# R&I Brief

## Circularity as a Driver of Resilience and Competitiveness

EFFRA
EUROPEAN FACTORIES OF THE FUTURE RESEARCH ASSOCIATION

## Table of Contents

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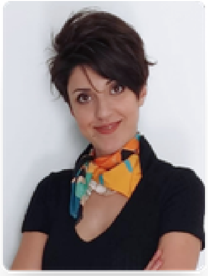

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**With special thanks to the EFFRA Team**

## Acronyms

**CBAM –** Carbon Border Adjustment Mechanism
**CE –** Circular Economy
**CEA –** Circular Economy Act
**CBM –** Circular Business Model
**CRMA –** Critical Raw Materials Act
**EoL -** End of life (EoL)
**EC –** European Commission
**EU –** European Union
**ESA -** European Space Agency
**EDTIB -** European Defence Industrial Strategy
**IAA –** proposed Industrial Accelerator Act
**NZIA -** Net Zero Industry Act
**ESPR -** Eco-Design for Sustainable Product Regulation
**DPP -** Digital Products Passports
**R2R -** Right to Repair Directive
**RD&I -** Research, Development & Innovation

## 1.Executive Summary

**The Shift:** Move from "Waste Management" to "Value Lifecycle Management" through circular strategies which deliver strategic autonomy, resilience and competitiveness

**The Goal:** Establish Europe as the global leader in **High-R Manufacturing** by 2050.

The EFFRA *Circularity Working Group (WG)* has developed a White Paper that positions circularity as a core driver of Europe's industrial competitiveness, resilience, and net-zero ambitions. The document provides a critical assessment of the current state of European manufacturing, highlighting persistent linear practices, recycling-heavy but reuse- and remanufacturing-light systems, fragmented reverse logistics, and R&I funding models that still prioritise vertical silos over systemic circular solutions.

The WG sets out a clear vision for 2026–2034 and beyond, calling for a shift from circular pilots at the margins to advanced circular strategies as the default model for European manufacturing. Central to this vision are high-value "R-strategies" (reuse, remanufacturing, refurbishment), OEM-led remanufacturing embedded in core business models, factories retooled for disassembly and reintegration, and operational digital product passports and data frameworks enabling high-value retention circularity through life-extension.

**Who is this brief for?** This brief is intended for the key actors involved in shaping and implementing Europe's industrial transformation. The White Paper provides concrete R&I and policy recommendations, including making FP10 a true circular economy agenda, linking funding to verified life extension and service revenues, deploying regional reverse-logistics hubs, developing EU-wide circularity indicators, and embedding circular skills and micro-credentials across manufacturing. Overall, the work of the Circularity WG positions Europe to move from linear survival to circular competitiveness, establishing a single circular market which positions the EU industrial base to evolve into global leaders in advanced circular manufacturing.

## Key Take Aways

**Circularity is key to EU Competitiveness, Resilience & Strategic Autonomy.** The systemic transition towards a circular economy is underpinned by a comprehensive, interconnected and mutually reinforcing regulatory frameworks and drivers which, by design under the EU Green Deal, set the pricing, targets, rules and support measures to enable the EU industrial system and economy transition delivering resilience and competitiveness.

**Commercially oriented circularity deployment in Europe is not failing due to lack of innovation, but due to lack of systemic alignment and critical mass of market pull for circular products and services**. Most initiatives remain pilot-based and peripheral as not yet commercially viable, while core business models, KPIs, and infrastructure remain linear.

Counterintuitively, **the key barriers to mainstreaming circularity are predominantly economic, organisational, and systemic** (e.g. regulatory, market & infrastructure conditions), rather than purely technological challenges.

**Mainstreaming circularity requires strategic collaboration within sectors and between sectors to deliver on its' transformation potential.** Closing the gap between circular ambition and industrial deployment requires system enablers that translate circular value into viable economic outcomes. Circular value creation needs to be investable, contractible, and operational across the lifecycle through aligning demand, data and infrastructure and value distribution which disrupts market conditions that currently still reward linear products.

**The top three recommended priority clusters for FP10 are:**

- (1) *Demand pull and incentive realignment* (market-making, circular KPIs, procurement),
- (2) *Data and DPP infrastructure* (digital traceability, condition monitoring, interoperability), and
- (3) *Industrial-scale reverse-logistics and remanufacturing systems.*

**In addition to embedding circularity RD&I into the DNA of FP10, key recommendations for policymakers are:**

- Establish a Single Market for Value Retention Operations
- Establish EU standards for "remanufactured" conformity
- Evolve the Waste Framework Directive for Circularity
- Create Market Incentives for Value Retention Operations
- Embed circular manufacturing within dual-use innovation

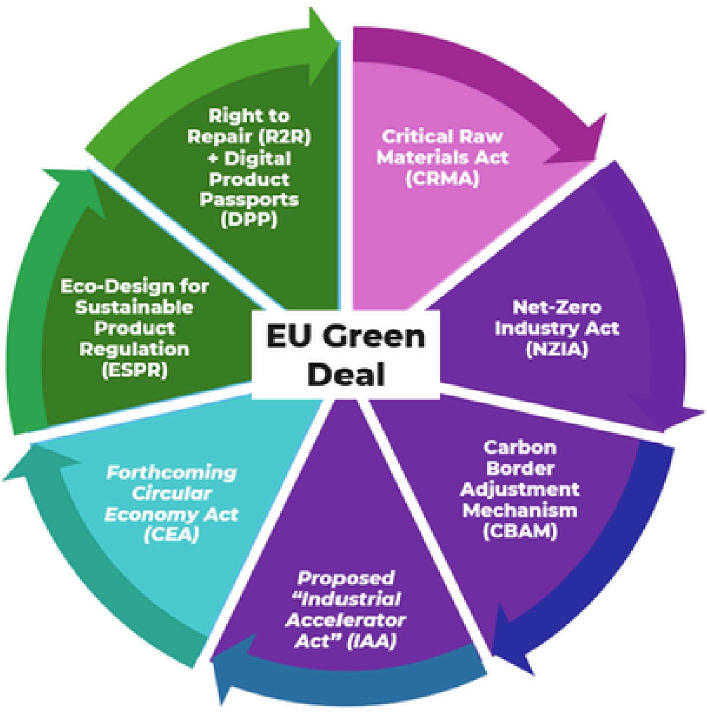
# 2.State of Play

## 2.1. Strategic Circularity - Resilience, Competitiveness & Strategic Autonomy

The circular economy is a strategic imperative for Europe's future. As a central dimension of the European Green Deal, it aims to deliver a cleaner economy while simultaneously strengthening Europe's global competitiveness. By reducing reliance on finite natural resources, it supports sustainable growth, creates quality jobs, and is indispensable for achieving the EU's 2050 climate neutrality objective.

The EU's Circular Economy Action Plan (CEAP), first launched in 2015 and expanded (V02.0) in 2020, targets both reduced emissions from EU consumption and increased usage of products, components and materials. Circularity seeks to decouple economic growth from resource use and whilst it is a key tool to achieve decarbonization it constitutes a foundation for long-term, sustainable, and inclusive growth. Mainstreaming, circular business models, enabled by data flows, can decouple value creation from the production of single-use goods and instead generate profit through product longevity, reuse, upgrades and lifecycle-extension services.

The systemic transition towards a circular economy is underpinned by a comprehensive, interconnected and mutually reinforcing regulatory frameworks and drivers which, by design under the EU Green Deal, set the pricing, targets, rules and support measures to enable the EU industrial system and economy transition (see figure below).



**From CRMA to NZIA and CBAM,** which are key to enabling supply-chain security, boosting domestic production and levelling the playing field for EU industries to the proposed **Industrial Accelerator Act (IAA)** which recognizes the fact that the strength of the manufacturing sector is essential to the EU's long-term economic resilience and is complementary with the forthcoming **Circular Economy Act (CEA)** (anticipated in H2, 2026). The **Eco-Design for Sustainable Product Regulation (ESPR)** sets the circular design requirements for products to be placed on the Single Market and includes **Digital Products Passports (DPP)** which provides material, component and usage data. The **Right to Repair (R2R) Directive** strengthens consumer rights and seeks to make it easier and more cost-effective for product-life extension.
By embedding circularity principles into all aspects of the EU Green Deal, Europe is sending a clear global signal: the circular economy is fundamental to building sustainable societies and competitive industries. Through innovation, new technologies, advanced business models, skills development, and cross-sector collaboration, the EU is positioning itself to lead the transition toward a profitable, net-zero economy.

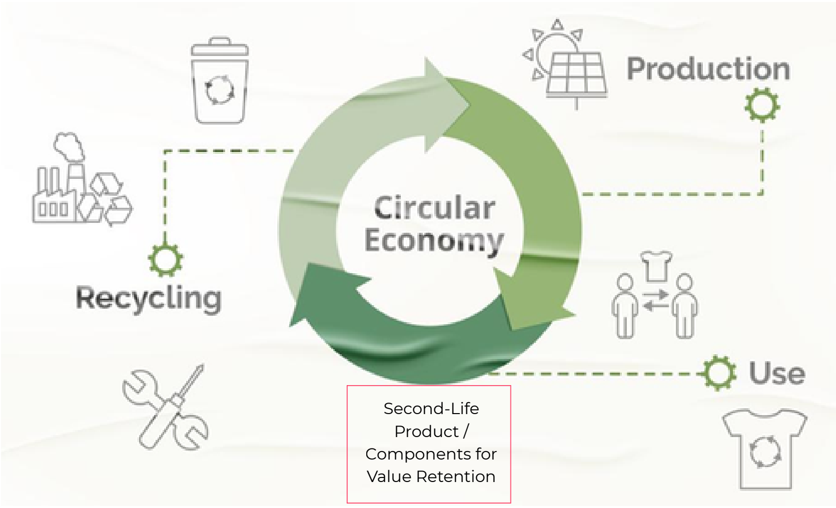
The efficiency of incumbent linear systems, optimized over decades, can make the mainstreaming of alternative circular product-service systems challenging if not immediately price-competitive – yet circularity is gaining significant traction across Europe. As of 2024, 24 EU Member States have adopted national circular economy strategies, with key initiatives focusing on research and innovation, education and awareness-raising, and financial support mechanisms.
At the EU level, several indicators demonstrate growing progress and leadership in circular implementation:

- **Circular Material Use Rate:** 11.8% in 2023 (up from 9.1% in 2010)
- **Increased intra-EU trade** in recycled metals, plastics, and construction materials within the Single Market
- **Municipal Waste Recycling Rate:** 48% in 2023 (with a 2025 target of 55%); packaging waste recycling reached 64% (notably paper, glass, and metals)
- **Circular Economy Employment:** Over 4.5 million jobs in circular sectors, including repair, recycling, and remanufacturing
- **Circular Economy Innovation:** Approximately 41,000 patents related to circular economy technologies filed in Europe

Crucially, the circular economy enhances Europe's resilience and strategic autonomy. In an increasingly unstable global context marked by supply chain disruptions and geopolitical uncertainty, reducing dependence on external resource inputs is essential. Circular systems strengthen Europe's capacity to withstand external shocks while reinforcing industrial leadership.

In sum, the circular economy represents a dual transformation: it is recognized as a cornerstone of a more competitive, resilient, and autonomous Europe whilst creating a pathway to delivering a greener economy.

## 2.2 Reflections on the forthcoming Circular Economy Act




The forthcoming **Circular Economy Act (CEA)** is expected to reinforce this shift by focusing on a functioning single market for secondary materials, improved material security, and the removal of regulatory and market barriers that currently limit circular value chains. The political emphasis is increasingly on value retention, high-quality secondary materials, and cross-border circulation of resources, rather than solely on waste management. This signals a move toward systemic, value-chain-level circularity. However, while this systematic shift focusing on a functioning single market for secondary materials is a significant step forward, it is only one element of the Circular Economy.

While the forthcoming CEA addresses material loops (Recycling), the European manufacturing industrial base is struggling to capture circular value-add and associated competitive advantage. The over-emphasis in current industrial policy on "Lower R" strategies (e.g. Recycling) which stimulates materials recovery and higher-quality reprocessing and recycling - ultimately destroys the embedded energy, capital, labour, and functional value of complex components and products which a transformative approach to circularity can preserve.

The CEA does not explicitly mention the **second life of products or components** which can be faciliated through 'as-is reuse', repair, refurbishment and remanufacturing.

This can be seen as a shortcoming especially for the European manufacturing industry whereby remanufacturing represents a commercially viable circular business model. Extending the usage phase of products over several lifecycles is an essential component of achieving the transformative potential of the circular economy.
Re-prioritization of industrial policy towards higher R-strategies and creating the framework conditions for commerically viable circular business models is necessary to enable European manufacturing companies to capture circular advantage whilst delivering environmantal and societal co-benefits for EU citizens.

## 2.3 Resource Security, Dual Use & Space

Moreover, the global geopolitical landscape of 2026 highlights the importance of increasing the EU industrial base' resilience to supply-chain volatility and shocks – which mainstreaming of circular supply-chains and business models (e.g. repair, refurbishment, remanufacturing and high-quality recycling) can deliver.

In addition, circular manufacturing has a key role to play as the EU develops greater industrial and defence-driven policy where dual-use innovation is key. Further opportunities also exist for EU manufacturers' given the European Space Agency (ESA)'s goal to implement a circular economy in space by 2040 through deploying circularity in 'in-orbit servicing' - from refuelling to active debris removal to refurbishment to manufacturing and closed-loop recycling.

## 2.4 Framework Conditions for Circular Manufacturing

Europe's manufacturing sector has set ambitious decarbonisation and circularity targets, supported by significant investments from OEMs, technology providers, and suppliers. Achieving this transition, however, requires more than incremental improvements: it demands new business models, redesigned industrial systems, and the systematic deployment of value-retention strategies across product lifecycles.
Despite a comprehensive and increasingly ambitious EU policy framework, circularity in European manufacturing remains structurally under-deployed. Progress has been strongest in recycling and material efficiency, while higher-value strategies, such as reuse, refurbishment, and remanufacturing, remain marginal.

Beyond value retention, Europe must embrace value enhancement: through modular product architectures and systematic upgrade cycles, products and components can not only be preserved but actively improved over successive use-lives, generating new customer value and competitive differentiation with each iteration.
The current framework provides direction, but not yet the market conditions, infrastructure, or incentives required for scale.
As a result, a gap persists between policy ambition and industrial reality: circularity is not yet operationalised at scale. Closing this gap requires a shift from regulatory alignment to system alignment where markets, data, industrial systems, and business models are configured to reward value retention.
This makes the next phase of EU action decisive. **Circularity must now be systematically embedded into Research, Development and Innovation (RD&I) to enable industrial-scale deployment.** The challenge is not technological, but systemic and it defines the starting point for FP10.

## 3.Why Circularity Doesn't Scale

This section outlines the key challenges and opportunities in mainstreaming circular manufacturing.

- Circularity deployment in Europe is not failing due to lack of innovation, but due to lack of systemic alignment and critical mass of market pull for circular products and services.
- Most initiatives remain pilot-based and peripheral as not yet commercially viable, while core business models, KPIs, and infrastructure remain linear.
- The key barriers are predominantly economic, organisational, and systemic, rather than purely technological.
- Mainstreaming circularity requires coordinated collaboration within sectors and between sectors as well as recognising the structural market conditions which reward linear products.

### 3.1 Fragmented Industrial Deployment to Date

Fragmented Industrial Deployment to Date reveals a persistent **"circular mirage"** - visible ambition without systemic transformation: Many initiatives remain pilots at the periphery rather than embedded in the core revenue logic and KPIs of firms. Europe talks in loops (pilot projects, commitments) but its core KPIs and revenue models remain linear. For this brief, EFFRA conducted stakeholder interviews with its industry members. The interviews confirmed that **pilot-scale circular initiatives** often stay at the margins, while structural incentives, data and current procurement logics lock firms into linear "take-make-use-dispose" patterns.

Moreover, industry stakeholders also cited unclear ROI with high upfront CapEx, fragmented reverse logistics, lack of availability of high-quality, interoperability, regulatory uncertainty, and skills gaps as barriers to circularity implementation.
More fundamentally, the transition to a circular economy is not being constrained by a lack of pilots, but by a lack of transformation in how companies define success.
As the EU moves forward with binding frameworks such as the Ecodesign for Sustainable Products Regulation (ESPR), firms are required to shift from volume-driven to value-retention-based models. Yet, most companies are structurally unprepared for this shift. Their target systems, financial metrics, and incentive structures are optimised **for linear throughput, not circular performance.** Without structured interventions to build markets for circular products and services, there is a structural contradiction: **companies are expected to comply with circular regulation while operating under linear profit logics hence risking value erosion and slow adoption.**

Key metrics illustrate this gap: the EU's circular material use rate is only ~12.2% (2024), and existing policy focuses heavily on recycled-input targets (Circular Economy Act preparation) rather than product and component life-extension strategies (e.g. "as-is reuse", repair, remanufacturing and refurbishment.
The top three priority clusters for FP10 are:

- (1) Demand pull and incentive realignment (market-making, circular KPIs, procurement),
- (2) *Data and DPP infrastructure* (digital traceability, condition monitoring, interoperability), and
- (3) *Industrial-scale reverse-logistics and remanufacturing systems*.

Addressing these not only advances the European Green Deal but also underpins **Open Strategic Autonomy** and **European Defence Industrial Strategy (EDTIB)** resilience by reducing external dependencies and strengthening asset availability. One critical enabler is upgrading the Digital Product Passport into a decision-grade **DPP 2.0** (including live lifecycle/condition data) to underpin Value-Retention metrics and sustainable procurement.

At the same time, scaling circularity depends on activating key enablers. These include the integration of circular design principles (such as design for disassembly, repair, remanufacturing and upgrading), the deployment of digital and data infrastructures to enable lifecycle transparency and informed decision-making, and the expansion of industrial-scale reverse logistics systems. Upgradability plays a critical role by enabling products and components to be improved over time, extending their functional lifetime while increasing performance and economic value across successive use cycles. Advances in automation, AI, and robotics further support circular production processes, making them technically and commercially viable.

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These enablers contribute to a shift toward value retention and life-cycle optimisation, where products and components are kept at their highest utility and economic value for as long as possible. Overcoming structural barriers while activating structural enablers is essential to move from fragmented pilots to systemic, market-driven circular manufacturing in Europe.

## 3.2 EFFRA Member Perspectives

Using the ranked challenges identified by EFFRA industry members consulted in development of this brief, suggests that the main barriers are not technological alone, but **economic, organisational, and systemic**.

The most critical bottlenecks are:
1.High upfront investment with uncertain ROI
2.Weak data infrastructure and skills gaps
3.Regulatory uncertainty
4.Interoperability and system integration challenges
5.Insufficient customer demand
6.Fragmented supplier collaboration

To address these, **FP10 and the Made in Europe Partnership** must shift from supporting circular innovation to enabling **circular scale-up**, through demand creation, data infrastructure, and industrial system integration.

| Challenges | Description | Representative company insights | FP10 R&I/Policy Needs | Impact if Addressed |
|---|---|---|---|---|
| **1. Market pull & procurement demand** | Lack of **first customer** or offtake commitments means circular solutions cannot compete on cost with mature linear models. | **Company B (machinery OEM):** *"Even if 100% funded, we won't develop a circular system unless a buyer is guaranteed."* **Company A (tier supplier):** *"OEM customer demand drives all our investments; without it we stick to proven designs."* | Pilot marketing building oriented **innovation procurement** mechanisms (PCP/PPI) and **Green Public Procurement (GPP)** for circular products; integrating range of circular criteria and life-cycle costing into tenders. Use public procurement volumes to create guaranteed demand and build | **Very High** |
| **2. Value Retention KPIs & incentive gap** | Current KPIs focus on material recycling or emissions, not on keeping products/components in use. In addition, economic incentives (taxes, modulated fees) often favor recycling. | **Company D (engineering):** *"We need clear economic signals and reporting targets for reuse/reman; right now only recycled-material targets matter."* **Company C (tech provider):** *"Circularity only pays off if customers' lifetime cost is lower – need KPI frameworks capturing that."* | Develop a **Value Retention KPI framework** pilot under FP10 (e.g. for remanufacturing yield, return rates, uptime) and adjust eco-modulation or subsidies to reward repairs/refurb/upgrades versus disposal. Mandate KPI tracking in projects. | **High** |

| Challenges | Description | Representative company insights | FP10 R&I/Policy Needs | Impact if Addressed |
|---|---|---|---|---|
| **3. Reverse logistics & core availability** | Fragmented take-back systems and cross-border flows mean many "cores" (e.g. used equipment) never return to EU remanufacturers. | **Company D**: *"End-of-life assets (e.g. vehicles) often get sold abroad instead of returning; without collection incentives, cores leak away."* **Company B:** *"We see plenty of used machines, but organizing efficient pickup or exchange schemes is unsolved."* | Fund interoperable **reverse-logistics platforms**: pan-EU trials of core pooling, digital traceability for returns, and incentives (deposit schemes, trade-in credits). Clarify waste/product status to reduce administrative hurdles (ties to upcoming Circular Economy Act). | **High** |
| **4. Data, DPP & interoperability** | Critical lifecycle data (usage, condition, maintenance) is scattered or nonexistent. Existing DPP (under ESPR) is designed for compliance, not dynamic condition data. | **Company D:** *"Digital twins and traceability are key, but today data lives in silos. We need trustworthy, standardised DPPs with repair/test histories."* **Company C:** *"Catena-X/GAIA-X frameworks exist but must be operationalised for circular use-cases. Data access/privacy remain open questions."* | Support **DPP 2.0 R&D**: prototypes that record repair/reman events, real-time sensor data, certified data exchanges (aligned with CEN/CENELEC CWA 18186 guidelines). Promote common data standards (CWA 18186:2025) and testbeds. | **Very High** |

| Challenges | Description | Representative company insights | FP10 R&I/Policy Needs | Impact if Addressed |
|---|---|---|---|---|
| **5. Industrial-scale production systems** | Circular manufacturing lines (automated disassembly, inspection, reman cells) lag behind linear assembly lines. Transition is still at lab/demo scale. | **Company A:** *"Circular production steps are still add-ons. We need full-scale demonstrators where efficiency (throughput, yield) matches new-production lines."* **Company D:** *"Other industries could adopt what automotive reman does, but we lack cross-sector scaling plans."* | Fund TRL7–9 **industrial demonstrators**: end-to-end remanufacturing / service factories (with automated QC) and replication studies for new sectors. Include SME and large enterprise consortia. | **Very High** |
| **6. Regulatory & skills readiness** | Uncertainty on liability, standards and technical feasibility (e.g. safety of refurbished components) slows adoption. Skills for new circular processes are limited. | **Company C**: *"We already remanufacture brake discs per new regs, but wider parts need clear rules for safety and liability when reused."* **Company B:** *"Our engineers need training in circular design and repair. FP10 should include workforce development."* | Combine tech R&I with **standardisation & training**: develop conformity protocols for reman parts, and integrate circular economy curricula. Fund regulatory sandboxes or CWA-style guidance (built on ESPR legal mandates). | **Medium** |

### 3.3. From Barriers to Scale: Aligning Systems for Circular Manufacturing

To understand why circular economy initiatives are struggling to scale, it is necessary to distinguish between barriers operating at different systemic levels. Many challenges are often addressed in isolation thus focusing, for example, on technology or firm-level innovation, while the real constraints emerge from their interaction across the system.

The three-level framework below highlights that circularity is not hindered by a single bottleneck, but by misalignments between internal firm logics, value chain dynamics, and external market and policy conditions. By separating barriers into **intra-organisational (Level 1), inter-organisational (Level 2), and macro-systemic levels (Level 3),** this lens makes visible where interventions are required, who needs to act, and why isolated supports and interventions fail to deliver commercially oriented scalable circular value propositions.

### 3.3.1 Level 1: From Linear Factories to Circular Operations

At firm level, circularity is constrained by production systems, product design, and organisational readiness. Manufacturing lines remain optimised for throughput rather than for inspection, disassembly, and reintegration. Products are often designed with limited modularity and accessibility, creating lock-ins that prevent reuse, refurbishment, and remanufacturing. Circular processes are therefore implemented as add-ons rather than embedded into core operations.

Companies also internalise the costs of circularity, including take-back systems, warranties, and reverse logistics. This leads to uncertain returns and high upfront investment requirements. Organisational readiness further constrains adoption, as circular operations require new roles, skills, and learning processes across production systems.

Scaling circularity at this level requires embedding circularity into both product design and industrial operations. Design for disassembly / re-assembly, modularity, and upgradeability must become standard practice. Production systems must evolve toward hybrid models capable of reintegrating components at industrial scale.

Critically, modularity must be reconceived: rather than serving only economies of scale and variant management, modular architectures should be designed for upward compatibility, enabling systematic hardware and software upgrades that extend product lifetimes by a factor of three to five while continuously increasing functional performance.

Circular production processes should be prioritised as an initial step. The reuse of components, remanufacturing, and upgrading within production systems can deliver immediate value retention while building operational capabilities. Where reuse is not feasible, high-quality recovery of materials can support these higher-value strategies.

At the same time, firms must shift toward business models that capture lifecycle value. Product-service systems, upgrade models, and service-based revenues enable value creation beyond first sales and align economic logic with circular performance. This transition requires pricing and contract structures that make lifecycle value visible at the point of purchase, including total cost of ownership and uptime-based value models. Standardised buy-back and return clauses are also critical to secure predictable product flows and enable scalable circular operations.

**Level 1: Intra-Organizational (The Factory & Firm Perspective)**

*Focus: Operations, Product Design, and Internal Culture.*

| Barriers | Application | R-Strategies | Key Enablers |
|---|---|---|---|
| **Linear factories & product lock-ins:** Lines optimized for throughput, not test–disassemble–replace–re-certify. | **Product & Component** | Remanufacturing & Upgrade | Design for X |
| **Human and organizational readiness:** Changes in roles (diagnostics, grading, disassembly) and embedded learning. | **Process-wide** | Maintenance & Repair | Workforce Upskilling & Micro-Credentials |
| **Economics & pricing (Internal):** Firms internalizing costs for take-back and warranties, leading to uncertain ROI/High CapEx. | **Product** | Remanufacturing / Refurbishment / Repair | Product-Service Systems (PSS) & Lifecycle Revenue Models |

### 3.3.2 Level 2: From Fragmented Value Chains to Integrated Circular Systems

At value chain level, circularity is constrained by fragmentation, lack of coordination, and limited lifecycle visibility. Reverse logistics systems remain underdeveloped, with unpredictable return flows and significant leakage of valuable products and components outside the EU.

***Company D***: *"End-of-life assets often get sold abroad instead of returning; without collection incentives, cores leak away."*

Without reliable access to returned products, circular operations such as remanufacturing cannot scale. Lifecycle data, including usage, condition, and maintenance history, is often fragmented or unavailable. This limits the ability to assess residual value, provide warranties, and automate decision-making.

***Company D***: *"Digital twins and traceability are key, but today data lives in silos."*

Interoperability challenges and unclear governance frameworks further constrain collaboration. Companies are reluctant to share data due to concerns around access rights, liability, and intellectual property.

***Company B***: *"We see plenty of used machines, but organising efficient pickup or exchange schemes is unsolved."*

Scaling circularity at this level requires integrated and data-driven value chain systems. Reverse logistics must be developed into industrial-scale infrastructure, supported by incentives that ensure predictable return flows and retain value within the EU. Aggregation mechanisms and shared infrastructure are necessary to pool volumes across actors. Multi-brand hubs for collection, testing, and grading can stabilise flows and support SME participation, while chain-of-custody systems help prevent leakage and preserve value.

Digital Product Passports (DPP) must evolve into operational systems that support decision-making across the lifecycle. These systems must capture bills of materials, usage data, component and product condition, and repair history, and be supported by standardised data contracts that define access rights, liability, and intellectual property.

Advanced analytics and machine learning can further support predictive maintenance, grading, and routing decisions.

More fundamentally, value chains must evolve toward distributed value creation models. This requires contractual frameworks that shares value created across actors and develops risk-sharing mechanisms that stabilise circular flows and support investment.

**Level 2: Inter-Organisational (Value Chain, Clusters & Sectors)**
*Focus: B2B Relationships, Data Exchange, and Power Dynamics.*

| Barriers | Application | R-Strategies | Key Enablers |
|---|---|---|---|
| **Power shifts along value chains:** Migration from raw materials to software, data analytics, and reuse logistics. | **Component & Data** | " As is Reuse"; Repair; Maintenance | Value-sharing and multi-actor governance models across value chains |
| **Collaboration vs. competitiveness:** Hesitation to invest in neutral hubs or data spaces due to IP concerns. | **Material & Component** | Remanufacturing | Trusted data-sharing frameworks; neutral data spaces and infrastructure *(e.g. Catena-X type)* |
| **Data gaps across lifecycles:** Need for operational data (condition, load cycles) to price residual value and underwrite | **Component** | Refurbishment & Repair | Operational Digital Product Passports (DPP 2.0) |
| **System fragility & "glass roof":** Dependencies on partners' waste streams; value capture collapses if one link fails. | **Material & Component** | Recycling (Lower R) to Reman (Higher R) | Stabilisation of value chains through aggregation mechanisms; distributed lifecycle manufacturing networks (e.g. microfactories) |

### 3.3.3 Level 3: From Linear Markets to Circular Market Design

At system level, the primary barrier to scaling circularity is market design. Current market structures continue to prioritise upfront cost over lifecycle value. Procurement practices rarely reward durability, upgradeability, or total cost of ownership, limiting demand for circular solutions and reinforcing linear production models.

***Company B (machinery OEM)***: "*Even if 100% funded, we won't develop a circular system unless a buyer is guaranteed*."

At the same time, policy frameworks remain skewed toward recycling and material recovery, with insufficient incentives for higher-value strategies such as reuse, refurbishment, and remanufacturing.

***Company D (engineering)*****:** "*We need clear economic signals and reporting targets for reuse/reman; right now only recycled-material targets matter.*"

This misalignment is compounded by pricing structures that fail to reflect lifecycle value. Circularity redistributes value across the lifecycle, yet firms are required to internalise costs such as take-back systems, warranties, and reverse logistics, resulting in uncertain return on investment and high upfront capital expenditure. Scaling circularity therefore requires a deliberate redesign of market conditions.

Circularity will not scale unless markets reward value retention. This requires lifecycle-based procurement, performance-based tendering, and market-shaping instruments that create predictable demand for circular solutions. Procurement frameworks must recognise the equivalence of remanufactured and refurbished products, while rewarding durability, upgradeability, and lifecycle performance. Tools that make lifecycle value visible, including total cost of ownership and uptime-based models, must be systematically applied.

This must be supported by lifecycle cost optimisation approaches that enable a shift from upfront capital expenditure to lifecycle-based investment logic, including models that balance capital and operational expenditure over time.

**Fiscal frameworks** must also be aligned. Differentiated tax regimes, eco-modulated fee structures, and targeted incentives for repair, refurbishment, and remanufacturing are required to correct current distortions and reward higher-value circular strategies.

A **harmonised framework** for value-retention KPIs is needed to guide investment, procurement, and reporting. Moving beyond recycling metrics toward lifecycle performance indicators, such as reuse rates, remanufacturing yield, and product uptime, is essential to make circular value visible and bankable.

**Regulatory fragmentation** continues to limit scale. Inconsistent definitions, particularly around waste and resource classification, create uncertainty and administrative burden, restricting cross-border flows and slowing adoption.
Establishing a Single Market for second-life products and components is therefore critical. This requires harmonised rules on classification, liability, and cross-border movement, as well as EU-wide standards and interoperable interface definitions that enable circular products and components to move seamlessly across value chains.

Clear certification pathways and equivalence frameworks for remanufactured and reused products must be developed, supported by lifecycle data and Digital Product Passport evidence. Harmonised definitions are essential to enable reintegration and cross-border circular flows.

At the same time, reverse logistics and grading infrastructure remain underdeveloped across Europe, preventing circular systems from operating efficiently. These must be developed into industrial-scale, distributed infrastructure networks. This includes decentralised collection, testing, and reassembly capabilities, supported by neutral, multi-actor hubs and coordinated across regions. Such distributed lifecycle manufacturing systems enable both reverse logistics and reintegration at scale, stabilising circular flows across the Single Market.

Public and co-investment models are required to establish this infrastructure as a strategic industrial asset, comparable to energy or transport networks. More broadly, regulatory frameworks must become more adaptive to support system innovation. Regulatory sandboxes and experimental frameworks are needed to enable testing of circular business models, digital systems, and cross-border logistics solutions under real-world conditions.

Finally, **circularity must be embedded within Europe's strategic autonomy agenda**. Retaining products, components, and materials within the EU strengthens industrial resilience and reduces external dependency. This requires targeted de-risking mechanisms, including EU-backed guarantees, blended finance instruments, and lifecycle-based financing models. Residual value must be recognised within financial systems, enabling its use as collateral and supporting investment in circular business models. Risk-sharing mechanisms, including insurance frameworks for reused and remanufactured components, are essential to accelerate market trust and adoption.

**Level 3: Macro-Systemic (Market, Regulation & Infrastructure)**
Focus: Policy, Logistics, and Cross-Border Flows.

| Barriers | Application | R-Strategies | Key Enablers |
| --- | --- | --- | --- |
| **Misaligned market incentives & pricing structures:** Circularity redistributes value across the lifecycle, yet markets and procurement remain focused on upfront unit price. This forces firms to internalise costs (take-back, warranties), resulting in uncertain ROI and high CapEx. | **Market / Profit** | Reuse, Refurbishment, Remanufacturing | Lifecycle-based procurement, Lifecycle cost optimisation models |
| **Fragmented regulatory frameworks & lack of EU-wide standards:** Inconsistent rules (e.g. waste vs. resource classification, certification pathways) create uncertainty, delays, and limit cross-border scaling of circular solutions. | **Policy** | All R-strategies (system enabler) | Harmonised EU definitions,) single market for second-life products and components, EU wide-interoperable standards |

| Barriers | Application | R-Strategies | Key Enablers |
|---|---|---|---|
| **Underdeveloped reverse logistics infrastructure:** Return flows remain unpredictable, cross-border shipment rules differ, and illegal exports undermine compliant systems thus, preventing reliable circular value chains at scale. | **Logistics** | Repair, Refurbishment, Remanufacturing | Industrial-scale reverse logistics systems |
| **Regulatory rigidity and slow adaptation to innovation:** Existing frameworks are not designed for AI, cross-border flows, or circular system innovation | **Policy/Innovation** | All R-strategies | Regulatory sandboxes for circular systems |

### 3.3.4 Reflections: From Pilots to System Alignment

Circularity in Europe is not constrained by a lack of innovation but by a lack of system alignment. At firm level, industrial systems are not designed for value retention. At value chain level, reverse flows and data remain fragmented.
At system level, markets and regulation continue to reward linear models. The result is a persistent gap between circular ambition and industrial deployment. Closing this gap requires a shift from fragmented pilots to coordinated system intervention aligning demand, data, infrastructure, and business models around value retention.

Circularity in European manufacturing is constrained by misalignment across firms, value chains, and market conditions. The missing link is not technology, but the absence of business models and system enablers that translate circular value into viable economic outcomes. Circularity will not scale unless value retention becomes investable, contractible, and operational across the lifecycle. The key enablers required are focused on Circular Business Models they are summarised below (see table in Section 3.4).

## 3.4 Key enablers of Circular Business Models

Reflecting the challenges reported as hindering commercially scalable industrial deployment of circularity by EFFRA Members' the table below summarises the enablers of circular business models (CBM)s.

| Key Enablers of Circular Business Models | |
|---|---|
| Demand formation and fair pricing | • Performance-based procurement that recognises reman/refurbished/reuse equivalence and rewards durability/upgradeability.<br>• Simple TCO/uptime calculators and warranty frameworks to make lifecycle value visible at purchase.<br>• Standard buy-back/return clauses to secure predictable flows for reuse/remanufacturing/refurbishment. |
| Shared, bankable reverse logistics | • Regional (brand?) neutral hubs for collection, testing, and grading (multi-OEM) to stabilise volumes for SMEs.<br>• Digital chain-of-custody to cut leakage/illegal exports and preserve value in the EU. |
| Data, DPP and risk-sharing | • Move from compliance-only to operational DPP: condition/use data for pricing, grading and warranties in PSS.<br>• Interoperable data contracts (access, liability, IP) plus AI/ML for predictive maintenance and automated grading.<br>• Insurance/risk pools for reused components to accelerate market trust. |
| Factory & Product Service System (PSS) Reconfiguration | • Design–operations handshake: modularity, testability, fast access; lines capable of reintegrating components at takt.<br>• Internal circularity first: rework/reuse scrap and rejected parts on site with quality gates and traceability.<br>• Robotics for disassembly/sorting and adaptive testing for mixed returns. |
| Finance & accounting innovation | • Capex-to-opex bridges for PSS ramp-up and data infrastructure; residual-value registers lenders accept as collateral.<br>• Outcome-linked incentives that reward life extension instead of tonnage recycled, avoiding “loop competition”. |
| Standards, certification and legal clarity | • Equivalence classes and fast-track conformity for remanufactured and reused modules supported by DPP evidence.<br>• Harmonised definitions to enable cross-border flows and reintegration and life-extension of materials, components and products. |
| Circularity Skills Development & Culture | • Embedded micro-credentials for circular operations (grading, disassembly, data stewardship) delivered in-work, with facilitators. |

## 4. R&I Priorities

The section's core point is that shifting from Closing the Loop (recycling) to Slowing the Loop (life extension) won't happen through "more pilots." FP10 has to fund the industrial and market infrastructure (reverse logistics, grading, rebuild capacity, data rails, certification, procurement pull / procurement as market building) and add accountability (KPIs, follow-up reporting) so reman/refurb/reuse becomes commercially viable at scale, especially in professional B2B contexts where assets, service networks, and warranties are decisive. This is the "how" that enables moving 35–40% of circular funding toward Higher-R strategies, with explicit focus on Professional Right to Repair and B2B operations.

To turn circularity from peripheral pilots into core industrial practice, FP10 must fund not only technologies but also the market-building infrastructure and accountability mechanisms that make higher value-retention strategies bankable at scale. The actions below summarise the EFFRA Working Group member's recommendations for concrete funding instruments and programme requirements.

### 4.1 Short Term: 2026-2027

**Key Objective: Make Circularity Mainstream, Measurable & Investable**

- **Mandate and budget for continuous circular market studie**s: Commission led recurring EU-wide, sector-specific market intelligence (e.g., for remanufacturing, refurbishment and 'as-is-reuse') covering demand, price formation, return-flow availability and quality, and barriers. Use the output to steer call topics, set realistic KPIs and identify where EU action can unlock circularity at scale.

- **Make FP10 a circular economy agenda, not a side topic:** Treat circularity as a cross-cutting programme objective: require a circularity pathway in all relevant manufacturing calls (design, factories, logistics, data, business models) and introduce minimum circular economy relevance criteria in evaluation, rather than isolated CE-only topics.

- **Integrate circular economy targets into digital transformation calls**: Incorporate high-R strategies into digital calls (AI, digital twins, automation, data spaces) by requiring operational DPP readiness, circular metrics and interoperable data-sharing arrangements (contracts, liability, cybersecurity) that enable grading, repair and reintegration decisions. Position these as "process calls": fund the physical circular operations (inspection → grading → disassembly → rebuild → recertification) as the core, with data as the booster that drives efficiency, automation and scale.

- **Embed Design for X and multiple use-lives in product development grants**: Make modularity, de-manufacturing, disassembly & re-assembly access, testability, upgradeability and recertification-by-evidence explicit eligibility conditions for product innovation projects. Reward designs that achieve multiple economically viable use-lives and can be serviced through standardised modules and processes.

- **Introduce gate-based funding funnels with automatic follow-on**: Design calls as staged funnels (e.g., TRL 4-6-8) with pre-defined milestones and automatic continuation for projects that meet evidence thresholds. This reduces administrative friction and prevents promising pilots from dying between programmes.

- **Tie R&I funding to post-project circular impact reporting**: Require projects to report a small set of harmonised circular impact KPIs after completion (e.g., verified life extension, share of service revenue, return-flow reliability, reuse/reman vs recycling loop mix, cost parity progress). Use light-touch follow-up reporting windows (e.g., 12/24/36 months) to drive accountability and learning.

- **Embed CE micro-credentials into all manufacturing R&I programmes:** Fund in-work micro-credentials for circular roles (diagnostics, grading, disassembly, data stewardship, warranty management). Make skills packages a standard work package in technology-heavy projects to accelerate adoption on the shopfloor.

- **Integrate requirements for social aspects and market viability assessments in R&I projects:** Highlight the need for active participation of Social Sciences in R&I projects, to ensure citizen's position in a central role, while demonstrating the financial viability of the innovations to support competitiveness and profit for the industry.

## 4.2 Medium-Term: 2028-2033

**Key Objective: FP10 scaling higher R-strategies & enabling infrastructure**

FP10 should prioritise calls that deliver measurable value retention on both existing product populations (brownfield first) and next-generation products designed for multiple use-lives. Calls should explicitly support the industrial infrastructure needed for commercially scalable circularity to mainstream circular practices: retooled factories, reverse logistics, operational data rails, and procurement-led demand formation and market building—so advanced circular strategies move from pilots to repeatable, cost-competitive industrial deployment.

**Critical – Very High Priorities**

- **Funding calls on Redesign Production-Lines Around Disassembly & Rebuild -** Fund retooling and advanced hybrid circular production systems able to test, disassemble, replace modules, re-certify and reintegrate components at industrial takt times (including automation/robotics, adaptive testing and quality gates). Prioritise factory demonstrators with measurable throughput, yield, quality assurance and cost-down trajectories.
- Service-set-up option (important implementation route): Recognise that many OEMs optimise main plants for new high-volume production, while phase-out / end-of-series activities are often handled in service locations. Calls should therefore explicitly allow (and incentivise) service-centre-based disassembly/rebuild capabilities—including tooling, certification, spare/module logistics, digital QA workflows, and coordination with central factories—so rebuild/upgrade operations can scale even when the primary production line remains dedicated to new products.

- **Finance Data Frameworks for Automated Reuse and Remanufacturing** Develop interoperable data and AI frameworks that route returned products to the highest feasible value-retention loop using inspection and usage signals (e.g., vision systems, predictive analytics). Fund the "data rails" that orchestrate grading, disassembly, sorting, reassembly and QA workflows—supported by standardised interfaces and contracts for lifecycle data sharing (access rights, liability, IP protection, cybersecurity) so DPP data becomes operational, not just compliant.

- **Fund Meaning-Shifting Products Where Circular Features Create Higher Customer Value** Support demonstrators that redesign products so circular features create higher customer value (performance, reliability, upgrade options, guaranteed service levels). Prioritise projects that prove cost/quality parity trajectories and deliver replicable playbooks for disassemble-rebuild-upgrade-reintegrate pathways.

- **Require Business-Model and Pricing WPs in Every Tech project** Make business-model, pricing, contract and warranty design (e.g., product-service systems, take-back clauses, residual value models, service SLAs) a mandatory work package in technology-heavy projects. Score proposals on verified life-extension, retained value, and service-revenue share—not pilots alone.

- **Fund Internal Circularity Projects That Reuse Scrap and Rejected Parts** Back industrial projects that recover and reintegrate manufacturing scrap, rejects and off-spec components into qualified secondary loops (within plants and across supplier networks). Focus on traceability, sorting/grading, requalification protocols, and process redesign that measurably reduces virgin input demand and disposal while maintaining performance and safety requirements.

- **Support Sector Specific Roadmaps for Scaling Advanced Circular Strategies** Fund sector roadmaps (e.g., electronics, mobility, textiles, appliances, industrial equipment) that align technical standards, certification, reverse-logistics design, data requirements, and financing mechanisms to scale higher R-strategies. Ensure roadmaps translate into callable investment pipelines (pilots → scale demonstrators → replication).

- **Interaction with EC through policy recommendation work package** Require a dedicated WP that translates technical evidence into implementable policy options and guidance for the European Commission (and relevant DGs). Deliverables should include policy briefs tied to project results (standards, incentives, EPR design, procurement criteria, DPP operationalisation), plus structured consultation moments (e.g., mid-term and final recommendation packages).

- **Research towards better understanding and modeling ecosystem dynamics** Fund research that models how circular value chains behave in the real world—feedback loops, rebound effects, capacity bottlenecks, price/quality parity dynamics, behavioural adoption, and policy-market interactions. Emphasise models that can be parameterised with industrial data and used to stress-test interventions before scaling.

- **Structured framework to assess business case and viability for different actors (Manufacturers/ EOL providers/ consumer/ raw material producers) -** Develop a harmonised assessment framework (methods + templates + KPIs) to quantify costs, value capture, risks and incentives across actors—OEMs, refurb/reman providers, logistics, recyclers, consumers, and virgin material producers. Include residual value logic, liability/warranty implications, data access costs, financing needs, and distribution of margins—so proposals can demonstrate bankable viability, not only technical feasibility.

- **Circularity of high investment long lifetime products (refurbish, servitisation, repurposting, re-x)** Prioritise programmes targeting capital-intensive, long-life assets (industrial machinery, medical devices, rail, aerospace subsystems, energy infrastructure), where value retention yields outsized economic and strategic benefits. Fund refurb/reman certification pathways, servitisation and uptime-based contracts, repurposing routes, and "re-X" options (requalification, reconfiguration, redeployment) supported by monitoring, maintenance and traceability.

- **Systemic view (e.g., CLD) on EFFRA project portfolio & actions** Introduce a cross-portfolio, systems engineering layer—using causal loop diagrams (CLDs) and complementary system mapping—to identify leverage points, overlaps, missing enablers and unintended consequences across the EFFRA-aligned FP10 portfolio. Use it to steer call topics, align KPIs, and sequence investments (data → logistics → factory → market pull) for cumulative impact rather than isolated projects.

**High Priority**

- **Assign JRC a mandate and Budget for Continuous Circular Market Studies** Provide a standing mandate and resources for ongoing market intelligence: cost curves, quality/performance parity tracking, capacity mapping (reverse logistics, testing, remanufacturing), barrier analysis, and sector readiness indicators—feeding directly into FP10 call design and evaluation criteria.

- **Use Public Procurement to Reward High-R Strategies and Cost Parity** Use pre-commercial procurement and outcome-based tender criteria to create demand for remanufactured/refurbished solutions and durable, upgradeable products. Reward contracts that prove life extension, uptime and resource savings (and demonstrate credible cost parity trajectories), accelerating market pull.

- **Launch Neutral Regional Reverse-Logistics and Grading Hubs** Co-fund multi-OEM, neutral hubs for collection, testing and grading, with clear governance, common processes and digital chain-of-custody. Align with EPR-linked financing to stabilise volumes, improve sorting quality, and preserve value across the EU.

**Medium Priority**

- **Fund Brownfield Reuse Pilots on Existing Product Fleets** Prioritise upgrade and value-retention programmes for equipment already on the market (retrofits, module upgrades, refurbishment and remanufacturing pathways), so impact is delivered before new design generations reach end-of-life—while building the evidence base and operational playbooks for scale-up.

### 4.3 Long-Term: 2034 & Beyond

**Key Objective: Single Market for Second-Life Value**

- To sustain competitiveness after FP10, Europe should complement R&I grants with market architecture, financial de-risking and regulatory clarity so higher R-strategies become the default investment choice.

- **De-risk higher R-strategies with insurance schemes and risk-sharing funds:** Create EU-backed insurance and risk pools that underwrite warranties and performance guarantees for reused/remanufactured components, accelerating trust and adoption.

- **Create an EU-wide advanced circularity index and sector scoreboard:** Establish an authoritative index that benchmarks circular performance (life extension, value retention, reuse/reman rates, leakage avoided) by sector, guiding policy, capital allocation and procurement.

- **Develop a European circular target compass for industrial decision-makers:** Provide a practical target-setting and decision framework linking product strategies, factory investments and data requirements to measurable circular outcomes, helping companies navigate changing target systems.

- **Establish residual-value registers for second-life assets:** Develop registries and valuation methods that lenders can accept as collateral, enabling investment in product-service systems and second-life markets.

- **Harmonise EU rules on waste-versus-resource to enable cross-border flows:** Clarify when components and materials are resources rather than waste, reducing friction and enabling compliant cross-border reverse logistics.

- **Create fast-track certification routes for refurbished and remanufactured components:** Develop equivalence classes, test protocols and evidence-based recertification pathways so second-life components can be legally and rapidly reintegrated.

Across all stages, calls should explicitly prioritise higher value-retention loops over end-of-life recycling where feasible, and reward projects that demonstrate scalable economics, reliable return flows, interoperable data and verified post-project impact.

## 5. Key Takeaways

### 5.1 Embed Circular RD&I in the DNA of FP10

FP10 should operationalise the shift from “Waste → Value” by moving circular funding away from end-of-life recycling and toward Higher-R life-extension strategies, especially in professional B2B markets and through Professional Right to Repair. That requires not only new technologies but industrial rebuild capacity, neutral reverse logistics and grading, operational data rails (DPP-ready), procurement-driven demand, and post-project KPI accountability—so remanufacturing, refurbishment and reuse become repeatable, cost-competitive, and financeable at scale across the EU.

### 5.2 Establish a Single Market for Value Retention Operations

The CEA aims at a single market for secondary raw materials, but does not (yet) articulate a single market for used products/cores/components suitable for remanufacture / refurbishment where legal status, liability, and cross-border movement are key.

### 5.3 Establish EU standards for “remanufactured” conformity

Harmonized approaches for demonstrating equivalence, safety, performance of remanufactured industrial goods and components are critical to mainstream circular business models particularly in regulated sectors and via public procurement.

### 5.4 Evolve the Waste Framework Directive for Circularity

Many circular value propositions related to industrial symbiosis, upcycling and remanufacturing fail because components / cores or products become classified as “waste” too early, triggering burdens not proportional to risk and blocking cross-border scaling.

### 5.5 Create Market Incentives for Value Retention Operations

Current policy emphasis and related market signaling privileges recycled materials / commodity markets without comparable instruments for value retention (repair/remanufacture), capital flows therefore are more likely to follow recycling-centric infrastructure relative to broader value retention business models / value propositions.

### 5.6 Embed circular manufacturing within dual-use innovation

Defence initiatives exist (EDIS/EDIP; EDA IF CEED), but there is no explicit bridge that treats value retention capacity as a security-of-supply asset in industrial policy.

## R&I Brief

European Factories of the Future Research Association (EFFRA)

Completed in April 2026 by the EFFRA's Working Group **Circularity**

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