

Summary

From #plasticfree to future-proof plastics

How to use plastics in a circular economy

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TNO innovation
for life

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Authors

Dr. Esther van den Beuken
Dr. Jan Harm Urbanus
Dr. Paul Stegmann
Toon van Harmelen MSc
Dr. Tom Ligthart

Dipl.-Ing. Jürgen Bertling
Dr.-Ing. Stephan Kabasci
Anna Schulte MSc

Coordinators

Dr. Esther van den Beuken

Prof. Dr.-Ing. Manfred Renner



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How to use plastics in a circular economy

State-of-the-art

Plastics are shrouded in controversial debates. While manufacturers highlight their benefits, more and more stakeholders refer to the problems associated with them: a considerable share in humanity's greenhouse gas emissions, plastic litter and microplastics polluting almost all environments, fossil resource depletion and import dependency. Neither continuing with the unlimited use of plastics, nor the radical renunciation appear to be reasonable or even feasible paths from a scientific and social perspective. We must develop a new, sustainable way of designing and using plastics. This will not be limited to minor adjustments but requires radical changes or even abandonment of previous values, production schemes and usage practices.

'Refuse' is promoted as the first circular economy strategy to decrease primary resource consumption and lower emission levels. However, we cannot refuse all the products we need in our daily lives. For most of their applications, we can replace plastics with alternative materials, which is a widely promoted consumer trend. Nonetheless, plastics have their benefits due to their unique properties as light-weighted, versatile, and cheap materials with high barrier properties. Alternative materials and products often have inferior product properties, and they also bear environmental impacts, which can be worse than those of plastics.

Systemic assessments are needed to soundly decide where the use of plastics is beneficial and where they can be refused or replaced. Those assessments need to consider (a) the functional properties of the target product, (b) the comparison to alternative products without plastics, (c) their impacts in a multitude of environmental, social, and economic categories, and (d) over their entire life cycle.

We conclude that plastics will and should remain an important part of our economy and our daily lives. Therefore, their use must be carefully considered, their disadvantages eliminated and their impact on the environment mitigated. We explored how a future-proof, circular and sustainable plastics economy should look like. To do so, we addressed manifold questions, such as: In which applications can plastics be refused or replaced? How do plastics need to be designed, used and recycled in the future? How can we take advantage of plastics' benefits while solving their drawbacks? Does the solution help in reaching the overarching goals: Achieve climate neutrality, zero pollution and technological sovereignty?

Our vision

We envision a future economy in which all applications are critically examined whether they can be refused, rethought or the material input reduced. For the remaining plastics applications, important improvements in product design, business models and material characteristics regarding durability, recyclability and degradability have enabled a circular economy for plastics. Reuse, repair, refurbishing and re-manufacturing of plastic products have become integral and dominating fields of regional economic cycles and have reduced littering to nearly zero. All components of modern plastics: polymers, additives, fillers, reinforcements etc. are produced from recycled plastics or renewable feedstock like biomass or CO₂. Moreover, the renewable electrification of the whole plastics industry contributes to the goal of a circular and sustainable plastics sector.

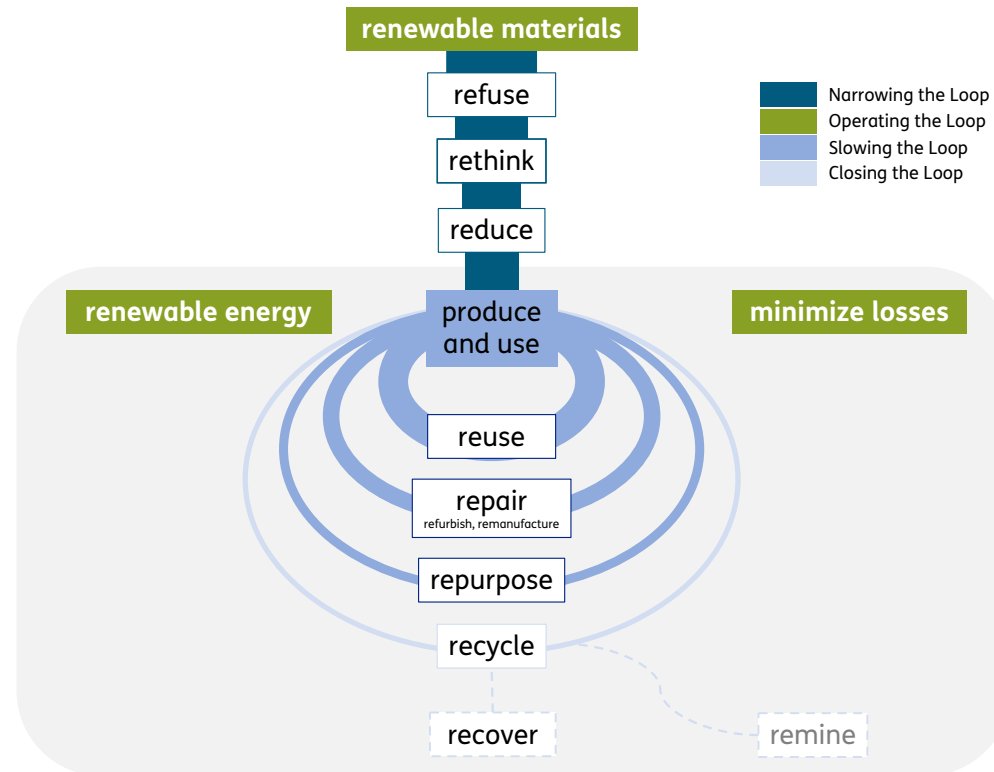


Figure 1. Vision of a future plastics economy based on limitation, circulation and renewables.

Approaches and strategies

Circular strategies must be set up and actions be taken for arriving at a sustainable future system. We have grouped the strategies into four main approaches, which form the basis for a well performing and sustainable circular economy that meets the previously mentioned overarching goals.

These approaches are: Narrowing the Loop, Operating the Loop, Slowing the Loop and Closing the Loop. We encourage to look first at Narrowing the Loop, then focus on the cross-cutting approach Operating the Loop, before addressing Slowing and Closing the Loop for transforming today's still largely linear plastics economy to a fully circular future. Narrowing the Loop attempts to reduce the quantities of materials mobilised within a circular economy. Operating the loop refers to using renewable energy and minimizing material losses in all processes as well as ensuring sustainable sourcing of feedstocks for plastics production.

Measures to preserve products and their functions as long as possible, such as extending their useful lifetime through durability, reuse, repair, refurbishment, remanufacturing and repurpose, are essential for slowing resource loops during product use phase. Closing the Loop as far as possible needs design, collection, sorting and recycling of plastic products optimized for the desired target applications. High recycling rates producing high-quality recyclates at lowest environmental impact must be targeted, instead of adapting recycling to the existing waste streams. The circular economy strategies are named as R-strategies for Narrowing, Slowing and Closing the Loop as well as O-Strategies for Operating the Loop.

The application of the O-Strategies requires no choice: All the three are to be used in parallel and as completely as possible. On the other hand, deciding on an appropriate R-strategy is a complex process. Typically, for a given product or service, more than one R-strategy is applicable. The relevant strategies need to be carefully compared with each other regarding their feasibility and impacts in the context of the status-quo as well as prospective changes. Case-by-case assessments can identify the preferential strategies. However, they provide limited general guidance on the prioritization of strategies.

As a guiding principle, we propose a default procedure for choosing the primary R-strategy following the waste hierarchy from refuse down to recover (cf. figure 1). The reason for this choice in our opinion is to preserve as many opportunities as possible for any end-of-use case of a plastics product. Any entry level in the hierarchy, however, renders the levels above it impossible: E.g., a thermally recovered (i.e. burnt) product or material can never be recycled again.

Therefore, a high entry level should be chosen and realized in a way, that the subsequent levels remain as future options. Choosing a lower ranked R-strategy should only be possible if detailed consensual environmental case studies clearly suggest so. The same proof is needed for consciously omitting an O-strategy.

Actions

The increasing demand for circular plastics in high quality applications, such as food packaging, car parts or synthetic textiles needs a holistic change. This transition can only succeed if cross-sectoral collaboration including science, industry, politics and citizens is fostered and implies several, partly quite drastic changes at 4 levels: legislation and policy, circular chain collaboration, design and development, and education and information. Actions to implement these changes are quickly needed:

- Firstly, legislation and policy should be implemented. Legislation should on short term simultaneously focus on narrowing, operating, slowing and closing the loop to accelerate the transition and give the industry a long-term perspective. In addition, internalization of external costs and environmental impacts that include littering and microplastics are needed. This will promote the use of sustainable plastics.
- Secondly, today's linear economic system has to transform to a circular network. Circular chain cooperation is essential. Waste management companies, recyclers, converters, plastic producers, end-users and brand-owners should implement the extended waste hierarchy in combination with O strategies as pointed out above. This needs the use of circular business models. In addition, competition between different waste options that all aim for suitable and sufficient feedstock should be managed consensually to strive for optimum quantity and quality as well as lowest environmental impacts.
- Thirdly, innovations in design and development are needed for a future proof plastics economy. This includes redesign of polymers to more oxygen rich ones based on biomass and CO₂ utilisation. Current recycling technologies have to be improved for high quantity and quality recycling. The useful lifetime of plastic products needs to be extended with strategies such as durability, reuse, repair, refurbishment and remanufacturing.
- Finally, information and education are of utmost importance and are needed for all stakeholders like product designers, marketers, buyers, citizens, investors etc. to make sustainable choices. The benefits of refuse and reuse must be made known above all. At the same time, a change to a culture of repair and longevity is required.

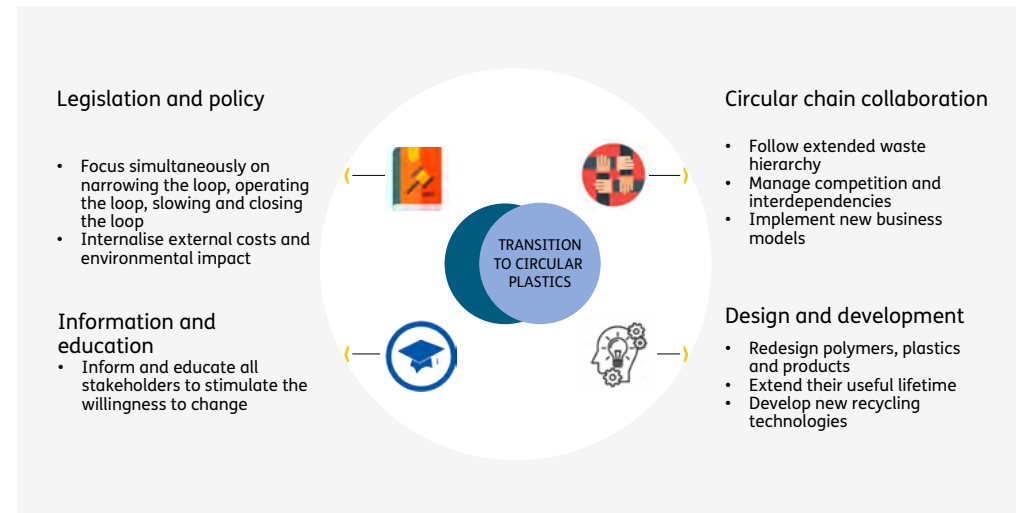


Figure 2. Actions needed for the circular plastics transition.

What are TNO and Fraunhofer doing?

Fact-based and scientific research is needed to make sustainable decisions. As independent research institutes working in the field of plastics on both societal and technological research and innovation, we see TNO's and Fraunhofer's role to inform all type of stakeholders about choices in the transition to circular plastics and to connect them as well as to be an adviser/prompter of the European Commission. TNO and Fraunhofer are also being part of the solution by delivering circular plastics and products as well as the necessary process technologies to fill in gaps identified in the system analysis and not taken up by others. We evaluate new and competing technology options through in-depth environmental and social life cycle assessments.

What's next?

TNO and Fraunhofer have decided to build a hands-on platform for plastics in a circular economy: European Circular Plastics Platform – CPP. It will give companies, associations and non-governmental organizations the opportunity to work together on existing barriers and promising solutions for a Circular Plastics Economy. Goal of the platform is to connect companies along the circular pathways and develop new cross-company business models. The platform will offer its members regular hands-on workshops on plastics topics, discussion panels on current issues, and participation in multi-client studies on pressing technical challenges. Regular meetings will be held in the cross-border region of Germany and The Netherlands as well as online – also planning to include customers and companies for transferring the transition into the public and industries.



Authors

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Dr. Esther van den Beuken

Prof. Dr.-Ing. Manfred Renner

Contact

Dr. Esther van den Beuken
Principal Consultant Circular Plastics

✉ esther.vandenbeuken@tno.nl

☎ +31 6 2242 8547

🌐 [linkedin.com/in/esther-van-den-beuken](https://www.linkedin.com/in/esther-van-den-beuken)

Dr.-Ing. Stephan Kabasci
Strategic Project Development Circular Economy

✉ stephan.kabasci@umsicht.fraunhofer.de

☎ +49 208 8598 1164

🌐 [linkedin.com/in/stephan-kabasci-88525477](https://www.linkedin.com/in/stephan-kabasci-88525477)



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