Circular Flooring

New Products from Waste PVC Flooring and Safe End-of-Life Treatment of Plasticizers

Policy Document

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10	Bavarian Research Alliance GmbH	BayFOR	Germany
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Glossary

DEHP	Bis(2-ethylhexyl) phthalate
DINCH	1,2-Cyclohexanedicarboxylic acid diisononyl ester
EU	European Union
LCA	Life Cycle Assessment
OECD	Organisation for Economic Co-operation and Development
POP	Persistant Organic Pollutants
PVC	Polyvinylchloride
PVC-P	Plasticized Polyvinylchloride
REACH	European Chemicals Regulation on the Registration Evaluation Authorisation and Restriction of Chemicals
rPVC	Recycled Polyvinylchloride
RC	Recycled Content
RTO	Research and Technology Organisations
SCIP	Substances of Concern In articles as such or in complex objects (Products)
SEA	Socio Economic Analysis
SVHC	Substances of Very High Concerns
SME	Small and Medium-sized Enterprises
TRL	Technology Readiness Level

Executive Summary

This document outlines policy recommendations for the European Union (EU) to transition towards a safe, circular plastics economy. It emphasizes the importance of keeping plastics in use for extended periods through recycling and reuse, minimizing waste, and addressing the challenge of legacy additives like harmful phthalate plasticizers.

Firstly, to boost the use of recycled PVC in floor manufacturing, a multi-pronged approach is recommended. Mandatory recycled content targets should be established, but with careful consideration of environmental impact, the current market potential for recycled PVC in flooring, and any technological limitations. Additionally, financial incentives can stimulate the market for high-quality recycled plastics, encouraging businesses to invest in new technologies and collection systems to meet the rising demand. Public education campaigns are also crucial to increase public acceptance of recycled plastic floors. By informing consumers about the environmental benefits and ensuring transparency about the quality of recycled materials, we can shift consumer preference towards sustainable flooring options.

Secondly, stable regulations are essential for effective recycling. Long-term restrictions on hazardous chemicals in plastics need to be established. Furthermore, clear and EU-wide metrics for recycling yield and recycled content applicable to advanced recycling technologies should be developed. Recognizing these advanced technologies and integrating quality aspects into recycling targets and policies will further strengthen the entire recycling system.

Finally, safeguarding the circular economy requires a focus on preventing contamination. Enhanced identification and monitoring of harmful substances in new plastics is crucial. Stricter controls on imported goods can prevent contaminated materials from entering the waste stream. Additionally, a potential ban on exporting plastic waste from the EU, which may contain hazardous substances, is an important consideration. Ultimately, updating the REACH regulation to incorporate recyclability considerations during product development is essential for a truly circular plastics economy.

By implementing these recommendations, the EU can achieve a more sustainable plastics economy that prioritizes safety, resource efficiency, and environmental responsibility.

1. Introduction

Our dependence on plastics, driven by affordability and convenience, has resulted in a global environmental issue. Every year, millions of tons end up in landfills, oceans, and ecosystems. The current "take-make-dispose" economic model is unsustainable for plastics. We need a circular economy.

A circular economy for plastics prioritizes keeping materials in use for extended periods. This means recycling, reusing, and minimizing waste. This shift benefits the environment by reducing pollution, but also creates economic and social advantages such as job creation, resource efficiency, and lower greenhouse gas emissions.

One major obstacle to a circular plastics economy is the presence of harmful legacy additives. These additives, once commonly used to enhance plastic's performance, are now known to be hazardous. One example is plasticized PVC (PVC-P) from flooring which contains phthalate ester acids (e.g. DEHP). Phthalate esters are persistent, accumulates in aquatic organisms, are reprotoxic and can pose risks to human health and the environment. These plasticizers complicate recycling and reuse as they risk releasing harmful chemicals back into the environment. Additionally, separating these additives from plastics is difficult, hindering the safety and sustainability of recycled plastic products. To counteract this, the European Union, created the REACH Directive, i.e. the European Chemicals Regulation on the Registration, Evaluation, Authorisation and Restriction of Chemicals in order to strictly regulate the handling of substances that are hazardous to our health or the environment.

The European Union's Horizon 2020 research and innovation program addresses this challenge through the Project CIRCULAR FLOORING. This project aims to tackle the problem of legacy plasticizers in a circular economy for PVC-P by developing a dissolution based recycling process to purify contaminated waste of flooring so it can be recycled. The aim here is to enable a circular use of waste flooring by separating plasticizers including hazardous phthalic acid esters and converting them into harmless plasticizers (e.g. DINCH). The project covers the entire recycling and production chain, from collection of waste, recycling of the polymer to high quality recycled PVC (rPVC), to the demonstration of the purified material in flooring applications. Thus, rPVC and the converted plasticizers are considered to be fed into a circular economy (see Figure 1) once the process is established and operational at scale.

Chemical and mechanical product analysis, process simulation, LCA, SEA and business modelling will support the process development, upscale and product design. The approach addresses exactly the scope of the call because (i) innovative solutions are developed for removing undesirable substances from secondary raw materials, (ii) removed plasticizers and additives pose health or environmental risks and would adversely affect the quality of the recycled materials and (iii) the hazardous compounds are handled safely and are post-processed to harmless, valuable products. Addressing the 500,000 t PVC flooring market with recommendations on design for recycling and novel circular materials produced at TRL 5-6, the expected impact on the flooring value chain will be substantial. An interdisciplinary team of 4 RTO, 6 industrial partners (3 SME) and 1 non-profit company will finally implement the new circular economy approach into PVC flooring production lines to demonstrate and evaluate the applicability of these approaches from the industry's point of view.

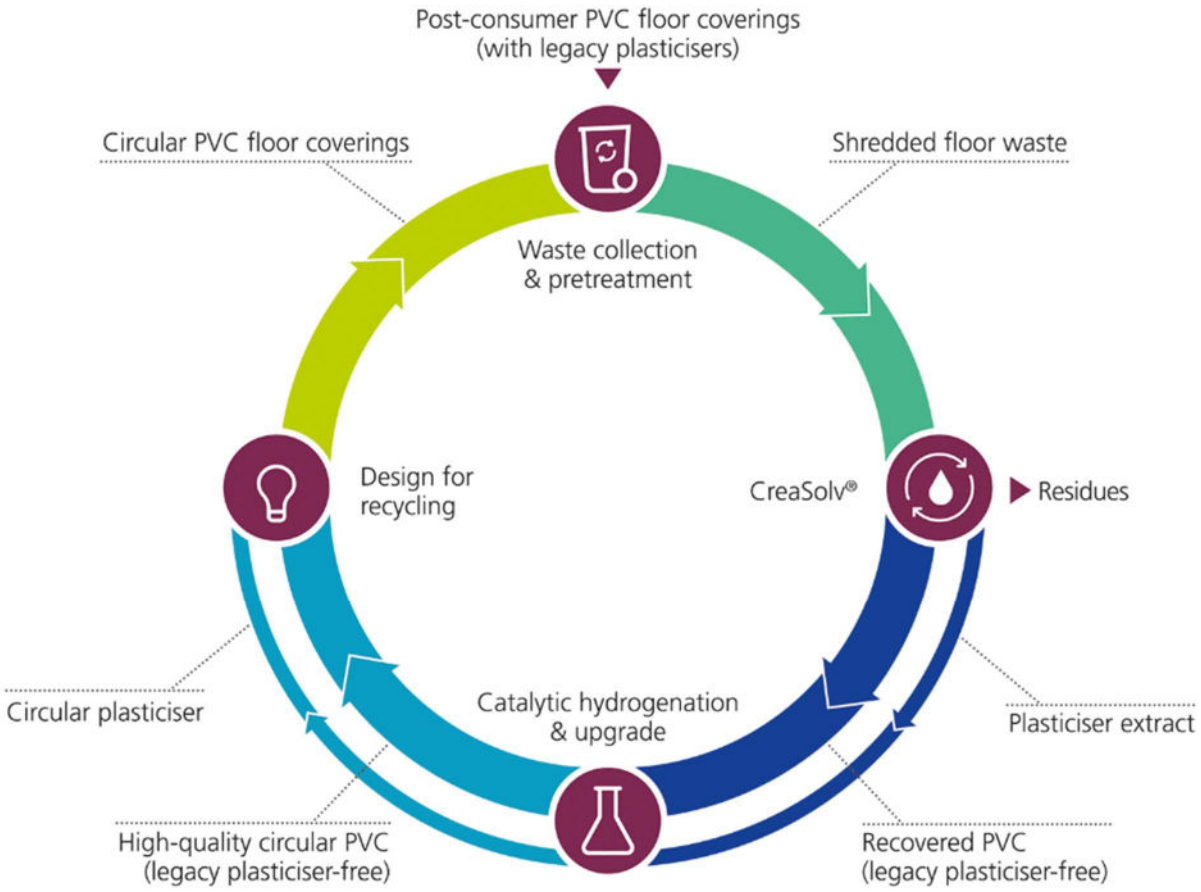

Figure 1: Schematic overview of the Circular Flooring project.

In 2022, a total over 58.7 Mt of plastics were produced in Europe, whereas only estimated 13.1 % of the production was gained from post-consumer material streams. The PVC share of the total European plastic produced is 9.1%, which corresponds to a total quantity of approximately 5.3 Mt[1]. Based on these figures, the impact of the project becomes clear as by implementing a dissolution based recycling process, the recycled share of the entire European plastic production would significantly be increased.

Besides the raw materials consumption, current production of the vinyl chloride monomer entails a high energy demand and corresponding emissions, various by-products detrimental to the environment as well as an interrupted value chain in terms of resources recovery. PVC is often used for long-lasting products (> 25 years) and contributes already (because of its nature) to the environmental protection, in contrast to single-use or less durable plastics. Through a dissolution based recycling process, the PVC life cycle is considerably extended, and indispensable PVC usage would become more sustainable. The PVC industry, which employs > 500,000 people in Europe, will become stronger the future. In addition, the PVC recycling activities will create new jobs and by this strengthen the economy of European member countries.

[1] Plastics Europe - Enabling a sustainable future (The Fast Facts-2023)

This policy document outlines eleven recommendations for the EU and its member states to implement or accelerate the transition to a safe, circular plastics economy.

This document is structured around three key categories and encompasses related policy and research recommendations in dedicated chapters for each theme.

The three categories include:

Boosting Recycled PVC Use in Floor Manufacturing

These proposals prioritize encouraging the PVC conversion flooring industry to incorporate more recycled materials. For the economic viability of the innovative recycling technologies developed in our projects, a consistent and substantial demand for high-quality recycled plastics is crucial.

Stable Regulations for Effective Recycling

This chapter focuses on establishing legislative frameworks that are both stable and promote the development of the most efficient recycling technologies for specific waste streams. Stable regulations allow recyclers to confidently estimate returns on investment. Additionally, the importance of life cycle assessments is emphasized to guarantee a demonstrably positive ecological impact from the transition to a circular plastics economy.

Safeguarding a Circular Plastics Economy

CIRCULAR FLOORING addresses a critical challenge for the future: preventing hazardous phthalate plasticizers from contaminating floor waste streams and hindering PVC recycling. This chapter outlines recommendations to ensure a safe circular economy for plastics. It focuses on two key areas: preventing future contamination and addressing existing hazardous substances in our waste streams.

This public report, funded by the EU's Horizon 2020 program (Grant Agreement 821366), aims to support European policymakers with practical recommendations derived from the project's partnerships. The content reflects the expertise of the consortia and does not necessarily represent the official position of the European Commission.

2. Boosting Recycled PVC Use in Floor Manufacturing

2.1. Link with the CIRCULAR FLOORING Project

CIRCULAR FLOORING targets the recycling of PVC-P of waste flooring, often limited by the presence of phthalate plasticizers and offers a valuable solution for this waste stream, creating high-quality recyclates by removing these hazardous sustances.

However, economic viability hinges on a stable market for these outputs. The current market faces hurdles:

- Competition with Virgin Material: Virgin PVC production costs are relatively low, partly due to limited producer responsibility for end-of-life management.
- Unstable Demand: Fluctuations in prices of virgin material lead to unsteady demand for recyclates, discouraging investment in high-quality production.

- Quality Concerns: There is often a lack of trust among PVC processing companies when it comes to the quality of recyclates. This prevents them from realizing their potential.

We advocate for strong policy measures and further research to address these issues and stimulate the market for high-quality recyclates. Importantly, increasing PVC recycling rates should not be the sole objective; it must create social, ecological, and economic benefits.

2.2. Policy Recommendations

Recommendation 1: Mandatory Recycled Content: Considerations and Supportive Policies

Several regulations and initiatives propose mandatory recycled content (RC) targets for specific products. This can increase demand for recyclates, benefiting recyclers and encouraging investment in advanced recycling technologies and collection systems.

However, setting effective RC targets requires careful consideration:

- Environmental Impact: Not all recycled materials offer equal environmental benefits compared to virgin plastic. Research is needed to determine the ecological gain for specific RC targets in different product categories.
- Market Growth Potential: We need to identify currently discarded plastics with high potential for high-quality recycling. This will inform which waste polymers can realistically contribute to market growth.
- Technological Feasibility: RC targets should be achievable with current recycling and production technologies.
- Market Availability: Sufficient quantities of high-quality recyclates must be available to meet the needs of specific applications and achieve RC targets.

However, if the technical feasibility of current recycling practice does not provide sufficient market availability of recylates to implement a reasonable RC target (as it is the case for recycled soft-PVC required in flooring), the gap moght be closed by feasible emerging recycling technologies with proven capabilities in research and development (e.g. dissolution). If recycled materials from emerging recycling technologies could comply with legal and technical requirements, a stepwise implementation of RC targets is recommended to enhance commercialisation of such emerging technologies. Thus, a low RC content could be fixed to be reached within 5 years after publication with increasing RC if market availability or recyclates increases after the 5th year.

Such a careful approach is important as reaching mandatory recycled content (RC) targets hinges on the sufficient availability of high-quality recyclates suitable for specific applications. Research highlights that poorly conceived RC targets, without considering existing material stocks, can incentivize production of short-lived plastics. This increases the supply of secondary materials but doesn't contribute to a sustainable plastics economy.

Furthermore, a scarcity of recyclates can lead to price spikes and potential fraud, where producers might resort to buying virgin plastic and misrepresenting it as production waste for higher profits.

Implementing RC targets will also raise costs for plastic converters, increasing competition with products made outside the EU. To ensure a level playing field, similar measures should be applied to imported goods.

To mitigate these challenges, we propose several financial incentives:

- Lowering the price of recyclates by offering tax breaks for their use.
- Providing financial support to adapt existing production processes to incorporate recyclates in new products.
- Financially stimulating recyclers to increase production of high-quality recyclates.

Recommendation 2: Building Trust and Demand for Recycled Plastics

Widening public acceptance of recycled plastics is crucial to boosting demand. However, promoting these materials requires a two-pronged approach: highlighting their recycled content and demonstrating their performance in real-world applications (e.g. flooring).

Currently, converter specifications often reference the performance of virgin plastics. Since recycled materials may have slightly different properties, converters may be hesitant to use them even if they meet the application's actual needs.

To address this, we need more demonstrations of recycled plastics in marketed products with clear performance data. Publicly funded projects often develop demonstrators showcasing the performance and aesthetics of recycled materials, and these should be actively promoted. Additionally, product standards should be reviewed to ensure they don't unnecessarily exclude the use of recyclates while still guaranteeing performance over time.

Recommendation 3: Levelling the Playing Field for Recycled Plastics

The economic viability of recycled plastics can be hindered by fluctuating prices of virgin materials, which can sometimes be cheaper than even high-quality recyclates. To address this, we propose measures that incentivize the use of recycled content:

- Supporting Plastic Converters: Financial incentives like reduced VAT on recycled plastics can directly encourage plastic converters to use them.
- Supporting Recyclers: Subsidies for investments in sorting lines and purification technologies, or reduced labor taxes in the recycling sector, could lower production costs and enable recyclers to produce more high-quality materials. To ensure technological progress, specific subsidies may be provided for investments in emerging technologies.

While alternative approaches like a levy on virgin non-sustainable feedstock or a higher CO_2 emissions tax are gaining traction, these require careful analysis. Simply implementing them within the EU could significantly alter the market, potentially harming the competitiveness of European plastic converters compared to non-plastic industries. Additionally, increased raw material costs could negatively impact other green goals.

Therefore, we advocate for a thorough evaluation of these alternative measures to ensure they mitigate negative impacts on the plastics industry and avoid hindering progress towards other environmental objectives.

3. Stable Regulations for Effective Recycling

3.1. Link with the CIRCULAR FLOORING Project

While many plastic recycling methods exist, each with its strengths and weaknesses, dissolution based recycling processes used in CIRCULAR FLOORING offer a game-changing approach. Unlike traditional mechanical recycling, they utilize solvents to target and remove specific contaminants like phthalate plasticizers from the plastic itself. This sets them apart from chemical recycling as well, by preserving the polymer chains for direct reuse in new products. This translates to lower energy use and less material waste.

As science sheds light on the dangers of certain substances, regulations will inevitably adapt, with stricter limits on unintentional contaminants. However, these necessary changes can create uncertainty for investors in novel recycling technologies, which thrive on predictability and stability in the regulatory landscape.

This section proposes to explore the challenges of evolving product and waste legislation. Our goal is to recommend policies that promote long-term sustainability and foster a thriving recycling industry.

3.2. Policy Recommendations

Recommendation 4: Long-term stability and clear targets for hazardous chemical restrictions are essential to create investor confidence in the recycling industry

Regulation that limits trace contaminants in new products, e.g., the POP[2] and REACH[3] regulation, put strict requirements on detection, sorting and purification technologies used in recycling. To foster a secure investment environment for innovative recycling and production technologies, clear and stable legislation on hazardous chemical limits needs to strike a crucial balance.

- Long-term vision with ambition: Regulations should establish clear, long-term targets for chemical restrictions. This allows the recycling industry to accurately assess potential returns on investment for new technologies. While ambitious goals are necessary, they should also be future-proofed.
- Scientific grounding: Stricter limits should be informed by evolving scientific understanding of chemical hazards, ensuring protection against future threats.
- Measurable practicality: Established limits should be realistic and measurable with existing or near-future continuous recycling processes. Unrealistic restrictions can hinder progress. Even worse, if current recycling with proven purification of contaminants stops due to stricter limits, the earlier recycled waste stream will not automatically send to hazardous waste incineration. In the past, such waste led to unintended environmental emissions due to improper waste management.
- Balancing risk and benefit: Exemptions might be considered for substances with already established safe usage and effective recycling processes. Ultimately, policy

[2] Regulation (EU) No 2019/1021 of the European Parliament and of the Council of 20 June 2019 on persistent organic pollutants

[3] Regulation (EU) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals

decisions require weighing the environmental and societal risks of controlled chemical use against the benefits of a robust circular plastics economy.

This revision emphasizes the need for a balanced approach. It highlights the importance of both ambition and practicality while acknowledging the inherent tension between these goals.

Recommendation 5: To ensure transparency and comparability, the EU should develop well-defined, EU-wide metrics for recycling yield and recycled content applicable to new physical recycling technologies

Unlike traditional mechanical recycling, where yield is simply output material weight divided by input, many advanced recycling technologies introduce complexities. These processes often add virgin materials to improve product quality or maintain chemical reactions. Additionally, some waste or virgin material might be lost, converted to energy, or become fuel during the process. This makes calculating total yield and recycled content in each output stream less straightforward.

To ensure a fair comparison between technologies, clear definitions for recycling yield and recycled content are crucial. These definitions should, as much as possible, reflect the actual physical flow of materials within the process, just like with mechanical recycling. Well-defined calculation rules are needed for recycled content. Importantly, free allocation based on mass balance (assigning recycled content solely to the most economically valuable output) should be avoided.

Recommendation 6: "Dissolution based recycling" deserves recognition as "Physical Recycling" within the EU Taxonomy for Sustainable Activities[4].

The EU taxonomy plays a vital role in promoting environmentally friendly economic activities and achieving the Green Deal's ambitious goals. By providing clear definitions, it guides companies, investors, and policymakers towards sustainable practices.

One crucial addition to the taxonomy is dissolution based recycling, which should be classified as "Physical Recycling." Unlike chemical recycling, this method preserves the polymer's molecular structure. This translates to a simpler process with less energy consumption compared to chemical methods. Additionally, it boasts superior separation selectivity compared to mechanical recycling, allowing for the effective reuse of polymers.

In essence, dissolution based recycling significantly contributes to all six environmental goals outlined in the Taxonomy Climate Delegate Act. Recognizing it as "Physical Recycling" will further promote its adoption and accelerate the transition towards a more circular plastics economy.

Recommendation 7: To achieve a robust circular economy for plastics, recycling rates and recycled content targets need to integrate factors like the quality of the recycling process and the final applications of the recycled materials

A true circular economy envisions endless plastic recycling after each use cycle. However, the quality of the recycled material and its suitability for future applications depend heavily on the recycling technology and the type of plastic waste processed. Each recycling process can degrade the polymer to some extent. To maximize the economic value of plastics

[4] Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment, and amending Regulation (EU)

throughout multiple cycles, we need to focus on both the quality of the recycling process and where the recycled materials are used.

Policies solely focused on increasing recycling rates and recycled content in products might boost initial recycling cycles, but their long-term impact on the recyclability of these materials in subsequent cycles remains unclear. Therefore, alongside recycling yield and recycled content targets, we need additional measures to incentivize high-quality recycling practices.

Crucial to this analysis is the establishment of clear, EU-wide definitions for recycling quality, based on scientific evidence. This will allow for a more comprehensive understanding of the true environmental and economic benefits of plastic recycling.

4. Safeguarding a Circular Plastics Economy

4.1. Link with the CIRCULAR FLOORING Project

CIRCULAR FLOORING showcases the potential of a safer circular plastics economy by removing hazardous phthalate plasticizers. However, no technology is perfect. Extra cleaning steps associated with these advanced methods raise costs for recyclers. Additionally, achieving 100% removal of harmful substances is practically impossible, and detecting them in waste streams can be error-prone. Since complete elimination during recycling might not be achievable, focus needs to shift towards minimizing the inclusion of harmful substances in new products from the outset. However, when such substances are inevitably present, robust tracing and control mechanisms are crucial.

The following section explores several proposals for managing the use of harmful substances in a circular plastics economy. This rewrite emphasizes the limitations of even advanced technologies while highlighting the importance of minimizing the introduction of harmful substances in the first place.

4.2. Policy Recommendations

Recommendation 8: Strengthen the ability to identify and monitor substances of concern embedded in new plastic products

Improved traceability of harmful substances embedded in new products offers a key solution for safe plastic recycling and compliant recyclates. The EU's SCIP database[5], where companies list products containing Substances of Very High Concern (SVHCs) above 0.1%, is a positive step. However, as the first SCIP report's[6] evaluation highlights, the information needs to be more useful for recyclers. Aggregated data on product families would be a significant improvement.

[5] The SCIP database gathers information on Substances of Concern In articles as such or in complex objects (Products) established under the Waste Framework Directive (WFD)

[6] PWC, European Chemicals Agency First ex-post Evaluation of SCIP, Final report - May 2022 FWC ECHA/2018/452 SC02, 2c677149-e876-f2b1-0ba7-3daca0a419ef (europa.eu)

Furthermore, SCIP currently only covers existing SVHCs. To be future-proof, it should include substances with a high risk of future inclusion. Retroactive information gathering for products already in use seems impractical for every new SVHC addition.

Finally, the database's effectiveness suffers from a high number of unverified entries, especially for imports. Addressing this issue is crucial.

Recommendation 9: Imported products pose a significant threat to a safe circular plastics economy.

A worrying 17% of imported goods checked by EU authorities in one study contained excessive levels of harmful Substances of Very High Concern (SVHCs)[7]. These products not only endanger consumer health but also contaminate waste streams and potentially recycled materials when discarded.

To ensure a truly circular and safe plastics economy, stricter controls on imported goods are essential. Consumers also play a crucial role. Raising awareness about the risks of unknown suppliers is vital. This holds also true for imports of recycled plastics if these contain SvHC. Additionally, a clear labelling system identifying products from verified suppliers could be a valuable tool for informed consumer choices.

Recommendation 10: To safeguard against hazardous materials tainting our recycling and harming the environment, the EU should prohibit plastic waste exports that might contain such substances

The current system for tracking plastic waste shipped outside the EU, particularly to non-OECD countries, lacks transparency and accountability. While the Basel Convention regulates hazardous waste movement, illegal trade persists. This poses a significant health and environmental threat to receiving countries and potentially undermines the EU economy if recycled materials from these sources are unknowingly re-imported.

Stricter controls on plastic waste exports containing hazardous substances are essential. However, realistically, detecting all such chemicals in every waste stream is impossible. Therefore, as recently proposed by the EU's Environment Committee on Environment, Public Health and Food Safety (ENVI)[8], a ban on exporting plastic waste from the EU altogether emerges as a powerful solution. This approach guarantees the removal of hazardous materials from our waste streams, preventing their return through recycled products.

By retaining all plastic waste streams within the EU, we gain tighter control over disposal methods. This facilitates responsible recycling where viable and ensures safe disposal or destruction when necessary.

Recommendation 11: Transform REACH into a driver for a circular future by incorporating recyclability considerations

The EU's REACH regulation plays a crucial role in safeguarding human health and the environment from chemical risks. However, for a truly circular plastics economy, REACH needs to evolve. Currently, companies demonstrate safe substance use during manufacturing and initial use phases.

[7] ECHA's Enforcement Forum – Are imported products safe?

[8] European parliament - Waste shipments: stricter rules to protect the environment and human health

To promote circularity, REACH should require additional information sharing. Here's a starting point for a non-exhaustive list of questions companies should address:

- Recyclability: Can the substance or products containing it be recycled after use, or does it require irreversible transformation or destruction?
- Safe Recycling Conditions: Under what specific conditions can the substance or products containing it be safely recycled?

By incorporating recyclability data into REACH, we can ensure informed decision-making throughout a product's lifecycle, fostering a more sustainable plastics economy.

5. Conclusion and Outlook

The transition towards a circular plastics economy presents a complex yet crucial challenge for the European Union. While significant progress has been made in developing innovative recycling technologies, addressing the presence of hazardous additives, and establishing policy frameworks, there remains much to be done.

This document has outlined a comprehensive set of policy recommendations aimed at accelerating the transition to a safe, circular plastics economy in the EU. These recommendations address the key challenges hindering the widespread adoption of circular practices, including the need for increased demand for recycled plastics, stable regulations for recycling technologies, and robust measures to safeguard against hazardous substances.

The successful implementation of these recommendations will require a concerted effort from policymakers, industry, and the public. Governments must provide clear and consistent regulatory frameworks that promote investment in circular solutions and incentivize the use of recycled materials. Industry must embrace circular principles throughout their operations, from product design to waste management. And consumers must play their part by making informed choices that support sustainable practices.

The transition to a circular plastics economy is not without its hurdles. However, the potential benefits are immense, not only for the environment but also for the economy and society as a whole. By embracing circularity, the EU can reduce its reliance on virgin resources, create new jobs and industries, and safeguard the environment for future generations.

Looking ahead, several key areas will require continued attention:

- Research and Development: Further investment in research and development is essential to refine existing recycling technologies and explore new approaches to address the challenges of recycling complex plastic waste streams.
- International Collaboration: International cooperation is crucial to ensure that circular principles are adopted globally and to address the issue of plastic waste exports.
- Public Awareness: Raising public awareness about the importance of a circular plastics economy and empowering consumers to make informed choices is essential for driving systemic change.

With a commitment to innovation, collaboration, and education, the EU can pave the way for a more sustainable future where plastics are no longer a source of environmental harm but a valuable resource within a circular economy.