Report
Roland Berger

THE NETHERLANDS

The Plastics Balancing Act

DRIVING THE TRANSITION AND
SEIZING ITS OPPORTUNITIES

Roland Berger

MANAGEMENT SUMMARY

Useful and durable, plastics have become an essential, if ubiquitous, part of life. But they come with two major challenges: waste and CO_2 emissions. With increasing pressure to make the plastics value chain circular, the industry knows it must act – and has, initiating several advanced recycling projects. The question is, is it enough? The purpose of this report is to provide a realistic assessment of how circularity can be achieved, and how industry players can define a concrete pathway to make it happen.

Using input from industry experts, our analysis took a three-pronged approach. We began with a macrosystemic analysis using a bespoke mass balance model, looking to pinpoint an optimistic, but realistic view of the extent to which plastics supply and demand can become circular. We then conducted a readiness assessment to identify the value chain's capabilities and gaps in closing the loop via recycling, looking in particular at opportunities around advanced techniques. From this we were able to draw concrete recommendations for plastics producers, in particular, for developing their circular pathways in a way that will accelerate the transformation of the entire plastics landscape.

The end game is clear. With only 10% of plastics being made with recyclate, there is still a lot to gain for recycling. A smart combination of mechanical and advanced recycling will be the linchpin in the plastics loop. That being said, even in a best-case scenario, 35% of plastics must still rely on some form of virgin sources. While recycling is not a silver bullet, it can, together with other technological advances like biobased material, go a long way towards making the plastics chain independent of fossil feedstock while also solving the waste problem.

The landscape of plastics is changing in important ways. This comes with a number of challenges, to be sure, but also with incredible opportunity – and the momentum is hard to ignore. Doing nothing is not an option. Material flows are going to shift, and with it the center of gravity of today's scale-driven asset base. With adapted business models and clear circular pathways, plastics players can embrace this change and profit in this new system, shifting their weight to establish a true plastics balance.

CONTENTS

1/ Plastic fantastic? Understanding the balancing act

From bottles and clothes to packaging and rocket parts, plastic has long been a ubiquitous material in our lives. Its combination of properties is hard to beat: cost-efficient, scalable, durable, lightweight and hygienic. It is an important tool in moves towards sustainability, helping, for example, preserve food and reduce fuel consumption. Plastic is the ideal solution for many applications, and the entire plastics value chain is tipped to leverage this downstream scale, producing a seemingly limitless supply of plastics in countless material combinations. Closely correlated with GDP, plastics demand is on a persistent and continuous rise.

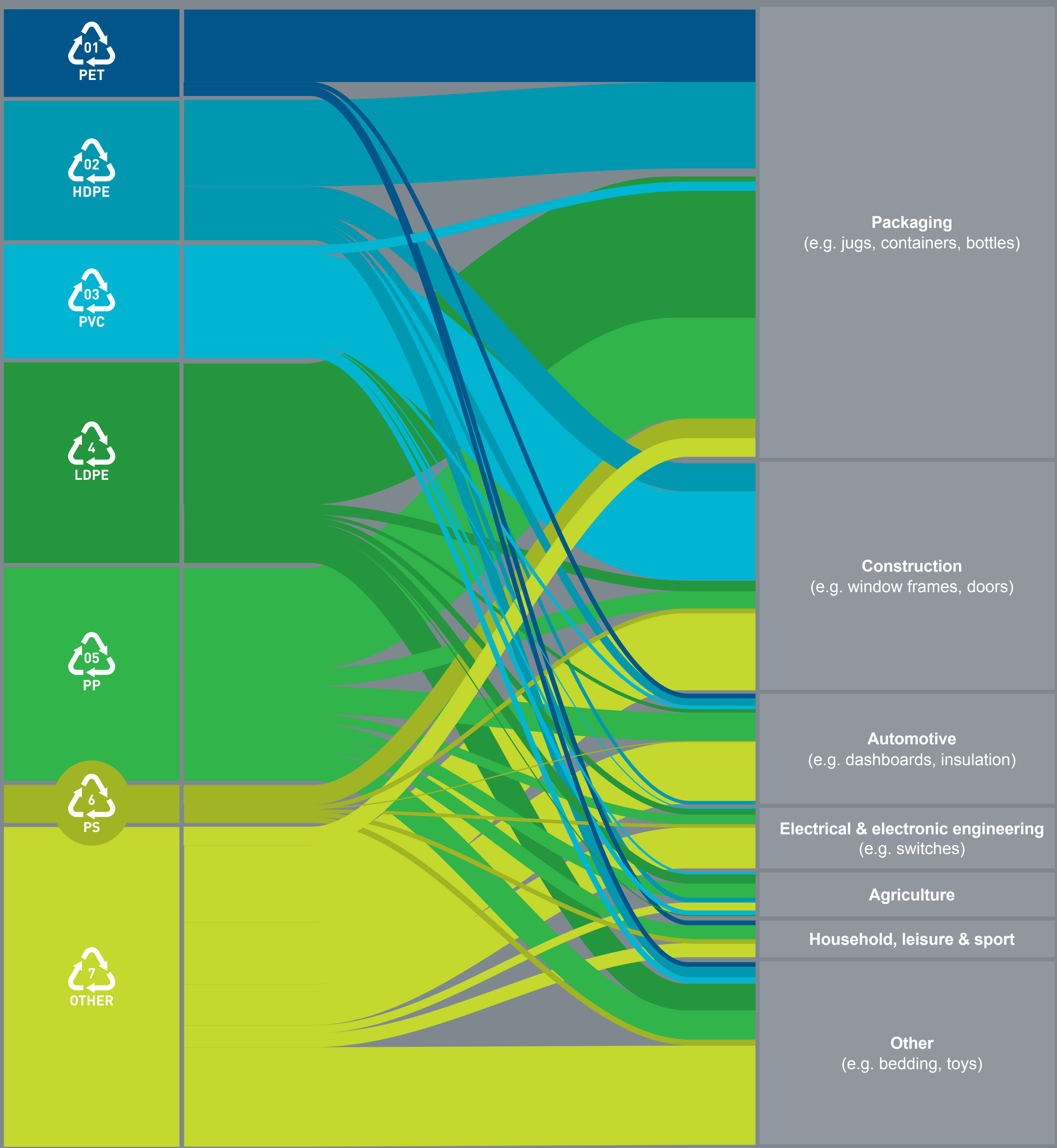
But with dozens of plastic building blocks out there, processed into millions of applications in seemingly infinite combinations of colors, additives, layers, and more, the variety of waste streams with their own particular collection and recycling requirements is considerable. This exemplifies the enormous imbalance in our system. Plastics are still predominantly fossil-based, with only 10% finding its way back as recyclate feedstock for new applications. Today's linear value chain has limited capacity for recycling and reuse, leaving most plastics untreated, landfilled or incinerated. → A

Still, the plastics industry is well on its way towards rethinking plastics. New startups with new concepts for reduction, reuse and recycling. The chemical industry's advanced recycling pilots. FMCGs' impressive targets for recycled content or substitution. Recyclers and waste management companies with improved technologies for collection, sorting and separation. And regulators with increasingly ambitious circularity plans and single-use plastics bans.

It is even possible to change a deeply rooted and large-scale system, one that is fully tuned to a cost-efficient linear system based on virgin fossil oils? Can recyclates become the industry's main raw material, given the approximate 350 million metric tons in annual global production today and the more than 1,000 million metric tons expected per year by 2050?

Participants in the plastic value chain have an important role to play here. For the industry to become circular, they have to put their full weight behind it: pulling the end of the current chain – the waste streams – back to the beginning, and pushing mega-volumes of these recycled plastics down the chain.

A / Linear plastics value chain with endless applications



Source: Plastics Europe, Roland Berger

2/ Reality check: Virgin plastics are here to stay

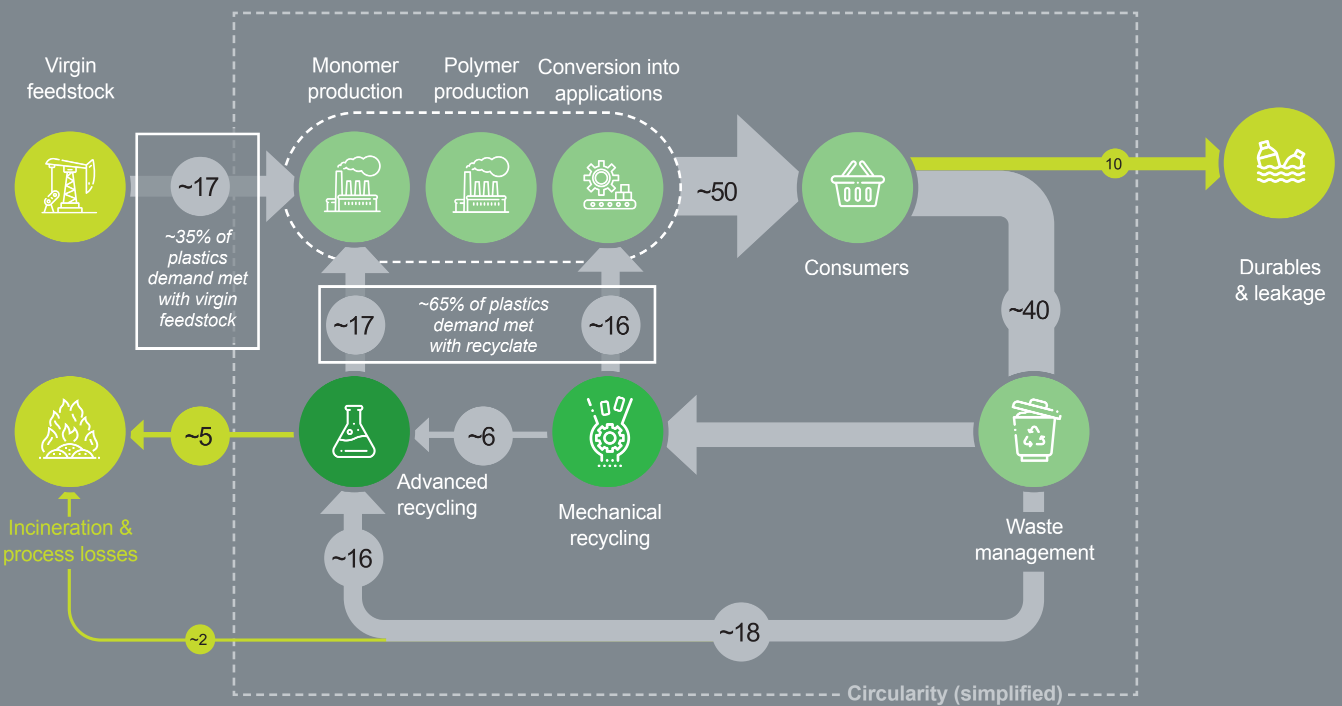
Today, about 20% of global plastics waste is leaked or dumped, 70% is incinerated or landfilled, and less than 10% is ultimately recycled. If the plastics industry does nothing, global plastics demand is expected to triple by 2050. Efforts to counteract this cannot simply be limited to replacement, like switching out plastic bags for paper ones. The industry must alsov rethink product designs and extend their lifetimes, and the entire collection infrastructure must improve and intensify.

To forecast an optimistic, but realistic scenario for plastics circularity by 2050, we modeled the industry's mass balance by taking Europe as an example – a continent that could play a frontrunner role in the transition – sourcing the latest insights from numerous studies and industry experts. We then set three levers that will help tip the balance: demand reduction, collection capabilities and recycling scale.

Because of the continent's efforts to cut waste, Europe's plastics demand will increase more modestly in a do-nothing scenario, from around 50 million metric

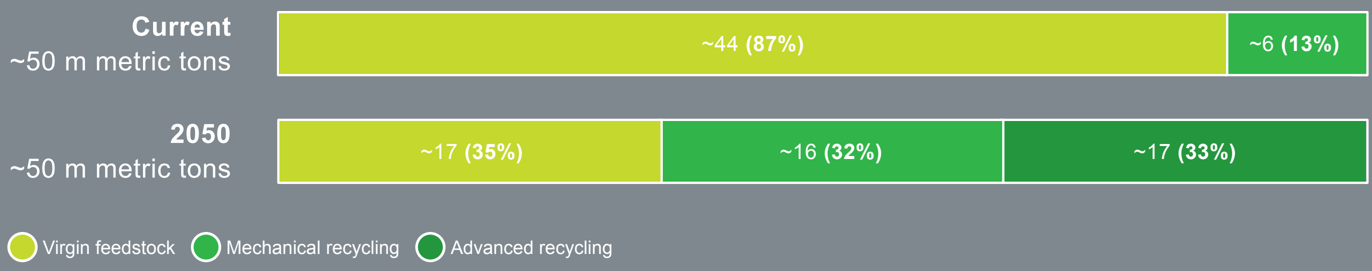
B / Best-case scenario for Europe's plastics mass balance

Best-case mass flow in 2050 [m metric tons]



Source: Material Economics, Plastics Europe, Roland Berger

C / Best-case scenario for Europe's plastics mass balance
Feedstocks [m metric tons, % of total]



Source: Material Economics, Plastics Europe, Roland Berger

tons today to 60-65 million metric tons by 2050. A best-case scenario would see roughly 15-30% of 2050 demand reduced via reduction and replacement, leaving about 50 million metric tons over – about where Europe is today. Two conclusions can be drawn from our model: there's a lot to gain for collection and recycling, and virgin plastic is here to stay.

2.1 / Big gains for recycling

Only 10% of today's plastics in Europe come from recyclates, but by 2050 this could reach 65% (around 30 million metric tons). To get there, the plastics value chain must contend with a wide variety of waste streams, each with its own characteristics. Given that large plastics producers are used to a clean and constant fossil feedstock, this entails a major step up in collection, sorting and recycling capabilities between now and 2050. There are fundamental limits to waste collection and recycling, however, including yield and quality losses. Our best-case scenario assumes collection rates increase to about 70-80%, meaning negligible incineration, leakage and landfilling. Better sorting and purification of waste streams could then bring mechanical recycling of plastics up to two-thirds of all plastics waste, with the associated yield increasing to around 70-75%. This can be complemented by advanced recycling technologies at commercial scale, with a yield, based on current knowledge, of up to about 70-80% for plastic not suitable for mechanical recycling. → **B**

2.2 / Virgin plastic here to stay

Even in the most optimistic scenario, about 35% of plastics (17 million metric tons) still need to come from virgin material due to process losses and the production of durables. Bioplastics could become the new virgin feedstock, of course. Together with CO_2 capture and storage, it is a promising route towards independence from fossil sources and could enhance the circularity of the chain, especially in areas where there are process losses in recycling and incineration of non-recyclable plastics waste. → **C**

3/ Recyclate uptake: Is plastic ready?

Is the industry ready to increase recyclates in plastics production from ~10% in 2019 to over 50% by 2050? We gathered input from several stakeholders in the value chain and leading market reports to take a critical look at current developments along five key factors: awareness, technology, investment, waste management, and regulation.

3.1 / Awareness

Many players have realized that circularity will have a big impact on their business models, not the least in the form of bans and tighter regulations, and the targets they are setting have ripple effects across the value chain. But on the whole, this has yet to translate into real volumes or reduced consumption, and large plastics consumers like the automotive, construction and fashion industries are only at the early stages of the transition.

FMCG companies, which face particular challenges because plastic packaging is so deeply ingrained in their business models, have set ambitious recycling target on both percentage of recycled material in their packaging and recyclability of the packaging material to close the loop on plastic use and prevent leakage into the environment. Nestlé, Henkel and Mars, for example, target 30% recycled plastics content by 2025, with players like L'Óreal even aiming for 50% in the same timeframe. → D

This heightened awareness is reflected in the investments made by FMCG players in sorting and recycling facilities, in some cases through partnerships with plastic producers. Recent examples include Unilever's Magnum ice cream tubs made from advanced-recycled PP from SABIC, and Yoplait's partnership with Total for yogurt tubs made from advanced-recycled PS. With rising public awareness and pressure, the greenification of consumer products has become a key lever for competitive advantage and market share. Consumer-facing marketing campaigns also enable companies to pass rising prices, like for recyclate feedstock, on to consumers. Such dynamics are milder in the B2B sector, where costs are central to decision-making and consumer opinion is less persuasive.

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Concrete ambitions and action from FMCG

Transition-oriented partnerships among plastics producers

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Limited urgency in the B2B market

B2B market transition lagging behind

D / FMCG recycle targets

Source: MGSSI, Ellen MacArthur Foundation (checked Dec 2021), Company websites (checked Dec 2021), Roland Berger

3.2 / Technology

Contamination, quality degradation, complex structures and mixed streams necessitate sophisticated sorting and a smart balance between the many recycling technologies. There is no silver-bullet recycling technique, but making sure all are deployed at the right spot in the value chain will go a long way. → E

Given its maturity, lower costs and reduced carbon footprint, mechanical recycling is a sound go-to, but it only works well for certain plastics, like PET, HDPE and PP, and for products made of a single type of plastic or from separable plastic parts, such as bottles. Additionally, only plastics that can be collected, separated

E / More recycling possibilities with advanced recycling

		Advanced recycling			
Technology	Mechanical recycling	Depolymerization	Pyrolysis	Gasification	Incineration
Description	Processes such as grinding, melting	Decomposition into constituent molecules (monomers)	Thermal degradation in absence of oxygen	Partial oxidation at high tempratures	Burning to provide energy
Process temperature [°C]	150-300° C	100-350° C	300-700° C	700-1200° C	1100-1200° C
Typical input	PP, PE, PET	PET, PA	PP, PE, PS	PP, PE, PET, PVC	All
Sensitivity to feedstock quality	Very high	Very high	High	Moderate	Low
Primary output	Polymer pellets	Monomers	Pyrolysis oil	Syngas	Energy
Range of application	Limited	Moderate	Broad	Broad	n/a
Plastic feedstock yield[1]	60%	80-90%	40-60%	n/a	None
Energy requirements [MJ/metric tons]	Medium 600-900	n/a	High 1200-1400	Very high 1800-2000	n/a
CO_2 emissions [t CO_2/t input]	Low 0.1-0.2	Medium 0.6-1	Medium 0.3-0.7	Medium 0.4-0.8	High 2.5-3
Scale needed for economic viability	Low	Moderate	Moderate	High	High

[1] Based on current situation

Source: Chemical recycling: State of play (2020), Vollmer et al (2020), Saebea, Dang, et al (2020), Fivga, Antzela, and Ioanna Dimitriou (2020), Larrain, Macarena, et al. (2020), Ügdüler, Sibel, et al. (2020), Roland Berger and concentrated at high purities can be mechanically recycled. Other problems with mechanical recycling include quality degradation, coloring (especially for black material) and limitations in food-grade applications. The technology is improving, but it cannot process large shares of the plastics waste stream.

> *"The first step is always mechanical recycling. But we definitely need to look at advanced recycling as the second step."*
>
> **Chemical converter**
> Executive

Advanced recycling technologies, which use chemical reactions to break plastics down into their building blocks, can fill in a lot of this gap. Advanced recycling can repurpose a much wider variety of plastics qualities for a multitude of applications, including food- and medical-grade plastics. Audi has recently completed a successful pilot of pyrolysis recycling of mixed automotive waste, for example, reusing the pyrolysis oil to produce new automotive components. And LyondellBasell, Dow and NOVA Chemicals are collaborating on a project in the recovery and recycling of food- and medical-grade PE and PP.

But converting plastics waste back into its building blocks is not cheap, and the energy needed to do so is much more than for mechanical recycling. It is also true that many of these technologies are still in pilot or development stages when it comes to plastics conversion; although the number of facilities is increasing in the EU and US, full commercial viability often still needs to be proven, making advanced recycling for recyclate feedstock a relatively costly route in the foreseeable future. Today, advanced recycling output is also frequently used in fuel applications, instead of in the reproduction of plastics. Although this might have a net positive environmental effect compared to incineration or landfilling, it does not help close the plastics loop.

> *"The scale for both gasification and pyrolysis is far from what it needs to be. But you could have a decentralized system with smaller production facilities."*
>
> **Plastics producer**
> Executive

Achieving sufficient circularity in the plastics value chain means a combination of recycling technologies, one that strikes the right balance between them in terms of input purity, output quality and overall environmental impact. This would look something like mechanical recycling of PET, HDPE and PP, and advanced recycling of complex streams.

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Increasing use of mechanical recycling

Heightened attention for advanced recycling

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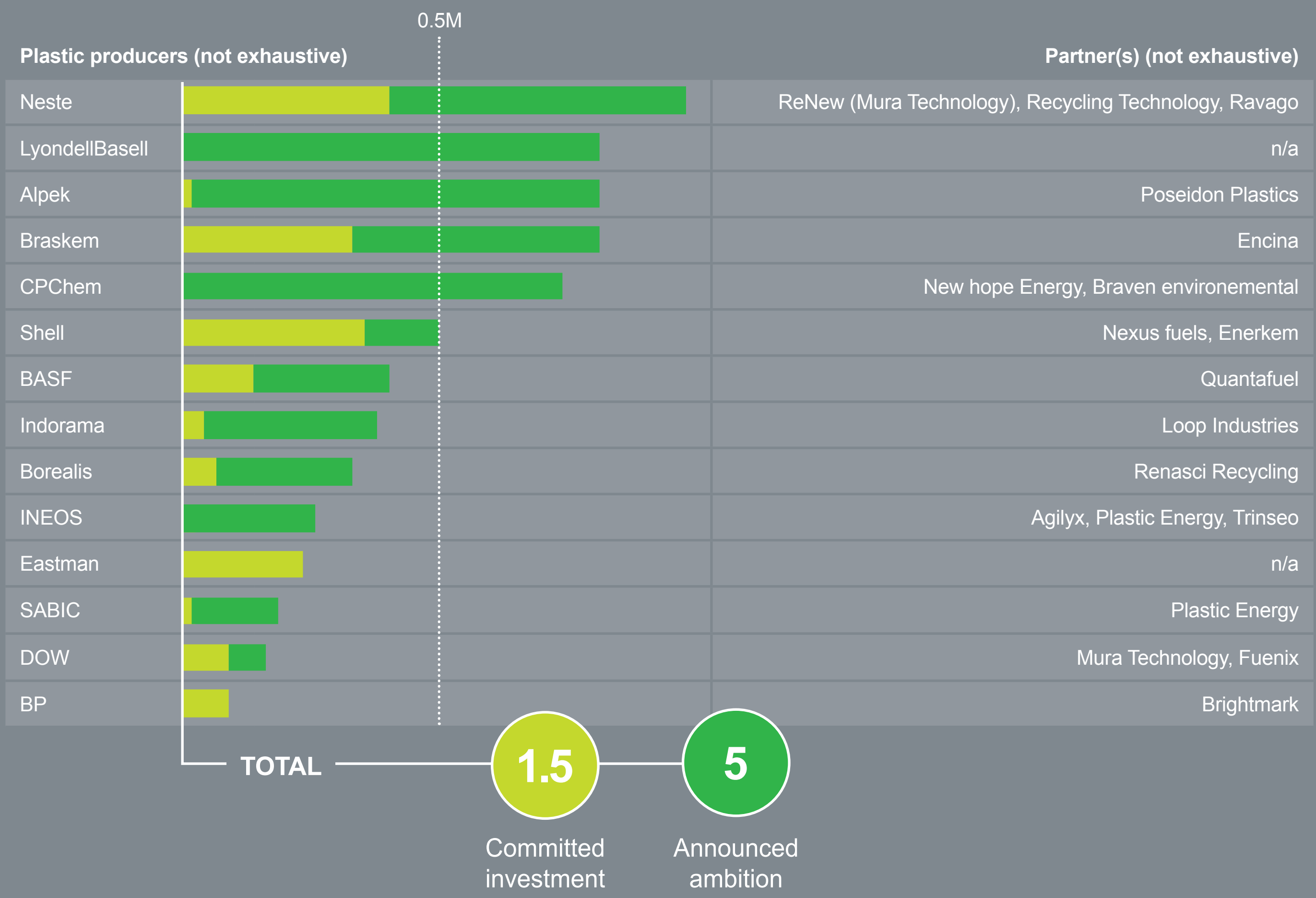
Competition between recycling technologies

Commercial-scale challenges in advanced plastics recycling

F / Plastics producers and partnerships in advanced recycling [global, m metric tons]



For companies with both advanced and mechanical technology, plastics waste input capacity is assumed at a 50-50 split. For companies with targets for processed capacity instead of input capacity, an efficiency of 60% is assumed to calculate input capacity. Some of the companies have defined target for 2025 and the rest have defined it for 2030. Based on publicly available information dated late 2021.

Source: Roland Berger

3.3 / Investment

Meeting the recycling target for 2050 requires numerous advanced recycling facilities, which means scaling today's pilots into commercial infrastructures. Investments necessitate security of plastics waste supply and offtake contracts to justify their magnitude. This may partly explain why some investment decisions are still sitting on the table.

Our model estimates that the total advanced recycling capacity needed in Europe by 2050 is approximately 17 million metric tons. If capacity develops in a linear way, then advanced recycling would have to process approximately 7 million metric tons of plastics waste each year until 2030. Current CAPEX investments for such plants are in the EUR 1,000-1,500 range per metric ton of plastics waste input for pyrolysis, and EUR 800-1,200 per metric ton of plastics waste input for gasification. This would entail a total investment of at least EUR 5-10 bn in Europe to meet 2030 targets.

According to Plastics Europe, European plastics producers have ambitions to invest a combined total of about EUR 7 bn in advanced recycling, which would equate to around an annual 5 million metric tons of plastics waste recycling capacity by 2030. For example, German chemical conglomerate BASF has plans to recycle approximately 250 thousand metric tons of plastics waste by 2025. But such ambitions still put the industry behind the 7 million metric tons required by 2030, assuming all ambitions translate into committed projects. And even if European plastics producers are able to reach the 2030 target, there is an assumption that the investment pace continues after 2030 – meaning that if construction slows down after the first plants are operational, a substantial capacity gap should be expected by 2050. More needs to be done. At the global level, the picture is quite similar. Leading plastics producers have announced ambitions to achieve 7 million metric tons of advanced recycling capacity by 2030, but only 1.5 million metric tons have been committed through partnerships with advanced recycling companies. The plastics industry must step it up. → F

There is an upside, though. Chemical conglomerates are used to hefty, long-term investments in production infrastructure, which means they can handle the CAPEX levels to achieve the recycling capacity necessary for plastics circularity.

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Multiple commitments on industrial scale

Plastics producers announcing large ambitions

Investment levels in the ballpark of what the chemical industry can handle

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Committed investments insufficient to meet targets on time

Uncertainties hampering approval of business cases

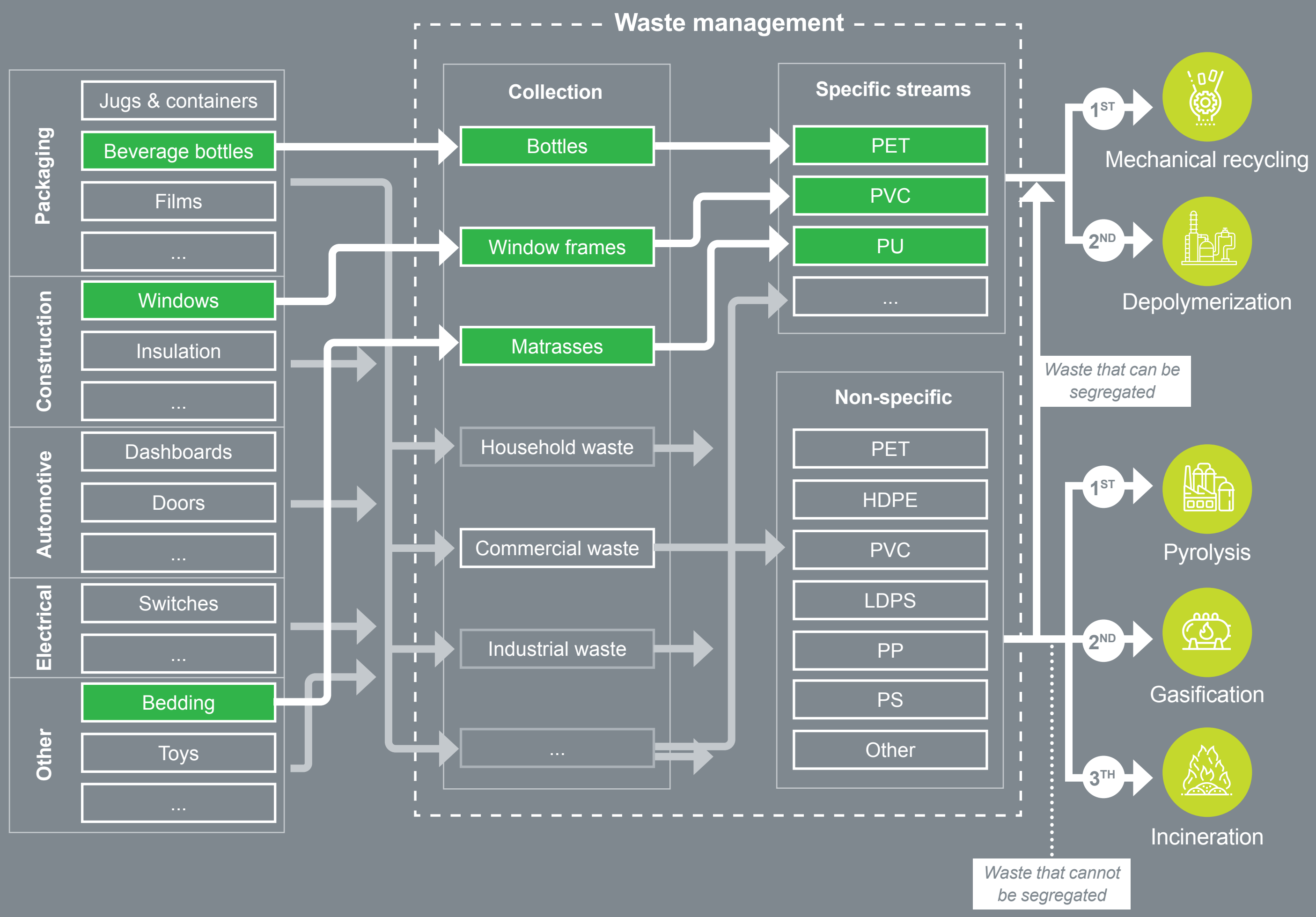
Relatively low investment scale limiting capital and operational efficiency

3.4 / Waste management

Today, plastics producers are geared towards a stable, ample supply of raw materials for commodity plastics. A switch to largely recyclate feedstock will require a major paradigm shift in the downstream flows. Waste valorization is key to making sure collection, sorting and quality certification reach the necessary scale, reliability and quality in order to make this shift.

For this to happen, the waste management chain needs to transform from a waste to a resource sector – meaning new business models, operational setups, and substantial investments in collection and sorting.

G / Pathways to circularity for various waste streams



Source: Conversio, Roland Berger

> *"A key issue is the availability of waste. Many initiatives just cherry-pick the best waste streams – but what are we going to do with the rest?"*
>
> **Waste management company**
> Executive

The majority of the plastics waste collected is mixed or contaminated with other waste, and collection varies heavily by region and application due to the more localized and fragmented nature of the sector. Recycling initiatives therefore often cherry-pick the readily available plastics waste streams: source-separated and single-material, such as via PET bottle deposit refund schemes (DRS). Even for waste streams separated at the source, significant volumes end up in mixed waste streams, which – until sorting and processing systems are optimized – are harder to recycle.

This naturally creates competition around the purer waste streams, which in turn leads to rising prices. This battle in the waste flows is hardly noticeable at the limited scale of current recycling initiatives, but when projects are scaled, the discrepancies become evident. The sector should prepare to manage the massive volumes that circularity will require. This will mean deep value chain integration: broad, horizontal and vertical partnerships between waste managers, technology companies and plastics producers which work together to collect and process massive volumes of specific waste flows (e.g. mattress PU, bottle PET) and non-specific waste flows (e.g. municipal waste). → G

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Growing number of partnerships across the value chain

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Primarily linear system

Cherry-picking of waste streams

Local and fragmented sector

3.5 / Regulation

Government regulation can support plastics circularity by putting clear targets and the right incentives in place. But the regulatory mindset must switch from managing waste in a linear system to ensuring recycled plastics as the primary feedstock in a circular one. For example, there is no comprehensive certification program that allows companies to create value from using recyclates, especially from advanced recycling. For some applications, such as food, recyclates are even prohibited, including when material has been recycled to its elementary building blocks (e.g. syngas).

The challenge is to incentivize change at the system level, not only at specific parts. This change requires a more holistic and collaborative approach, for example: ensuring that waste is treated as a raw material; encouraging product designs that can easily be recycled; incentivizing large-scale and comprehensive collection and sorting of plastics waste; limiting recycled content leakage to fuels; smarter rules for food-grade applications; and expanded DRS programs.

It is clear that a circular plastics value chain comes at a cost. Compared to today's linear system, circularity will add – and intensify – complex and expensive processes such as collection, separation and recycling. But the environmental benefits over the current linear system are undeniable. Regulation that introduces and maintains a level playing field, clear targets and incentives will be critical, both within Europe and beyond. The right frameworks can drive companies' efforts. Right now, only in certain countries and for selected waste types (e.g. packaging) responsibility is well defined, for example through EPR. However, in general, there is still often much uncertainty on who is responsible for what. To have the right incentives in place, clear policies are required that give a long-term perspective to investors. → H

> *"Change in the industry can be two-fold. Either the business case starts to make sense and we will start to invest, or regulation will provide the required imperative."*
>
> **Waste management company**
> Executive

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Longer-term European ambitions

Concrete translation into short-term, European targets

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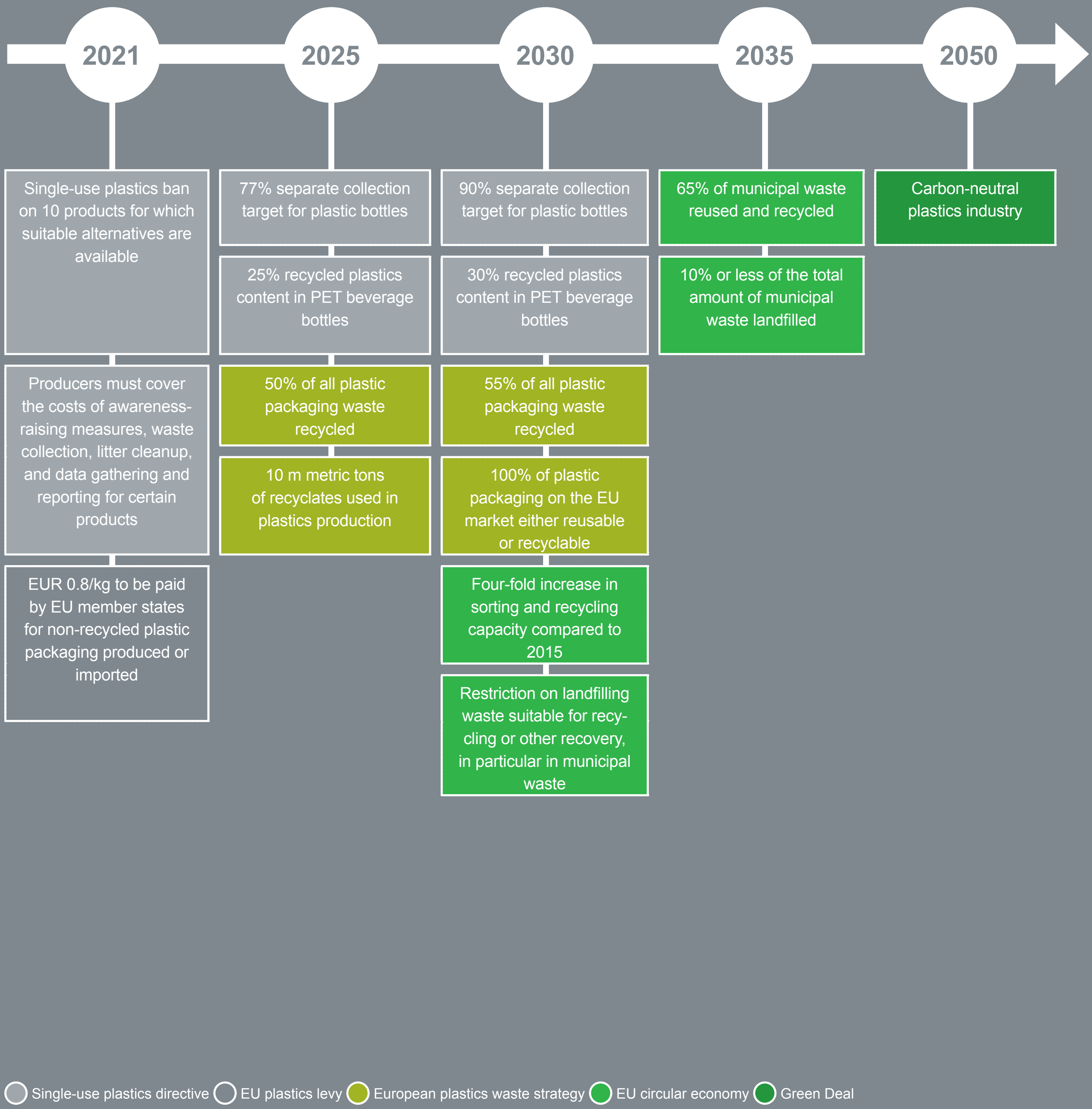
No comprehensive framework to stimulate and certify materials from advanced recycling

Waste regulation not designed for raw materials

H / EU plastics ambitions and targets, 2021-2050



Source: Roland Berger

I / Considerations for plastics producers

- What are the expected volumes for the current assets?
- How can current assets be optimally leveraged while increasingly working with more flexible feedstock sources?
- What new assets are required?

Large-scale assets for specific flow 〉 **Flexible assets to support multiple flows**

ASSET BASE

- How can product design accommodate recycling readiness (e.g. additives, colors, laminates, mulitmaterials) and make it easier to collect, separate and recycle?
- How can new business models enhance recyclability and what role could plastics producers play?

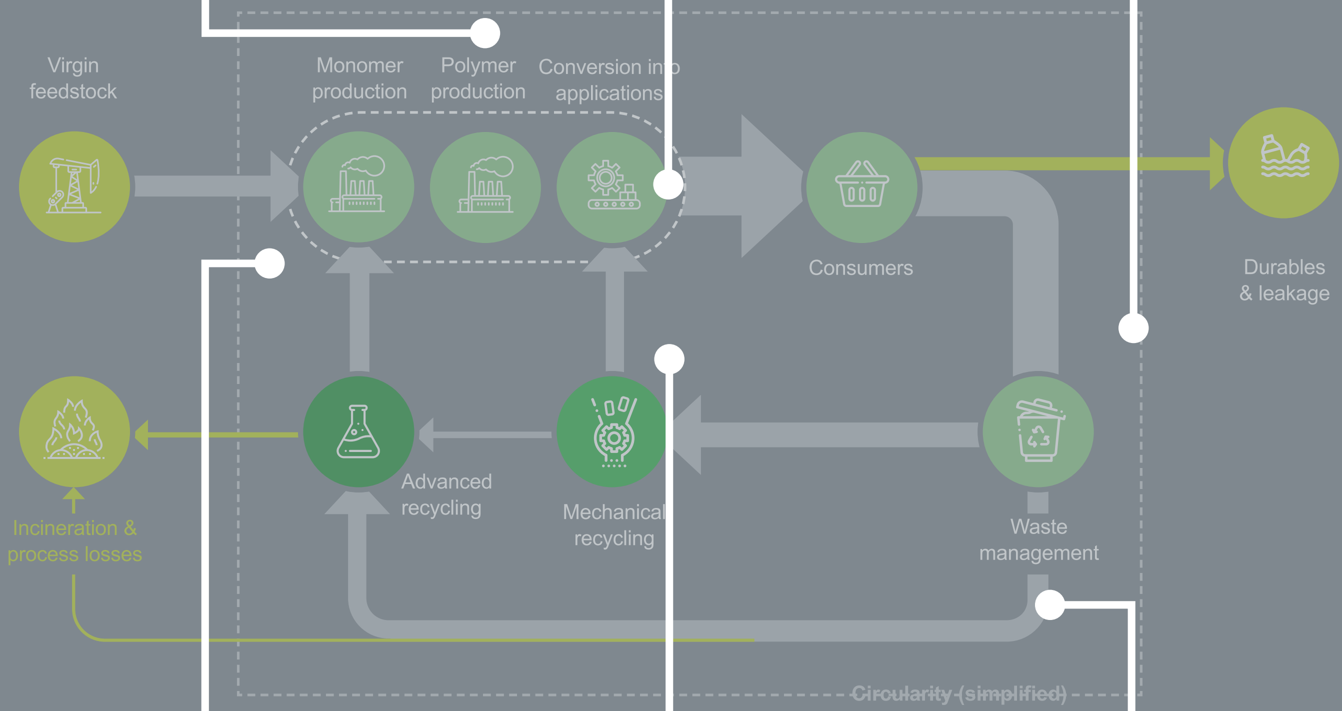
Designed for product use 〉 **Lifecycle perspective in product design**

PRODUCT DESIGN

- How can the supply of waste materials be secured, and how can scale be created?
- What are the quality tolerances and how do they need to be managed?
- What can be realized through partnerships and what through integration?

Isolated step in the value chain 〉 **Collaboration and integration**

VALUE CHAIN



MATERIAL FLOWS

Linear system 〉 **Circular system**

- Which material flows have sufficient scale and properties and are collectable for specific recycling (like PET or PU), and which flows are generic and mixed?
- What material flows fit with the required application?

BUSINESS MODEL

Spread on raw materials 〉 **Value from circular participation**

- Where to play and how to win?
- How to create value from recyclates and develop a sustainable business model?
- What is a player's aspiration and what does it mean for its participation in the plastics value chain?

TECHNOLOGY

Linear chemistry 〉 **Integrated recycling capabilities**

- Which recycling technologies should be applied for what waste flows?
- What is the expected end-state circularity mix for material flows in terms of mechanical recycling, advanced recycling and virgin?

Source: Roland Berger

4/ Conclusion: 6 pillars in the plastics balance

The end game is clear, and the time to act is now. Virgin feedstock flows will drop, and waste recycling flows will take their place. The industry must get ready. Players across the chain, from plastics producers to recycling players, need to rethink their roles. This means redefining their capability line-up, material flows, how to deal with raw feedstocks, their business model, and new responsibilities in the value chain. As the plastics balance shifts, plastics producers will feel it most. Scale will still play a part, but the winners will be those companies or consortia that reestablish scale with fragmented and mixed waste flows, and secure the supply of raw materials.

There's a lot to gain here, not the least from new value creation from waste, CO_2 reduction and repurposed infrastructure. And fortunately, the will to find a plastics balance already exists across society, governments and industry. This can translate into partnerships upstream, horizontally and downstream to manage risks, drive scale and guarantee security of supply.

Despite the uncertainties, the end game is clear enough that companies can make a timely start in the shift towards circularity. We have developed six key pillars that plastics players can use to ascertain their circular pathways and find their own equilibrium. Incorporating these pillars will lay the foundations of full-scale circularity on the company level, and cumulatively establish a plastics loop system-wide. It is time to close the loop on plastics once and for all. →|

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2022

RB_REP_22_065