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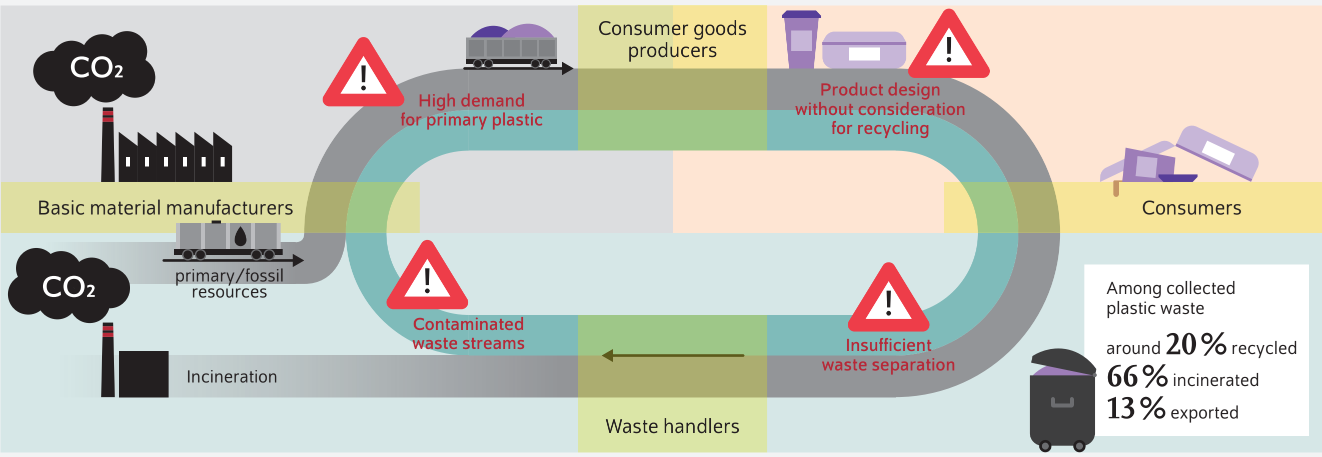
AT A GLANCE

Climate neutrality requires coordinated measures for high quality recycling

By Xi Sun, Frederik Lettow, and Karsten Neuhoff

- Climate targets will not be achieved with climate-neutral production alone; waste avoidance and recycling are equally important
- For plastics, high quality recycling avoids most of the emissions from conventional production and incineration
- This potential remains untapped due to insufficient policy framework along value chain
- Only a package of well-coordinated measures can help
- Pricing the carbon costs of basic materials as well as standards and incentives for recyclability are key

Current policy framework remains insufficient for high quality recycling of plastics



Source: Authors' own depiction.

FROM THE AUTHORS

"In the case of plastics, large amount of greenhouse gas emissions are released not only at the production stage: currently around two-thirds of plastic waste is incinerated with high emissions. Increasing the share of material recycling and reuse is critical for reaching climate targets."
— *Xi Sun* —

MEDIA

Audio Interview with K. Neuhoff (in German)
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Climate neutrality requires coordinated measures for high quality recycling

By Xi Sun, Frederik Lettow, and Karsten Neuhoff

ABSTRACT

For Europe to reach climate neutrality by mid-century, it needs to move toward a circular economy. Waste avoidance, reuse, and recycling save primary resources and avoid emissions in the production of basic materials like steel, cement, and plastics. Without exploring circular economy potentials, switching production to climate-neutral processes alone would result in significant costs and tremendous demand for clean energy. However, enabling the circular transition requires coordinated policy measures. Carbon costs must be fully reflected in basic material prices, while product standards and stakeholder incentives should be aligned with the recyclability of products. In addition, consumer awareness should be raised through reliable information on product environmental impacts, while investment in sorting and recycling infrastructure should be stimulated. Clear targets and definition of responsibilities are necessary for the effective implementation of these measures.

70 percent of industrial greenhouse gas emissions result from the production of basic materials like steel, cement and chemicals.[1] Decarbonizing the basic materials sector via climate-neutral manufacturing processes is possible, but would induce significant costs and demand for clean energy.[2] Hence, material efficiency and circular economy strategies, including waste reduction, reuse, and recycling, are gaining momentum in long-term scenarios, such as those of the EU or the International Energy Agency (IEA) for climate neutrality by 2050.[3]

The move toward a circular economy requires a package of policy measures, for which a coordinated European framework is equally important as national implementation. In mid-July 2021, the European Commission will present the "Fit for 55 package" to reform the EU emissions trading system,[4] providing an opportunity to align an effective CO_2 price with incentives for material efficiency and circular economy strategies. In addition, the sustainable products initiative announced for the end of the year offers the opportunity to create further necessary conditions for a climate-neutral and resource-efficient basic materials sector.[5]

At the national level, important tasks lie ahead for the German government. So far, the focus has been on measures that promote climate-neutral production processes in heavy industry. This should be complemented with waste prevention and recycling measures. Both formulating targets in the Climate Change Act (Klimaschutzgesetz) and enhancing waste management policies can contribute. For instance, by

1 See International Energy Agency, *Net Zero by 2050: A Roadmap for the Global Energy Sector* (2021) (available online, accessed June 24, 2021; this applies to all other online sources in this report unless stated otherwise).

2 See Olga Chiappinelli et al., "A green COVID-19 recovery of the EU basic materials sector: identifying potentials, barriers and policy solutions," *Climate Policy* (2021): 1-19 (available online).

3 See European Commission, *Impact Assessment on Stepping up Europe's 2030 climate ambition* (2020) (available online); International Energy Agency, *Net Zero by 2050*.

4 As part of the "Fit for 55 package," the EU Commission intends to propose legislative changes in various policy areas aimed at achieving the increased climate target for 2030 of a 55 percent reduction in emissions compared with 1990. However, it is still unclear whether the measures can effectively price in climate costs in the production and use of basic materials. See EU Commission, *Commission Work Program for 2021* (2020) (available online).

5 See European Commission, *Sustainable products initiative* (2021) (available online).

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January 1, 2022, the German government will need to decide on mandating further alignments of the advanced disposal fees with recyclability.[6]

These questions are be examined in this report using the example of plastic packaging, around two-thirds of which is currently incinerated at the end of its use life (Figure 1).[7] While there is a large untapped potential for increased and higher quality recycling, significant barriers also persist for realizing these potentials. To overcome the barriers, policy makers must deploy concrete policy measures that not only strengthen high quality recycling, but also stimulate material saving and reuse.

Explore the untapped potential of high quality plastics recycling

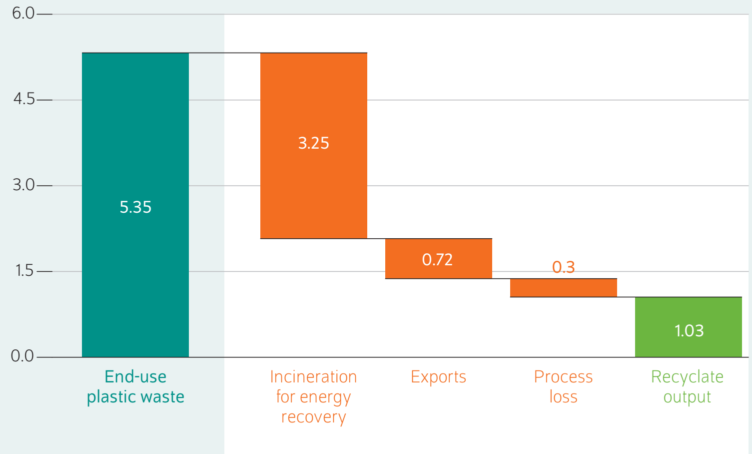
A circular economy refers to a regenerative system in which the use of resources, the generation of waste and emissions, as well as energy losses are minimized by slowing-down and closing material cycles.[8] This requires extending the life of products, reusable systems, and increasing material efficiency. Basic materials are then recovered (reused or recycled) to an ever increasing extent from waste streams instead of from new resources. This process saves energy and emissions.[9] In the case of plastics, this saves not only almost two metric tons of CO_2 emissions during primary production – or the high costs and renewable energy requirements otherwise associated with climate-neutral processes – but also a further 2.7 metric tons of CO_2 generated during the incineration of one metric ton of plastic waste.[10] Overall, the reduced use of resources also contributes not just to reducing risks to biodiversity but also to reducing pollution of air, water, and land.[11]

However, this potential is currently insufficiently exploited. Not only is less than 20 percent of plastic waste actually recycled in Germany,[12] but even where it is recycled, the quality of recycled plastics (recyclates) is mostly low. Much of the recyclates can only be used in low-quality applications such as pipes or flower pots. Meanwhile, recyclates accounted for only 11 percent of the material used for plastic packaging in 2019. To achieve the recycling targets set by the EU for plastic packaging, recycling efforts must be significantly increased.[13]

Figure 1

Recycling routes and losses for end-use plastic waste in Germany in 2019

Plastic volumes generated in millions of metric tons



Note: The quantities stated relate to the total plastic waste generated by end consumers, which also includes non-packaging. In addition, small quantities were landfilled (0.03 million tons) and recycled for raw materials (0.01 million tons).

Sources: Illustration of Circular Economy Initiative Germany (2020), data from Conversio (2020).

Only less than 20 percent of the plastic waste generated by end users is recycled.

Mechanical recycling is fundamentally suitable for achieving a closed-loop economy and is already widespread today. However, at the moment closed-loop recycling is only technologically feasible for clear polyethylene terephthalate (PET) and requires single-variety waste streams, for example from a deposit system, which is associated with relatively high costs. Mixed plastic waste collected via a dedicated recyclables system (the yellow garbage bin in Germany), for example, must be sorted according to different types of plastic, with additives and impurities further complicating the recycling process.[14] As a result, these are usually recycled into low-quality material with very limited applicability.[15] Improved sorting

6 Packaging Act § 21 paragraph 4.

7 Of the plastic waste generated by end consumers, 61 percent is recycled for energy, plus six percent from losses in the recycling process, which are assumed to be incinerated as well. See Conversio Market & Strategy, *Stoffstrombild Kunststoffe in Deutschland 2019* (abridged) (2020) (in German; available online).

8 See Martin Geissdoerfer et al., "The Circular Economy – A new sustainability paradigm?," *Journal of Cleaner Production* (2017): 757-768 (available online).

9 For example, recycling aluminum, steel, and plastics each requires only about three percent, 26 percent, and 30 percent, respectively, of the energy required by conventional primary processes. See Chiappinelli et al., "Green COVID-19 recovery."

10 In addition, emissions can arise from the production of fossil raw materials. See Material Economics, *Industrial Transformation 2050: Pathways to Net-Zero Emissions from EU Heavy Industry* (2019) (available online).

11 At the same time, this can save costs, create local jobs, and improve the resilience of supply chains. See, for example, Paul Ekins et al., *The Circular Economy: What, Why, How and Where* (2019) (available online); Ellen MacArthur Foundation and Material Economics, *Completing the Picture: How the Circular Economy tackles Climate Change* (2019) (available online); International Resource Panel, *Resource Efficiency and Climate Change: Material Efficiency Strategies for a Low-Carbon Future, UNEP Report* (2019) (available online).

12 See Conversio Market & Strategy, *Stoffstrombild Kunststoffe* (in German).

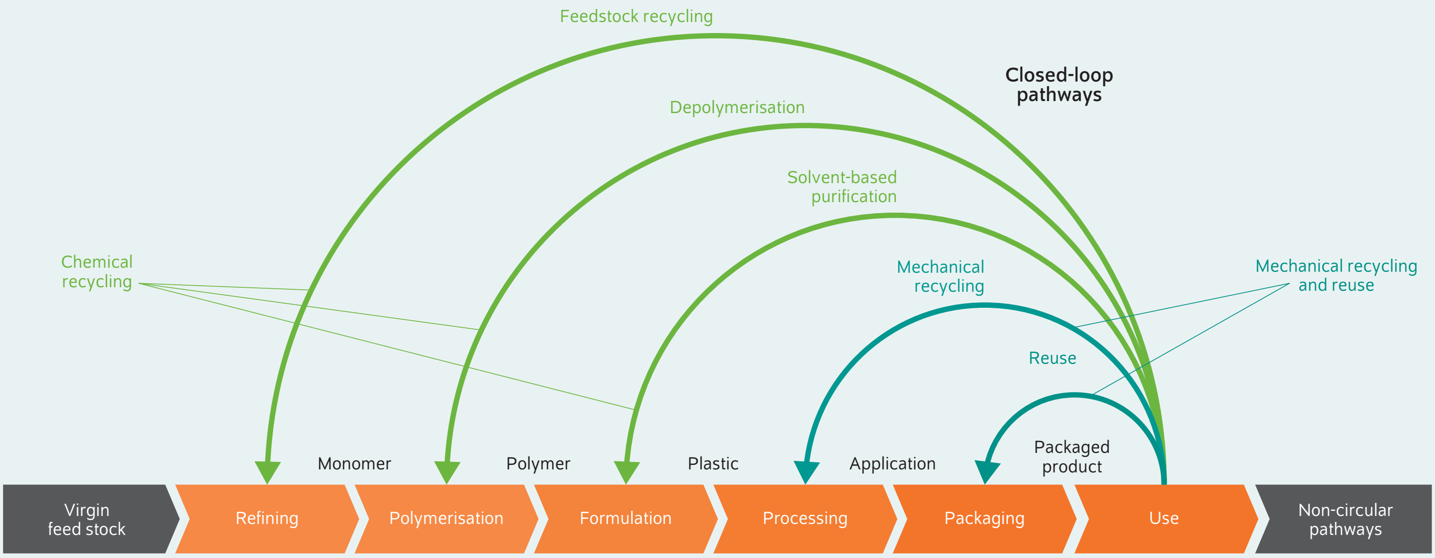
13 The targets specify that 50 percent of plastic packaging waste should be recycled by 2025 and 55 percent by 2030. While 2018 data suggests Germany is only three percentage points away from the 2025 target, the gap is likely to widen to more than 10 percentage points once the revised European methodology for determining recycling rates is applied. This is because the old methodology counted inputs to recycling as recycled, while the new methodology is more closely aligned with actual outputs from the recycling process. See European Court of Auditors, *EU action to tackle the issue of plastic waste* (2020) (available online).

14 See Raymond Gradus, "Postcollection Separation of Plastic Recycling and Design-For-Recycling as Solutions to Low Cost-Effectiveness and Plastic Debris," *Sustainability* 12, no. 20 (2020) (available online).

15 In addition, the thermal-mechanical process can degrade the quality of the material with each recycling cycle. While additives can be used to reduce this problem, these also increase the complexity of the recycling process. See Kim Ragaert et al. "Mechanical and chemical recycling of solid plastic waste," *Waste Management* 69 (2017): 24-58 (available online).

Figure 2

Circular paths of plastics production



Source: Illustration based on European Commission (2019): A circular economy for plastics: Insights from research and innovation to inform policy and funding decisions (available online).

Mechanically recycled materials can only be used to a limited extent, while chemically recycled material is more energy intensive but has a wider range of applications.

technologies, based in particular on increased digitization, robotics and artificial intelligence, have the potential to significantly improve the performance of mechanical recycling of mixed waste streams, but are not yet widespread due to their higher cost.[16]

Chemical recycling returns plastic to its basic chemical building blocks, which can then be used as a direct feedstock for new plastic or as a base material for the chemical industry (Figure 2). Thus, chemical recycling offers the potential to turn plastic waste that is mechanically difficult or impossible to recycle into high-quality and multi-use products.[17] However, since chemical recycling technologies are still under development, their economic and ecological influence is currently uncertain. As recycling back to the basic chemical building blocks requires more energy, chemical recycling is more energy and emissions intensive than mechanical recycling (Figure 3). In addition, it is still uncertain to what extent mixed and contaminated plastic waste can be recovered in chemical recycling processes, thus the purity of waste inputs is likely to remain important.

Current policy framework remains insufficient for high-quality recycling

The potential of recycling cannot be fully exploited at present. This is mainly because the function of all three main markets of the circular economy – the basic materials market, the consumer goods market and the waste goods market – is impaired under the current framework (Figure 4).

In the basic materials market, consumer goods producers demand either primary or secondary (recycled) basic materials. In this context, a major barrier for high-quality recycled plastics at present is that their price is higher than that of primary plastics.[18] On the one hand, this is because improved sorting and recycling involve relatively high capital and operating costs. On the other hand, the environmental impact of primary plastics is not reflected in the price.[19]

In the consumer goods market, it is essential that producers design packaging that can be recycled. However, currently

16 Experts interviewed assumed that with more widespread use of the best available sorting and recycling technologies, around 50-75 percent of plastic packaging material could be materially recycled. See Olga Chiappinelli et al., "Green COVID-19 recovery."

17 For an overview and assessment of chemical recycling, see for example Umweltbundesamt, *Chemisches Recycling* (2020) (in German; available online). Simon Hann and Toby Connock, *Chemical Recycling: State of Play* (2020) (available online).

18 The low oil price during the coronavirus crisis exacerbated the problem, causing the price of virgin material to fall well below that of high-quality recyclate. At the end of 2020, the price of high-density polyethylene (HD-PE) recyclate was €1050, about €150 higher than that of primary HD-PE. See S&P Global Platts, *Recycled plastics recover from pandemic but economics remain challenging* (2021) (available online).

19 In addition, voluntary commitments by large companies to use a certain proportion of recyclate have driven up demand and, thus, prices. See Circular Economy Initiative, *Kunststoffverpackungen im geschlossenen Kreislauf: Potenziale, Bedingungen, Herausforderungen* (2020) (in German; available online).

they lack incentives to do so. Consumers rarely pay attention to the environmental impact of packaging, partly because these costs are not reflected in the selling price. Even if the environmental impacts of waste incineration were covered by the EU Emission Trading System (EU ETS), these environmental costs would fall solely on waste handlers. The same applies to the benefits of improved recyclability (split incentives).

In the waste market, consumers can dispose of their packaging waste in a recycling center (such as a reverse vending machine in a supermarket), a recycling garbage bin (waste separation), or together with other household waste in the residual waste garbage bin. Complete waste separation enables high-quality recycling and has the lowest environmental impact. Again, however, there is the problem of split incentives: the benefits of improved separation accrue to waste handlers, but consumers are generally not compensated for the increased effort associated with waste separation. As a result, the consumer's incentive to contribute to effective sorting is restrained.

In addition, behavioral failures stand in the way of improved recycling. Stakeholders are reluctant to change their behaviors, for example, manufacturers in terms of product design for recyclability or consumers in terms of product choice or waste sorting. Further, behavioral change, for example on the part of consumers to choose environmentally friendly products, is hampered by a lack of easily accessible and reliable information on the environmental impacts of their consumption choices. Finally, long-term benefits of improved recycling are less valued than short-term costs of the behavioral change required to achieve them.

Policy measures for effective recycling must be applied at various stages

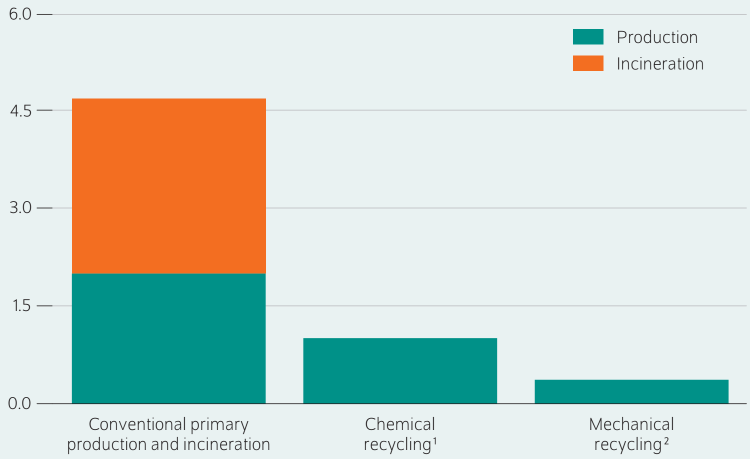
There are a number of policy instruments that can be used to shape the policy framework of a circular economy. However, these still have crucial weaknesses in their implementation.

Fully internalizing climate costs in basic material prices

Emissions from refineries and the chemical industry for the production of plastics are subject to the EU Emissions Trading Scheme (EU ETS). Therefore, in principle, CO_2 costs could be expected to affect plastic prices. However, since plastic products are traded globally, it is assumed that manufacturers are not able to pass on the full costs to product prices. To avoid shifting production – and the associated emissions – to third countries (known as carbon leakage), producers are allocated free allowances that cover the majority of their emissions. This is why the significant climate impact of plastics production is not reflected in product prices.[20]

Figure 3

Emission intensity of different plastic disposal methods
In tons of CO_2 per ton of plastic



1 Due to the still early stage of development and the diversity of technologies, the environmental impact of chemical recycling is still subject to uncertainties; as such, the emission intensity may be higher or lower than illustrated here, depending on respective technology application.

2 With full use of electricity from renewables, mechanical recycling can achieve near-zero emissions.

Notes: Here the recyclate of both recycling processes is assumed to replace primary plastic by a ratio of 1:1.

Source: Material Economics (2018 and 2019).

Both, mechanical and chemical recycling, generate significantly less emission than conventional primary production.

The EU Commission has announced a legislative proposal for mid-July as part of the "Fit for 55 package" to reform the EU ETS to ensure effective CO_2 pricing and avoid carbon leakage risks. To this end, a move to the full auctioning of allowances and a border adjustment mechanism is envisioned. If, as early drafts suggest, basic chemicals are excluded from this reform, then other mechanisms will be required to internalize climate externalities; for example, a plastic tax. However, a more effective and efficient solution from an administrative and legal point of view would be to supplement the EU ETS with a climate contribution.[21] This would be levied on the production of basic materials, including basic chemicals, at the level of the emission intensity of conventional production and the EU ETS emission price. To avoid double pricing with the EU ETS, conventional production processes then receive free CO_2 certificates if they pursue a transition plan to climate-neutral processes. Additional costs of climate neutral production processes can be financed with CO_2 Contract-for-Differences from the revenues of the climate contribution.

20 See Karsten Neuhoff and Robert Ritz, "Carbon cost pass-through in industrial sectors" (Cambridge Working Papers in Economics) (2019) (available online).

21 See Climate Strategies, *Policy proposal: A design of the carbon border adjustment mechanism for an inclusive transition to climate neutrality* (2021) (available online); further analysis on administrative, economic, and legal aspects on the website of the Climate Friendly Materials Platform (available online).

Emissions from waste incineration are exempt in most EU member states from the EU ETS.[22] In the case of plastics, however, waste incineration generates even more emissions than primary production. Therefore, such exemptions should be removed. It also needs to be ensured that the carbon costs associate with waste incineration will be relevant for the product decisions choices of manufacturers and for the purchasing choices of consumers.[23]

One policy instrument that could ensure that the carbon costs of waste incineration are relevant for product design and consumer purchasing choices is the Extended Producer Responsibility (EPR). The Packaging Act makes manufacturers and distributors of packaging for private consumption responsible for the costs of waste treatment by obliging them to participate in a dual system. Dual systems are Producer Responsibility Organizations, which are responsible for the collection and treatment of packaging waste from private consumers. The associated costs are covered by participation fees levied on the companies that put packaging into the market.[24] A comprehensive consideration of the climate costs of packaging under the EPR would not only strengthen incentives for increased and high-quality recycling, but at the same time encourage more reuse and saving of packaging.

Creating incentives for recyclability of packaging

For the extended producer responsibility to create the desired incentives, it is not enough to determine waste disposal costs based on the weight of packaging. Rather, disposal fees need to reflect the environmental costs caused by the respective packaging. In 2018, the players in the German Dual System were obliged to create such incentives, for example through lower fees for recyclable packaging.[25] However, actual implementation was left to the individual providers of the dual systems. They have, arguably, only made limited adjustments to their fee structures and, thus, many argue that incentives for improved eco-design remained low.[26] An EU-wide comparison shows that the adjustment of EPR fees based on recyclability was implemented more concretely and transparently in other countries.[27] For example, in France, Italy, Spain, Sweden and the Netherlands, disposal fees are assessed according to sortability, recyclability, and the existence of sorting instructions.[28]

Harmonized standards for additives can increase recyclability

Waste streams will play an increasingly important role as a resource and, therefore, should be protected from impurities that limit the further recyclability of the waste. Currently, a variety of additives are used to achieve flexibility, thermal stability, and permeability, among other purposes. However, due to the large number of additives, it is impossible to sort the waste streams according to the additive used in each case, particularly because, in many instances, even small amounts of specific additives preclude high-quality recycling.[29] A similar problem exists for metals due to the variety of alloys. A limitation of the number of admissible additives in packaging to the additive types necessary for variety of purposes would therefore appear to be sensible.

The EU Ecodesign Directive can be a starting point for such harmonization.[30] It outlines binding minimum requirements for the energy efficiency of selected energy-related product groups, supplemented by mandatory labeling regulations. Currently, the EU is planning to extend the Ecodesign Directive to cover a wide range of products, beyond those related to energy. For example, this should also include criteria for the recyclability of plastic packaging. In addition to limiting additives, clear requirements regarding the simplifications of packaging are needed. For example, packaging consisting of multiple, inseparable layers of different materials should be restricted due to their poor recyclability.

Strengthening consumer awareness of waste separation and sustainable consumption

The separate collection of waste enables a significantly higher recycling rate.[31] Although waste separation is laid down by law in Germany and a good infrastructure already exists for this purpose, too much packaging waste is still not separated correctly; in some cases, the misthrow rate is as high as 60 percent.[32]

22 Incineration emissions from municipal and hazardous waste are excluded from the EU ETS, but member states have the option to opt-in to cover this activity. See EU Directive 2018/410 amending Directive 2003/87/EC to enhance cost-effective emission reductions and low-carbon investments and Decision (EU) 2015/1814 (2018) (available online); The opt-in clause is used, for example, by Denmark. See OECD, *OECD Environmental Performance Reviews: Denmark 2019* (2019) (available online).

23 Similar incentives have been implemented in other countries, such as a pay-as-you-throw fee on waste or a tax on single-use plastic packaging (as in Denmark, Latvia, and Lithuania, for example). See Matthias Runkel and Alexander Mahler, *Steuerliche Subventionierung von Kunststoffen. FÖS short study commissioned by Bündis 90/Die Grünen* (2017) (in German; available online).

24 The dual system exists as a second (dual) system alongside public-legislative disposal. There are currently ten dual systems (operators) in which manufacturers of packaging can participate. The best-known dual system in Germany (DSD, *Der Grüne Punkt*) has a market share of 16 percent for lightweight packaging. See Central Packaging Register Office, *Market shares of the systems for the second quarter of 2021* (2021) (available online).

25 The Federal Environment Agency and the Central Packaging Register publish minimum standards for recyclability annually as a guide, and the dual systems are required to submit annual reports on implementation. Based on experience with this system, the Packaging Act stipulates that a decision on a more far-reaching regulation is to be made by January 1, 2022. The exact amount of the participation fees is not publicly available.

26 See criticism of the insufficient incentive effect, functioning of the financing mechanism and necessity of the new formulation of requirements for the dual system in Section 5.3, Circular Economy Initiative Germany, "Kunststoffverpackungen."

27 See Eunomia, *EC Waste Framework Directive EPR Recommendations for Guidance* (2020) (available online).

28 See PRO-Europe, *Participation Costs Overview 2020* (2020) (available online).

29 See Zoe Schyns and Michael Shaver, "Mechanical Recycling of Packaging Plastics: A Review," *Macromolecular Rapid Communications* 4, no. 3 (2020) (available online).

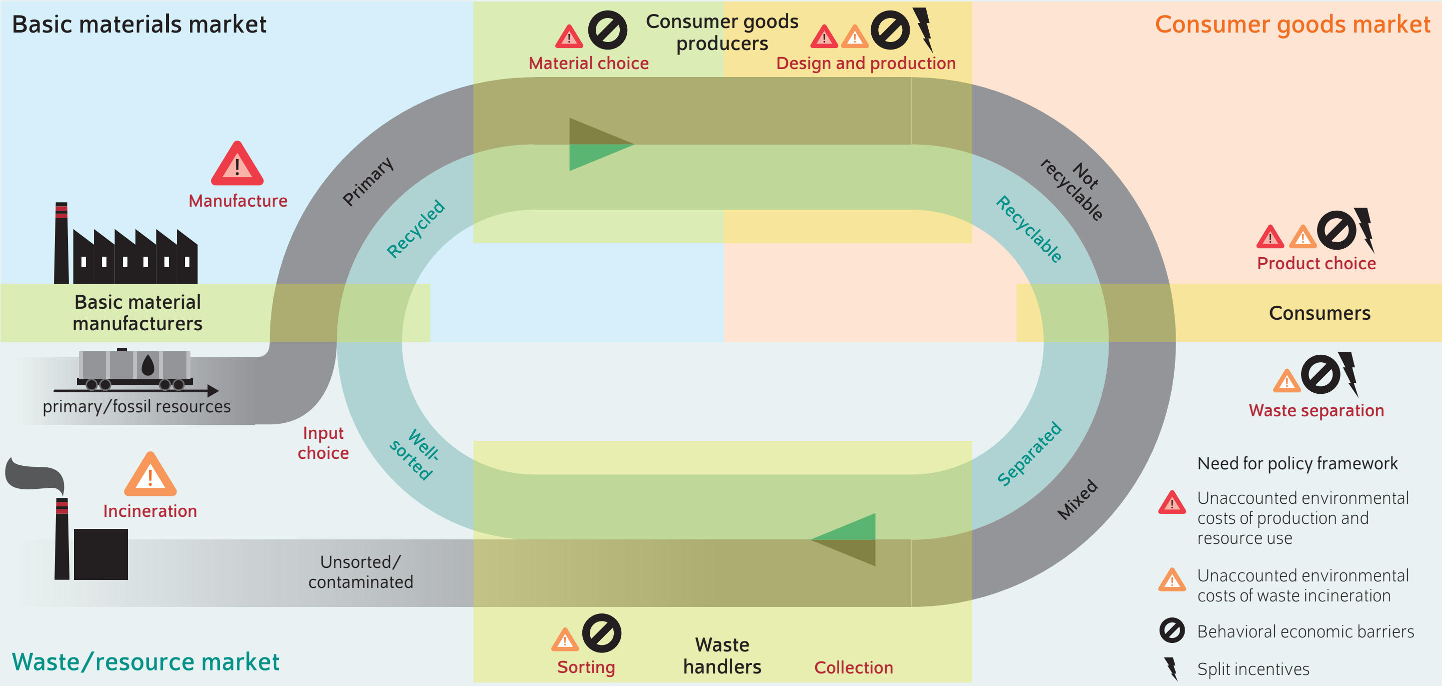
30 As a central element of the EU's energy policy framework, the EU Ecodesign Directive has contributed to the successive increase in energy efficiency. See Tobias Fleiter et al., "Assessing the impact of the EU Ecodesign Directive on a member state level," Conference paper: Summer study on energy efficiency (2015) (available online).

31 Of the 48 percent of plastic waste that is collected separately in Europe, 62 percent is recycled, while only six percent of the remaining plastics that are not collected separately are recycled. See Plastics Europe, *The circular economy for plastics. A European Overview* (2019) (available online).

32 Bundesverband Sekundärrohstoffe und Entsorgung, *Die dualen Systeme starten Test-Kampagne zum Recycling in Euskirchen* (2019) (in German; available online).

Figure 4

Under the current framework condition, all three main markets of a circular economy confront challenges



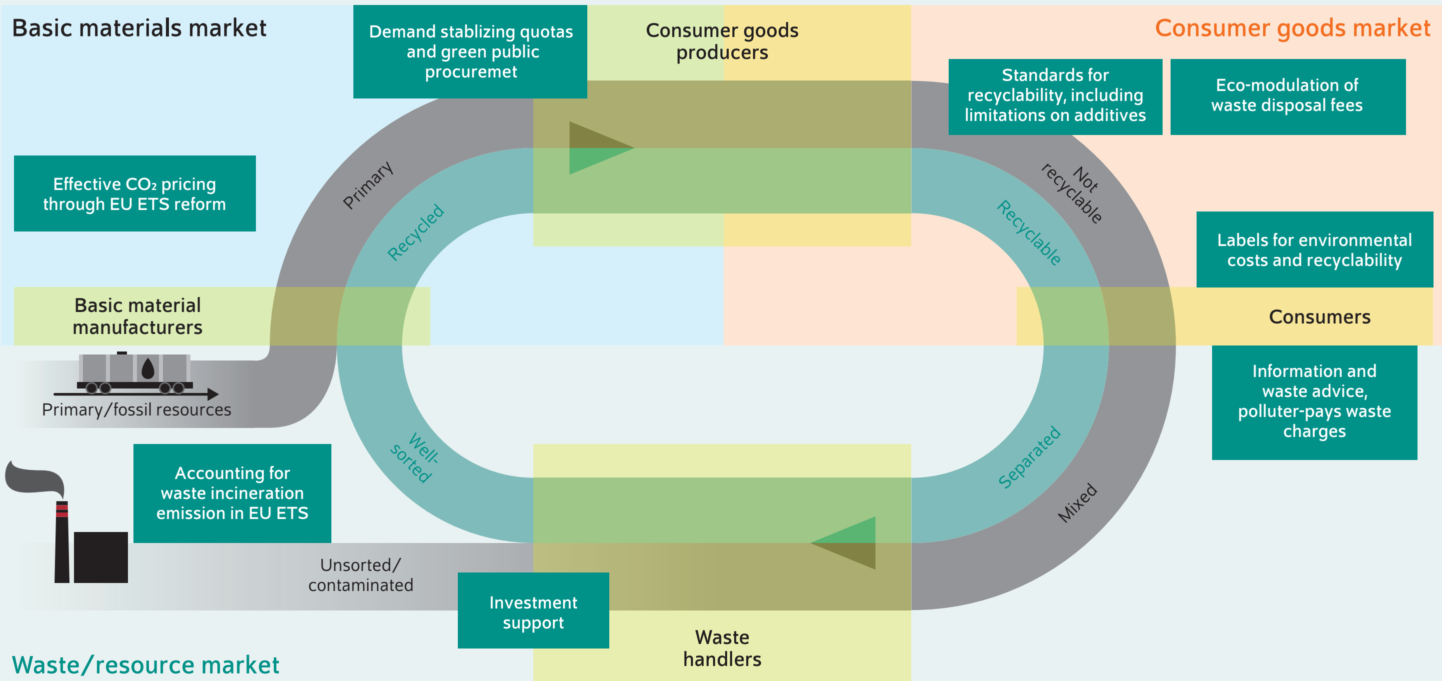
Notes: The large warning signs and symbols for behavioral economic barriers and split incentives indicate a need for direct policy action, such as emissions not being priced effectively. In the places with small warning signs, this also has an impact, but should be addressed elsewhere.

Source: Authors' own Illustration.

Policy measures need to cover the entire value chain so that every market participant contributes to a circular economy.

Figure 5

Policy measures to ensure functioning main markets in a circular economy.



Source: Authors' own Illustration.

Policy measures must cover the entire value chain to ensure requested incentives and information available for all actors.

An increase in the rate of separate collection requires changes in consumer behavior. This can be supported, for example, through targeted communication campaigns or by providing local information and waste advice to private households. In addition, an obligation to label separation information on packaging can facilitate pre-sorting at the consumer level.[33] Furthermore, reliable and mandatory disclosure of information on the environmental performance of product packaging, for example in the form of a label, enables consumers to better identify environmentally friendly products.[34] This can be complemented by monetary incentives such as polluter-pays (i.e. weight-based) charges on unsorted waste.[35] Pilot projects combining both targeted information and pricing measures have been successfully implemented in several cities.[36] Overall, this also contributes to a more economical use of materials for packaging and greater use of reusable systems.

Reducing demand uncertainty to promote investment in sorting and recycling

For plastic packaging that is not avoided or reused, the full potential of recycling should be exploited. This requires investment in improved sorting and recycling technologies. To date, however, the evolution of demand for recycled materials in competition with primary plastics has been difficult to predict. The associated risks delay or prevent investments in a transition to climate neutrality. Minimum quotas for a proportion of recycled materials in plastic products or preference for recycled products in public procurement contracts could play a demand-stabilizing role. A minimum use quota for recyclates was introduced by the EU in 2019, but only for single-use beverage bottles. However, this is only 13 percent of the plastic packaging volume and, in Germany, the recycling share is already quite high due to the deposit system.[37] As part of its renewed circular economy action plan, the EU Commission is currently considering the introduction of targets for recyclate use for other types of packaging, as well as binding minimum criteria and targets for environment-friendly and green public procurement for packaging.[38]

An obligation for public bodies to give preference to products containing recyclable and recycled materials in public tenders was introduced in 2020;[39] however, as the implementation of the regulation is difficult to enforce, at best this can be seen as a step in the right direction.[40] To strengthen it, for example, more concrete targets should be introduced as well as criteria for the evaluation of products that provide guidance, especially for smaller public institutions with limited capacities.[41]

Since recycling targets play an important role in investment decisions for dual systems, consistently increasing them can also enable to invest in improved facilities.[42] However, it must be ensured that it is not just more recycling that takes place, but also higher-quality recycling. In addition, innovative climate and resource policies can stimulate investment. Finally, the EU Sustainable Finance Taxonomy can also encourage investment in less emissions-intensive recycling technologies by setting standards for sustainable plastic production.[43]

Clear definition of national responsibilities is essential for achieving recycling targets

Mere adoption of the above mentioned policy measures is not enough; they must be effectively implemented (Figure 5).[44] It is critical to ensure that the design and political negotiation of all individual policy decisions are aligned with the overall goal. In this regard, clearly defined targets, transparent and

33 The French PRO CITEO, for example, grants a bonus to packaging manufacturers if they display complete sorting guidelines on the packaging or raise awareness of the issue of sorting via TV/radio, advertisements, press, and digital media, for example. See PRO-Europe, *Participation costs.*

34 One example of such a label—albeit a voluntary one—is the EU Ecolabel, which is awarded to products and services that meet high environmental standards throughout their entire life cycle. See Bundesministerium für Umwelt, Naturschutz und Nukleare Sicherheit, *EU-Umweltzeichen (EU Ecolabel)* (2021) (in German; available online).

35 A study on the introduction of unsorted waste pricing showed that a one-cent price increase (with relatively high prices above nine cents) could reduce the amount of unsorted waste by five to ten percent and increase recycling by two to six percent. See Marica Valente, "Heterogeneous effects of waste pricing policies," (2020) (available online).

36 For example, in a project in Berlin Wedding between 2009 and 2012, such fees were introduced in combination with monitored waste locks that could only be accessed with chip cards, which could also be used to allocate waste quantities to households. In addition, intensive advice on waste separation took place, for example. The result was a 64 percent reduction in the volume of residual waste and a 35 percent increase in the volume of separately collected light packaging. See Günter Dehoust and Holger Alwast, *Kapazitäten der energetischen Verwertung von Abfällen in Deutschland und ihre zukünftige Entwicklung in einer Kreislaufwirtschaft* (2019) (in German; available online).

37 Although a large proportion of single-use plastic beverage bottles from the deposit system are already recycled, more than half of this goes into non-bottle applications, such as plastic films. The proportion of recyclates in new plastic bottles was 34 percent in 2019, which is already well above the 25 percent required by the EU for 2025. See Gesellschaft für Verpackungsmarktforschung, *Aufkommen und Verwertung von PET-Getränkeflaschen in Deutschland 2019. Kurzfassung der Studie im Auftrag vom Forum PET* (2019) (in German; available online); Directive (EU) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment (available online).

38 See European Commission, *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: A new Circular Economy Action Plan for a cleaner and more competitive Europe* (2020) (available online).

39 § 45 (2) KrWG.

40 This includes, for example, that the obligation to give preference to stronger circular products only applies if their procurement is not associated with unreasonable additional costs. However, the point at which additional costs are unreasonable is not further defined. See Naturschutzbund Deutschland, *Anmerkungen des NABU Bundesverband zum Entwurf einer Novelle des Kreislaufwirtschaftsgesetzes* (2020) (in German: available online).

41 See Olga Chiappinelli et al., "Green Public Procurement: Climate Provisions in Public Tenders Can Help Reduce German Carbon Emissions," *DIW Weekly Report* no. 51/52 (2020): 433–441 (available online).

42 The dual systems are already obliged to comply with certain recycling quotas. For plastic packaging, it is currently 65 percent. From 2022 it will be 70 percent, although this relates to the input into recycling. § 16 2 VerpackG.

43 The purpose of the circular economy as a key criterion of the EU taxonomy is to channel capital into innovations that are more circular than the status quo, thus accelerating the transition to a circular economy. While substantial circular economy activities are broad, high-value recycling technologies such as mechanical recycling and energy-efficient chemical recycling could be included in the categorization to receive further investment. See Forum Ökologisch-Soziale Marktwirtschaft, *Introduction to the EU Taxonomy for a Circular Economy* (2021) (available online).

44 In this respect, lessons can be learned from climate protection legislation, where inconsistent coordination of climate policy measures has been identified as a major problem for insufficient emission reduction measures. See Heiner von Lüpke and Karsten Neuhoff, "Ausgestaltung des deutschen Klimaschutzgesetzes: Grundlage für eine bessere Governance-Struktur," *DIW Wochenbericht* no. 5 (2019) (in German; available online).

timely reporting on progress, as well as coordination across the value chain are necessary for an effective implementation.

Conclusion: Only a package of measures can help

High quality recycling of plastic products cannot be achieved by individual market players. The problem of heterogeneity and contamination of waste streams requires product design for greater recyclability, more careful separation of waste at collection, as well as improved sorting and processing. Each stakeholder along the plastic product value chain can either improve or worsen the outcome of the collective effort.

To ensure that the emissions associated with plastics production are accounted for by market participants, effective CO_2 pricing is essential. Beyond that, a coordinated package of measures is needed to ensure that the post-use environmental costs are also taken into account in decisions regarding product design or choice. This includes, among other things, ensuring these costs are relevant at the point of sale, clearly defined product standards, incentives for increased recyclability, reliable information on environmental impacts, as well as support for investment in recycling technologies.

The barriers and the need for political measures are not only relevant for plastic packaging. These insights can be applied to other basic materials and applications in a similar way. The implementation of the envisaged measures will not only contribute to strengthening effective recycling, but also to more efficient material use, packaging avoidance, and reuse. Overall, this process can reduce the economy's reliance on primary basic material production, thus facilitating the transition to climate neutrality.

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