Syschemiq

D7.6 – Summary of economic and environmental scenario assessment in the ARRRA region

Executive Article Based on the SYSCHEMIQ Full Economic and Environmental Assessment (D7.7)

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Responsible Author(s)	Sjoerd Herlaar, Simon Roberts, Celine Fellay, Geert Cremers, Lina Rambausek
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Building a Circular Plastics Economy Starts Before Recycling

Why feedstock quality, packaging design and system-wide collaboration matter more than technology alone

Europe's transition towards a circular plastics economy is often framed as a technology challenge. New recycling technologies, advanced sorting systems, and chemical recycling pathways are frequently presented as the key to closing the plastics loop. However, the final assessment of the SYSCHEMIQ project demonstrates that the greatest opportunities lie elsewhere: in the quality of plastic packaging waste streams, packaging design, collection systems, and value-chain coordination. Across all scenarios evaluated, these factors have a stronger influence on circularity, environmental performance, and economic viability than recycling technology alone.

Using an integrated modelling framework, SYSCHEMIQ assessed future pathways towards a circular plastics economy in the Antwerp-Rotterdam-Rhine-Ruhr Area (ARRRA) up to 2050. The analysis examined how policy interventions, technology deployment, waste management systems and climate policies jointly affect plastics' circularity, greenhouse gas emissions, and business performance. The findings presented in this summary are derived from Herlaar et al.(2026).

Looking Beyond Recycling Technology: Regional Lessons

Lesson 1 – Circularity is a regional jurisdictional challenge

The assessment found that regional factors including feedstock quality, collection and sorting systems, recycling infrastructure and industrial demand had a significant influence on circularity outcomes. Differences between Belgium, the Netherlands and North Rhine-Westphalia, as a result of different regulation around plastic packaging waste management and processing, often explained performance more clearly than technology choices alone. Availability of feedstock for wide-scale Chemical Recycling remains a challenge for the ARRRA region and should be tackled at the regional and multi-regional level.

Lesson 2 - The Right Feedstock is not always produced where it is needed

High-quality waste streams consistently delivered better circularity, environmental and economic outcomes. However, waste generation, recycling capacity and industrial demand are not evenly distributed across the ARRRA region, and infrastructure in nearby regions can handle the same waste, with similar infrastructure. Nearby regions (e.g. Germany and ARRRA) should not try to outcompete each other for the same small pool of mixed plastic packaging waste, especially as this could lead to competition in gate fees, hampering commercial viability in either region.

Lesson 3 – Regional Differences Matter
Belgium consistently outperformed the Netherlands and North Rhine-Westphalia across several indicators despite using broadly similar recycling technologies. The key difference was the purity of material entering the system. The difference in waste stream purity is a product of how these regions handle sorting and collection differently, reinforcing the importance of collection, sorting and feedstock purity in determining recycling performance.

Lesson 4 - Circularity Requires Different Interventions Across the Value Chain across a Region
The strongest-performing pathways combined interventions in packaging design, collection and sorting, recyclate demand and recycling technologies. Mechanical recycling remained the preferred route for high-quality streams, while chemical recycling played an increasingly important role in processing residual mixed plastics and achieving higher circularity levels.

Lesson 5 - Regions Need To Tailor Their Own Circularity Strategies
The assessment found no single solution that worked best in every case. Regions differ in waste composition, infrastructure and industrial demand, meaning that circularity strategies should focus on local strengths, bottlenecks and opportunities rather than applying a uniform approach across all regions.

Key Takeaways for Policymakers and Industry

The SYSCHEMIQ assessment points to five priorities for accelerating plastics circularity:

- **Improve feedstock purity by improving collection and sorting systems.** Follow the example of Belgium's system to meet Plastic Targets.
- **Promote design-for-recycling and packaging simplification** to enhance recyclate quality. Upstream interventions should be tackled as much as possible to reach higher Circularity targets.
- **Create stable demand for recycled materials** through recycled-content requirements and long-term offtake agreements.
- **Deploy chemical recycling strategically** for mixed waste and residual streams that cannot be recycled mechanically to reach higher circularity targets. Make the business case for mechanical recycling work while making the strategic case for chemical recycling.
- **Align circular economy and climate policies** to maximize environmental and economic benefits.

These key takeaways are further described below, after the method.

The Method

The assessment used the **SYSCHEMIQ Modelling Framework (SMF)**, which combines several complementary models into a single decision-support framework. A geographic forecasting model (GEO Tool) projected future plastic waste generation across the ARRRA region. The societal optimization model **PRISM** evaluated how collection, sorting, and recycling systems could be organized to maximize circularity and environmental performance (Herlaar et al., 2025). The **CIMS** model assessed the business case for alternative feedstocks and recycling technologies from the perspective of the Chemelot industrial cluster (Felay et al., 2024). In addition, recycling quality models (**RQ^{MECH}** and **RQ^{CHEM}** (Pieres da Mata Costa et al., 2026)) were used to assess the quality and usability of mechanically and chemically recycled materials. Together, these models enabled an integrated assessment of environmental, circularity, and economic impacts under different policy and climate scenarios.

The analysis compared two future climate pathways: a Business-as-Usual pathway represented by SSP2-Base (3.5°C warming trajectory) and a Paris Agreement-aligned SSP2-RCP19 pathway (1.5°C warming trajectory). These were combined with three policy packages focused on recycled-content demand, packaging simplification, and eco-modulation measures.

Feedstock Quality Is the Primary Driver of Circularity

One of the strongest findings of the assessment is that waste quality remains the most important determinant of system performance. Regions with cleaner and more homogeneous waste streams consistently achieve higher circularity rates, lower greenhouse gas emissions, and lower overall system costs[3].

Belgium emerged as the strongest performer throughout the analysis. The primary reason was not superior recycling technology but better collection and sorting performance, enabling a larger share of waste streams to be treated through mechanical recycling rather than chemical recycling or energy recovery. Table 1 below shows an overview of each region's performance.

3. System costs are defined as the total operational and capital costs of the recycling system, from collection, to new, recycled feedstock (less investment costs).

Table 1- Better collection and sorting outperform additional recycling capacity. Regional performance comparison (BEL vs NL vs NRW)

KPI	Belgium	Netherlands	NRW
Circularity	High	Medium	Medium
GHG emissions	Lower	Higher	Higher
Cost	Lower	Higher	Higher
Mechanical recycling share	High	Medium	Medium

This finding shifts attention upstream in the value chain. Investments in collection systems, sorting infrastructure and material separation can generate larger system-wide benefits than investments in additional recycling capacity alone. The quality of incoming feedstocks ultimately determines which recycling pathways remain available. While aspects like culture and behaviour were out of scope for this assessment, they could also influence the efficiency of recycling system, bearing in mind that a simpler system where consumers do not have to sort themselves at all eliminates an uncertain degree of freedom.

Packaging Design Shapes Recycling Performance

The study demonstrates that packaging decisions made today will determine recycling opportunities tomorrow. Multi-material structures, difficult-to-separate components, and incompatible polymers reduce recycling efficiency and lower recyclate quality. Conversely, simplified packaging designs and mono-material solutions significantly improve recycling outcomes. This is shown in the "Eco-modulation" policy, PP4 in Kemp & Nieboer (2026), below.

The "Simplified Packaging" policy, PP2 in Kemp & Nieboer, 2026), combines both packaging simplification and long-term recyclate offtake agreements. The combination of packaging simplification and long-term recyclate offtake agreements consistently delivered the strongest overall performance. By improving feedstock quality and creating market certainty for recyclers, these measures increased circularity while simultaneously improving environmental and economic performance. More information on the policy packages is available in Kemp & Nieboer (2026).

The findings reinforce the importance of design-for-recycling strategies already being explored by many brand owners and packaging producers. Circularity begins at the design stage, long before materials enter the waste management system.

Business Cases Depend on Feedstock Economics

From an industrial perspective, the assessment highlights the importance of feedstock availability, supply security, and economic incentives. The Chemelot business-case analysis found that future technology choices are driven primarily by feedstock economics rather than by recycling technology itself. The assessment showed that there is not enough plastic waste feedstock available to continuously feed a naphtha cracker year-round. To utilize the plastic waste, it would need to be supplemented by other feedstocks.

If supplements are available, waste-derived feedstocks can become attractive when supported by favourable economics. For example, the analysis assumed gate fees of approximately **€200 per tonne** for municipal solid waste and untreated plastic waste, creating a significant advantage compared with fossil feedstocks such as naphtha. At the same time, results showed that business cases remain highly sensitive to future policy design, feedstock availability, and carbon-pricing mechanisms. Stable market conditions, predictable regulation and long-term feedstock availability are critical enablers for recycling investments.

Mechanical Recycling Remains the Preferred Route; Chemical Recycling needs strategic deployment

Across all scenarios, mechanical recycling remained the preferred recycling option whenever sufficient feedstock quality was available. Mechanical recycling consistently outperformed chemical recycling on both economic and environmental indicators when clean waste streams were present, also with mechanical recyclate requiring additional virgin material for higher quality.

However, the analysis also identified a practical limit. Circularity levels for Polymer-to-Polymer recycling of Plastic Packaging above approximately **60%** increasingly require chemical recycling technologies such as pyrolysis to process mixed and contaminated residual streams that cannot be effectively recycled mechanically even at the lowest grades.

Table 2- Higher circularity increasingly depends on chemical recycling, but only after optimizing feedstock quality and mechanical recycling. Circularity versus recycling pathway contribution

Circularity level (Polymer to Polymer)	**Dominant solution**
0-40%	Collection & sorting improvements for feedstock purity with **Mechanical Recycling**
40-60%	**Mechanical Recycling** with decreasing product quality. Strategic **Chemical Recycling**
>60%	Increasing role for **Chemical Recycling**

The study further shows that increasing circularity beyond these levels creates diminishing returns. Additional material recovery requires more energy-intensive treatment routes, causing both economic costs and environmental impacts (CO_2-emissions) to increase. Chemical recycling therefore should be viewed as a complementary technology, deployed strategically for residual streams after collection, sorting and mechanical recycling have been optimized.

Climate Policy and Circularity Reinforce Each Other

The comparison between the 3.5°C and 1.5°C background scenarios explained under the Method section revealed the strong influence of climate policy on recycling system performance. Carbon pricing and a highly decarbonized energy system substantially reduced the attractiveness of energy recovery and increased deployment of recycling technologies across nearly all scenarios.

Under the Paris-aligned pathway, greenhouse-gas emissions were consistently lower and recycling technologies became more competitive. The results show that climate policy and circular-economy policy are mutually reinforcing. Strong decarbonization improves the environmental and economic performance of recycling systems, while circular plastics systems contribute to broader climate objectives. It should be recognised that the more energy and carbon intensive nature of chemical recycling, should be coupled with decarbonisation of energy systems, while at the same time reducing reliance on Energy Recovery for treating the majority of plastic waste.

Table 3 - Packaging simplification combined with recycled-content uptake delivers the best balance between circularity, climate performance and economics. Policy package comparison.

Policy package	Kemp & Nieboer (2026)	Circularity impact	Cost impact
Cap & Trade System	PP1	High	High cost
Simplified Packaging	PP2	High	Moderate cost
Eco-Modulation	PP4	Moderate	Low cost

Conclusion

The central message from the SYSCHEMIQ project is straightforward:
the transition to a circular plastics economy begins long before recycling.

The quality of waste streams entering the system ultimately determines recycling performance, circularity outcomes, and business viability. Clean feedstocks enable efficient mechanical recycling while limiting the amount of virgin blend-in required to increase the quality, reduce environmental impacts, and minimize costs. Poor-quality streams increase dependence on energy-intensive technologies and make ambitious circularity targets more difficult to achieve.

The most effective pathway combines improved packaging design, high-quality collection and sorting systems, stable demand for recycled materials, and targeted deployment of chemical recycling where necessary. Achieving a circular plastics economy will therefore require coordinated action across the entire value chain, not just technological innovation at the end of it.

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