmental sustainability between 2021 and 2030.

197 | See EIB 2019b; 2020a.

In 2007, the EIB became the first institution to issue **green bonds**.[198] In 2020, the **German government** followed suit by issuing Green Federal securities.[199] The experts suggest to build on lessons learned when it comes to **anchoring sustainability criteria** in the design and implementation of major **economic stimulus packages**.

The vast majority of the experts interviewed welcome the EIB's stronger focus on sustainability and resilience. However, some have reservations about **redefining its role as a climate bank** and about calls to strengthen its investment activities in **projects outside of Europe**, especially in developing and newly industrialised countries. Others counter that this type of investment can deliver particularly significant sustainability gains and can also generate export opportunities for European businesses.

The misgivings expressed by some experts about expanding the scope of the EIB's activities are largely fuelled by the perception that, **in the past, the EIB has tended to compete with private investors** over investment projects, rather than acting as a complementary partner. Instead of enabling additional investment that would not have otherwise occurred (**additionality**), they warn that it could squeeze out private investors or, conversely, that it could cause a deadweight effect if the instruments and framework for EIB investments are poorly designed.

> *"What can the EIB do that private investors can't? It can implement policy goals. And private investors can then follow its lead."*

The experts also stress that if the EIB is to **play a complementary role to private investors**, it should not invest in low-risk ventures where there is already plenty of interest among private investors. Instead, it should focus on **absorbing the highest risks** in riskier ventures, thereby making it more attractive for private investors to finance the rest of the venture. Accordingly, some of the experts propose an **iterative process** that would allow the EIB and other development banks to withdraw their initial investment if a venture was heavily oversubscribed among private investors.

The experts also believe that a similar complementary role should be taken on by the development banks of the individual member states, such as Germany's **Kreditanstalt für Wiederaufbau (KfW)**. They recommend that the national development banks should continue to **coordinate initiatives and bundle resources with the EIB**, as they are already doing in relation to the short-term measures for addressing the economic impacts of the pandemic.[200]

The Just Transition Mechanism and smart specialisation – region-specific innovation funding

The **Just Transition Mechanism** aims to provide targeted support for **regions** that are particularly badly **affected** by structural change. This instrument is primarily intended to finance **retraining, professional development and infrastructure** projects that help the affected regions to overcome the challenges posed by structural change. The goal is to prevent a disproportionate burden on individual regions and to strengthen the **social dimension of sustainability**. The economic impacts of the pandemic have made this even more important.

It is intended that this mechanism should mobilise around **EUR 100 billion**.[201] However, some of the experts think that this is not enough to accomplish the relevant goals, and it will now be even more difficult in the wake of the SARS-CoV-2 pandemic.

In order to **avoid artificially maintaining outdated structures** and to reduce deadweight effects, the experts stress that these funds should be used to support forward-looking initiatives that are focused on innovation. However, there is considerable disagreement concerning the extent to which this is guaranteed by the mechanism's design. Some experts think that the mechanism's chief role is actually to **win over** the member states that are sceptical about the Green Deal.

Regardless of their views about the Just Transition Mechanism itself, the experts are fundamentally in favour of region-specific investment programmes that should ideally require the **regions' active engagement**, for example through concrete, locally developed mind maps. They also recommend that more attention should be paid to regions' existing **comparative strengths**, and called for the regions to **share their experiences** with each other. As part of the recovery packages, these programmes could tie in with the EU's **smart specialisation** strategy or the Federal Ministry of Education and Research's "WIR!" innovation and structural programme in Germany.[202]

198 | See EIB 2019a.
199 | See BReg 2020; Deutsche Finanzagentur 2019.
200 | See EIB 2020b.
201 | See EU COM 2019d; 2020h.
202 | See BMBF 2019c; EU COM 2012.

Green public procurement and carbon contracts for difference – generating demand and a reliable planning basis for investment in climate-friendly production

The **transition to climate-friendlier production** often fails due to a lack of demand, because the relevant products are more expensive than their traditionally manufactured counterparts. Consequently, investments in many climate-friendly production processes only become worthwhile if the carbon price is set above a particular threshold. The first problem can be addressed through the continued expansion of **green public procurement**. Rather than always awarding contracts to the cheapest provider (of steel or cement, for example), **weight should also be attached** to the products' **carbon footprint** as determined by transparent criteria and metrics. **Other sustainability dimensions** – such as the social standards in the regional and federal regulations – are already a well-established part of the public procurement process and could be strengthened even further.[203]

For this to happen, the public sector must be willing to pay more for green products and services. The fact that government spending would be contributing directly to the accomplishment of sustainability goals would not be the only benefit of such an approach. It would also generate **demand** – it is estimated that a **volume of EUR 500 billion** would be enough[204] to create **significant markets** for sustainably produced **goods** and **services**. According to the experts, this would enable production methods to be **scaled up and refined**, which would in turn bring down production costs and make the relevant goods more affordable. In the best-case scenario, these would become competitive on the free market in the medium term.

The second problem is that the carbon price must be set above a particular level for investments in certain industrial processes and facilities to be profitable. This can be addressed by carbon **contracts for difference** (CCfD), an instrument that can also be employed in the energy sector.[205] Many companies are currently reluctant to invest due to the **uncertainty surrounding the future carbon price**.

CCfDs could allow companies to secure investments in climate-friendly technologies, for example with the EIB. These contracts are based on a **carbon price** that is higher than the current price, thereby making the investment economically viable. The **difference between the real price and the target price is effectively subsidised for the company** until the real carbon price reaches the target level. The subsidy must be repaid when the real price rises above the target price.[206] The experts believe that this instrument has huge potential, since it can provide **businesses with a reliable planning basis** by guaranteeing that they will be paid a price commensurate with the size of the challenge. As well as the carbon price, contracts for difference can also be used for other variables such as the electricity price.

The Carbon Border Adjustment mechanism – seeking instruments to create a level playing field by counteracting global variation in sustainability standards

Various different instruments have been discussed with a view to creating a **level playing field** between European suppliers, who have to comply with increasingly stringent sustainability criteria, and suppliers from **markets with lower climate and sustainability standards**. The Green Deal itself provides for a Carbon Border Adjustment mechanism in certain sectors.[207]

While the exact design of the Carbon Border Adjustment mechanism has yet to be finalised, in essence it will **make imports** from markets with lower carbon prices **more expensive**. Some models also include export measures. As well as creating a level playing field in the European single market, it also aims to reduce **carbon leakage risks**, i.e. the risk of production being relocated to markets with lower environmental standards.[208]

In principle, the experts interviewed for this publication agree that **a level playing field is necessary** in a global economy where different markets are pursuing climate goals at different speeds and with different levels of ambition, and where the introduction of a global carbon price remains highly unlikely in the foreseeable future. However, it is **unclear** whether it is actually possible to create a level playing field and which **measures** would be necessary to do so. Many of the experts express the **concern** often heard in the public debate that the unilateral introduction of a Carbon Border Adjustment mechanism by the EU could trigger extensive **trade disputes**.

203 | See Sack et al. 2016.
204 | See BMU 2020.
205 | See DIW 2019.
206 | See Ibid.
207 | See EU COM 2019d.
208 | See Ismer et al. 2020.

5.2 How can Europe's strong research base be more successfully translated into economic value?

Even during times of crisis, it is vital to maintain Europe's strong research base, since it provides a source of new ideas for responding to unforeseen events and for developing innovations. The European Innovation Council (EIC) could act as an umbrella brand for the EU's transfer and innovation programmes. As part of the recovery programmes, these – and IPCEIs – can help to overcome the "European paradox" by translating good ideas into innovations and value added within Europe.

Horizon Europe – a vital early seedbed for open-ended innovation

In general, the experts **welcome the current framework programme**. In particular, they stress the importance of maintaining the European Research Council (**ERC**), which they believe to be key to **guaranteeing the scientific excellence** of European research.

In spite of Brexit and the damage to the economy caused by the pandemic, the experts therefore recommend that **significant financial resources** should be made available for the next **Framework Programme for Research**. They maintain that **substantial cuts** to the Framework Programme's original budget would **threaten** Europe's **strength in research and innovation**.

35% of the budget of Horizon Europe – the new Framework Programme for Research and Innovation in the EU's next Multiannual Financial Framework – is earmarked for **climate-related projects**.

However, the experts make the general point that open-ended **basic research** focused solely on excellence should not be neglected in favour of programmes that are limited to specific topics or that are initiated in response to current events. Particularly during times of crisis, it is vital to cultivate **"early seedbeds"** of basic research that produce unpredictable but often **groundbreaking innovations**.

> *"The ERC turns money into ideas. The EIC must turn ideas into business models."*

In the medium to long term, research funding that is too strongly focused on practical, short-term outcomes will threaten Europe's strength in innovation, which is also the key driver of sustainability. Consequently, the experts urge the **German government to lobby in favour of retaining the original budget** for the next Framework Programme for Research and to advocate the further **expansion of the European Research Area** (ERA).

The European Innovation Council – creating an umbrella brand for European transfer and innovation funding

The experts are particularly **concerned** that the new **European Innovation Council** (EIC) could be affected by cuts to the Framework Programme's final budget. The EIC is less established than bodies such as the ERC. Moreover, the experts report that the relatively high sum of **ten billion euros** allocated to the EIC in the original budget attracted the attention of sceptics. In the budget negotiations held in September 2020, the EU's research ministers decided to reallocate some of the EIC's original budget to the Marie Skłodowska Curie programme.[209]

To accept this decision would be to sanction cuts to an instrument designed to **engage new actors such as start-ups, SMEs and spin-offs** from research institutions, as well as to **strengthen the transfer of knowledge and technology** from research to concrete value-added applications. This is an area where Europe still has considerable room for improvement.

The fact that Enhanced EIC Pilot funding lines were oversubscribed many times over demonstrates the need for and interest in such an instrument.[210] In the first round, **a total of EUR 307 million** was awarded to **64 start-ups** working on innovations to support the Green Deal.

The EIC is due to commence its full work programme in 2021. Some of the experts believe that the EIC could be developed into an **umbrella brand for EU transfer and innovation funding**, enabling better coordination and leveraging of individual measures. In the long run, this could help to address Europe's renowned weakness when it comes to translating research into value-added applications, often referred to as the "European paradox".

The experts identify two particularly promising approaches to the future development of the EIC. Firstly, they recommend that the EIC should establish close ties with national institutions for funding disruptive innovations, such as Germany's **Agentur für**

209 | See Science Business 2020.
210 | See EU COM 2020m.

Sprunginnovationen. Successful projects funded by national agencies could, for instance, be granted faster and easier access to **EIC funding** to help **scale them up throughout Europe**. However, this would revolutionise the scope of the EIC's current funding, requiring an expansion of the EIC to include funding for large-scale industrial networks for scaling up disruptive technologies.

Secondly, the EIC Accelerator Pilot employs a **blended finance** approach in which the funding offered comprises a mixture of **non-repayable grants** (up to EUR 2.5 million in the pilot scheme) and **equity capital** (up to EUR 15 million in the pilot scheme). The experts believe that this approach has benefits for both the public and private sectors. As far as businesses are concerned, it helps them to bring innovations to market. EU funding can act as a **positive signal for private investors**, thereby facilitating access to additional capital. As far as the public sector is concerned, it can sell its stake in successful projects in order to **generate capital for funding further projects**.

Some experts regard blended finance as a valuable instrument for addressing the **difficulty in accessing venture and growth capital encountered by many of the burgeoning technology companies** offering innovative green tech solutions. This is true in general, but especially in times of crisis, when the survival of many start-ups is under threat. Even before the SARS-CoV-2 pandemic, it was harder-than-average for green tech companies to access venture and growth capital in the European market.[211]

The experts also identify a number of other possible solutions for improving the growth capital ecosystem and **preventing** the crisis from causing the **disappearance of an entire generation** of innovative new competitors in leading-edge fields. As part of the recovery packages, **hybrid co-financing platforms** could be established for public and private investors, or a **jump-up initiative** could be launched for fast-growing green tech companies.[212] These solutions could be tied in with the direct assistance available through the SARS-CoV-2 Matching Facility.

The mobilisation of **institutional investors** could also generate significant momentum. Restrictive statutory regulations mean that the amount of venture and growth capital currently made available by institutional investors is extremely low.

IPCEIs – joining public and private sector forces for ambitious innovation projects

Since 2014, it has been possible to use **Important Projects of Common European Interest** (IPCEIs) to facilitate the approval of State aid, provided that it is for the purpose of addressing a market failure and that there is a **coalition of the willing** involving several **member states, research and industry** that is ready to invest in the innovation-driven project.

The experts are largely **positive** about the first IPCEIs to be actively promoted by Germany, on the topics of **microelectronics** and **battery cell production**.[213]

Based on the lessons learnt from these initiatives, they believe that the **speed with which future IPCEIs are implemented** is the main area where there is room for improvement.

> *"Europe can develop the technologies to decarbonise the global economy."*

According to the experts, **green technologies** are in general a **good candidate for IPCEIs**, since their testing, commercial launch and scaling often come up against the very barriers that this instrument is designed to address. Consequently, they recommend that **Germany should continue to engage** in the design, funding and implementation of IPCEIs and associated research initiatives, for instance on the topic of **hydrogen** (see Chapter 2.1).

211 | See atomico et al. 2019; Keilhauer 2015.
212 | See acatech 2019b.
213 | See BMWi 2020b.

Appendices

Appendix A: Key elements of the Green Deal as published in 2019

The key points of the EU Green Deal as published by the European Commission in 2019 were as follows:

- The **overarching goal** of the Green Deal is for the **EU** to achieve **climate neutrality by 2050**. All of the other goals are subordinate to this fundamental aim. As part of its efforts to achieve net zero greenhouse gas emissions by 2050, the EU intends to set an **interim target** for the reduction of greenhouse gas emissions by **2030**. This is currently the subject of a public consultation, with the Commission proposing a reduction of **50%-55%** below 1990 levels. The EU also plans to pass a **European Climate Law** to make these overarching targets legally binding.
- The EU plans to mobilise **EUR 1 trillion of public and private investment** over the next decade. Just under half of this sum (EUR 485 billion) would come from the EU budget, while the remainder would be provided by the member states and private investors (see Figure 14).
- **EUR 100 billion** will be allocated to a **Just Transition Mechanism** – EUR 7.5 billion from the EU budget and the rest from other public and private sources such as the European Investment Bank (EIB). The aim of the Just Transition Mechanism is to provide **financial support to regions** such as coal-mining regions, where achieving the desired structural transformation of the economy is particularly difficult.
- The **Circular Economy Action Plan** was conceived as a central pillar of the new **EU Industrial Strategy**. It aims to promote product, business model and behavioural innovations that help to decouple value creation from virgin resource consumption.

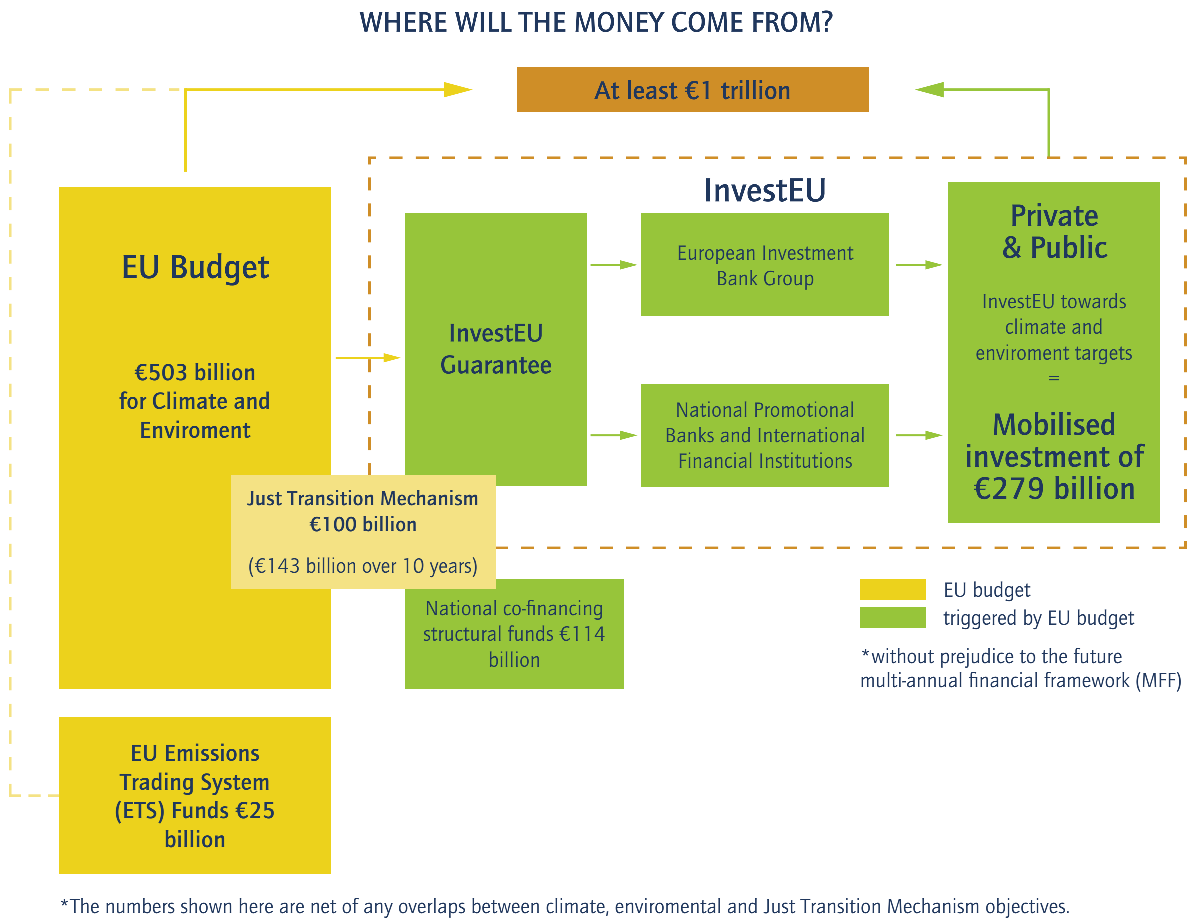


Figure 14: Overview of the planned funding of the EU Green Deal as published in 2019 (source: authors' own illustration based on EU COM 2020h)

- At least **35%** of the budget of the new **"Horizon Europe"** Framework Programme for Research and Innovation will be devoted to funding research and innovation projects investigating new **climate solutions**.
- A **Carbon Border Adjustment mechanism** will aim to ensure the competitiveness of goods that have been sustainably produced in Europe by imposing levies on unsustainably produced imports from other parts of the world.
- The **"Farm to Fork" strategy** aims to strengthen sustainable regional food production and significantly reduce the use of fertilisers, chemical pesticides and antibiotics in agriculture.
- Coupled with increases in the price of pollution rights, a range of new and tougher **regulations**, such as new emission limits, energy efficiency regulations and recycling standards will seek to further strengthen environmental protection and reduce CO_2 emissions.
- **Additional measures:** accelerate expansion of the renewable energy supply, promote energy-efficient retrofits of buildings, roll out of sustainable mobility strategies; support development and implementation of standardised financial reporting for natural capital.

InvestEU – the EU's central investment programme

The InvestEU programme is the Green Deal's **central instrument** (see also Figure 14). It was already proposed for the EU's next Multiannual Framework Programme as long ago as 2018, building on the European Fund for Strategic Investments (EFSI). According to the Green Deal published in 2019, InvestEU will allocate **30%** of mobilised investments to **climate- and environment-related projects**. Among other things, the allocation from the EU budget will serve to guarantee loans from the European Investment Bank Group, which it is hoped will in turn **stimulate private investment**.

Under the Green Deal, InvestEU may also be used to provide **resources and advisory support** for identifying, developing and implementing appropriate projects.[214] InvestEU is conceived as a **flexible programme** capable of responding to changes in the market and new policy priorities, the SARS-CoV-2 pandemic being a case in point.

214 | See EU COM 2020h.

Appendix B: Carbon Capture and Utilisation/Carbon Capture and Storage (CCU/CCS)

In addition to the cross-industry and cross-sectoral drivers of the economic transformation described in Chapter 2 (use of hydrogen and electrification, digital and biological transformation, circular economy), CCU/CCS will also play an important part in achieving the relevant climate goals.

There is a consensus among scientists that in order to **achieve the climate goals**, it will be necessary to employ **technologies that are not just carbon-neutral but carbon-negative**. As well as making use of natural carbon sinks in agriculture or those created through afforestation, it is also possible to sequester CO_2 from the atmosphere and use it for other purposes (CCU) or store it on a long-term basis (CCS).

Both CCU and CCS are technologically **challenging solutions** that **should only be used where it makes sense** to do so. The use of CCU/CCS to ensure that climate targets are met should be considered for industrial processes where it is not possible to prevent CO_2 emissions through efficiency gains, electrification and the use of different energy sources, processes and materials.[215] Some of the experts stress that these technologies are **not a free pass to continue with business as usual and simply sequester the CO_2 emissions at the end of the process**.

"We need negative emissions, and we cannot achieve this without CCU/CCS technology."

Although the complex processes involved in carbon storage and utilisation are in many cases not yet economically viable, this changes once the carbon price rises above a certain threshold. The speed at which **industrial CCU/CCS is rolled out at scale** will be heavily **dependent on increases in the carbon price**.

Most of the experts agree that although **filtering CO_2 from the air** is technologically possible, the high energy requirements mean that it **does not make** environmental **sense**. Instead, they **advocate carbon capture during production** as the most **appropriate** solution.

B.1 Carbon Capture and Utilisation (CCU)

In industrial processes where it is impossible to prevent CO_2 emissions when processing certain materials, solutions that **capture the CO_2** before it enters the atmosphere can make an important contribution to reducing these emissions. The captured CO_2 can be used **as a feedstock**, for example in the production of **synthetic fuels, plastics or fertiliser**.[216]

There are already a number of **successful pilot projects** in which CO_2 is captured and utilised in other industries, for example **Carbon2Chem** and various **oxyfuel applications**.[217] The experts expect the number of CCU applications to increase in years to come, especially in heavy industry.

B.2 Carbon Capture and Storage (CCS)

There is still **no definitive scientific consensus about whether the best solution for the long-term storage of CO_2** is as a **solid**, or by injecting it underground in **liquid** form.[218] Either way, it should **ideally be possible to retrieve the stored CO_2 on demand** so that it can be used as a feedstock.

Broadly speaking, **CCS tends to be more controversial than CCU**, although many experts consider it indispensable to meeting the 2050 climate targets. The **IPCC** scientists maintain that the **use** of CCS (in conjunction with other measures) is the **only way that the 1.5 °C target can still be met**. It is only the extent to which CCS is used that varies across the different IPCC scenarios.[219]

There are **currently still major differences of opinion** regarding the potential **risks** of storing CO_2 underground and thus in the level of **acceptance** of this technology.[220] As with nuclear power, there is also no consensus about the risks of CCS among the EU member states.

215 | See EU COM 2020k; IPCC 2018.
216 | See McKinsey & Company 2018.
217 | See HeidelbergCement 2020; Weikl/Schmidt 2010.
218 | See UBA 2008.
219 | See IPCC 2018.
220 | See acatech 2018.

Appendix C: Creating more sustainable value networks in the plastics industry

The following sections illustrate the challenges involved in the transition to a sustainable plastics industry and various possible approaches to its accomplishment. The application of circular economy principles throughout the value cycle is also illustrated (see Figure 15). The following aspects are addressed:

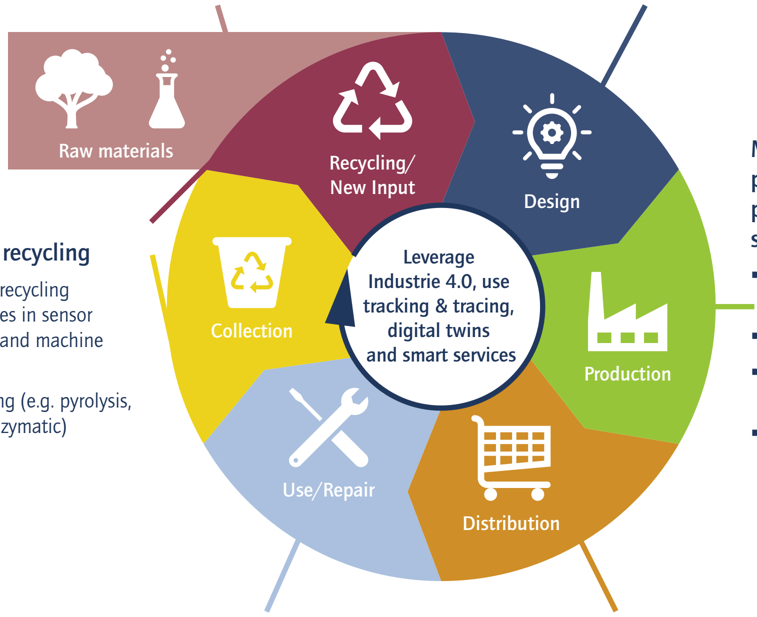
- Plastics today and in the future (D)
- Designing recyclable plastics and the associated conflicts (E)
- Decoupling plastics production from fossil resources (F)
- More sustainable manufacturing processes (G)
- Enabling more sustainable plastics use through new business models and changes in consumer behaviour (H)
- Improving plastics recycling (I)

Using secondary and renewable feedstocks – decoupling plastics production from fossil resources

- Secondary feedstocks from recycling
- Bio-based feedstocks

Designing for circularity and avoiding harmful characteristics – improving plastics design

- Develop optimised plastics and circular business models
- Based on life cycle assessments



Closing the loop – increasing plastics recycling

- Improve mechanical recycling (e.g. through advances in sensor technology, robotics and machine vision)
- Use chemical recycling (e.g. pyrolysis, depolymerisation, enzymatic)

More efficient, modular production – producing and processing plastics more sustainably

- Electrification of energy-intensive production stages (e.g. e-crackers)
- Modular, biointelligent production
- Industrial symbiosis for material cycles in manufacturing
- Increase resource efficiency through Industrie 4.0

Extending useful life and increasing resource productivity – reusing plastics

- As-a-service business models (e.g. for packaging)
- Reusable solutions, especially in B2B market
- Digital product passports for tracking and tracing of material flows
- Modular products make it easier to reuse and repair

Figure 15: Plastics industry value cycle (source: authors' own illustration based on wbcsd/BCG 2018)

Appendix D: Plastics today and in the future

Plastics have a key place in people's everyday lives and perform a number of important functions. However, in their current form, the production, use and disposal of plastics have negative impacts on sustainability. To make the production and use of plastics more sustainable, it will be necessary to accomplish a transformation of the entire value network, driven by product, process and business model innovations, and based on a holistic analysis of the relevant effects and impacts across the entire life cycle.

Plastics are **ubiquitous** in modern society – **annual per capita plastic consumption** in the EU stands at around **100 kg**. Thanks to their durability, their relatively light weight, and a wide range of uses that can be expanded even further through additives and composites, plastics are found in a **huge number of different value networks and areas of people's lives**.

Plastics perform a number of **important functions**. Plastic packaging helps to protect products in the logistics chain, to **prevent food waste** and to ensure product hygiene and safety. The fact that they are also often **lighter** than alternative materials means that they can help to **reduce** transport **energy requirements**. Because of this **secondary potential to contribute to sustainability**, the experts agree that plastics will continue to play a **central role** in the future global economy.

However, the use of plastics also has **negative impacts** that have implications for meeting the UN **Sustainable Development Goals**. The **high levels of CO_2 emissions** associated with plastics production and recycling contribute to **climate change**, while end-of-life plastics that find their way into the environment cause **macro- and microplastic pollution**. Plastic pollution has been a particularly prominent topic in recent years[221] and is the subject of current research initiatives such as the **Federal Ministry of Education and Research´s framework programme "Research for Sustainable Development"** (FoNa) and, more specifically, the University of Bayreuth's Collaborative Research Centre on microplastics.[222]

In a sustainable plastics value network, **solutions must be found** for **both** the climate and the environmental issues. The vast majority of plastics are **used** in the following **areas**: packaging (40%), buildings and infrastructure (20%), automotive industry (10%) and electronics (6%). **Germany** is by far the **largest processor** of plastics in Europe, accounting for just under 25% of the total volume.

Global plastics production is forecast to **double by 2050**. While the forecast growth **in Europe** is lower, plastics production is still expected to increase by **18%** by 2050.[223] This rise in **global plastics production** could cause plastic's share of global **oil consumption to increase from the current level of 2%** to as much as **23%**, depending on which oil production scenario is used.[224]

At present, **five kilogrammes of CO_2 are emitted for every kilo of plastic that is produced**, primarily during its manufacture and at end-of-life.[225] However, the use of plastics in products such as building insulation or as a lightweight construction material can generate a net reduction in CO_2 emissions. Nevertheless, it remains **vital to transform the entire plastics life cycle** in order to prevent plastics production alone from using up a significant proportion both of the **remaining carbon budget** for meeting the **Paris targets** and of the **remaining fossil fuel reserves**. The systematic use of **circular economy principles**, including the use of plastic waste as a resource, can make an important contribution to achieving this goal (see Figure 16).

> *"If effective recycling can keep plastics in the value chain for a long time, they can be more sustainable than many alternatives."*

One model for the sustainable use of plastics is the **waste hierarchy**, the fundamental principles of which underpin the relevant **EU and German legislation** (see Figure 17). However, the hierarchy should not be interpreted as **a rigid corset**.[226] Instead, the regulatory framework should reflect **innovations and new findings from holistic life cycle assessments** in order to ensure

221 | See SAPEA 2019; UBA 2019b.
222 | See BMBF 2015a; 2015b; Breg 2018; Universität Bayreuth 2018.
223 | See Material Economics 2019.
224 | See Material Economics 2018b.
225 | See European Bioplastics 2016; Material Economics 2019.
226 | See European Parliament and European Council 2008.

Figure 16: Key actors in the plastics value network (source: authors' own illustration based on wbcsd/BCG 2018)

that the use and recycling of a wide range of plastic products is as environmentally and economically sustainable as possible.

In **economic terms**, the way we currently use plastics means that **95% of the value** of all plastic packaging produced globally (USD 80-120 billion) **is lost after a single, brief use.** Process losses and the fact that recycled plastic is used in lower-quality polymers means that **just 5% of the plastic's original value** is retained. Globally, just 14% of plastic packaging is collected for recycling.[227]

One **specific challenge** involved in the transformation of the plastics industry is the **fragmentation of its value network**. A transformation is required at **every stage of the plastics life cycle**, from design and feedstock input to production, use, recycling and disposal. This will call for cooperation between a **range of actors** including plastic manufacturers, plastic processors, wholesalers and retailers, recycling and waste management companies, state-owned enterprises, government agencies and, last but not least, consumers (see Figure 16).

The desired **results are unlikely to be achieved** if the individual **stages are considered separately** when formulating **policy options** – the different elements are often interconnected, and interventions in one area can often give rise to **complex interactions**.

> *"The most sustainable solutions can only be found by analysing the products and processes in the plastics industry at the system level and throughout their entire life cycle."*

227 | See WEF et al. 2016.

Consequently, decisions about how to address potential conflicts should, as far as possible, be based on a **systematic analysis** of the **entire product life cycle**. Furthermore, **closely coordinated, targeted cooperation** between actors from government, science, industry and civil society will be needed in order to drive the **necessary innovations**.

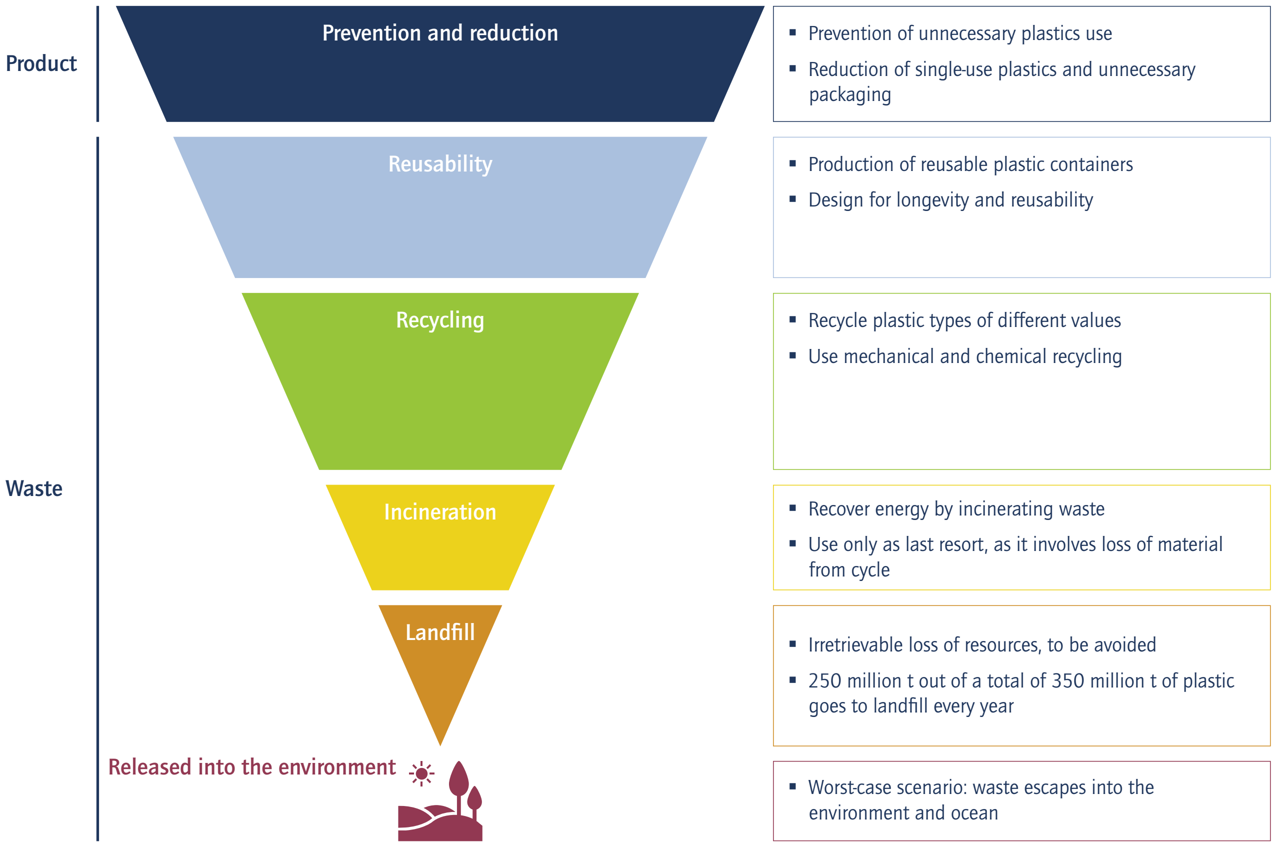


Figure 17: The plastics waste hierarchy (source: authors' own illustration based on European Parliament and European Council 2008)

Appendix E: Designing for circularity and avoiding harmful characteristics – improving plastics design

The design of plastics and plastic products is key to their sustainability. Conflicts can arise, for example between a plastic's recyclability and its performance characteristics. Even in the future, it will not be possible to completely resolve these conflicts through technological innovations alone. Policy decisions based on life cycle assessments will also be required.

The material and product design stage is **key to determining** how sustainably a plastic can be produced and used. **This stage must therefore also be addressed** as part of the transition to a sustainable plastics industry.

> *"Sustainability starts with design. If products are not designed with reusability and recycling in mind, there is very little that can be done in the subsequent value creation stages."*

E.1 Sustainable design choices

There are both **synergies** and **conflicts** between the various different approaches to designing more sustainable plastics and plastic products. Different approaches can yield the most sustainable solution, depending on the specific application in question. Accordingly, design problems should always be approached from **several different angles**.

"Design for circularity"

The experts identify **"design for circularity"**, i.e. product design that follows **circular economy principles**, as a particularly promising approach to designing more sustainable plastics and plastic products. A key goal of this approach is to make products **easier to reuse and recycle**.

This calls for a focus on factors such as **separability and component standardisation**. It also encompasses the principle of **reducing the number of different materials used** and making greater use of **mono-material solutions** in order to increase the volume of **single-material streams** that can be recycled **cost-effectively**.[228]

Sustainable chemistry and "benign by design"

As well as recyclability and resource utilisation, another aspect of sustainability addressed in both the EU Green Deal and the German government's High-Tech Strategy concerns the **potential environmental hazards** associated with plastic products.[229]

Macroplastics that escape into the environment or are sent to landfills will eventually break down into **microplastics**. While the **potential threats** posed by microplastics to human and animal **health** have yet to be definitively established, the **negative impacts** of macroplastics **on the animal kingdom** are already well documented.[230]

Potentially toxic by-products can also be generated during regular plastic waste treatment and disposal.[231] Although the EU's **REACH Directive** establishes high standards for reducing the risks posed by potentially harmful chemicals, some experts believe that more needs to be done in this area. This includes **simplifying** the **bureaucracy** associated with the Directive.

Approaches that seek to solve these problems **systematically** are often referred to under the headings of **"sustainable chemistry"**, **"green chemistry"** or **"benign by design"**. **In essence**, these approaches begin by **analysing** and **testing** the intended **application** to establish whether it requires the use of specific materials. If it does, then every effort should be made to ensure that the materials' design is tailored **as precisely as possible to the relevant requirements**. The **molecular composition** of the materials should be **as simple as possible**, and they should **break down easily and completely** after use or be fully recoverable.[232]

Benign by design was developed as a new design concept for persistent **pharmaceuticals** that do not break down in the environment after use. However, its goals can also be applied to **plastics**.[233]

228 | See EU COM 2019a; WEF/Ellen MacArthur Foundation 2017; WEF et al. 2016.
229 | See BReg 2018; EU COM 2019d.
230 | See SAPEA 2019.
231 | See Kümmerer et al. 2020.
232 | See Deutsche Welle 2016; Kümmerer 2017; Kümmerer et al. 2020; Zimmerman et al. 2020.
233 | See Deutsche Welle 2016; FAZ 2018; Kümmerer et al. 2020.

> *"It's not about making existing products 'slightly less bad', it's about designing products to be sustainable from the outset."*

It is necessary to **draw a fundamental distinction** in this context. Products that are intended to be **kept within the loop** in a circular economy model must be durable so that they **can be used for as long as possible**. On the other hand, products that will either intentionally or in all likelihood end up **in the environment or the sewerage system** (fertilisers, pesticides, cleaning agents, pharmaceuticals, fishing gear, etc.) should be as fully **biodegradable in nature** as possible.[234] In this context, some of the experts mention that there is a tendency for both the **education** system and the **funding system** only to recognise **increasingly complex solutions as innovative**. In their view, **solutions** that are as simple and **elegant** as possible should at least be given equal weight and potentially even be prioritised as **innovation goals**.

Recyclability versus functionality – design conflicts

All design processes are confronted with fundamental **challenges** arising from partial **conflicts** between different **goals and requirements**. This general rule, which applies to **products and processes** in many different **industries**, can be **illustrated** by some of the specific conflicts that occur when designing **plastics**. For instance, some biodegradable plastics can cause problems in conventional recycling systems (see Appendix I.3), while reducing the number of different plastics in a product may make it easier to recycle, but can also be at odds with the goal of using more bio-based plastics.[235]

One of the **most common conflicts** in the design of plastic products is between their **recyclability** and the **specific functions** that they are intended to perform. As a rule, **the more complex** a plastic product and its functions, the **harder** it is to recycle.

Food packaging, for example, must meet particularly high hygiene standards, while also being as robust and light as possible. At present, this is often achieved by using **complex composite plastics** or by **layering different types of plastic**. However, these types of packaging are particularly **difficult to recycle**, since it is virtually impossible to separate the individual types of plastic in the product (see Appendix I).[236]

In terms of the product's overall **sustainability footprint**, it can therefore sometimes **make more sense not to design** certain types of plastic packaging **to be recyclable**, for instance if this is necessary to prevent large quantities of food from spoiling. Consequently, the experts recommend that plastics which can be easily **recycled** without **compromising on functionality in any meaningful way** should be at the top of the research agenda, since these plastics have the potential to **combine sustainability and value creation**.

E.2 Product design regulation

The experts are of the view that it will **not always be possible** to fully **resolve** these **conflicts** by researching and developing new materials and processes. A **systematic analysis** should therefore be carried out to establish which combination of solutions offers **the greatest overall sustainability potential** for each function that a product is intended to perform. This analysis should underpin subsequent R&D and implementation efforts.

There are **some differences of opinion** among the experts about the best way of **regulating** the use of materials that are potentially harmful to the environment. However, most were **sceptical about drawing up explicit lists of banned materials**, since certification agencies are unable to keep up with the rate at which new products are coming onto the market.

There is some support for the idea of drawing up alternative or supplementary **white or green lists** of materials that are definitely known to be harmless and sustainable. Companies predominantly using the materials on these lists would be able to **invest with confidence**, while their use could also be promoted through **incentives**.

Critics of this proposal warn that it could **compromise** the principle of **technology neutrality**, and that innovations could be held back if new materials or materials not yet tested for sustainability took a long time to make it onto the relevant lists.

In principle, the experts consider a continued focus of the **EU's Ecodesign Directive** on sustainability criteria based on life cycle assessments to be an **appropriate instrument** for the relevant regulatory action. However, they also stress that it is necessary to **strike a balance**, since overly detailed definitions could potentially inhibit innovation and confuse or overburden producers.

234 | See Kümmerer et al. 2020; Kümmerer 2017.
235 | See Bauer et al. 2018.
236 | See Bauer et al. 2018; Kümmerer et al. 2020; Material Economics 2018a; 2018b; WEF/Ellen MacArthur Foundation 2017.

E.3 Further potential plastic design innovations

Programmable plastics are one area where there is considerable potential for innovation. Programmable plastics can be used to replace and perform the functions of components such as relays, switches and sensors, that are often very complex to make and contain rare earth elements. Moreover, the plastic polymers used in this application are potentially **recyclable**.[237]

Bio-inspired materials and products are another source of innovations. For example, **lightweight designs** modelled on nature can significantly **reduce the material requirements and weight** of plastic components in sectors such as the automotive industry. Combining this approach with **additive manufacturing** using recyclable plastic polymers (see Appendix G.3) further increases the potential implementations and applications while at the same time improving the products' sustainability profile.[238] While these solutions are not necessarily entirely new, the experts believe that their potential to create innovations and new applications has **yet to be fully leveraged**.

These concepts are also particularly well-suited to exploiting the **secondary sustainability potential** of using plastics. Lighter products **have lower** transport **energy** and **primary material requirements**, while the use of recyclable plastics instead of complex components containing rare earth elements helps to **close value loops** and **prevent negative environmental externalities**.

Outlook

Materials research is a **core competence** of the German research landscape and of innovative businesses. This applies to everything from basic research at universities and non-university research institutions to the development work carried out in the laboratories of SMEs and large enterprises. The experts therefore welcome the fact that this field is included in the **German government's funding programmes**.

As far as the future is concerned, they would like to see techniques such as **machine learning, AI and big data** included in materials engineering courses and **integrated even more strongly** in the field of materials science. Materials research and development could potentially also be a candidate for the first important commercial applications of **quantum simulators and computers**, a technology that promises to enable a new **qualitative leap**.

In addition to direct efforts to develop better materials, it is also necessary to work on **the refinement and standardisation of life cycle assessments** in order to provide as accurate a basis as possible for making the systemic trade-offs needed to achieve the most sustainable design choices. It is important for the **different actors** from research institutions, businesses, industry associations and government agencies **to work together** to develop viable and appropriate solutions. In the opinion of the experts, the practical experience gained from trialling new concepts in **large-scale regulatory sandboxes** (see Boxes 6 and 7) could make a valuable contribution in this regard.

237 | See acatech 2019c.
238 | See acatech 2019c; FhG 2018; 2019; VDI-Gesellschaft Materials Engineering 2014.

Appendix F: Using secondary and renewable feedstocks – decoupling plastics production from fossil resources

At present, the carbon footprint of plastics is negatively affected by the fact that they are mostly made from fossil resources. The use of more sustainable alternatives such as secondary feedstocks (recycled plastic) and bio-based polymers is not usually economically viable in today's market. The appropriate policy incentives must be introduced in order to create a level playing field for these alternatives.

The transition to a sustainable plastics industry will require plastic producers to **stop using primary fossil resources** as far as possible. The **circular economy** and the **biological transformation and bioeconomy** offer two alternative approaches: **secondary feedstocks** (recycled plastic) and **renewable primary feedstocks** (biomass). As well as the **positive environmental impacts**, switching to higher percentages of secondary feedstocks and primary feedstocks made from biomass could help to make plastics production **less dependent on global feedstock supply chains**.

Around 94% of all plastic is made from **virgin feedstock**. Most of this is produced by refining, cracking and subsequent polymerisation of **crude oil**, and to a lesser extent from natural gas. It is not only the extraction of the oil and the subsequent production stages that generate **CO_2 emissions**. The plastic polymers themselves also comprise **compounds that contain carbon** and can thus release substantial additional quantities of CO_2 at end-of-life, for instance if they are incinerated.[239]

A **low oil price reduces** the relative **competitiveness** of secondary feedstocks made from **recycled plastic** and primary feedstocks made from **biomass**. If the long-term oil price remains at a very low level due to the **economic crisis triggered by the SARS-CoV-2 pandemic**, there are likely to be long-term implications for the economic viability of producing plastics from alternative feedstocks.

In order to address this **competitive disadvantage** – which is also due to the fact that **the environmental costs** of extracting and using fossil fuels **are not internalised** –, the experts advocate the creation of a **level playing field for the different feedstocks** used to produce plastics. Some of the **instruments** that are being discussed are listed in Appendix I.5.

F.1 Secondary feedstocks

Secondary feedstocks for producing plastics are made from **recycled plastic waste**. Appendix I provides further information on different recycling methods and the associated challenges and opportunities.

In principle, the use of secondary feedstocks offers **several sustainability benefits**. The **CO_2** embedded in recycled plastic **remains in the usage cycle** instead of being released at end-of-life, for example if the plastic is burnt to produce heat. Moreover, plastic that is recycled **does not end up in landfill or the environment**, where it would gradually break down into **potentially harmful microplastics**.

Depending on the recycling pathway, this way of producing plastic can also be significantly more **energy-efficient** than using primary feedstocks, since it **eliminates various energy-intensive production stages**. It can also help to make plastics production **less reliant on feedstock imports** and thus **more resilient to** global supply chain **disruption**.[240]

Recycled plastic quality and the regulatory framework

According to many of the experts, one of the **main reasons** that recycled plastic is not more widely used is that it often contains high levels of impurities and is thus of **lower quality than primary feedstocks**. The poorer quality of secondary feedstocks means that they either produce lower-quality plastic and plastic products or have to undergo **costly additional processing to remove the impurities**. Variable quality may be more or less acceptable, depending on the application. However, there are **several applications** where recycled plastic is unsuitable because the plastic used has to meet **high quality standards**.

Coupled with the fact that **primary feedstocks are extremely cheap** and will remain readily available in **consistently high quality** for the foreseeable future, the variable quality of secondary feedstocks constitutes a significant competitive disadvantage. **There is some disagreement** among the experts about whether norms and standards establishing tougher **rules for recycled plastic quality** are an appropriate tool for increasing recycled plastic demand.

239 | See Material Economics 2018b; 2019; WEF et al. 2016; WEF/Ellen MacArthur Foundation 2017.
240 | See BCG 2019a; Material Economics 2018b; WEF/Ellen MacArthur Foundation 2017; WEF et al. 2016.

Some experts also cite **regulatory restrictions** on the use of plastics made from recycled material. In the interests of **consumer protection**, regulatory restrictions on the use of recycled materials in packaging are found mainly in the **food industry**, but also in other areas such as the **cosmetics industry**. According to other experts, an in-depth analysis should be carried out to **check** whether these regulatory restrictions are actually evidence-based and whether they could be **relaxed in certain areas**, thereby increasing the potential applications of recycled plastic.

Creating a market for recycled plastic

The experts also identified a **chicken and egg problem in terms of supply and demand** for high-quality recycled plastic. Plastic manufacturers often complain that it is **difficult to find out** where they can obtain a particular quality and quantity of recycled plastic.

One possible solution would therefore be to use **digital platforms** to provide an **overview of recycled plastic availability** and improve communication between producers and suppliers.[241] The German start-up Cirplus, which is supported by EIT Climate KIC, is already using this type of business model.

> *"Someone has to cut the Gordian knot of plastic recycling."*

The experts **welcome** the fact that the **German government** recognises and supports the **importance of digital solutions** in a circular economy.[242] However, they are concerned that it **could be difficult** to attract **enough private investment** for these solutions once the initial project funding dries up, since investors are reluctant to take big risks due to the industry's uncertain medium to long term outlook.

The **public sector** could make a significant, direct contribution to the establishment of a sizable market for recycled plastic by adopting a **sustainable procurement** policy that promotes greater use of recycled products. Other instruments such as a general recycled content requirement are discussed in Appendix I.5.

F.2 Bio-based plastics

Even in optimistic scenarios, factors such as the unavoidable process losses that occur during recycling mean that in the future **it will still not be possible** to meet **more than 60%-70% of demand for plastics with secondary feedstocks**.[243] An **alternative primary feedstock source** must be found in order to decouple plastics production as fully as possible from fossil fuel inputs. **Plastics made using biomass** could in principle perform this function.[244]

Bio-based plastics form an important part of the **German and EU bioeconomy strategies**.[245] There is often some **confusion** among the public about the meaning of the term **"bioplastic"**. This is not surprising, since it is an imprecise term that is best **avoided**. Figure 18 illustrates the **meanings of the different terms** used in this area. The distinction between **bio-based and fossil-based plastics** refers solely to the source of the original feedstock. The second criterion that can be used to distinguish between different plastics is whether or not they are **biodegradable** (see also Appendix I.3). Both bio-based and fossil-based plastics can be biodegradable. However, not **all bio-based plastics** are automatically **biodegradable**.[246]

Current market and projected growth

In principle, **many common plastic polymers** can also be made from biomass.[247] The necessary biotechnological plants such as biorefineries can be operated as **decentralised facilities located near to biomass sources**, and can thus provide an opportunity for **sustainable value creation**, particularly in **structurally weaker regions**.

> *"A lot of progress has already been made regarding the development of bio-based plastics, and many products are market-ready. The real problem is whether there is enough demand for them and whether they are commercially viable."*

However, the conversion stages involved in making plastics from biomass mean that the associated **energy costs** are often **higher** than if using primary fossil resources. These **higher production**

241 | See Berg/Wilts 2019.
242 | See BMBF 2018; 2020b.
243 | See Material Economics 2019.
244 | See Bauer/Nilsson 2019; DECHEMA/FutureCamp Climate GmbH 2019; Material Economics 2018b; 2019; WEF et al. 2016; WEF/Ellen MacArthur Foundation 2017.
245 | See BMBF/BMEL 2014; 2020; EU COM 2018a.
246 | See European Bioplastics 2016.
247 | See Ibid.

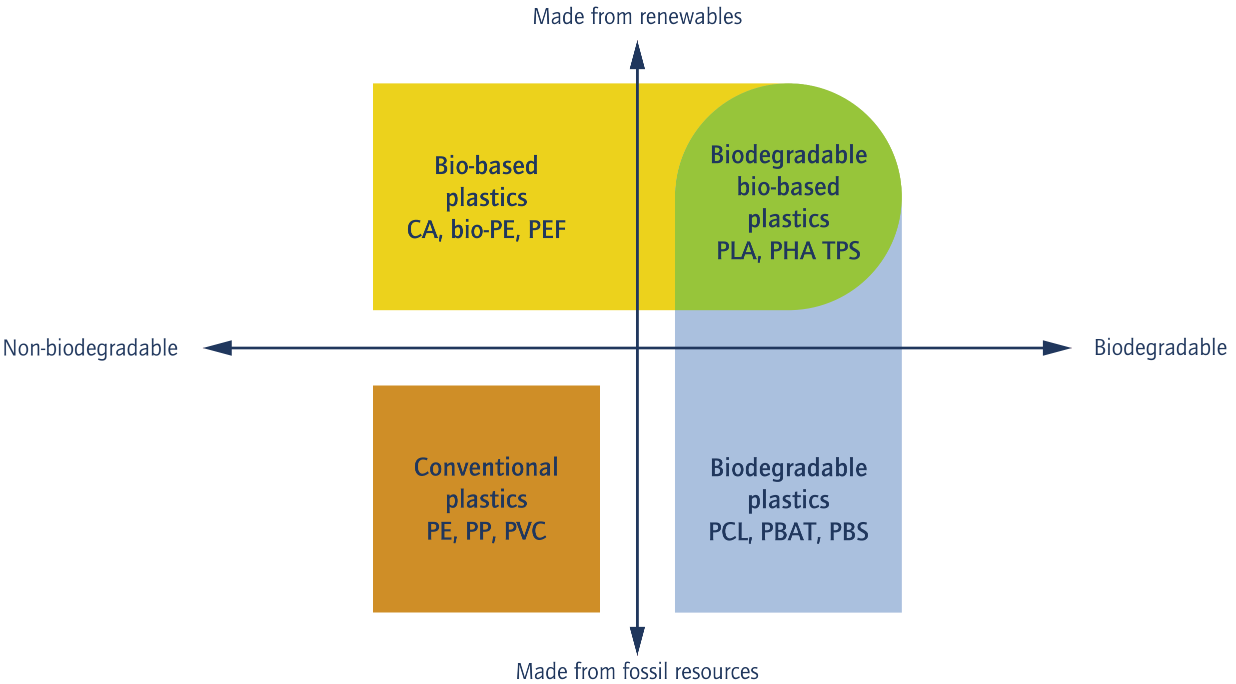


Figure 18: Overview of different types of plastic (source: authors' own illustration based on European Bioplastics 2016)

costs put bio-based plastics at a **competitive disadvantage**.[248] As a result, **bio-based plastics account for just 1% of the total global plastics market**. Unless there are dramatic changes in the economic situation or regulatory framework, the industry is expected to experience only **modest growth** over the next few years, with production of bio-based polymers forecast to rise by 3% a year (CAGR).[249]

The challenges of rising demand

Nevertheless, studies looking at how the plastics industry can become climate-neutral predict a **pronounced increase** in biomass demand if the **industry** is to achieve full **decarbonisation**. According to one such study, 75-95 million tonnes of biomass a year will be required to adequately meet Europe's demand for bio-based polymers in 2050.[250] This would represent a significant increase compared to the 1.3 million tonnes that were used in 2019.[251]

Although the land area needed to produce 75-95 million tonnes of biomass is relatively small compared to the land area devoted to agriculture, **rising demand for biomass** to produce plastics will nonetheless result in **competition** with agriculture and forestry, land restoration projects geared towards climate and biodiversity protection, and the production of biomass for other purposes (such as fuel production).[252]

Consequently, the use by the plastics industry of individual biomass or **waste stream** components such as chitin, lignin and terpenes has particular potential in terms of avoiding conflicts with primary biomass uses.

Comprehensive studies must therefore be carried out in order to **prioritise the use of limited biomass resources**. Some existing studies conclude that the use of **biomass to make plastics is more energy-efficient** and therefore more sustainable than its use for **fuel or to generate electricity**.[253] Further investigation of these **conflicts and potential solutions in a bioeconomy** is being carried under the auspices of various German and European programmes.[254]

248 | See VCI 2019b.
249 | See nova-Institute 2020.
250 | See Material Economics 2019.
251 | See nova-Institute 2020.
252 | See acatech et al. 2019.
253 | See BCG/Prognos AG 2018; Material Economics 2018b; 2019.
254 | See BMBF/BMEL 2020; EU COM 2018a.

Research, development and transfer solutions

In order to avoid conflicts with primary biomass uses, it will be important to prioritise the further development of solutions that can use **feedstock derived from organic waste**, such as the B-Plas demonstrator project in Italy.[255] In addition, **material and process innovations** can make the **production** of plastics from biomass even more **efficient**. Appendix I.5 discusses solutions for addressing any remaining inherent competitive disadvantages of bio-based plastics.

Many experts believe that there are currently **advantages** to using bio-based feedstocks, particularly for **complex plastic products in the fine and specialty chemicals sector**. Further **R&D** may increase the number of applications where the biomass remains close to the **original polymer structure** and does not first need to be broken down into the simplest possible chemical structures. This would reduce the high energy consumption involved in bio-based plastics production, helping it to compete with production methods that use primary fossil resources.

In principle, the experts are **positive** about the **research funding landscape**, identifying several relevant programmes, especially in Germany. However, some criticise the **lack of funding opportunities** for explicitly **interdisciplinary research projects**, and the fact that these projects tend to be less highly rated by monodisciplinary project selection committees. They also feel that greater emphasis could be placed on teaching **university** students **interdisciplinary collaboration skills**.

> *"We mustn't overlook capacity building in our discussions about access to capital, pilot projects or technology funding. People need the skills to actually put things into practice."*

These issues are addressed by Germany's National Bioeconomy Strategy. Moreover, **interdisciplinary** initiatives such as the Fraunhofer Cluster of Excellence for Circular Plastics Economy are researching how bio-based polymers can best form part of a holistic, **sustainable, circular plastics economy**.[256]

This type of **platform** can provide a good basis for bringing together **different actors** from the **relevant sectors** – such as plant engineering, biotechnology, the plastics industry, and the waste management and recycling industry – as well as for showcasing **new technologies** and how they can help to **transform value creation processes**. The inclusion of NGOs would also ensure that the views of the wider public are fed into the process.

However, the experts stress that as well as carrying out research and demonstrator projects, it is particularly important to **identify ways** of translating research findings into **economically viable products and processes**.

"Regulatory sandboxes for a materials transformation" (see Box 6) could be one way of addressing this challenge. They provide an opportunity to test whether products and processes are **suitable for everyday use**, facilitate even closer **coordination of the relevant actors**, contribute to the establishment of appropriate **norms and standards**, and help to identify any existing **regulatory barriers and differences between member states**. It is also vital that this approach should include **government agencies** right from the outset. Moreover, the regulatory sandboxes should be tasked with finding viable solutions for **simplified,** pan-European **certification procedures**, allowing new materials to be introduced safely but without unnecessary delay, even in sensitive areas of application.

255 | See EIT Climate-KIC 2019.
256 | See BMBF/BMEL 2020; Fraunhofer CCPE 2019; 2020.

Appendix G: More efficient, modular production – producing plastics more sustainably

Making plastics requires a lot of energy. Provided that a high percentage of renewable electricity is used, the electrification of individual production stages could significantly improve the sustainability footprint of plastics production. Concepts drawn from Industrie 4.0 (digital twins, predictive maintenance, IoT applications) and the biological transformation (biointelligent value creation, modularisation) can make plastics production and processing much more efficient and thus also more sustainable.

Over **one third of the CO_2 emissions** that a plastic product is responsible for throughout its life cycle are generated during its **production** (see Figure 19).

These emissions can be **minimised** by **combining** more sustainable **technologies** with enhanced and more efficient **production processes** and new **production network** models. **New production concepts can also deliver efficiency gains** in the **next link in the value chain**, i.e. the industries that use plastics in their products.

Like all basic materials industries, the plastics industry has **long investment cycles** of around 20 years. The situation is further complicated by the fact that the transition to a climate-neutral plastics industry will require significant investments in **new or enhanced technologies and manufacturing facilities** to be made simultaneously at **several different points in the value chain**.

One study found that, depending on the scenario, the total investment required to achieve a **climate-neutral European plastics industry by 2050** would need to be between **150% and 199% higher than the level of investment that would normally be expected** over this period. This figure is much higher than the 76%-107% average increase that the same study calculated for all of the basic materials industries that it investigated, and corresponds to **additional annual investment of between 3 and 4 billion euros**. For some businesses, the required investment can amount to a **"bet the company"** decision.[257]

It is vital that the modernisation initiatives undertaken in the next few years – including those supported by the economic stimulus packages – should **invest in genuinely sustainable, climate-friendly systems** and **avoid lock-in to carbon-intensive technologies**. Consequently, the experts call for immediate changes to the **policy framework** in order to give companies the confidence to make the necessary investments.

G.1 Electrification of production

The **cracking and subsequent polymerisation** of the feedstock during plastics production are particularly **energy-intensive processes** that are currently powered mainly by **fossil fuels**. Between them, they generate around **1.5 tonnes of CO_2 emissions per tonne of plastic produced** under today's production standards (see Figure 19).[258]

At present, the high temperatures needed to crack the naphtha in the **steam cracker** are mostly generated by burning **natural gas** and in some instances by using part of the primary feedstock as a fuel. **Electric crackers** that use electricity to generate the necessary heat are on the verge of demonstrating their readiness for **industrial applications** (Technology Readiness Level (TRL) 7).

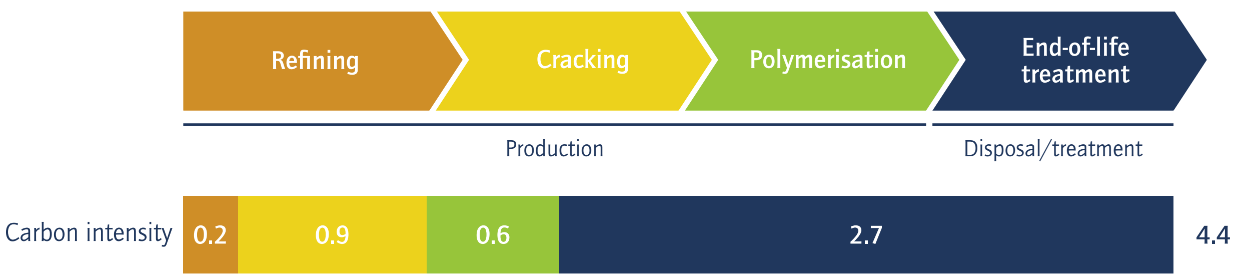


Figure 19: Carbon intensity of the plastics value chain (source: authors' own illustration based on Material Economics 2019)

257 | See Material Economics 2019.
258 | See Ibid.

If the electricity used were to be derived entirely from **renewable sources**, **greenhouse gas emissions** would be almost completely **eliminated** from this production stage.[259]

The key to the **sustainability and economic viability** of this technology is the availability of large amounts of **renewable electricity** at the **lowest possible price**. [260]

In addition to the electrification of production processes, the replacement of naphtha by **other (lighter) feedstocks** such as ethane can also help to significantly **improve** the **energy efficiency** of plastics production and **reduce** the associated **CO_2 emissions**.[261]

Both electrification and the use of alternative feedstocks require production facilities to be **converted or new facilities to be built from scratch**. This makes it especially important to create a long-term framework that provides companies with the **confidence to invest**.

G.2 Industrie 4.0/green tech in manufacturing

The experts believe that **most of the necessary reductions in CO_2 emissions** in other **areas of manufacturing industry** outside of the energy-intensive basic materials industries can be delivered through the efficiency gains enabled by **Industrie 4.0 and green tech** solutions.

Studies of the **plastics industry**, on the other hand, estimate that **efficiency gains and process optimisation** will be able to deliver **CO_2 emission reductions of around 15%-20%** by 2050.[262] In order to realise these efficiency gains, the plastics industry will need to fully leverage the relevant **Industrie 4.0 and green tech** drivers.

Industrie 4.0 offers solutions such as **digital twins**, which help to reduce material and resource consumption by making it possible to develop and optimise products and processes as far as possible in the virtual domain. In addition, industrial **AI and machine learning solutions** (optimisation and learning techniques, evolutionary algorithms and swarm intelligence) and solutions such as **predictive maintenance** enable continuous optimisation of production processes and resource utilisation planning. This makes it possible to achieve **efficiency gains** and reduce resource consumption and CO_2 emissions.[263]

Meanwhile, green tech solutions such as **smart energy and resource management systems** and smart **metering and process sensors** can also play an important role. Many **German businesses** are well placed to benefit from growth in the market for these "conventional" energy efficiency solutions.[264]

IoT applications such as RFID tags can also enable **digital tracking and tracing** of individual products and the different materials that they contain, from production right through to end-of-life treatment or recycling. In conjunction with the relevant process sensor technology, these applications play a vital role in enabling **effective sustainability controlling** and optimal **utilisation of the relevant materials**, for instance by helping to measure a manufacturing operation's carbon intensity in real time so that the relevant interventions can be made if necessary.[265]

The experts believe that these **integrated digital industrial solutions** offer **huge value creation potential** for innovative German businesses in the Industrie 4.0 sector, providing an opportunity for them to **strengthen their position** in the global market and potentially become established as **leading suppliers**.

G.3 Biointelligent, modular production

Concepts for achieving a **biological transformation of manufacturing industry** can complement the Industrie 4.0 and green tech solutions described in the previous section.[266]

One example from the plastics industry involves the **production of biopolymers** for bio-based plastics**.** Biorefineries could produce different **types of polymers** and **flexibly adjust** production volumes in line with **demand** and individual **customer requirements**. These flexible, modular production processes are enabled by a **combination of biotechnological processes** (use of bio-based materials, bioconversion by microorganisms), **digital processes** (artificial intelligence, IoT, big data) and **hybrid processes** (biosensors), and can help to reduce the time needed to build or convert production facilities.

259 | See Axelson et al. 2018; BASF 2019; DECHEMA 2017; Material Economics 2019.
260 | See Bauer et al. 2018; BCG/Prognos AG 2018; Material Economics 2019; VCI 2019a; 2019b; WEF et al. 2016; WEF/Atkins Acuity 2017; WEF/Ellen MacArthur Foundation 2017; Wyns et al. 2019.
261 | See DECHEMA 2017; Material Economics 2019.
262 | See Material Economics 2019.
263 | See acatech/Fraunhofer IML 2019; RNE 2016; Wilts et al. 2020; ZVEI/Wegener 2020.
264 | See BMU 2018.
265 | See UBA 2019c.
266 | See FhG 2018; 2019.

Regional economic ecosystems that function in **closed regional loops** similar to natural systems can operate a **modular** production model using multiple **distributed production facilities**. The production of adaptable modules allows **material cycles to be closed more efficiently** than if only the materials themselves are recycled.

Distributed production architectures allow **innovative manufacturing processes or process combinations** (additive – subtractive) to be implemented more easily and flexibly, potentially **reducing material consumption** and waste. They also make it possible to use **materials that are easier to recycle** and produce new composite materials that can be separated again at end-of-life, allowing the different components to be reused or reconditioned.[267] This makes it easier to **design for circularity,** even with highly functionally integrated products such as **fuel cells and battery systems**.

Neural and evolutionary optimisation techniques or deep learning solutions can be applied to these flexible production architectures to ensure that products are **made** as **efficiently and resource-efficiently** as possible.

Decentralised **production facilities** can be built near to biomass sources, tailored to **regional conditions** and needs, and **scaled up as required**. This way of organising production can help to make the plastics industry more **sustainable and resilient**, for example by reducing transport requirements and dependency on complex supply chains.

"There are major synergies between the objectives of the Green Deal and the goal of increasing the resilience of our value networks. These can be leveraged through the principles of the biological transformation."

The biointelligent value creation solutions described above could also be used to build **modular production capacity** in an **as-a-service model**. Intelligently controlled and connected production systems could be provided by a third party, allowing companies to hire the systems that they require on demand, using AI to calculate and implement the optimal system requirements. **Modularisation** of production also makes it easier to **implement rapid changes in the items produced**.

This would be particularly **beneficial for SMEs and start-ups**, since it would provide them with **access** to efficient, modern **production architectures** that can be tailored to their requirements, **without** the need to **finance** major direct **investments in infrastructure** or maintain **unused production capacity**.

The high **optimisation of capacity utilisation** enabled by this type of business model can save additional resources and emissions.

Industrial symbiosis

In manufacturing industry, the **waste products** (material waste, emissions, heat, water) from one stage in the manufacturing process can often be reused **as feedstocks** for other **industrial processes**. Consequently, there are also opportunities to **create closed loops** within industrial process networks, further increasing production **resource efficiency** and reducing **resource demand** and **dependency on global supply chains**. Industrial symbiosis concepts are also **central to the bioeconomy**.[268]

The BASF group makes use of this principle internally in its large-scale **Verbund sites**. But different **companies and institutions** can also join forces and establish common **waste/material streams that are of mutual benefit**. Examples include the Kalundborg Eco-industrial Park in Denmark (see Figure 20) and the Pomacle-Bazancourt biorefinery complex in France, where the focus is on the industrial bioeconomy.[269]

An EU project that analysed the potential of **symbiotic industrial parks** concluded that universal implementation of industrial symbiosis across Europe could reduce **greenhouse gas emissions** from industrial manufacturing processes by up to **10%**.[270] **Plastic manufacturers** could, for example, cooperate **more closely with paper mills** in order to source organic waste for the production of bio-based primary feedstocks.[271]

One of the challenges associated with projects of this type is to strike a **balance** between **maximising synergies** among the individual partners and achieving the necessary **diversification of feedstock sourcing**. If one partner is experiencing problems, this

267 | See acatech et al. 2019.
268 | See BMBF/BMEL 2020.
269 | See EU COM 2020g; OECD 2018.
270 | See EU COM 2020g.
271 | See Material Economics 2019.

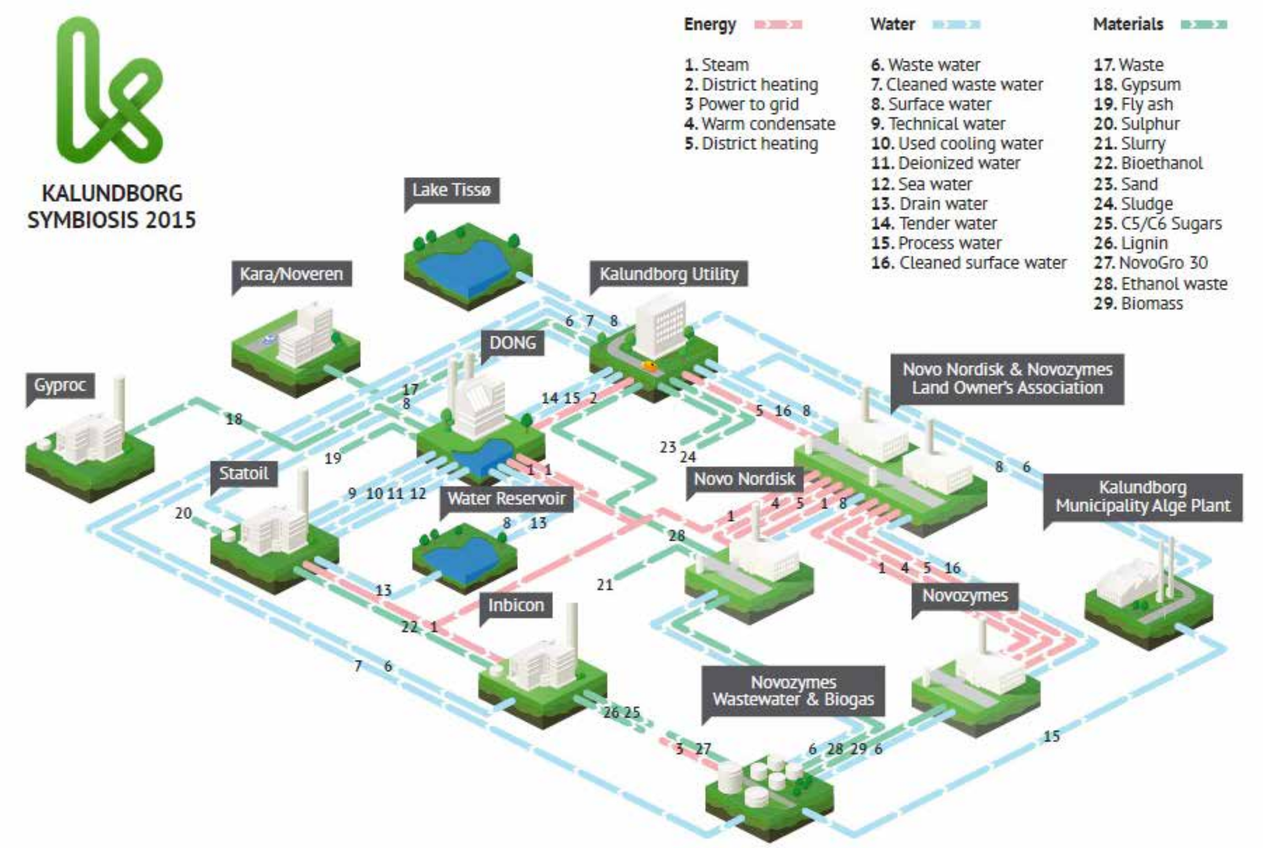


Figure 20: Industrial symbiosis in the Kalundborg Eco-industrial Park, Denmark (source: Kalundborg Symbiosis 2020)

should not directly bring another partner's production operations to a complete standstill.

Research, development and transfer

A significant amount of research and development is still required to translate biointelligent value creation and industrial symbiosis concepts into industrial applications. The key research fields include **more precise (bio)sensors** and optimised use of **big data and artificial intelligence** to improve the **planning, coordination and control** of production processes.

Germany's **National Bioeconomy Strategy** already addresses these potential synergies between the digital and biological transformations.[272] The experts hope that the forthcoming agenda "From Biology to Innovation" will generate further momentum in this field.

Two **examples** of research projects developing this type of solution are SWAP, which is building a **swarm-based production architecture to optimise utilisation**, and EVOLOPRO, in which digital twins are employed to optimise products using **algorithms inspired by evolutionary processes**.[273]

Realisation of these R&D projects requires collaboration between **researchers from different disciplines** such as biotechnology, materials science, computer science and mechanical engineering. The experts identified **significant gaps in the transdisciplinary research landscape** both in Germany and at European level. This is mainly due to the fact that evaluation committees are often entirely composed of members of one particular discipline.

> *"We mustn't confine our thinking to our own particular discipline. We need holistic solutions."*

But it is not just researchers who need to collaborate across disciplines. The **different** value network **actors** must also be brought together to **discuss their shared interests**, build **mutual trust**

272 | See BMBF/BMEL 2020.
273 | See FhG et al. 2020; Fraunhofer IPT 2019.

and identify **highly visible**, large-scale **projects**. This could be accomplished through **joint research projects or regulatory sandboxes**, for example.

G.4 Carbon Capture and Utilisation/ Carbon Capture and Storage

Wherever **large quantities of CO_2 are generated**, **CCU/CCS is one option** for preventing direct emissions (see also Appendix B).[274] While this is also true of plastics production, the fact that in this case the emissions are generated at **several different points in the value chain** makes CCU/CCS technology less efficient or means that **several separate systems** must be built.

According to the experts, the production stage with the greatest potential is cracking. However, **there have not yet been any** large-scale **pilots** to investigate the use of CCU/CCS technology with **steam crackers**. Nevertheless, it is believed to be **technically possible**, with some further development. The **sustainability** of this approach mostly depends on **how** the captured CO_2 **is used**. If it is used to produce fuel, the **emissions are simply deferred**. On the other hand, if green hydrogen is used to convert the CO_2 into **platform chemicals** (e.g. methanol) for the plastics industry, the **overall impact will be more positive**.[275]

Since the installation of **large-scale CCU/CCS systems** in the plastics industry would also require **high levels of investment**, it would be **competing with other** capital-intensive **technologies** such as electric crackers. And if the industry did switch to **electrically powered production processes**, **there would be no need for CCU/CCS**, since there would no longer be any direct emissions from production.

Despite these objections, some simulations show that CCU/CCS can **help** the plastics industry to achieve **climate neutrality** by 2050 in certain **specific scenarios**.[276]

274 | See acatech 2018.
275 | See Material Economics 2019.
276 | See Ibid.

Appendix H: Extending useful life and increasing resource productivity – reusing plastics

Plastics have a negative sustainability footprint in many areas where they have short usage cycles and are used to make single-use products. A positive impact on sustainability can be achieved through business models that enable reuse of plastic products, as well as through return schemes – especially for packaging – and digital product passports. Consumers can also make an important contribution through their behaviour and purchasing decisions.

There are several ways in which **changes to usage practices and business models** and switching to **alternative solutions** can **reduce demand** for plastics and thereby indirectly **cut** harmful **emissions**.

It is important to harness these opportunities, even if the **use of plastics generates relatively low levels of direct greenhouse gas emissions** compared to other parts of their life cycle. Other negative environmental impacts also tend to be concentrated at end-of-life if plastics are not properly disposed of and recycled.

H.1 Modular products and as-a-service business models

One of the key principles of the **circular economy** is to **reuse, repair and remanufacture** products in order to keep them in use for as long as possible before they are recycled.[277] **The repairability and reusability** of complex products can be **increased** by making greater use of **robust, standardised, modular plastic components**.

> *"If the product isn't designed for repairability or reuse, there is nothing the consumer can do."*

An **online platform** to which **instructions on how to repair** different products can be uploaded is one example of how **digital solutions** can help to increase the number of products that can be repaired. This solution also uses **augmented reality applications** to guide the user through the repair process by overlaying instructions onto the physical object.[278]

Digital product passports that record exactly what a product is composed of are another idea that enjoys widespread support among the experts. Product passports would offer the following **benefits**:

- they would simplify trading and remanufacturing by making it easier to **track material flows**,
- they would make it easier to carry out any necessary **repairs** by providing detailed information about individual components,
- by replacing physical data sheets, they would facilitate **information sharing** and **reduce paper consumption**,
- depending on the data stored, they could also provide **information** about a product's **sustainability** (raw material consumption, carbon footprint),
- they could help to ensure that the product enters the **appropriate recycling stream**.

However, the experts point out that this may require **sensitive business information** to be disclosed and that **all the actors in the ecosystem** must therefore be involved in developing these solutions.

As-a-service business models are already being trialled in other parts of the chemical industry (e.g. **"chemical leasing"** for solvents and disinfectants).[279]

As-a-service models could also be employed in the **plastics sector**, for example for **packaging and logistics**. Instead of supplying plastic packaging, businesses could provide a service guaranteeing that the product will be safely delivered in a defined condition. This would serve to **decouple value added from the volume** of packaging, giving companies an economic incentive to reuse packaging as much as possible and to **minimise the amount of materials used**. Customers would also benefit from the supplier's expertise regarding the most effective use of different packaging types.

H.2 Reusable packaging and deposit return schemes

One way of using plastics more sustainably is for a larger proportion of plastic products to be **reused multiple times**. **Packaging**

277 | See BCG 2019a; Ellen MacArthur Foundation et al. 2015; Ellen MacArthur Foundation 2019a; RNE et al. 2017; wbcsd/BCG 2018.
278 | See EPC 2020.
279 | See Kümmerer et al. 2020; Schülke & Mayr GmbH 2012.

in particular is currently often thrown away after just a **single use**. Provided that all the actors in the value network are properly coordinated, **reusable products and deposit return schemes** can provide a means of **reducing demand for plastic**. At present, however, **there are hardly any economic incentives** for this approach.

The use of reusable products is particularly promising in the **B2B market**, where it is easier to implement tracking, and where **business models** can be **scaled up more easily** and must necessarily be **less fragmented**. Standardised, reusable packaging could be used in many logistics settings, for example. This approach can be combined with **IoT technology** such as RFID tags and sensors, not only to **simplify reverse logistics**, but also to **grow business models** and **optimise processes** through the provision of additional packaging functionality.[280]

In the **consumer market**, too, there are more and more examples of business models based on **reusable or refillable packaging**, for instance for cleaning or personal care products and food delivery services.[281] **Deposit return schemes** such as those that already exist for beverage packaging are another possible solution.[282] However, some experts warn that it will be important to avoid creating **too many parallel** structures, in order to ensure sufficiently widespread take-up and the necessary level of system efficiency.

H.3 Consumer behaviour

Consumer **behaviour** can also influence the use of and demand for plastics. **Greater demand** for **recycled plastic** products can act as an incentive for industry to use a higher percentage of secondary feedstocks. The success of **reusable products** will also be partly determined by demand. At the same time, **industry** should be **increasing the supply** of these products of its own accord.

Labels providing information about a product's sustainability – for instance its recyclability, resource consumption or carbon footprint – can help consumers **to shop sustainably**. However, the experts warned that consumers are likely to become **confused** if there are **too many different labels**.

They felt that the introduction of a single, **harmonised** label **that is easy to understand** (with a single, aggregate sustainability score) is key to the success of this approach. Additional, more detailed information could then be accessed digitally.

> *"We must create a level playing field for sustainable plastic products. Ultimately, in both the B2B and B2C markets, even well-informed customers' purchasing decisions are usually determined by price."*

The experts also point out that **price** will continue to be the **decisive factor** for **most people**. Consequently, a **more effective** solution would be to factor externalised **environmental costs into the price** of less sustainable products

H.4 Alternatives to plastic products

As well as **reducing plastic consumption**, promoting **reuse** and ensuring effective **recycling**, another way of achieving the desired sustainability goals is to **replace plastic products** with alternatives made from more sustainable materials.

In some areas, for example certain types of packaging, **fibre-based products made from renewable resources** or paper can provide a suitable alternative. Particular attention should be paid to finding alternatives to plastic products that are especially **difficult or impossible to recycle**.[283]

Product sustainability assessments should always be based on the **entire life cycle** – from raw materials to reuse and recycling – under real-life conditions. A **technology-neutral** approach should be taken to determining whether plastics or alternative materials offer the best solution.

280 | See Ellen MacArthur Foundation 2019c; EPC 2020.
281 | See Ellen MacArthur Foundation 2019c.
282 | See PwC 2011.
283 | See Bioökonomierat 2017; FhG 2018; WEF et al. 2016; WEF/Ellen MacArthur Foundation 2017.

Appendix I: Closing the loop – increasing plastics recycling

Increased recycling rates and the use of recycled plastic in high-grade products are key drivers of more sustainable plastic value networks. Optimisation of the recycling system will call for further development and greater use of mechanical recycling, complemented by innovative techniques such as chemical recycling. This will require policymakers to create a framework based on life cycle assessments that removes market barriers to recycled plastic, strengthens demand, and avoids providing incentives for its use in energy production.

In order to meet existing and potentially even more ambitious plastic recycling **targets**, an appropriate **regulatory framework** is needed to promote **intelligent combinations of different recycling methods**.[284]

According to the experts, a **value creation system** that optimises sustainable plastics utilisation by combining **established and innovative methods** and processes will not come about without **policy support**. This will be particularly important for achieving the necessary **networking of actors** from different industries, a **regulatory and organisational framework** that makes it possible to **demonstrate** the technological and commercial **scalability** of new technologies, and a **holistic approach to assessing the sustainability** of different solutions.

Plastic recycling options

Figure 21 provides an overview of the plastics industry value chain (as illustrated by plastic packaging) and **the points at which different recycling options** are used.[285]

Plastics made from recycled material have a significantly **better carbon footprint and use fewer resources** than virgin plastics (see also Figure 22).[286] Studies estimate that a sharp **increase in the** plastics industry's **effective recycling rate** could **reduce its CO_2 emissions by up to 50% by 2050**.[287]

The EU is strongly committed to **closing material loops** as part of a circular economy. Accordingly, increased recycling of materials such as plastic is a central pillar of the **EU's Circular Economy Action Plan**.[288] The **German government**'s new **Packaging Act** also sets **higher recycling targets**, for instance 65% for plastic packaging (increasing to 70% from 2022).[289]

In 2018, **32.5% of plastic waste** in the EU **was recycled** (although just 81% was recycled inside the EU, with the remainder being exported). The total amount of plastic recycled doubled between 2006 and 2018.[290] Nevertheless, **recycled feedstock** still accounted for **less than 10%** of the total input for plastics production in the EU in 2016.[291]

The difference between these two figures can be attributed to **process and quality losses** in the recycling process, as well as to the fact that some plastics are used to make **longer-lived products**, while others **are not disposed of at all or end up in the wrong waste streams**.[292]

284 | See BCG 2019a; Material Economics 2018b; 2019; WEF et al. 2016; Wyns et al. 2019.
285 | See EU COM 2019a; WEF 2016; WEF/Ellen MacArthur Foundation 2017.
286 | See Material Economics 2018b.
287 | See Material Economics 2018b; 2019.
288 | See EU COM 2020c.
289 | See BReg 2019c.
290 | See PlasticsEurope 2019a.
291 | See Material Economics 2019.
292 | See Material Economics 2018a; 2018b; 2019; PlasticsEurope 2019b.

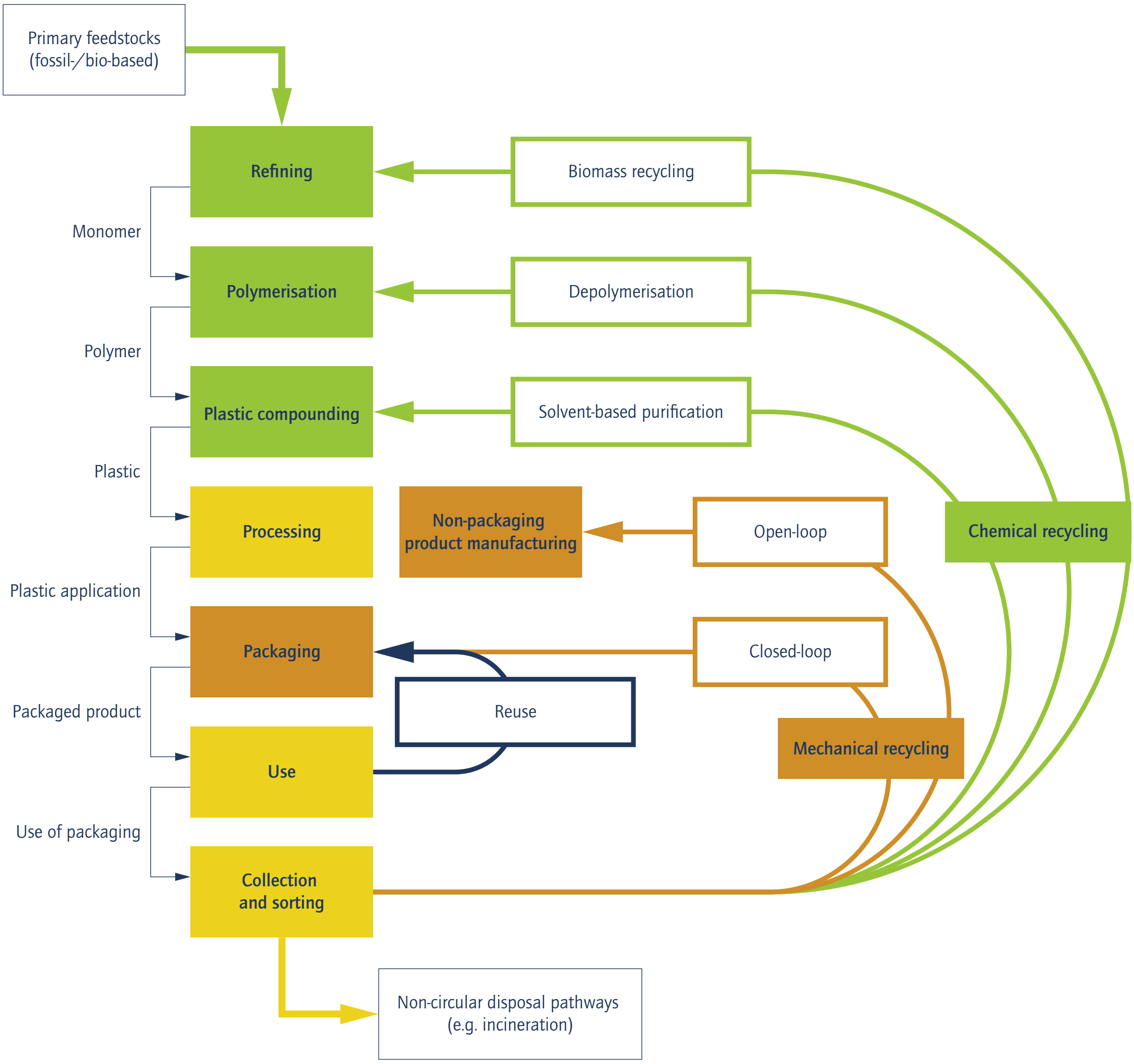


Figure 21: Plastics value chain and recycling pathways for plastic packaging (source: authors' own illustration based on EU COM 2019a; WEF et al. 2016)

I.1 Mechanical recycling

Mechanical recycling is probably the best-known form of recycling. It is also the **only form** currently **used on a commercial scale**. It involves **mechanically grinding** waste that has been **sorted** as carefully as possible into single-material waste streams.

In the case of plastic, the waste is then processed into **plastic granulate** that can be used in the **plastic processing industry** to produce new packaging, for example (see Figure 21).[293] The use of this granulate to produce plastics has a much **smaller carbon footprint** than plastics made from primary feedstocks (see Figure 22).[294]

293 | See EU COM 2019a; WEF et al. 2016; WEF/Ellen MacArthur Foundation 2017.
294 | See Material Economics 2018b; 2019.

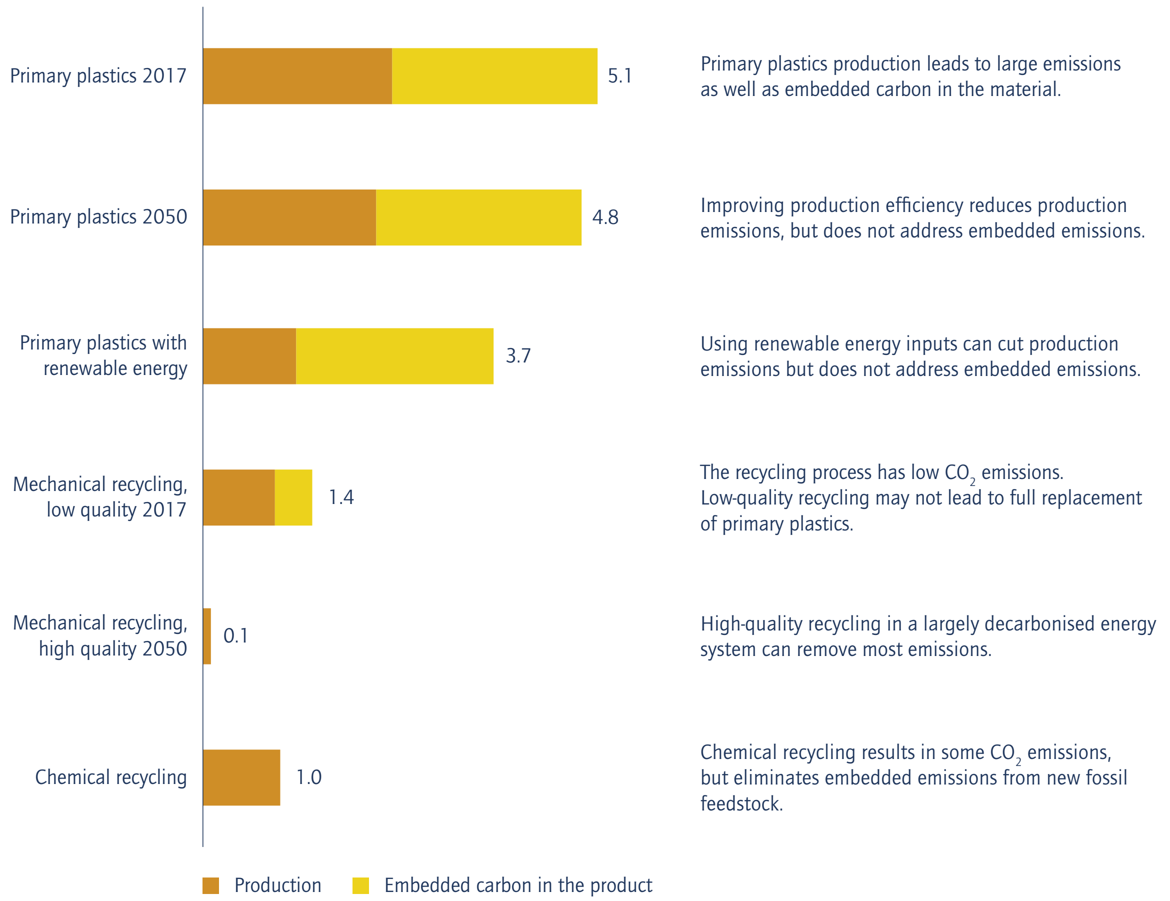


Figure 22: CO2 emissions for different plastics production pathways (source: authors' own illustration based on Material Economics 2018b)

Challenges for mechanical recycling

The **efficiency** of mechanical recycling is determined by **product composition** and **design** (see also Appendix E.1), and by how effectively the waste input has been **sorted and purified**. Consequently, the trend towards increasingly **complex, specialised composite plastics** is **not conducive to mechanical** recycling, since these plastics cannot be separated into single-material recycling streams.

Additives, certain **dyes** and major **impurities** can also lead to some plastics not being recognised by recycling machinery. As a result, they are either not recycled at all, or the **quality of the recycled plastic is compromised**. Rough machine handling of the recycled plastic during the recycling process can also impair quality, as can repeated mechanical recycling, which permanently damages the polymer structure.

Recyclability varies significantly depending on the type of plastic and its area of application. **PET** is the plastic with the **best** mechanical recycling **rates** – in Germany, these are already in excess of 80% in some instances. This is possible because PET is easy to identify as a recyclable plastic, is often used in a relatively **pure form**, is **widely found** in the market, and is used in applications where very few impurities get into the plastic (e.g. drinks bottles). In Germany, the deposit return scheme for PET bottles has played a major role – the recycling rate for items covered by the scheme is over 95%.[295]

However, mechanical recycling is not economically viable for special plastics or plastics that are not usually collected separately (e.g. expanded polystyrene fast food containers). This is because the **waste streams are too small** and contain too many **impurities**. In the **absence of technological solutions** for recycling

295 | See PwC 2011; UBA 2019a.

these plastics, more sustainable **alternative materials** should be investigated.[296]

A large proportion of mechanically recycled plastic is in fact **downcycled** – the recycled material can only be used for relatively **"low-grade" plastics and products** such as plant pots and park benches (see Figure 21).[297] Since many of these items can also be produced using **alternative materials** that are not made from limited fossil resources, this form of recycling is widely **criticised** by the experts **as unsustainable**.

Some **major (retail) companies** such as the Schwarz Group have started to **integrate** the different parts of the **recycling value chain** for packaging (including waste treatment and recycling companies). They hope that this will provide **better solutions** to some of the challenges facing them, such as the **poor quality** of the available recycled plastic or the **lack of coordination** between the individual links in the value chain.[298]

Potential for improved mechanical recycling

According to the experts, there is still considerable untapped potential to use both **existing technologies and innovative technologies that are ready for deployment** in order to significantly improve the efficiency of mechanical recycling and the quality of the resulting recycled plastic. However, they also point out that the **high levels of investment** required to do this **do not make financial sense** under the current conditions.

Nevertheless, they also believe that there is still significant **potential** for the **R&D community** to develop **innovations** that improve the **quality** and **throughput volumes** of mechanically recycled plastic. **More accurate sensors** can improve waste stream identification and sorting, while **more efficient, modular processes** can make it profitable to recycle smaller material streams.[299] Improved **sorting** can also be accomplished by making greater use of **machine learning and AI** in recycling facilities.[300]

> *"There is still plenty of potential to optimise mechanical recycling, but investing in innovations doesn't make financial sense at the moment."*

If conditions change and **demand** for high-grade recycled plastic **rises**, there would be an incentive to invest in modern recycling and sorting facilities. The experts believe that this could be **an important potential market** for innovative German companies in the **machinery and plant engineering sector**.

Coupled with a **focus on sustainability targets**, the forecast **increase in global plastics production** could also generate **export opportunities** for these technologies or for complete recycling solutions as-a-service. This would allow **German green tech companies** to consolidate their **strong position** in the global recycling and waste management market.[301]

As well as optimising the actual recycling processes, **designing for recyclability** (see also Appendix E.1) can play a major role in **improving** mechanical recycling **efficiency**. **More precise** waste stream **pre-sorting** thanks to optimised **collection infrastructure** or other **process enhancements** can also help, as can **more diligent waste sorting** by private households. However, some experts warn that going too far the other way and **over-separating waste streams** could be **counterproductive** due to the increased logistics requirements and complexity.

At least in theory, greater use of **manual sorting** could provide an alternative to technological solutions as a means of reducing **impurities** and creating **low-skilled jobs**. However, without far-reaching changes to the taxation system, it is hard to see how this could be **economically viable** in **high-wage** countries like Germany, even in the long run.

There are differences of opinion among the experts regarding the option of **shipping** waste for further processing to **lower-wage countries** within the EU or to neighbouring non-EU countries.

The current legal framework places strict constraints on cross-border waste trade. Some experts are critical of this, pointing out that global value networks require **global waste management solutions**. They also emphasise that the recycling and reprocessing of complex products in particular has huge **economic potential** for the recipient countries.

Other experts stress that the relevant **infrastructure is often lacking**, and highlight the difficulty in checking whether the

296 | See WEF et al. 2016.
297 | See WEF et al. 2016; WEF/Ellen MacArthur Foundation 2017.
298 | See Handelsblatt 2019b.
299 | See Material Economics 2019.
300 | See Wilts et al. 2020.
301 | See BMU 2018.

countries in question – especially non-EU countries – are complying with **environmental and social standards**, or even knowing whether they have any intention of doing so. They also cite the large quantities of exported plastic waste that end up entering the environment. Under the current conditions, they believe that exporting plastic waste is **unlikely to have a positive overall sustainability footprint** if the environmental, economic and social dimensions are fully taken into account.

Shipping **plastic waste** over larger distances is highly likely to have a **negative sustainability footprint**, even if the recycling process is significantly more efficient due to greater use of manual sorting in the countries in question. This may not necessarily be the case for other, more complex types of waste such as electrical equipment.

I.2 Chemical recycling

Chemical recycling is one solution that could potentially be used even for **mixed or contaminated waste streams** that are unsuitable for mechanical recycling.

Chemical recycling refers to processes in which **plastics** are **broken back down into their chemical constituents**, which can then be used to **make new plastics**. Chemical recycling techniques include pyrolysis, catalytic cracking, gasification, depolymerisation and solvolysis.[302]

> *"It will be impossible to close the plastic loop without at least some chemical recycling."*

Current technologies

There are major differences between **individual techniques** in terms of the **purity and quality requirements** for the waste input, the extent to which the plastic waste is broken down, and the purity and quality of the recycled plastic product (see Figure 23).[303]

Two parts of the chemical recycling process have **high energy requirements**. The **chemical conversion process** that breaks plastics back down into oligomers, monomers or even simpler constituents is itself energy-intensive.[304] Moreover, the **manufacture of plastic from chemically recycled feedstocks** involves several **energy-intensive process stages** that are not required in mechanical closed-loop recycling (see Figures 21 and 22).

Depolymerisation and solvolysis produce oligomers or monomers of the **original polymer** that require relatively little energy to be turned back into plastics. On the other hand, the end products of **pyrolysis and gasification** are **pyrolysis oils, syngas, or chemical intermediates such as methanol**. Additional energy is required to reincorporate these products into the plastics production process at the **refining** stage (see Figures 21 and 22).

Sustainable chemical recycling is therefore highly dependent on the availability of a **large and stable supply of renewable electricity**. In simplified terms, the technologies with **lower input purity requirements** and higher polymer breakdown levels have the **highest energy requirements**.[305]

Several chemical recycling technologies already have a **high Technology Readiness Level** (TRL 8–9), and the first commercial facilities have already opened in Europe. However, some experts caution that the actual waste input **purity and quality requirements are relatively high**, especially for the technologies with the highest TRLs.[306]

Moreover, many of the experts maintain that it is not **commercially attractive** to operate chemical recycling facilities under the current conditions. The **high investment and energy requirements** and the time needed to build large-scale facilities and the **necessary infrastructure** must also be taken into account.

Chemical recycling technologies still have room for improvement, for example with regard to their **efficiency**, input quality **requirements**, and the **quality of the end product**.[307]

Another promising approach that is still at a much **earlier stage in its development** is **enzymatic recycling**, which uses **biotechnological methods** to recycle plastic polymers.[308]

Regulatory framework

The **regulatory framework** governing the use of chemically recycled plastics **varies** across Europe, and is **particularly different in Germany** compared to many of its neighbours. Most European

302 | See Bauer et al. 2018; BCG 2019a; cefic 2020; DECHEMA/FutureCamp Climate GmbH 2019; EU COM 2019a; Solis/Silveira 2020; WEF et al. 2016.
303 | See DECHEMA/FutureCamp Climate GmbH 2019; EU COM 2019a; Solis/Silveira 2020.
304 | See DECHEMA/FutureCamp Climate GmbH 2019; Solis/Silveira 2020.
305 | See Solis/Silveira 2020.
306 | See Ibid.
307 | See EU COM 2019a; Solis/Silveira 2020.
308 | See Tournier et al. 2020.

Technology	Scale of operation (at present)	Temperature (°C) (in process)	Sensitivity (to feedstock quality)	Polymer break-down level	TRL
Conventional pyrolysis	Commercial	300-700	High	Moderate	9
Plasma pyrolysis	Laboratory	1,800-10,000	Low	Very detailed	4
Microwave-assisted pyrolysis	Laboratory	Up to 1,000	Medium	Detailed	4
Catalytic cracking	Commercial	450-550	High	Moderate	9
Hydrocracking	Pilot	375-500	High	Detailed	7
Conventional gasification	Commercial	7,000-12,000	Medium	Detailed	9
Plasma gasification	Commercial (for hazardous waste)	1,200-15,000	Low	Very detailed	8
Pyrolysis with in-line reforming	Pilot	500-900	Medium	Detailed	4

Figure 23: Chemical recycling technologies (source: authors' own illustration based on Solis/Silveira 2020)

and many neighbouring countries do not distinguish between different types of recycled plastic based on their origin, i.e. whether they were mechanically or chemically recycled. In Germany, however, a **distinction** is drawn **between "raw material" and "material" recycling**.

Chemically recycled plastics come under the first of these two categories, meaning that under German law they **do not count towards packaging production recycling targets**.[309] This restrictive regulatory framework and the resulting low demand for chemically recycled plastics mean that there are currently **no companies in Germany** using these technologies **on a commercial scale**.

"The current regulatory framework means there is no commercial chemical recycling activity in Germany at this point in time."

Several other **European countries** (such as Denmark, Italy, the Netherlands and Spain) have already opened their first **chemical recycling facilities** or are in the process of building them.[310] As a result, **German chemical companies** such as BASF are now looking abroad for partners for their chemical recycling trials.[311]

In complex, large-scale production processes where chemically recycled plastic is included in the feedstock mix, it can be **difficult** to **specify the exact proportion of recycled content** in the end product. One potential solution that has been discussed in this context is the **mass balance approach**, which works along the same lines as the method used to specify the percentage of renewable electricity in the electricity mix.

Under this approach, independent **third-party certification bodies** would be able to guarantee that the percentage of recycled plastic that plastic manufacturers claim is contained in a product always corresponds to the actual input of recycled material.[312] However, this will require the establishment of an **appropriate regulatory framework**.[313] Moreover, some of the experts caution that the mass balance approach does **not guarantee transparency regarding the actual percentage of recycled content** in the end product, making it harder for consumers to make informed purchasing decisions.

Assessing the sustainability of chemical recycling

A number of criticisms have been levelled at chemical recycling. These include the charge that all chemical recycling technologies involve very **energy-intensive** processes. The higher the **percentage of fossil fuels in the energy/electricity mix** used for chemical recycling, the **worse** its **environmental footprint**.

Moreover, some forms of chemical recycling employ **solvents or catalysts**. The potential health and environmental impacts associated with the **disposal** of these substances must also be taken into account when **assessing** their **sustainability**.[314]

Some experts express **concern** that the lower feedstock purity requirements for **chemical recycling** could lead to it becoming the **preferred recycling method** even for plastic waste types where

309 | See PRE/VCI 2019.
310 | See Solis/Silveira 2020.
311 | See BASF/QuantaFuel 2019.
312 | See Ellen MacArthur Foundation 2019b.
313 | See EU COM 2019a.
314 | See BCG 2019a.

mechanical recycling would actually have a significantly better environmental footprint. As a result, **developments** potentially leading to improvements in mechanical recycling or product design **might never come about**. The experts also highlight the danger of different technologies **competing for the purest material streams** – even though chemical recycling has lower purity requirements in principle, purer inputs still make it more efficient and thus more profitable.

Other experts do not share these concerns, emphasising instead the need for a **framework** that supports selection of the **optimal recycling pathway** based on a **holistic assessment** of the individual product's **life cycle**. However, one point that the experts do **agree** on is that it will **be impossible to fully close the loop** in the plastics industry **without using chemical recycling at all**.

A regulatory sandbox for an integrated, optimised recycling ecosystem

A **large-scale regulatory sandbox** that brings together the **relevant actors from the entire** plastics industry **value cycle** – potentially even at European level – could provide valuable insights into how recycling ecosystems can be optimised and the role that chemical recycling could play (see Box 7). **Government will need to take the initiative in bringing together** these actors, who are spread across the chemical industry, waste management and recycling sector, research institutions, municipal utilities and government agencies.

A regulatory sandbox would make it possible to carry out real **life cycle assessments** while also identifying potential **regulatory, systemic and process-inherent barriers** and potential **synergies or optimal ways of sharing infrastructure with mechanical recycling** or other production processes. It would also help to promote better **networking of the relevant actors**.

Since there are major differences in the EU member states' statutory regulations in this area, it would make sense to establish the regulatory sandbox at **European level**. This would enable direct **sharing of regulatory best practices** and would also promote **harmonisation of the relevant regulations**.

I.3 Biodegradable plastics

Biodegradable plastics can be **broken down** by microorganisms or fungi into **water, carbon dioxide or methane, and biomass**.[315] They can be either bio-based or petrochemical-based (see also Figure 18). Some experts believe that they could have **benefits**, especially in **niche markets** such as plastics that will probably be **mixed with organic waste** (e.g. food packaging, net bags used for food shopping, etc.) or that are highly likely to **remain in the environment** and never enter the formal waste disposal system (e.g. plastic sheeting used in agriculture and fishing gear).[316] As a result, some experts believe that biodegradable plastics will primarily contribute to greater sustainability in **countries with a less developed recycling infrastructure**.

Regulatory framework

The definition of which materials may be classed as biodegradable is regulated by national and international **norms and standards**. To meet this definition, a material must break down in an **industrial composter** under specific conditions and within a reasonable timeframe. However, this definition **says nothing about how long the material takes to break down in the environment**.

The **regulations** governing the uses of biodegradable plastics **vary significantly across Europe**. For instance, some experts report that there have already been positive experiences with biodegradable plastics in **Italy**, where **contamination of organic waste streams** by non-compostable plastics **decreased** following the introduction of a statutory requirement for all plastic bags used for the sale of food to be biodegradable.[317]

> *"Biodegradable plastics can help to reduce contamination of organic waste streams."*

Germany has **banned** the disposal of **biodegradable plastics** in organic waste streams, with the exception of industrially compostable bags used for the collection of organic waste that comply with the EN 13432 standard. One reason for this is that the short composting period in German industrial composters does not guarantee that the plastics will break down completely. However, recent studies have found that standard commercially available products made from industrially compostable plastics break down significantly faster than required by EN 13432.[318]

Challenges and criticisms

According to the experts, it should be possible to accelerate the breakdown of biodegradable plastics by **researching and**

315 | See UBA 2009.
316 | See WEF et al. 2016; WEF/Ellen MacArthur Foundation 2017.
317 | See European Bioplastics 2017.
318 | See van der Zee/Molenveld 2020.

developing better materials. Some experts also support a general lengthening of the composting period in German industrial composters, since this produces higher-quality compost.

Apart from the fact that they take a long time to compost, a number of other **criticisms** have also been levelled at the use of biodegradable plastics. For instance, because they are used to make **single-use** items that must subsequently be disposed of, biodegradable plastics are considered to be **less environmentally-friendly** than non-biodegradable but **more robust plastics** that can be reused and/or recycled.

Furthermore, **while they are breaking down into compost**, a significant percentage of the **energy stored** in biodegradable plastics **is lost without being used**. This compares unfavourably with the incineration of plastic waste to produce energy.[319]

There is some **debate** in the literature about whether biodegradable plastics can **compromise recycled plastic quality** if they enter **mechanical recycling material streams**.[320] Having to remove them from the relevant material streams in order to achieve an acceptable recycled plastic quality would make the necessary sorting processes even more complex.

There are also concerns about a possible **rebound effect** if **consumers use more** biodegradable plastics in the belief that they are a sustainable product, but **fail to dispose of them properly**.[321]

In order to address these criticisms, the aim should be to develop plastics or alternative materials that are both **easily recyclable** and **biodegradable**. This would diminish the problems caused if they enter the wrong waste stream. Moreover, **amendments to the relevant standards and norms** could require biodegradable plastics to **break down** rapidly **under normal environmental conditions** without producing microplastics or harmful residues.

However, this could potentially lead to **conflicts with the intended function and durability** of the plastics during use. It would also be necessary to find solutions that **make it easier for consumers** to choose the **optimal disposal method** for every product.

Further technological advances will not be enough on their own to **fully resolve these conflicts** – **policy decisions** regarding the use of biodegradable plastics will also play a vital role.

Detailed life cycle assessments for the product's intended use are once again essential in order to establish **whether and when** the use or further development of biodegradable plastics is **desirable from a sustainability perspective**. These must take a **range of factors** into account, for instance the **recycling infrastructure** in the country in question and the likelihood of biodegradable plastics entering the **wrong waste streams**.

I.4 Energy recovery from waste (waste incineration)

At present, a **large proportion** of the plastic produced in Europe (around 43% in 2018) and Germany (around 60% in 2018) is incinerated at end-of-life in order to **produce energy**.[322] According to the literature, **around 2.7 tonnes of CO_2** are emitted **for every tonne of plastic that is incinerated**.[323]

Existing legislation coupled with the EU plastics landfill ban currently under discussion[324] could create **incentives** to **burn an even higher proportion of plastic waste**. Furthermore, **waste-to-fuel technologies** that use **chemical recycling** to convert plastic waste into fuel for heating and transport are in some cases currently classified as a form of recycling that is eligible for government support.

> *"If the incentives for waste-to-energy get too big, no-one will bother recycling anymore."*

The experts are critical of many aspects of this framework. They recognise that incineration prevents plastic waste from ending up **in landfill, where it remains unused** and eventually breaks down into microplastics, with potentially **harmful consequences for the environment**. However, they **maintain** that regulatory incentives are required to **maximise the amount of plastic that is recycled**.

319 | See Behr/Seidensticker 2018; UBA 2009; 2012; 2020.
320 | See Samper et al. 2018; van den Oever et al. 2017.
321 | See Haider et al. 2019.
322 | See PlasticsEurope 2019a.
323 | See Material Economics 2019.
324 | See PlasticsEurope 2016.

But even if the amount of plastic waste that is recycled increases significantly, there will still be a certain percentage that **is unsuitable for recycling**. This is where incineration can make a meaningful contribution to sustainability, since it allows at least some of the **energy** stored in the waste to be **recovered** and used.

However, if the plastics industry is to become **greenhouse gas neutral** in the medium to long term, the **CO_2** emitted from the incineration of this non-recyclable waste will need to be **stored using CCS technology** or used through CCU. The **challenge** is that the production of energy from waste is based on a **decentralised system** involving a large number of waste-to-energy plants. As a result, the plants are **less efficient**, the **investment costs** for building several separate plants **are higher**, and the **cost of transporting** the CO_2 to the place where it is stored or used **is also higher**.[325]

I.5 Framework and infrastructure

The experts are of the unanimous view that any **decisions** regarding the best recycling or disposal solution for individual products should be based on a **holistic assessment of the entire product life cycle**. The **sustainability aspects** that should form part of these assessments include:

- direct and indirect CO_2 emissions from production, use, transport and end-of-life,
- other environmentally harmful emissions or by-products,
- biomass availability requirements for bio-based plastics.

In addition, the framework should make it possible to respond **dynamically to the development of new technologies** or to more widespread availability of **renewable electricity** in the future.

The experts believe that the best way of approaching this is through **technology-neutral targets**. In some cases, however, **strategic policy decisions** will also need to be taken in Europe regarding the future role of specific technologies, e.g. for recycling plastic. This will be especially important in order to enable the construction of the necessary **infrastructure**, provide a **reliable basis** for companies to **invest**, and **remove barriers to market entry**. It will be necessary to strike a **balance** between these partially conflicting goals.

Recycled content requirements

A **recycled content requirement** would provide the **most direct incentive** to use a higher percentage of recycled plastic. Current regulations usually focus on **recycling quotas** that measure the percentage of total plastic waste that **enters the recycling process**. This approach makes no attempt to consider the level of process losses during recycling or the products that are subsequently made with the recycled plastic (downcycling).

At least in the case of packaging waste, the **amended EU Directive** changes the way that the recycling quota is calculated. Only the percentage that remains after the waste has been sorted and decontaminated for recycled plastic production now counts as recycled.[326]

In contrast, **recycled content requirements** are based on the percentage of recycled content that is **used in a product**. As a result, a recycled content requirement has the **advantage** of supporting the use of recycled plastic in the **higher-grade plastics** made in Europe, as well as making it less attractive to **downcycle** plastic waste or remove it from the value cycle by burning it to **produce energy**. A recycled content requirement is already referenced as a policy instrument in the EU's **Circular Economy Action Plan**, although no concrete percentages are mentioned.[327]

Some of the experts interviewed for this publication recommend a cautious approach to recycled content requirements, since **the recycling capacity** needed to achieve high percentages **will not be available in the short term**. However, they believe that a long-term strategy to **gradually increase the recycled content requirement** can be a valuable instrument that provides companies with a **reliable basis for planning investments** to build and expand recycling capacity and improve recycled plastic quality.

In addition, the **public sector** can directly grow the recycled plastic market by stipulating recycled content requirements in its **sustainable procurement rules**. There is broad agreement among the experts that this is an **important driver** that has yet to be fully leveraged.

Creating incentives through fiscal and market-based instruments

Fiscal instruments can also be used to **create more of a level playing field** that allows recycled **secondary feedstocks** to compete with fossil-based primary feedstocks in plastics production. As well as a **carbon price that is set at an appropriate level**, some experts propose a **tax on extracted raw materials**. Both instruments could help to internalise the costs of the climate and environmental damage caused by extracting primary fossil resources, and thus to create a **level playing field for recycled plastic**.

325 | See Material Economics 2019.
326 | See European Parliament and European Council 2018.
327 | See EU COM 2020c.

> *"Even with access to the full range of technologies, a circular economy for plastics is not economically viable at this point in time."*

> *"There are serious limits on what a circular economy can achieve with 27 different waste management systems."*

On the other hand, there is little support among the experts for the idea of a **plastics tax**. They fear that the revenue from a plastics tax **would not be used to expand the recycling infrastructure** and that it would cause the public to see plastic as an intrinsically bad thing.

Some of the experts suggest the alternative approach of an **extended producer responsibility fee** that would be paid directly into a fund for **improving the recycling infrastructure or for R&D** in this area. The fragmented and complex nature of the value networks in the plastics industry and in particular the packaging sector means that it will also be important to include **all the relevant actors**, from producers and processors to distributors and retailers.

The European dimension

The fact that the **EU has only limited legislative powers** for the waste and recycling market means that the relevant regulations and standards vary significantly between the individual member states. This circumstance is also partly responsible for the fact that **a significant European market** for recycled plastic **has not yet developed**, and for the fact that certain types of plastic lack **sufficiently large waste streams** to make it worthwhile recycling them.

It is therefore important to create **platforms at European level**, where member states can harmonise the relevant regulations as closely as possible and share best practices and experiences with different types of regulation. According to the experts, the **European Plastics Strategy** and the **Circular Economy Action Plan** already set out an appropriate pan-European vision.[328] However, they stress that this vision must now be **rigorously implemented** by the member states.

In some EU member states, the plastic waste **collection and sorting infrastructure** remains in the hands of the public sector, while in others it is operated by private companies. Regardless of who is responsible for it, however, a substantial level of investment will be required to **upgrade and expand** this infrastructure in order to enable **improved recycling efficiency and quality** through better **separation of material streams**.

The role of the consumer

Consumers can help to keep plastic waste separate from other waste streams so that it is easier to recycle. Children should therefore be taught **responsible attitudes towards waste** and learn about **its importance as a raw material** from an early age. The "Plastic Pirates" initiative of the Federal Ministry of Education and Research is one good example of how this can be done.[329]

Other factors that can help to **optimise material streams** include **better labelling of products** and how to dispose of them (potentially supported by **digital applications** such as scannable product codes), and an adequate, user-friendly, nationwide **waste collection and separation infrastructure**.[330] **Deposit return schemes** can also help to produce particularly pure waste streams and even generate a **positive financial return** for the collection infrastructure providers, as demonstrated by Germany's deposit return scheme for single-use PET bottles.[331]

However, it is important not to **confuse** consumers with **overly complex instructions** for sorting waste and collecting different categories of product. Complex parallel structures should also be avoided for the collection and return infrastructure. The optimal **balance** could be determined and scientifically tested in **near-real-life projects**.

328 | See EU COM 2018c; 2019a; 2020c.
329 | See BMBF 2020a.
330 | See EPC 2020.
331 | See PwC 2011.

Appendix J: Overview of other reporting standards

In addition to the WEF Common Metrics and Value Balancing Alliance reporting initiatives that are described in detail in Chapter 4.4, there are several **other initiatives** in which businesses, institutional investors and asset managers undertake to observe certain reporting standards.

A rough distinction may be drawn between two different types of reporting standard:

- **Some standards simply provide a basis for sustainability reports** or for establishing how exposed a company is to climate change impacts, **and do not involve any additional agenda setting**.
- **Other initiatives** go further, seeking to **contribute to the achievement of climate and sustainability targets** through transparent reporting.

Some companies choose to observe several different reporting standards, in part because different investors prefer different standards.

Figure 24 provides an overview of four additional reporting standards.

Global Reporting Initiative (GRI)

The GRI is one of the oldest **sustainability reporting** initiatives for large corporations, SMEs and NGOs. The **GRI Sustainability Reporting Standards** were established more than 20 years ago and have been **continuously developed** ever since, **using a participatory approach**. The **reporting process** is modular and comprises over **120 indicators**. This **globally recognised** system ensures standardised comparability with a **high level of detail**. However, the level of detail has also been criticised, since it can cause difficulties, especially for SMEs.

Task Force on Climate-Related Financial Disclosures (TCFD)

The **G20's Financial Stability Board** established the TCFD in order to formulate clear reporting guidelines that create transparency for businesses with regard to their climate-related risks and climate strategies, thereby helping to **prevent a carbon bubble** on the financial markets. It is hoped that the voluntary disclosures made by participating companies will facilitate **more transparent** assessment of **climate-related impacts by the financial markets**.

Carbon Disclosure Project (CDP)

Once a year, the CDP collects voluntarily provided, **standardised data and information** from institutional investors and businesses **regarding CO_2 emissions, climate-related risks, and reduction targets and strategies**. In Europe alone, 1800 businesses took part in the most recent survey, accounting for more than 75% of publicly listed companies. The data is used to create **greater transparency for investors**.

Net Zero Asset Owner Alliance

The members of this **alliance of institutional investors** have voluntarily committed to transition their **portfolios** to **net-zero GHG emissions by 2050**. The companies promise to publish **regular progress reports** and to establish concrete, quantifiable intermediate targets every five years.

Figure 24: Overview of other selected reporting standards (source: authors' own illustration based on CDP 2020; GRI 2020; TCFD 2020; UNEPFI 2020)

Appendix K: List of figures

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Editors:

Dr. Martin Brudermüller
BASF SE Germany
Carl-Bosch-Strasse 38
67056 Ludwigshafen am Rhein | Germany

Prof. Dr.-Ing. Reimund Neugebauer
Fraunhofer-Gesellschaft
Postfach 20 07 33
80007 Munich | Germany

Reiner Hoffmann
DGB – German Trade Union Confederation
Henriette-Herz-Platz 2
10178 Berlin | Germany

Prof. Dr.-Ing. Günther Schuh
RWTH Aachen University
52056 Aachen | Germany

Prof. Dr. Henning Kagermann
acatech – National Academy of Science and Engineering
Pariser Platz 4a
10117 Berlin | Germany

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Munich Office
Karolinenplatz 4
80333 Munich | Germany
T +49 (0)89/52 03 09-0
F +49 (0)89/52 03 09-900

Berlin Office
Pariser Platz 4a
10117 Berlin | Germany
T +49 (0)30/2 06 30 96-0
F +49 (0)30/2 06 30 96-11

Brussels Office
Rue d'Egmont/Egmontstraat 13
1000 Brussels | Belgium
T +32 (0)2/2 13 81-80
F +32 (0)2/2 13 81-89

info@acatech.de
www.acatech.de

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The European Green Deal is an important blueprint for the transformation of Europe's industrial basis towards environmental, economic and social sustainability. A successful implementation of the Green Deal requires broad approval and support among the population and by businesses, especially in times when the financial leeway is narrowing. Therefore, in addition to climate protection and the preservation of biodiversity further policy design goals must be applied to the new status quo in Europe after the SARS-CoV-2 pandemic: strengthened international competitiveness of Europe and a sustainable structural transformation of industries and regions, which includes workers and opens up new perspectives for the people.

This acatech IMPULSE publication presents hydrogen and electrification from renewable energy sources, the digital and biological transformations as well as circular economy as promising drivers for a sustainable transformation of industry, building on the strong German and European research base. High investments are needed to set these drivers in motion. Consequently, next to technological innovations this publication also presents approaches to make Europe an attractive location for investment in sustainability.