INSIGHTS
REPORT

ALLIANCE
TO END
PLASTIC
WASTE

THE QUEST FOR QUALITY

Scaling Advanced Mechanical Recycling to Meet Recycled Content Targets for Flexibles

Contents

→ About the Alliance to End Plastic Waste

The Alliance to End Plastic Waste is an independent, global non-profit organisation that strives to lead the creation of a circular economy for plastic and end plastic waste and pollution. We go beyond existing solutions, by building unique and impactful circular solutions.

The Alliance convenes companies across the plastic value chain, governments, local communities, civil society groups, intergovernmental organisations, and academia. The expertise, knowledge, experience, and resources of this network enable our work to help end plastic waste and pollution.

Together, we work towards economically viable, environmentally beneficial, and socially responsible solutions.

→ Find out more: endplasticwaste.org

The principal authors of this report are Martyn Tickner, formerly chief technical advisor to the Alliance, and Pranav Goenka, director of the Alliance's Flexibles Program, and the project manager for ValueFlex.

Other contributors were Dana Mosora (CEFLEX), Michael Langen (HTP), Dragos Popa (Roland Berger), and Hendrik Dullinger, Jean-Loup Masson, Kim Stengert and Justin Wood (the Alliance).

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→ About CEFLEX

The Circular Economy for Flexible Packaging (CEFLEX) is a European collaboration of more than 150 companies, organisations and associations across the value chain. Through its shared 'Mission Circular', CEFLEX works to accelerate delivery of the circular economy for flexible packaging by improving how materials are designed, collected, sorted and recycled to replace virgin resources.

→ More information: **CEFLEX.EU**

→ About Roland Berger

Roland Berger is a global consultancy with 53 offices in 36 countries. Within the last 5 years, it has served more than 40% of the Fortune Global 500 companies, and work with industry leaders and specialists across all geographies and industries. Its extensive experience in materials, packaging & processing, and circular economy industries covers all relevant value chains in the waste management, recycling and resource recovery space.

→ About HTP

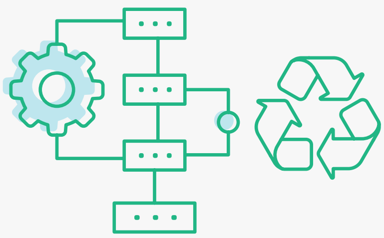
HTP is an independent, owner-managed engineering and consulting firm specializing in the recycling and waste management sectors. Expertise, flexibility and dedication, combined with more than 30 years of experience, have manifested HTP among the leading engineering service providers in Europe. The core competencies of HTP cover the entire range of technical services including strategic consultancy, engineering across all project phases and project management for any types of solid waste streams.

Executive Summary

Advanced mechanical recycling can successfully transform household flexible plastic waste into high-quality film.

This report details insights and lessons learned from the “ValueFlex” project, a collaborative initiative between the Alliance to End Plastic Waste, CEFLEX, Roland Berger, and HTP Engineering to design a first-of-a-kind advanced mechanical recycling facility for household flexible plastic waste capable of achieving closed-loop quality. The project aimed to develop a large-scale, commercially viable recycling facility, supported by detailed design, engineering plans, and a business case.

This document releases the full blueprint of a comprehensive technical and economic analysis of a 50,000-tonne (input capacity) plant within EU/UK regional context in the public domain. It is a practical foundation for recyclers, brands, and policymakers developing strategies to meet recycled content targets and drive the transition to a circular economy for flexible plastics.



KEY LESSONS LEARNED

▶ Advanced mechanical recycling is technically capable of high-end outputs

- The ValueFlex project demonstrated that it is possible to process post-consumer household flexibles into high-quality recyclates by using existing advanced, sensor-based sorting, hot-washing, and double-melt filtration systems.
- These materials are suitable for 30%+ incorporation in demanding film applications, such as shrink films, labels, and pouches.

▶ Chemical recycling will be complementary to advanced mechanical recycling

- Rather than competing with each other, advanced mechanical and chemical recycling are highly complementary. Both can produce high-quality recyclates, but each will focus on different fractions of the flexibles waste stream and target different "end" application segments.
- Chemical recycling will focus notably on multi-material films targeting food-contact applications, for example.

▶ Achieving high-quality recyclates needs a shift in operational philosophy

- Competing in quality-driven markets requires a shift towards a “market-pull” mindset based on the requirements of end-markets.
- Moving away from low-cost high-volume 'commodity' processing of plastic waste towards high-quality output requires greater capital and operational expenditures, as well as advanced competencies in polymer science.

▶ Systemic enablers remain vital for the business case

- Favourable economics for high-quality recycling currently rely heavily on market interventions.
- To bridge the economic gap with virgin polymers, companies in the recycling value chain must leverage enablers such as Extended Producer Responsibility (EPR) policies to fund collection and sorting, mandated recycled content targets to drive demand, and access to concessionary capital to reduce costs.

▶ Optimise capital via brownfield expansion and upstream sorting

- Greenfield civil works (31% of CAPEX) and complex sorting equipment (25% of CAPEX) strain project economics, particularly given ~50% yields on raw bales.
- To create a viable business case, operators should leverage brownfield site upgrades and shift the heavy sorting burden upstream to centralised Plastics Recovery Facilities (PRFs).

STRATEGIC RECOMMENDATIONS FOR INDUSTRY ADOPTION

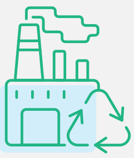
The transition to a circular economy for flexible plastics requires a coordinated, value-chain-wide approach. Advanced mechanical recycling, complemented by evolving decontamination such as deinking, extraction, and delamination technologies, offers a highly practical and immediate solution for meeting recycled content targets in new packaging – especially those due to be implemented in Europe in 2030. However, achieving this at scale requires distinct actions from all market participants.

▶ For policymakers and producer responsibility organisations (PROs)

Enact and enforce systemic enablers
High-quality recycling cannot currently compete with virgin polymers on market forces alone. It is critical to enforce EPR policies to fund collection and sorting, and firmly implement national recycled content targets ahead of 2030 to drive sustained demand.

Incentivise infrastructure development
Provide subsidies, development grants, and tax breaks to enable access to low-cost capital, bridging the current economic gap for first-of-a-kind recycling facilities.

Champion secondary sorting
PROs are uniquely positioned to support and fund investments in large-scale plastics recovery facilities (PRFs) that sit between primary sorting in material recovery facilities (MRFs) and recyclers, and are a vital step for driving rapid system change.



▶ For waste management and recycling operators

Shift the operational mindset to "quality first"
Operators must pivot from Volume focused low-cost commodity processing to prioritising high-quality, premium outputs based on "market pull". This transition requires developing deeper competencies in polymer understanding and advanced analytical capabilities.

Capitalise on brownfield upgrades
Instead of bearing the heavy civil infrastructure costs of greenfield megaprojects (which account for roughly 30% of CAPEX), operators should focus on upgrading existing mechanical recycling facilities. Adding washing capabilities such as hot-wash, chemical-driven wash-off, and water purification, or advanced extrusion technologies like enhanced degassing, double-filtration, and deodorisation to existing sites offer a much faster, lower-risk pathway to scaling capacity.

Specialise through upstream sorting
In regions where foundational waste collection and primary sorting networks are already well-established, implementing centralised secondary sorting becomes a critical next step toward achieving system maturity. While this infrastructure shift may not yet apply to all geographies, sourcing from mature, centralised facilities allows downstream recyclers to bypass the heavy capital burden and ~50% yield losses associated with sorting raw household bales. Consequently, operators can focus their capital and expertise purely on advanced washing and extrusion for specific, high-value product lines.

▶ For brands and converters

Forge long-term strategic partnerships
To secure the high-quality post-consumer recyclate (PCR) needed to meet imminent incorporation targets, brands and converters must treat advanced recyclers as long-term partners, similar to traditional petrochemical suppliers, rather than transactional vendors. Long-term offtake agreements will be vital for de-risking these new recycling investments.

Support the integration of emerging technologies
To achieve food-contact status for recycled flexible packaging, brands and industry stakeholders must actively participate in and champion next-generation solutions. Future investments, in addition to the solutions demonstrated in the ValueFlex blueprint, are required to scale advanced detection and granular sorting capabilities (such as identifying surface versus sub-surface prints or separating food from non-food packaging), alongside highly effective decontamination and devolatilisation technologies (such as removing oils, adhesives, inks, etc.) that significantly elevate the purity and quality of the final recyclate.

▶ For investors and financial institutions

Leverage advanced mechanical recycling as the immediate bridge for near-term targets
The clock is ticking on the European Packaging and Packaging Waste Regulation (PPWR), which mandates 35% post-consumer recycled content in non-food packaging by 2030. This impending milestone has exposed a severe and immediate shortfall in high-quality recycling capacity. A robust, long-term circular economy will ultimately require a holistic system design that integrates all available technologies. Chemical recycling currently carries higher costs and requires more time to mature and scale, while the first level in advanced mechanical recycling represented by ValueFlex is the most actionable, immediate opportunity.

Direct capital toward centralised plastic recovery facilities
Investing in large-scale, centralised secondary sorting centres offers economies of scale, allows for the deployment of the most advanced sorting technologies, and fundamentally improves the business case for the entire downstream recycling sector.

Acknowledge a multi-technology ecosystem
While mechanical recycling is the immediate priority, chemical recycling, dissolution, and other advanced decontamination technologies like delamination, deinking, and extraction will be essential long-term solutions within the ecosystem to handle specific sub-fractions and achieve demanding end-market requirements.

> *Circularity only works if materials have a place to go. Today, systems across Europe are still uneven, and too much material does not meet the quality needed for demanding applications. If we don't align collection, sorting, recycling and end markets, recycling rates will plateau. ValueFlex gives us a blueprint for higher quality mechanical recycling and helps show what needs to change in practice to deliver both the volume and the quality required at scale.*
>
> **Dana Mosora**
> CEFLEX

01.

Introduction

01. Introduction

In 2022, the Alliance to End Plastic Waste teamed up with several partners to develop what it hoped would be a groundbreaking project in plastic recycling. The goal was to develop a large-scale, commercially viable mechanical recycling facility capable of converting household flexible plastic packaging waste into high-quality recyclates for use in film applications.

Flexible plastic packaging waste is difficult to recycle back to a quality that is good enough to be reused in new packaging. The material has long been recycled into lower-grade applications such as plastic lumber and bin bags. But achieving “closed loop” recycling – packaging waste back into new packaging – has remained stubbornly hard.

And yet, with new regulations – such as Europe’s Packaging and Packaging Waste Regulation – increasingly requiring the incorporation of recycled plastic into new packaging, there was a strong need to work on new solutions.

For more on this, download the recent Insight Report from the Alliance:

The Challenges and Solutions for Flexible Plastic Packaging Waste

Download

The project was called “ValueFlex”. It was developed in collaboration with the Circular Economy for Flexibles (CEFLEX) initiative, Roland Berger, and HTP Engineering.

Full design and engineering plans were developed for the plant. It was put out for tender, and many industry consortia submitted bids to build the facility. Ultimately, the project did not go ahead, largely a result of changing macro-economic and policy conditions at the time.

Nonetheless, the process of developing the plans for the plant unearthed highly valuable insights into how mechanical recycling of flexibles could achieve closed-loop quality. These insights covered not only technology choices and plant design, but also business model issues and the critical levers that determine economic viability.

In writing this report, the Alliance is sharing these valuable lessons and insights. In particular, the report is designed to:

- **Describe the technical design of a 50,000 (input) tonnes per annum advanced mechanical recycling plant and the corresponding economics and key sensitivities;**
- **Encourage adoption by open-sourcing the ValueFlex basic engineering design, business case considerations, and technical overview. This provides a foundational blueprint, which operators can methodically customise to align with specific regional feedstock compositions, existing infrastructure integration, and unique investment objectives;**
- **Share key insights, learnings and opportunities for improvement, which can strengthen investment economics for such a plant, and potentially facilitate system change;**
- **And create a platform from which the Alliance can share further experiences in evaluating new technologies that complement the capabilities of advanced mechanical recycling.**

Background and History of the ValueFlex Project

02.

Prior to the initiation of ValueFlex, CEFLEX had conducted a series of trials known as the Quality Recycling Process (QRP) with companies across the value chain. These trials successfully validated the individual operational elements required to enhance conventional mechanical recycling. To prove the viability of these solutions holistically, the ValueFlex blueprint systematically integrated these critical upgrades into a commercial-scale, end-to-end facility. This state-of-the-art baseline configuration combined highly granular near-infrared (NIR) and optical sorting, rigorous hot-washing decontamination, enhanced extrusion technologies featuring double-melt filtration, and advanced deodorisation.

By deploying this configuration, the ValueFlex plant produces high-quality recycled polyethylene and polypropylene grades, processing mono-material packaging from household waste to unlock premium end-use applications that were previously unattainable.

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The plant's sorting process isolates four distinct material fractions, whose technical viability, particularly the ability to achieve 30% recycled content in demanding applications, was successfully demonstrated and validated during the CEFLEX trials:

PE Natural
This fraction consists of cleaner, transparent polyethylene films targeted for demanding, higher-value film structures. The CEFLEX trials successfully validated the use of this rPE-Natural in mono-material sealable pouches and collation shrink films.

PE Flex
Comprising coloured, printed, or more complex polyethylene films, this fraction is intended for flexible applications with lower aesthetic requirements. Trials validated this durable rPE-Flex for use in recycled garbage bags, irrigation pipes, and pallets.

PP Film
This fraction isolates polypropylene films to maximise both the purity of the PE streams and supply high-quality packaging applications. The targeted isolation of rPP films was successfully validated for use in BOPP and cast packaging films.

Mixed PO (Polyolefins)
This aggregated mixed polyolefin fraction is targeted specifically as a raw, unpelletised feedstock optimised to supply advanced chemical recycling pathways. Additionally, trials validated that this mixed rPO can also be utilised for high-end injection moulding.

While the ValueFlex project integrates the best of these proven technologies, there remains a powerful opportunity for continuous innovation. As the market matures, the value chain must actively evaluate and include evolving decontamination technologies – such as advanced delamination, deinking, and solvent or supercritical fluid extraction – to further elevate recyclate purity and expand the boundaries of flexible plastic circularity.

> *ValueFlex addresses a range of end-markets for recycled flexible plastics, tailoring the feedstock, the sorting, the cleaning, and the recycling technologies needed for each end application. Not only are recycling rates maximised (outputs across multiple end markets), but the quality is optimised for highly demanding applications, while costs are controlled for less demanding applications. Enabling a range of complementary paths such as this is essential to achieve recycling at scale for flexible packaging.*
>
> **Lucie Charbonnel**
> Amcor Flexibles EMEA

SETTING UP THE PROJECT

To take the project forward, the Alliance and CEFLEX, with the support of Roland Berger, engaged 50 stakeholder companies from across the packaging value chain, conducting interviews, staging workshops and seeking input.

After widespread consultation, the objectives for ValueFlex were set:

- Demonstrate the technical and financial viability of recycling flexible plastic packaging from typically available sorted streams (bales) of household waste in a fully commercial and industrial-scale plant.
- Clarify that financial viability meant a sufficient return to attract market capital.
- Provide a platform to support replication, sharing key insights, and performance data to inform second-generation design.

The general framework and guidelines for the project were established as:

Focus on quality

Produce high-quality recyclates suitable for 30%+ incorporation in demanding film applications (surpassing low-value uses like garbage bags) and high-end injection moulding. A specific emphasis was placed on recycled polypropylene (rPP) solutions. While the process aspired to reach food-contact quality, formal European Food Safety Authority (EFSA) approval was excluded from the baseline business case.

Use widely-available feedstock

Primarily process the lightweight fraction of flexible household waste – such as PP/PE from yellow bins and material recovery facilities (MRFs) – including problematic materials like heavily printed and multi-material laminates. If needed, post-commercial waste – generally cleaner and more consistent in composition than household waste – could be used as a supplement feedstock to optimise plant economics.

Use integrated, existing commercial technologies

Maximise advanced mechanical recycling using only commercially available technologies. But also recognise that other technologies, such as chemical recycling and dissolution, would play an important complementary role in processing subfractions unsuitable for mechanical recycling.

Apply pragmatic economic parameters

Target a location in the European Union (or UK). The financial baseline assumed zero-cost feedstock and the inclusion of EPR fees. It did not include any additional gate fees for receiving the waste.

FROM HIGH-LEVEL CONCEPT TO DETAILED PLANS AND BIDDING

After extensive consultation with the plastic value chain, the Alliance engaged Roland Berger and HTP Engineering to design the plant. This involved not only configuring the processes and component technologies but also building a multi-year discounted cash flow model to test the facility's economics under a wide range of assumptions for inputs, outputs, yields, costs, prices, regulation scenarios, and investment/ capital cost assumptions.

→ *See Section 04 for more on the economic model.*

Once ready, a structured bidding phase was staged to secure an industry partner to fund, build, and operate the plant. The value proposition for potential operators was a de-risked investment model that could position them as an early adopter, with a fully developed engineering design, as well as access to concessionary debt finance from the Alliance to support construction costs. In return, the operator would agree to act as an industry catalyst, hosting facility visits and sharing operational learnings to drive broader market adoption.

During the bidding phase (Nov 2022 – Dec 2023), the project attracted 17 expressions of interest (EOIs) from major European recyclers and consortia. This pool was systematically narrowed to three leading candidates by April 2023, culminating in the selection of a final preferred consortium in December 2023. The consortium of investors included not only a leading waste manager/recycler, but also a major consumer brand company and a large petrochemical company.

The 2024 decision to pause the ValueFlex project serves as a critical lesson: technical capability alone cannot overcome macroeconomic and regulatory barriers. The "perfect storm" that undermined the project’s immediate investment economics – plummeting virgin polymer prices, escalating energy and capital costs driven by global conflicts, and the critical deferral of anticipated enabling policies like local Extended Producer Responsibility (EPR) frameworks and stringent PPWR targets – underscored the conditions required for commercial viability.

03.

ValueFlex Plant: Design and Engineering

The ValueFlex plant is designed to process 50,000 tonnes per year of flexible plastic waste, producing approximately 25,000 tonnes per year of high-quality polyolefin recyclates. The facility comprises two identical sorting lines, three washing lines, and three extrusion lines, housed across four main buildings. Material flows sequentially through the plant from raw material intake and storage, through sorting, washing, and extrusion, to finished product storage and packaging.

Initially, it was hoped that the plant would also process mixed polyolefin fractions – flexibles that contain different materials sandwiched together. The goal was to build an additional washing and extrusion line to process these mixed polyolefins and send them to chemical recyclers capable of recycling such materials. However, industry feedback indicated that chemical recyclers prefer raw, unpelletised feedstock and typically utilise their own preparation capabilities, rendering this extra processing step unnecessary. As such, while chemical recycling offtake for the mixed polyolefins fraction is a key part of the plans, there is no need for processing.

Additionally, anticipating lower incoming volumes of PE-Natural and PP-Film, the design was efficiently consolidated to process both fractions batch-wise on a single, higher-capacity extrusion line rather than utilising two smaller, dedicated lines.

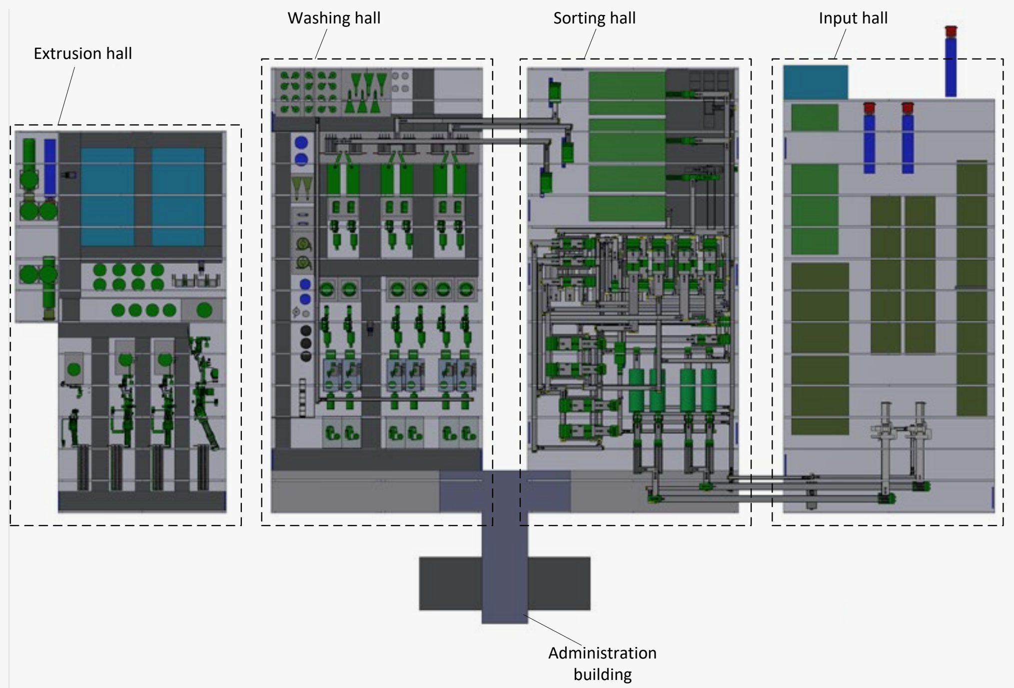
Ultimately, the design phase underscored that equipment configurations – such as the number and sizing of processing lines – must remain highly adaptable to regional feedstock variations and existing site infrastructure. Consequently, the ValueFlex technical package presented here should be viewed as a foundational blueprint rather than a rigid prescription. As demonstrated during the project's tendering phase, incoming bidders successfully adapted and optimised this baseline design to construct tailored, highly viable investment cases that met their specific strategic and commercial needs.

SITE BUILDINGS & INFRASTRUCTURE

The ValueFlex facility is designed as a greenfield industrial plant consisting of four main halls and supporting infrastructure. Material flows sequentially through the site from right to left → *see Figure 1*, including:

1. **Raw material intake and bale storage (approximately two weeks of feedstock inventory)**
2. **Sorting hall**
3. **Washing hall**
4. **Extrusion, pellet storage silos, and packaging area**

Figure 1 Valueflex plant design



Source: AEPW, CEFLEX, Roland Berger, HTP

The extrusion building includes five product silos (100m³ each) and a big-bag filling line. Finished products are stored in a warehouse with capacity for approximately 45 big bags.

In addition, the plans include supporting infrastructure, notably:

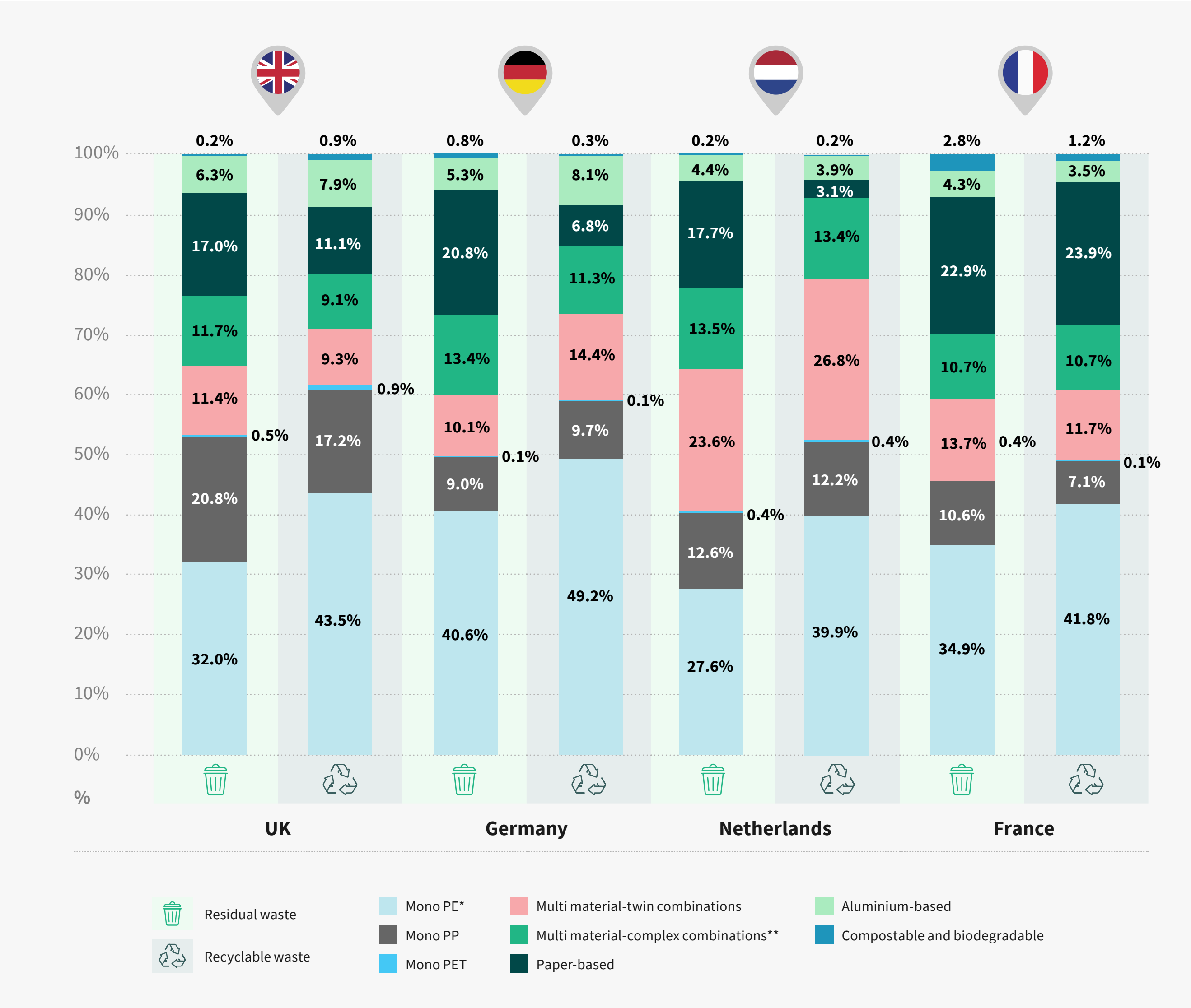
- Internal roads
- Surface water management
- Drainage systems
- Utilities and process water treatment
- Administration building

The plant layout is designed to ensure efficient logistics, continuous material flow, and separation between raw material handling and finished product storage.

FEEDSTOCK

A clear understanding of the available waste stream is essential to ensure the facility is configured appropriately. To ensure the greatest scope of success across multiple markets, the ValueFlex plant is designed to process bales of sorted flexible plastic packaging waste from post-household collection systems. The plant needed to be located in a country with sufficient waste volumes, which narrowed the focus to France, Germany, the UK, and the Benelux countries. Of these, the Netherlands was selected as the basis for bale composition data because it represents the most median waste profile — giving the plant design the broadest applicability across all shortlisted countries. → *see Figure 2.*

Figure 2 **Waste characterisation for flexibles in the recycling stream**



** not including carrier bags/bin liners* *** includes meatallised films*

Source: CEFLEX

Typical feedstock consists primarily of polyethylene films, polypropylene films, multilayer flexible packaging, and residual contaminants such as fines, rigid plastics, metals, and non-plastic materials.

The composition of flexible packaging waste typically contains a higher share of polyethylene films and a lower share of polypropylene films, with a portion of multilayer polyolefin structures. The plant is designed to efficiently recover polyolefin fractions while maintaining operational flexibility to accommodate variations in feedstock composition.

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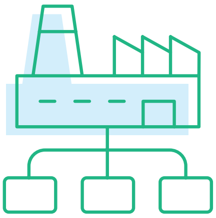

SORTING

Incoming bales are de-wired, de-baled, and stored in a buffer area to ensure a consistent feed to the sorting system. Material is then processed through two identical sorting trains operating in parallel.

Initial treatment includes ferrous metal separation, followed by screening and wind-sifting to remove:

- Fines (<40 mm)
- Heavy materials, including rigid plastics
- Light flexible plastics

Rigid plastics are further processed using near-infrared (NIR) sorting and baled for sale to external recyclers.

Flexible plastics then undergo several sorting steps to produce purified polyolefin fractions. Optical and NIR sorting are used to separate LDPE films, natural polyethylene films, polypropylene films, and mixed polyolefin fractions.

The sorting system in the base design uses 22 NIR sorters and 8 optical sorters, with several units arranged in series to maximise sorting purity in a single pass.

Prior to re-baling, the flexible materials undergo a five-step, sensor-based sorting process:

1. Roughing
Initial NIR separation to split LDPE and PP streams.

2. LDPE Sorting
Optical separation of transparent (natural) from colored films.

3. PP Sorting
NIR polishing to maximise the purity of the PP fraction.

4. Scavenging
Targeted recovery of residual LDPE and PP from reject streams.

5. PO Sorting
Final NIR isolation of a mixed polyolefin (PO) fraction to serve as chemical recycling feedstock.

The exact number of sorters and the configuration of the sorting system may vary depending on local feedstock characteristics, available markets for sorted fractions, and site constraints, particularly when adapting the design to brownfield locations with limited space.

The design also allows the potential integration of multi-sensor based sorting technologies, including digital watermark detection, enabling additional separation of packaging categories such as food versus non-food applications.

WASHING

After sorting, the flexible plastics are pre-shredded and processed through three identical washing lines. Each washing line includes:

- Pre-shredding and pre-washing
- Full shredding
- Cold-wash friction cleaning
- Hot washing
- Density separation
- Dewatering and drying
- Water treatment

The pre-shredding stage reduces compacted films to 60–80 mm particles, followed by a pre-wash that removes heavy contaminants such as stones and glass to protect downstream equipment. Material is then fully shredded and cleaned using a cold-water friction washer, followed by centrifugal dewatering.

A key feature of the process is extensive hot washing, where material is treated for 10–15 minutes at 80–90°C in batch or continuous operation. Chemicals such as caustic soda may be added to remove organic residues, inks, adhesives, and contaminants.

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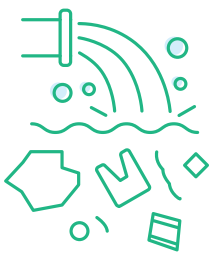


Following hot washing, materials undergo:

- Fresh-water rinsing
- Density separation
- Mechanical dewatering
- Thermal drying

Process water is managed through extensive recirculation. Fresh water is used only in the final rinsing stage, while used process water is treated through mechanical filtration and chemical-physical flotation before being recirculated or discharged as effluent.

EXTRUSION

Clean polymer flakes from the three washing lines are processed through three extrusion lines:

- One extrusion line for rPP-Film
- One extrusion line for rPE-Natural
- One larger extrusion line for rPE-Flex

Each extrusion line includes:

- Pre-compaction of flakes
- Additive dosing (masterbatch, peroxide for vis-breaking, UV stabilisers)
- Single-screw extrusion*
- Two-stage melt filtration
- Vacuum degassing
- Pelletisation

After pelletisation, the granulate passes through a refresher stage, where hot air is circulated in counter-current contact to remove residual volatiles and homogenise the material. Granulates are then blended in mixing silos before final storage. Finished products can be stored in bulk silos or packed in big bags for shipment. The extrusion configuration allows operational flexibility to respond to variations in feedstock composition and market demand for specific recyclate grades.

* *Twin screw may be applicable for specific operators based on their targeted end markets and operational capabilities*

Access the detailed plant plans

The engineering details of the plant configuration as above are available for download at endplasticwaste.org/quest-for-quality

These details comprise:

- Process flow diagrams
- Plant and process description
- Basis of design and guidelines
- Mass balances and utility requirements
- Layout drawings
- Business case and value engineering summary

Capital & Operating Costs

04.

Based on the completed engineering design and subsequent value-engineering exercise in the first half of 2023, total capital expenditure for the base project was estimated at €106m.

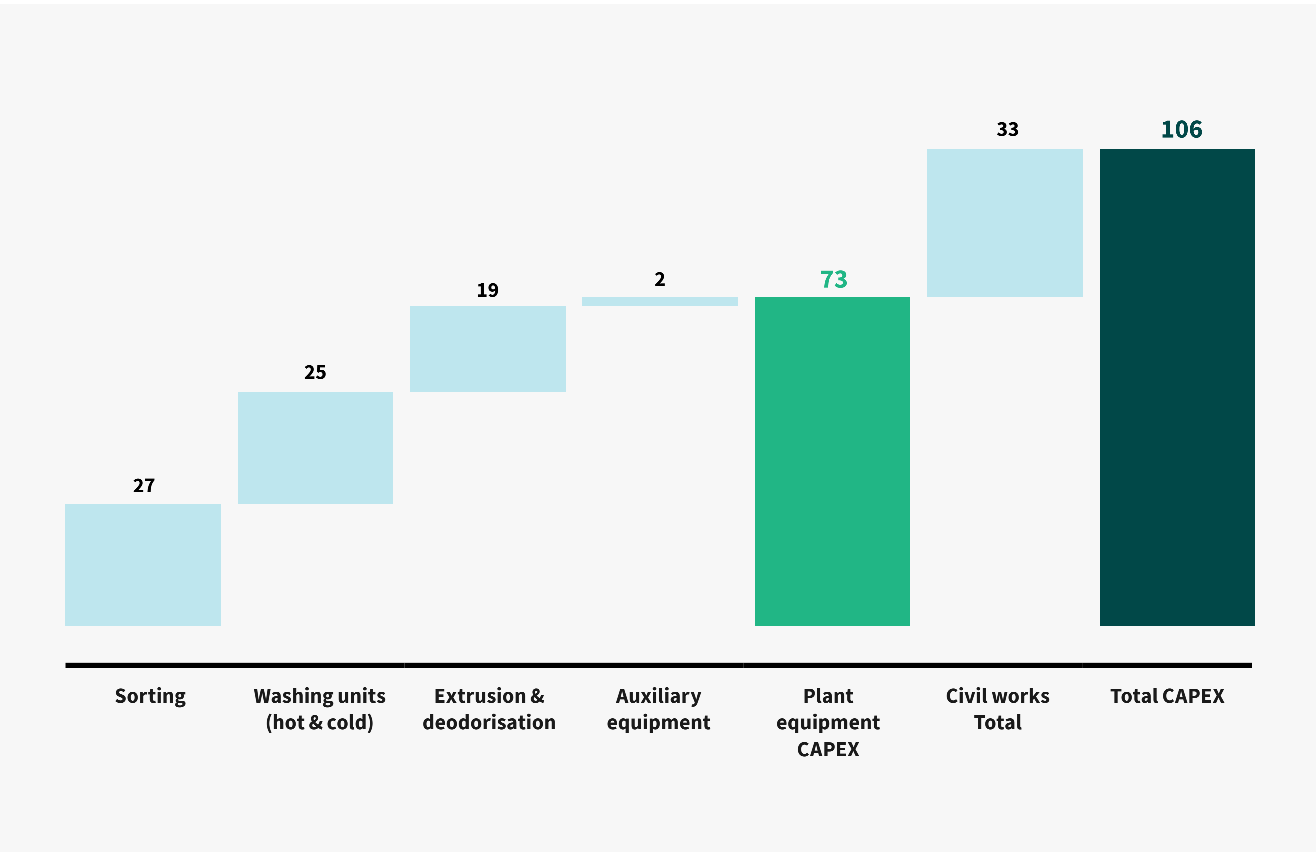
A large share of the investment cost is driven by sorting equipment (approximately 25%) and civil works (approximately 31%). Because the project was designed as a greenfield facility, civil infrastructure such as buildings, roads, drainage, and utilities represents a significant portion of the cost.
→ *see Figure 3.*

Opportunities exist to reduce overall capital expenditure through:

- Utilisation of existing infrastructure by developing the plant on a brownfield site
- Sourcing partially sorted feedstock from large-scale secondary sorting facilities – plastic recovery facilities – thereby reducing the sorting burden within the recycling plant
- Retrofitting existing material recovery facilities to provide better feedstock and thereby reducing the number of machines

Moving part of the sorting upstream could also allow recyclers to specialise in specific polymer streams (e.g., PP or PE films), potentially reducing both capital requirements and operational complexity.

Figure 3 Capital expenditure breakdown for Valueflex



Source: AEPW, CEFLEX, Roland Berger, HTP

LABOUR AND UTILITY COSTS

Given high capital costs, a 24/7 plant operation is envisaged, with 15 operators per shift resulting in a total of 111 employees, and an annual labour and salary cost of €12m. → *see Figure 4.*

This provides for a self-sufficient site, including 25% over-staffing for holiday and sickness coverage. This could be reduced as the operation matures.

The plant is, however, assumed to be part of a larger company and hence additional headcount is not included for functions such as corporate accounting, executive management, and marketing and sales.

From the equipment design, electrical consumption is estimated at 15 MW per annum.

FURTHER COST CONSIDERATIONS

The figures presented here show a reference case developed for a European facility based on the Netherlands feedstock characteristics and engineering assumptions at the time of the study.

In practice, capital and operating costs may differ depending on several factors, including:

- Local feedstock composition and availability
- The degree of upstream sorting or pre-processing
- Site selection (greenfield versus brownfield)
- Regional construction, labour, and utility costs
- Plant configuration and level of automation
- Market and price conditions at the time of project development for equipment, energy, and construction markets

As a result, individual project developments may require adaptation of both plant design and cost assumptions to reflect local conditions and commercial realities.

Figure 4 **Breakdown of labour costs for ValueFlex**

Staff group	Function	Number of employees [#]	Total plant staff cost in Year 7 [EUR m]
General staff	Management & administration	6	0.8
General staff	General plant staff*	30	3.6
Specialised staff	Sorting lines	30	2.7
Specialised staff	Washing lines	25	2.5
Specialised staff	Extrusion & deodorisation	20	2.5
Total		111	12.1

** Logistical personnel, laboratory, electricians, technicians, administration etc.*

Source: AEPW, CEFLEX, HTP, Roland Berger

05.

Economic Evaluation

A project such as ValueFlex can only succeed if the plant is profitable and delivers an investment payback within an acceptable timeframe. This section therefore reviews the market assumptions, the financial model, and the sensitivity of project economics to these assumptions. While the underlying data is from 2023, the analysis remains directionally robust and allows meaningful conclusions to be drawn.

The discounted cash flow (DCF) model supported the project along two main dimensions:

1. **Economic optimisation (CAPEX, OPEX and margins) through:**
- Scale effects
- Technical design choices
- Input and output product mix

2. **Investment robustness**
- Base-case economics
- Sensitivity to operational parameters, location, and financing structures

MARKET ASSUMPTIONS (2023 WAS YEAR OF ASSESSMENT)

Feedstock pricing
- Feedstock is assumed to be free of charge, with no gate fee or EPR fee for recycling, reflecting the use of unsorted flexible waste streams.

Recyclate pricing
- These are expressed relative to virgin polymer prices in the table below.
- Virgin reference prices used in the model were €1,828/t for PP and €1,640/t for PE.

Product	Pricing Assumption versus Virgin
rPP Film	+25.9% premium
rPE Film Natural	+28.9% premium
rPE Flex	–17.3% discount

Product Differentiation
- A distinction is made between rPE Natural and rPE Flex, reflecting differences in feedstock quality, appearance, and end-use potential. → *see table below.*
- "Natural" grades are intended to substitute virgin LDPE in demanding film structures, while "Flex" grades enable material recovery from more contaminated streams where aesthetic requirements are lower.

Other revenue
- A selling price of €150 per tonne is assumed for sorted but unprocessed polyolefins destined for chemical recycling.

Table Product Differentiation

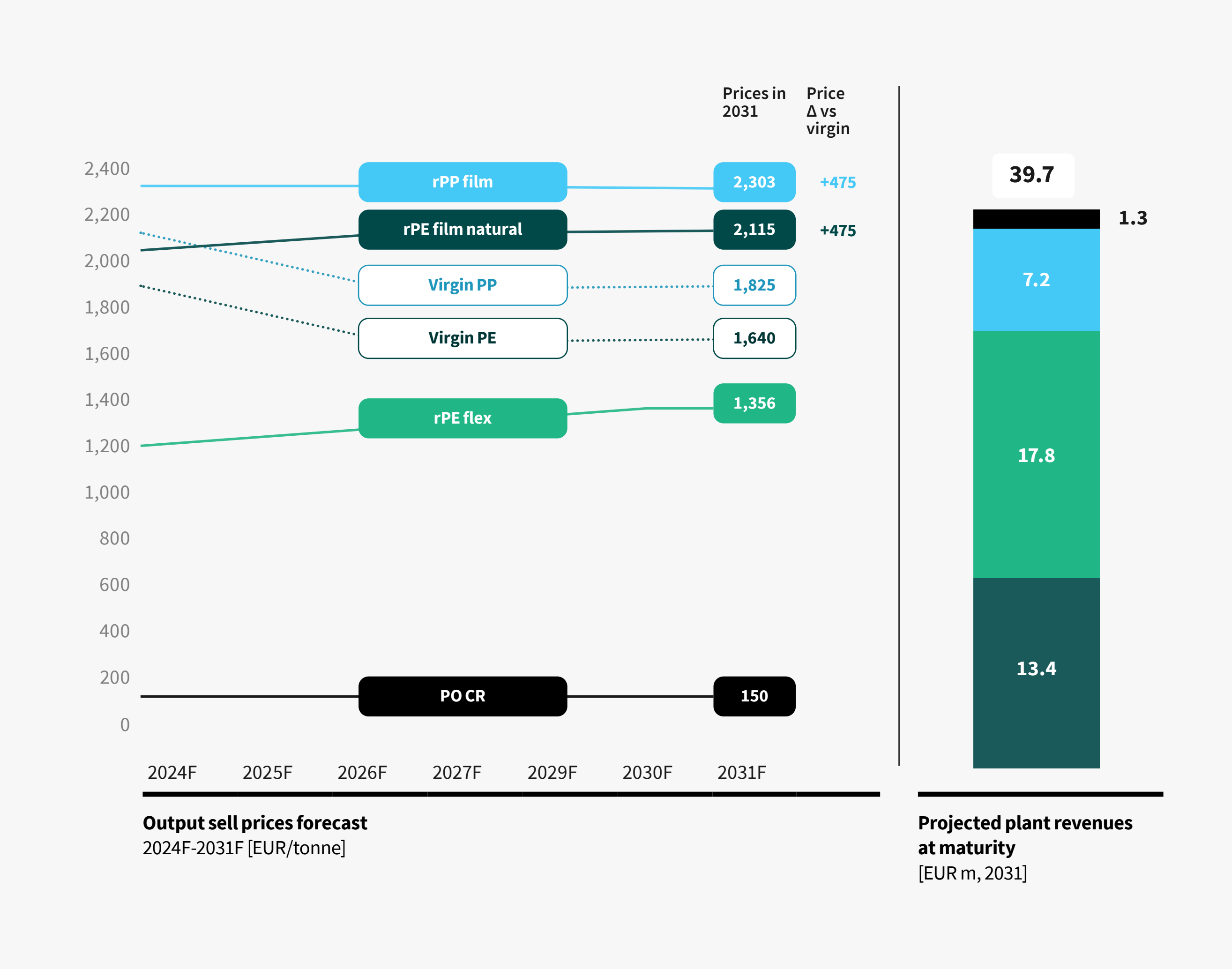
Attribute	rPE Natural	rPE Flex
Feedstock quality	Cleaner PE film fractions	Mixed / printed / complex flexibles
Colour & appearance	Light / "natural"	Darker / heterogeneous
Mechanical properties	Good, LDPE-comparable	Adequate, application-dependent
Target use	Higher-value film layers	Lower aesthetic flexible applications
Role in ValueFlex	Virgin LDPE substitution pathway	Valorisation of difficult flexibles

FINANCIAL MODELLING

In the base case, all output volumes are assumed to be sold. The analysis projects a €40m annual turnover for a plant producing 25 ktpa of output. → *see Figure 5.*

While absolute revenue levels may be debated, the relative contribution of each output stream remains relevant both at project completion and under current market conditions.

Figure 5 Revenue forecast for ValueFlex in 2031

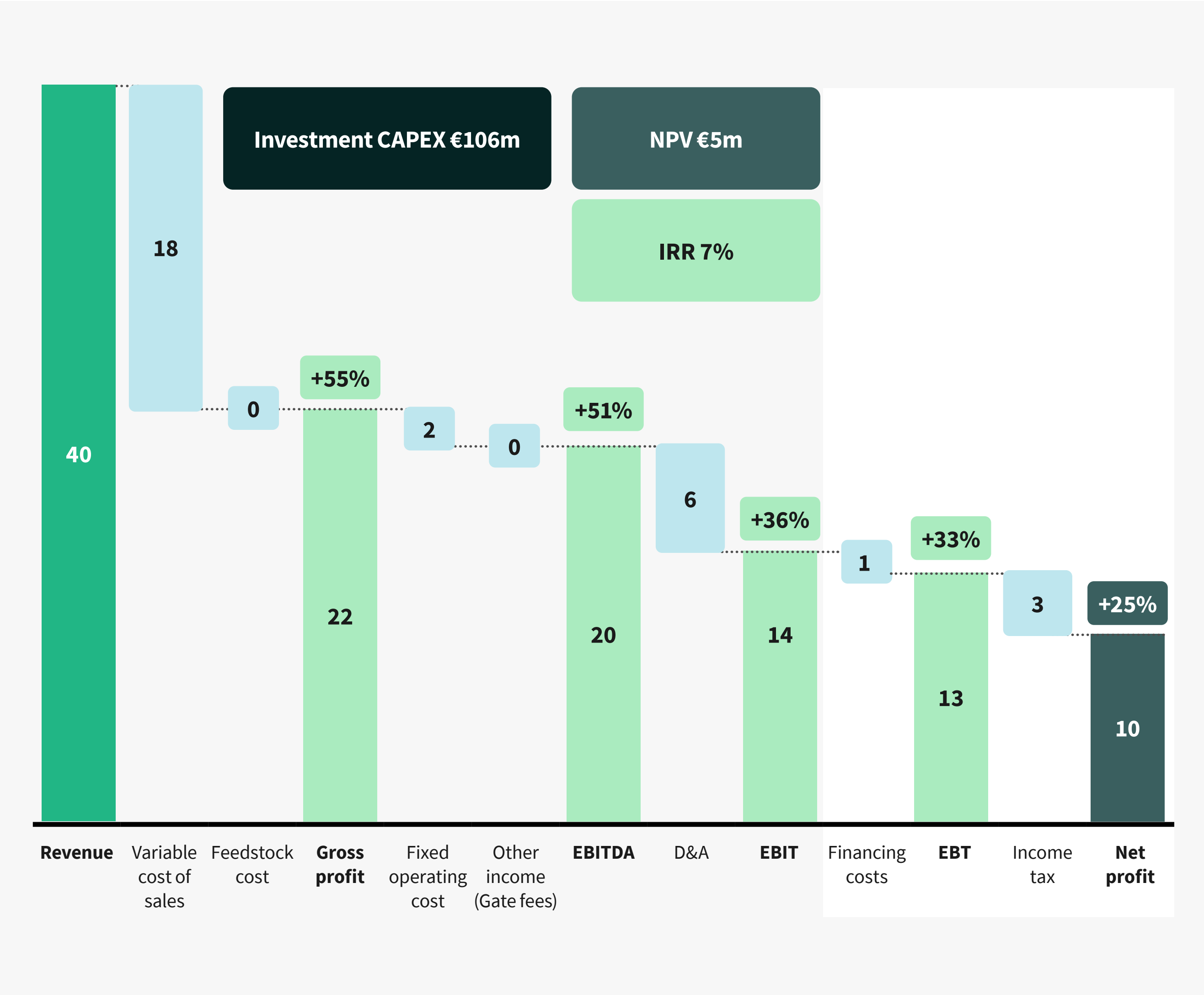


Source: AEPW, CEFLEX, Roland Berger, HTP

Moving from modelling revenue to modelling profitability, the plans calculated a net profit of €10m, based on revenues of €40m.

Figures 6 and 7, below, show the breakdown of the profit calculation and the assumptions used to make it.

Figure 6 Modelling the profitability of ValueFlex



Source: AEPW, CEFLEX, Roland Berger, HTP

Figure 7 Assumptions used in the ValueFlex financial assessment (analysis in 2023)

Parameter	Base Case Assumption
CAPEX	€106 million
Operating period	7 years
Terminal value	1.3× final-year operating cash flow
Tax rate	25%
Gross margin	55%
SG&A	4% of revenue
EBITDA margin	51%
Net margin	25%
Operating cash flow	€17 million p.a.
Inventory (DOI)	35 days
Receivables (DSO)	45 days
Payables (DPO)	60 days
Financing structure	55% debt @ 2%, 35% equity, 10% concessionary finance
IRR	7%
NPV @10%	€5 million

Source: AEPW, CEFLEX, Roland Berger, HTP

Balance-sheet simulations indicate a total equity requirement of €48 million, assuming:
- Long-term debt repaid over 15 years
- Short-term loans repaid within four years

SENSITIVITY ANALYSIS AND VALUE DRIVERS

The revenue and profit assumptions underpinning ValueFlex reflect the market conditions at the time of the business case development in 2022-23. In 2026, under current market conditions, the standalone viability of a ValueFlex facility would be challenged. Nevertheless, the developed business case remains a valid baseline and approach for long-term economic planning and sensitivity analysis.

While the base-case economics are relatively weak when set against the commercial and execution risks of a technically and economically first-of-a-kind facility, robust opportunities exist to strengthen the financial model. These strategic levers cluster around three core pillars:

1. Strategic financial and capital structuring
Big up-front investments necessitate a highly active and optimised capital strategy.

- **Location Strategy**
The selected country or region could have a significant impact on both CAPEX and OPEX, while also dictating critical operational considerations such as access to consistent feedstock and the viable sale of outputs.

- **CAPEX Optimisation**
Capital intensity can be reduced through brownfield development – minimising civil works costs – and by securing public subsidies or development grants.

- **Capital Structure Optimisation**
Optimising the debt-to-equity ratio avoids excessive reliance on equity, with possible implications on overall cost of capital.

- **Tax Optimisation**
Operators should leverage the project's innovative, R&D-driven nature to secure targeted fiscal support and evaluate locations with favourable corporate tax regimes.

2. Market and revenue maximisation
Advanced mechanical recycling revenues are highly sensitive to market pricing, requiring proactive commercial strategies.

- **Strategic Offtake Agreements**
Securing premium output pricing must be anchored by long-term offtake agreements with brands and converters.

- **Monetising Waste via Gate Fees**
Operators can unlock critical upside revenue by collaborating with PROs to establish gate fees for processing complex waste streams.

3. Operational and Technical Excellence
Rigorous operational discipline is a critical factor in determining the facility's long-term financial performance.

- **Feedstock and Yield Optimisation**
High yields must be secured through long-term feedstock sourcing agreements and the deployment of high-performance sorting and decontamination equipment.

- **Utility Management**
Transitioning toward renewable energy sources is vital to stabilise highly variable operating costs.

- **Staffing Efficiency**
Operations must target gradual headcount and labor optimisation as the plant's processes mature.

- **Accelerated Ramp-Up**
Comprehensive planning must ensure a rapid commissioning phase, as delays in scaling to full capacity will materially erode project value.

"THEN AND NOW" – MARKET ADJUSTMENTS AS OF 2026

As already noted, adverse market developments undermined the immediate viability of ValueFlex, including rising energy costs following the outbreak of the Ukraine war, a decline in virgin polymer prices driven by structural overcapacity, and a deferral of PPWR targets and delays in implementing local EPR schemes. Such issues reinforce the need for recycling business plans to remain resilient regardless of external factors.

Nonetheless, for European recyclers, the implementation of PPWR in 2030, with its call for recycled content in plastic packaging, should provide much-needed support for the economic viability of recycling. In this context, the ValueFlex economic assessment remains a useful reference for policymakers and PROs, helping to quantify the level of EPR fees and policy support required to make high-quality recycling investments viable.

> *The biggest challenge of flexibles circularity is represented by difficult economics along the collection-sorting-recycling value chain, as demonstrated in the context of the 2024-2025 plastic prices. Robust business model consideration along with incentives from private and public sector stakeholders can improve the economics for feedstock streams and output applications, but it has to be carefully curated from the beginning of the business opportunity.*
>
> **Dragos Popa**
> Roland Berger

06.

Key Learnings

While construction of the ValueFlex facility was paused, the initiative produced critical, evidence-based blueprints for the industry. Furthermore, the extensive engineering and economic assessment developed can now serve as learnings to strengthen the economics of future projects, guide holistic system design, and inform policymakers and PROs on the conditions required to make advanced mechanical recycling viable.

INSIGHT #1

Advanced mechanical recycling can deliver quality for premium film applications

The completed ValueFlex engineering designs demonstrate that advanced mechanical recycling can process household flexibles into high-quality recyclates at 30%+ incorporation alongside virgin polymers in demanding applications such as shrink films, pouches, closures, and labels.

> *The ValueFlex project – and the work of CEFLEX that preceded it – shows clearly that high quality mechanical recycling of post-consumer flexibles is possible. Modern sorting plants are already isolating streams such as PE natural and PP film at industrial scale. Building fully integrated recycling processes – hot-washing, extrusion with highly effective double filtration, and deodorisation – will ensure this feedstock reaches the quality needed for PPWR targets.*
>
> **Clemens Kitzberger**
> Erema Group

Key technical learnings from the trials include:

- **Contamination removal**
Standard cold-washing is insufficient for producing the low-gel recyclates required for film quality; however, integrating rigorous hot-washing efficiently removes the vast majority of organic and fibre contamination.

- **Unwanted polymers removal**
Double filtration helps remove all non-polyolefins which passed the various sorting steps.

- **Odour removal**
Refreshing step as final deodorisation reduces odour to a level largely accepted by converters.

- **Colour optimisation limits**
Flake sorting provided negligible improvement to the final colour profile of materials originating from already sorted bales, indicating that colour quality is largely dictated earlier in the value chain.

INSIGHT #2

Systemic policy and financial enablers are essential prerequisites

High-quality recycling currently requires significant market and financial interventions to compete effectively with the economics of virgin polymers. As highlighted, creating a sustainable business case relies heavily on the implementation of the following systemic enablers:

- **Robust extended producer responsibility schemes**
Strong EPR frameworks are essential to organise and fund the upstream collection and sorting infrastructure.

- **Mandated recycled content targets**
Clear, enforceable regulatory targets are required to drive sustained market demand and ensure accountability for recyclate incorporation.

- **Access to concessionary capital**
Subsidies, development grants, and tax incentives are vital to lower the cost of capital, thereby improving overall business profitability and de-risking first-of-a-kind infrastructure investments.

INSIGHT #3

Cultivating a "Quality First" operational and commercial mindset

To succeed in high-quality mechanical recycling, operators must pivot from traditional low-cost, high-yield commodity processing to prioritising premium output. This strategic shift requires accepting higher capital and operational expenditures to support advanced technologies and more granular sorting, which inherently results in lower initial yields and increased residue disposal costs.

To command the value commensurate with this investment, recyclers must develop deeper technical competencies, including advanced analytical capabilities and expertise in polymer science. Furthermore, commercial strategies must evolve. Recyclers should view themselves as long-term strategic partners engaging global brands and converters with the same rigour and reliability as traditional petrochemical suppliers. Ultimately, targeting premium markets requires a steadfast, board-level commitment to the circular economy and an understanding that transitioning to become an advanced recycler demands time and significant investment.

INSIGHT #4

Optimising capital intensity through brownfield integration

The comprehensive engineering study revealed that greenfield capital costs are substantial. While still lower than chemical recycling or dissolution plants, this level of investment presents a significant barrier for many recyclers and investors in the current macroeconomic climate.

A key finding is that approximately 30% of this greenfield capital is tied to civil infrastructure, such as buildings, warehousing, roads, and utilities. Consequently, a highly viable pathway to scaling capacity is through brownfield development. By leveraging existing facilities or implementing a "scrap-and-build" approach to upgrade current equipment, operators can drastically reduce initial capital exposure.

Brownfield integration can reduce one of the largest barriers to scale by avoiding up to 30% of greenfield capital tied to civil infrastructure.

Practical opportunities include:

- Utilising existing administration buildings, control rooms, weighbridges, and warehousing.
- Leveraging established utility systems, such as electrical supply, fire water, air supply, and surface water management.
- Upgrading current operations by integrating targeted modules, such as advanced sorting or hot-washing capabilities, into an existing line.
- Replacing older extrusion equipment with modern, vacuum-degassing extruders with double-filtration to elevate final product quality.
- Add a de-gassing unit at the end of extrusion to maximise odour removal which increases acceptance of the PCR in the conversion process.

INSIGHT #5

Enabling systemic change via centralised upstream sorting

Integrating comprehensive sorting at the individual recycling facility presents a profound economic bottleneck. In the ValueFlex design, sorting infrastructure accounted for 25% of total capital expenditure, while processing raw bales resulted in ~50% yield losses due to inherent contamination.

This dynamic effectively doubles transportation, warehousing, and purchasing costs while forcing recyclers to manage unwanted sub-fractions. The practical solution is to shift this burden upstream by establishing large-scale, centralised plastics recovery facilities that bridge the gap between primary material recovery facilities and final recyclers.

Consolidating volume into PRFs (Plastic recycling facilities – secondary sorting) delivers several critical advantages:

- **Economies of scale**
  PRFs provide the volume needed to justify the capital for the most advanced, granular sorting technologies, an upgrade that remains impractical for individual MRFs.
- **Operational specialisation**
  By receiving highly optimised feedstocks, downstream recyclers bypass heavy upfront capital costs and significant yield losses. This allows operators to focus their expertise and investments exclusively on advanced decontamination and extrusion for specific, single product lines.
- **Maximised resource recovery**
  Centralised sorting naturally aggregates specialised sub-fractions (roughly 10-15% of incoming material) into commercially viable volumes for alternative pathways like chemical recycling, avoiding double-handling or disposal.
- **Accelerated industry upgrades**
  Removing the sorting burden from the recycler significantly lowers the barrier to entry, facilitating faster, lower-risk capacity upgrades across existing recycling networks.

Encouragingly, this structural shift is already gaining traction, with major secondary sorting investments successfully emerging across Europe, including a 200,000-tonne capacity site in Sweden, alongside developments in Austria, Germany, and Norway. Whether owned by PROs or private enterprises, these centralised facilities represent a vital new commercial pillar in achieving a mature circular economy.

TRANSLATING INSIGHTS INTO ACTION: THE VALUEFLEX INVESTMENT READINESS CHECKLIST

Translating these strategic insights into actionable, bankable infrastructure requires rigorous project evaluation. To support stakeholders in moving from ambition to execution, the key learnings from the ValueFlex blueprint have been distilled into an Investment Readiness Checklist. This checklist serves as a practical tool for operators, investors, and policymakers to assess project feasibility and ensure alignment with the critical enablers necessary for advanced mechanical recycling.

To support stakeholders in moving from ambition to execution, the key learnings from the ValueFlex blueprint have been distilled into an Investment Readiness Checklist.

Feedstock and Technical Adaptability

- Is there access to sufficient flexible plastic feedstock?
- Has the feedstock composition been accurately characterised, and does the business plan account for potential shortages in specific fractions?
- Is the feedstock from household, commercial, MRF, PRF or mixed sources?
- Is there an upstream secondary sorting / PRF option to alleviate severe yield losses and heavy capital burdens?
- Is the equipment configuration adaptable to regional feedstock variations, such as combining smaller fractions for batch-processing to maximise equipment utilisation?

Site and Capital Optimisation

- Is the project greenfield or brownfield?
- Can existing buildings, utilities, roads, warehousing or equipment be reused to bypass the heavy civil infrastructure costs typically associated with greenfield megaprojects?
- Is there a credible financing structure, including grants, subsidies or concessional capital to de-risk first-of-a-kind infrastructure investments?

Commercial and Market Strategy

- Are target product specifications clearly defined and driven by a 'market-pull' and 'quality-first' mindset, rather than traditional low-cost commodity processing?
- Are end-users willing to sign long-term offtake agreements?
- Are there established synergistic offtake pathways for the isolated mixed fractions?
- Has the business case been comprehensively stress-tested against virgin polymer prices, energy costs, yield losses and ramp-up delays?

Policy and Operational Excellence

- Are EPR fees, gate fees or other policy-supported revenues available?
- Are recycled-content mandates or other demand drivers firmly in place ahead of approaching regulatory milestones?
- Is there a qualified operator with the right technical capability and advanced polymer science competencies?
- Are energy, labour, water, wastewater and residue disposal costs thoroughly understood?
- Are permitting, wastewater, odour, fire safety and environmental approvals clearly mapped and understood based on local and site-specific factors?

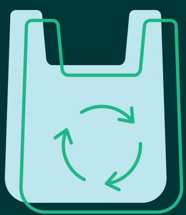
Conclusion

07.

07. Conclusion: Accelerating the Adoption of Advanced Mechanical Recycling

Flexible plastic packaging plays an essential role in modern economies, offering lightweight, cost-efficient solutions that protect goods, extend shelf life, and support the convenience of modern retail and e-commerce. Today, flexible plastics account for more than half of the global plastic packaging market, and demand is expected to continue growing. However, the systems needed to recover and recycle these materials have not developed at the same pace. Material complexity, collection and sorting challenges, stringent quality requirements, and economic constraints continue to limit circularity and create a critical gap in high-quality recycling capacity. This challenge is increasingly becoming a regulatory imperative; the European PPWR mandates 35% post-consumer recycled content in non-food packaging by 2030, underscoring the urgent need to scale effective recycling solutions.

Scaling advanced mechanical recycling is the immediate priority. The most rapid, lower-risk pathway to bridging the 2030 capacity gap is through brownfield developments, upgrading the foundational mechanical recycling infrastructure that already exists today.



While chemical recycling will ultimately be required to supply food-contact and speciality grade recyclates, these processes are still evolving and currently carry higher costs, a larger carbon footprint, and longer implementation timelines. Consequently, scaling advanced mechanical recycling is the immediate priority. The most rapid, lower-risk pathway to bridging the 2030 capacity gap is through brownfield developments, upgrading the foundational mechanical recycling infrastructure that already exists today.

To make these advanced facilities highly investable, the industry must advocate for large-scale secondary sorting centres or plastics recovery facilities. PROs are ideally positioned to champion this systemic shift, which optimises the feedstock supply for both mechanical and chemical recycling pathways. However, depending on regional maturity and operational strategy, fully integrated facilities that combine sorting, cleaning, and recycling on a single site may still offer competitive advantages in maintaining rigorous quality control and process efficiency.

To accelerate this transition, the Alliance is prepared to support high-impact projects that improve flexible packaging circularity. Because technological innovation has progressed steadily since the original plant design, the Alliance has launched a new project under its Flexibles Thematic Program to evaluate the technical and economic capabilities of recent advancements. Phase I of this initiative specifically targets PP film, with the ultimate objective of achieving food-contact status. To address the complex challenge of granular sorting, the Alliance is collaborating with several organisations as part of Holy Grail 2030 program including CEFLEX. This phase utilises digital watermarks to accurately separate surface-printed from sub-surface-printed materials, as well as distinguishing food-contact packaging from non-food-contact household waste.

Following this advanced sorting stage, the highly targeted material streams will be processed in commercial-scale pilots alongside various technology partners to test emerging decontamination and deinking methods. These trials will evaluate the efficacy of steam, supercritical water, supercritical CO_2, and solvent dissolution, applied either before or during the extrusion phase. The resulting recyclates will be rigorously analysed and subsequently extruded into film by major converters to validate their practical performance.

Integrating the most successful of these emerging technologies into an advanced mechanical recycling blueprint – building directly upon the ValueFlex model – provides the industry with actionable pathways to achieve premium quality outputs. Furthermore, the data generated from these trials will facilitate objective comparisons with parallel processes, such as chemical recycling, providing stakeholders with clearer insights into the relative capabilities and economics of each approach. These findings will be detailed in a comprehensive report in 2027, helping to define the precise, complementary roles different technologies must play in establishing a practical circular system for flexible plastics.

> *ValueFlex is more than a brand for creating value from the recycling of flexible polymer structures; it represents a pinnacle of industrial technologies, extending the success of PET bottle and HDPE recycling. While many stakeholders doubt the viability of technical cases for more complex materials such as flexibles, evolving legal, market, and technical conditions will drive these opportunities – and prove they can be achieved.*
>
> **Michael Langen**
> HTP

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To find out more, visit **endplasticwaste.org**

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