FEICA The European voice of the adhesive and sealant industry

Brussels, 18 May 2026

Position Paper on Debonding-on-Demand (DoD)

This paper outlines the concept of Debonding-on-Demand technologies, their purposes and applications, and the considerations needed when discussing their role in EU sustainability policies[1]. Therefore, with this paper, **FEICA urges the European Commission to**:

1. **Acknowledge and implement FEICA's proposed definition** of Debonding-on-Demand.
2. Apply in EU sustainability policies a **technology-neutral approach** and assess the effects of DoD adhesives on a **case-by-case basis**, taking into account the repair or recycling path relevant to each product category placed on the EU market.

Context

As the EU advances its circular-economy goals, the A&S industry has been developing Debond-on-Demand (DoD) solutions that support repair, reuse, repurposing, and high-quality recycling across a wide range of sectors, including medical equipment, textiles, packaging, construction products, electronic devices, automotive, transport and others. DoD technologies allow bonded materials to be separated, improving circularity whilst maintaining the required level of performance during the life cycle of the product.

This paper outlines the concept, applications and policy considerations for integrating Debond-on-Demand into EU sustainability frameworks with a technology-neutral approach.

Definition of Debonding-on-Demand

Debonding-on-Demand serves maintenance, repairability and recyclability of products. By Debonding-on-Demand, we understand **the separation of bonded materials, triggered by a controlled change** of adhesive strength based on **chemical, physical and/or mechanical effects** or processes. These triggers allow for debonding within a **practical time frame**.

Debonding-on-Demand should be understood as a functional umbrella term encompassing a wide range of technically distinct approaches. The feasibility, impact and suitability of these approaches vary significantly depending on the specific product design, adhesive application, exposure conditions during use and end-of-life process, as well as on their implications for repairability, recyclability, process compatibility and safety. As a result, Debonding-on-Demand solutions cannot be assessed in a uniform manner and require differentiated, case-specific technical evaluation.

[1] This includes, but is not limited to, the following EU legislation: Ecodesign for Sustainable Products Regulation ('ESPR', 2023/1542); Packaging and Packaging Waste Regulation (2025/40); Circular Economy Act; Advanced Material Act. The regulatory imperative for Debonding-on-Demand has been further strengthened by the adoption of the Directive on common rules promoting the repair of goods (the 'Right to Repair Directive' 2024/1799), to be transposed by Member States by 31 July 2026. This Directive establishes a manufacturer's obligation to repair certain consumer products, prohibits practices that impede repair, and extends the statutory warranty by twelve months when consumers opt for repair. Together with the Ecodesign for Sustainable Products Regulation and the Directive on empowering consumers for the green transition (2024/825), it creates a comprehensive legislative framework covering the entire product life cycle from design to end-of-life in which DoD adhesives play a direct enabling role.

The time frame for DoD processes may differ per product, i.e. adjusted to the product needs and end-of-life processes. **Feasible time frames may vary significantly**, depending on the debonding technology or process.

A systematic overview of debonding methods can be found in **ISO 21037:2026**, which provides a guideline for separating adhesively bonded joints enabling repair and improving recycling.

Purposes and applications

Debonding-on-Demand technologies can provide, **on a case-by case basis**, practical **solutions both for repair** during a product's use phase **and for material recovery and recycling** at end-of-life. Depending on the product category, DoD solutions may prioritise either repair or recycling, as optimising both objectives simultaneously is not always technically feasible. This flexibility enables designers in different sectors to choose the most appropriate circularity strategy for each product category. To fully harness this potential, **regulation should remain open and outcome-oriented**, allowing the value chain to identify the best solutions rather than imposing technology lock-ins or unnecessary burdens that hamper innovation.

Repair[2]

For long-lived products (e.g. mobile phones, cars), designed for reusability, repairability and repurposing, DoD technologies allow bonded materials to be **separated efficiently when needed**. Specific needs and requests could include **debonding without leaving residues, maintaining substrate integrity**, and allowing the separated materials or components to be replaced, reused, repaired or re-bonded.

Recycling

In products designed for short lifetimes (e.g. food packaging), where material recovery is generally prioritised, **certain Debonding-on-Demand adhesive concepts may support efficient and high-quality recycling,** provided that the debonding mechanism is compatible with targeted industrial

[2] The Right to Repair Directive reinforces this relevance by requiring manufacturers to offer repair services for Annex II products at a reasonable price and time frame, including beyond the warranty period. For adhesively bonded products such as smartphones, tablets, displays and household appliances, DoD technologies enable controlled component separation (e.g. batteries, displays, seals) without substrate damage, directly addressing the Directive's prohibition of practices that impede repair. The twelve-month warranty extension for repaired products and the annual expansion of Annex II is expected to progressively widen adoption of DoD adhesives across the repair economy. The European Commission should ensure that Right to Repair Directive Annex II expansions and ESPR repairability assessments recognise the contribution of DoD adhesives to non-destructive disassembly and component-level repair.

recycling conditions. **Recycling-compatible adhesive** systems and material combinations that are intrinsically compatible with the recycling processes, or that can **even enhance recycling performance**, contribute to closing material loops. Adhesive residues generated during debonding do not necessarily hinder recyclability; in many cases[3], material compatibility is maintained, ensuring high-quality recycling outcomes.

For concrete examples of DoD adhesives applications in different sectors, please refer to Annex I.

Conclusion

DoD adhesive technologies provide a valuable contribution to the EU's circular economy objectives by enabling controlled separation for repair, refurbishment, reuse and material recycling—while preserving strong bonding performance during use. It must be recognized that Debonding-on-Demand technologies involve inherent trade-offs between durability during use and controlled separation at later stages. These trade-offs are application-specific and must be assessed accordingly. Please refer to Annex II for more concrete examples of such trade-offs. Their ongoing development across sectors demonstrates that these solutions can support diverse product-specific sustainability objectives, provided they are assessed in the context of appropriate repair or end-of-life routes.

Existing and emerging DoD technologies can inform future EU repairability and recycling requirements. To support such innovation while keeping sustainability rules effective and proportionate**, the European Commission should**:

1. Formally **recognise and adopt FEICA's definition** of Debonding-on-Demand, ensuring harmonised interpretation across EU sustainability legislation and technical assessments.
2. **Ensure technology neutrality** across all current and upcoming EU sustainability policies. Adhesives should **not be evaluated by blanket rules**, but rather by case-by-case assessments targeted to the specific repair and recycling pathways relevant to each product group on the EU market.

[3] For instance, mono-material adhesive concepts designed to match the chemistry of the bonded substrate (e.g. polyolefinic adhesives on polyolefin substrates).

Annex I

Below, readers can find concrete examples of DoD adhesive applications in different sectors.

Automotive

In the automotive sector, DoD adhesives enable the disassembly and easy removal of components[4], parts or materials. This facilitates repair[5,6] and rework/redesign[7] during manufacturing and maintenance without damage[8], and supports the achievement of recycling and recovery[9] targets established under the End-of-Life Vehicles Regulation.

When employed in electric vehicle batteries, DoD adhesives can be used to bond battery cells to cooling plates. At the repair stage or at battery end-of-life, damaged battery modules can be disassembled without destroying surrounding components, enabling refurbishment or targeted material recovery.

The examples below provide insights into the respective debonding technologies and access to FEICA's members patented solutions for the automotive sector:

1. Example 1: Electrically triggered debonding[10] is a prominent example of a debonding technology. The adhesive is applied between two electrically conducting substrates, which enable high bond strength providing structural properties. This allows for high performance and safety throughout a product's use phase. If the bond is to be disassembled, electricity is applied performing the debonding process. This allows for easy disassembly, for example, by hand. The process can be adapted to the scale of the to be debonded area and application.
2. Example 2: Thermal treatment is the most common method for creating debondable adhesives[11]. Almost all polymeric adhesives can be thermally debonded due to their melting or decomposition at specific temperatures. One approach to make the process feasible at lower temperature is using thermally expandable microspheres. When heated, they expand rapidly, generating internal pressure. This pressure disrupts the adhesive's structure, weakening

[4] Cf. the following publicly available sources for automotive headlamps and EV batteries: https://next.henkel-adhesives.com/in/en/debonding-landing-page.html?gad_source=1&gad_campaignid=22125627104&gclid=EAIaIQobChMIzObUsrHvkgMV3LCDBx0WKwnpEAAYASAAEgIdMPD_BwE

[5] Cf. the following publicly available sources: Henkel, TEROSON® BOND 15- Features and Benefits, 2024, https://www.henkel-adhesives.com/de/en/product/windshield-adhesives/teroson_bond_150.html ; Sika, Glass Replacement Systems, 2024, https://automotive.sika.com/en/solution-products/assembly-line-adhesives/glass-replacement-systems.html ; 3M, 3MTM Windshield Repair Kit, 2024, https://www.3m.com/3M/en_US/p/d/b40069636/ ; Henkel, Repair a Cracked Bumper, 2024, https://www.henkel-adhesives.com/de/en/applications/all-applications/how-to/repair-cracked-bumper.html ; Sika, Adhesives for Composite Systems, 2024, https://industry.sika.com/en/home/advanced-resins/composite-resin-systems/adhesives-for-compositesystems.html ; How to Bond Carbon Fiber, Permabond, 2024, https://www.permabond.com/materials_bonded/how-to-bond-carbon-fiber-2/ ; P Kovács, Adhesive Bonding of Carbon Fiber Reinforced Polymer Composite, IOP Conference Series: Materials Science and Engineering 1313 (September 1, 2024): 012019, https://doi.org/10.1088/1757-899X/1313/1/012019; 3M, Bonding and Assembly - Adhesives for Composite Material Applications, 2024, https://www.3m.com/3M/en_US/bonding-and-assembly-us/composite-bonding/ ; Panther Tools Eco Cut Windshield removal tool - YouTube- ; PP-WST100 Panther Cut Pro System ; PP-WST80 27 Piece Knife & Scraper set ; Windshield Replacement with SikaTack® ELITE

[6] Cf. ISO (2026). ISO 21037:2026 — Adhesive bonding — Separation methods for adhesively bonded joints. International Organization for Standardization, Annex A.2.1 and Annex A.3.1.2.2

[7] Cf. the following publicly available sources: Henkel, Automotive Gasketing Solutions, 2024, https://www.henkel-adhesives.com/de/en/industries/automotive/automotive-gasketing-solutions.html ; Austin Weber, New Technology for Form-in-Place Gaskets, 2024, https://www.assemblymag.com/articles/98576-new-technology-for-form-in-place-gaskets; Sika, Polyurethane – The Windshield Adhesive, 2024, https://industry.sika.com/en/home/knowledge-hub/polyurethane-windshield-adhesive.html ; Bostik, Airbag Adhesive Films, 2025, https://www.bostik.com/us/en_US/markets-applications/automotive/automotive-assembly/automotive-interior/airbag/ ; Airbag Industry, PPI Adhesive Products, 2024, https://www.ppiadhesiveproducts.com/segment/airbag-industry

[8] Henkel, Structural Bonding Solutions, 2024, https://next.henkel-adhesives.com/us/en/applications/structural-bonding-solutions.html

[9] Cf. the following publicly available sources: Dominik Goes et al., Separation of Adhesive Joints of Pouch Cells in the Context of Battery Module Disassembly (ELSEVIER, 2024), https://www.sciencedirect.com/science/article/pii/S2214993724003543 ; Yuchen Lu, James Broughton, and Pat Winfield, A Review of Innovations in Disbonding Techniques for Repair and Recycling of Automotive Vehicles (RADAR, 2014), https://www.sciencedirect.com/science/article/pii/S0143749614000220 ; Innovative Adhesive Solutions for the Automotive Industry - Strong Connections for a More Sustainable Future (Tesa, 2024), https://www.tesa.com/en/files/download/11062803,3,tesa-innovatine-adhesive-solutions-for-the-automotive-industry.pdf ; Henkel, Innovating for Zero-Emission Mobility, 2024, https://www.henkel.com/our-businesses/adhesive-technologies/about-us/innovating-for-zero-emission-mobility-1937652

[10] Cf. the following Henkel's patents: Electronics assembly having electrochemically debondable components' (2023, pending) ; 'Curable and debondable two-parts (2K) thermally conductive adhesive composition' (2023, pending)

[11] Cf. the following Henkel's patents: 'Water-based thermally debondable primer composition' (2023, pending) ; 'A thermally debondable primer composition' (2023, pending)

the bond between the joined surfaces. As a result, the bonded parts can be separated with minimal force. This controlled thermal debonding process offers a clean and efficient way to disassemble adhesive joints without damaging the underlying materials.

Electronic devices

For electronic devices, manufacturers must combine durable product design with the possibility of safe and efficient repair. For these products, adhesives and sealants are widely used to ensure protection against moisture, dust and mechanical stress. DoD solutions provide access to internal parts when repair or replacement[12,13] is required, thereby extending product lifetimes and reducing electronic waste.

Textiles and footwear

The use of adhesive for bonding different materials for textiles allows for high-performance applications such as sports shoes or creative fashion designs. DoD adhesives ensure the separation of multilayer materials at end-of-life for efficient recycling and re-manufacturing of textiles, for example, of footwear[14].

Packaging

Debonding on demand is a critical requirement for reaching the recycling goals of flexible packaging according to the Packaging and Packaging Waste Regulation (PPWR). An example for this is found in PET/PE multilayer food trays[15], where the PE sealing layer, typically used to enhance sealability under moist conditions, can be separated from the PET substrate. Debonding is triggered by mechanical friction under caustic conditions when using suited adhesive technology. This demonstrates that lamination adhesives for multilayer packaging systems can be designed to enable effective material separation without compromising performance, aligning with guidelines from RecyClass or TCEP/ Petcore Europe.

Multilayer packaging applications provide another resource-efficient and high-performing solution that protects goods during transport and storage. At end-of-life, the ability to delaminate these structures - for instance via a separating medium based on mixtures of water and specific essential

[12] Cf the following publicly available sources: Kevin Purdy, Ask iFixit: What Is Stretch Release Adhesive (and Why Do We Love It)?, iFixit, 2024, https://www.ifixit.com/News/45779/ask-ifixit-what-is-stretch-release-adhesive-and-why-do-we-love-it ; Janhoi McGregor, Apple Confirms iPhone 16 Has Advanced New Battery Tech, Forbes, 2024, https://www.forbes.com/sites/jaymcgregor/2024/09/20/apple-iphone-16-battery-removal-new-adhesive-technology/ ; Henkel, Debonding-on-demand adhesives in electronics applications, https://next.henkel-adhesives.com/in/en/articles/sustainability-we-make-it-happen.html

[13] Cf. ISO (2026). ISO 21037:2026 — Adhesive bonding — Separation methods for adhesively bonded joints. International Organization for Standardization, Annex A.3.1.1.3

[14] Cf the following publicly available sources: UHU, Shoe & Leather, 2024, https://www.uhu.com/en-en/products/uhu-shoe-leather-blister-30-g-33-ml-multi-lan ; LOCTITE, Good Footing: Everything You Should Know about Shoe Glue, 2024, https://www.loctiteproducts.com/ideas/fix-stuff/shoe-glue.html ; Bostik, Shoe Repair Adhesive, 2024, https://diy.bostik.com/en-ZA/bostik-diy-solutions/repair/shoe-repair-adhesive ; FORESTALI, The Second Life of a Shoe, 2024, https://www.feica.eu/application/files/7516/1539/1580/2018-07-19_pdf_from_Forestali_shoe_repair.pdf ; loveyourshoes, What Is the Best Glue for Shoe Sole Repair, 2024, https://www.loveyourshoes.ca/finding-the-best-glue-for-shoes/ ; Emmanuel Stevens, Glue for Shoes: Best Adhesives for Long-Lasting Repairs, Stickyn (blog), 2024, https://stickyn.com/glue-for-shoes/

[15] Cf https://recyclass.eu/wp-content/uploads/2026/03/RecyClass-DfR-Guidelines-Transprent-clear-PET-Thermoforms.pdf and https://www.tcep-europe.org/design-guidelines/products

oils[16] or with essential oils[17] alone - allows for the removal of barrier layers, printing inks, and laminating adhesives[18], enabling higher-quality recycling[19,20] of base materials.

Finally, wash-off label technologies, as a distinct category of recycling-compatible solutions based on predefined process conditions, further support recycling processes by allowing energy-efficient removal of labels from plastic packaging, thereby improving PET flake recycling quality[21]. Wash-off label technologies are also successfully used in returnable glass bottles, ensuring their reuse[22].

[16] Covestro Deutschland AG, Use of mixtures of water and essential oils for separating multilayered composites for the segregated recycling of polymer/metal films, WO 2021/191059 A1, published 30 September 2021.

[17] Covestro Deutschland AG, Use of essential oils for separating adhesive bonds, US 12,084,600 B2, granted 10 September 2024.

[18] Definition available at: https://www.feica.eu/search_results/preview/pop-ex-k11-064-terminology-and-definitions-be-used-context-adhesives-recycling-packaging?id=3b16a0e4-1b17-45a6-8396-30b0c5810792&filename=POP-EX-K11-064+Terminology+and+definitions+to+be+used+in+the+context+of+adhesives+in+the+recycling+of+packaging.pdf

[19] Cf the following publicly available sources: Morchem, Recyclass Recyclability Approval for Morchem PI 2727 AR + CF-740 R Laminating Adhesive, Morchem (blog), 2023, https://www.morchem.com/recyclass-recyclability-approval-for-morchem-pl-2727-ar-cf-740-r-laminating-adhesive/ ; Bostik, Recyclable Adhesive for Mono-Material Flexible Packaging, 2024, https://www.bostik.com/uk/en_GB/markets-applications/flexible-lamination-adhesives/sf10M-lamination-adhesive/ ; Henkel, Henkel Adhesives Gain RecyClass Approval for Recyclability, 2024, https://www.henkel-adhesives.com/de/en/spotlights/all-spotlights/news/recyclass-approval-for-recyclability.html ; DOW, Dow Packaging Adhesives Receive RecyClass Approval for Mechanical Recycling in European Markets, 2022, https://corporate.dow.com/en-us/news/press-releases/dow-packaging-adhesives-receive-recyclass-approval-for-mechanical-recycling-in-european-markets.html ; RecyClass, Recyclability Approvals, RecyClass, 2024, https://recyclass.eu/recyclability/approvals/

[20] Cf. ISO (2026). ISO 21037:2026 — Adhesive bonding — Separation methods for adhesively bonded joints. International Organization for Standardization, Annex A.3.3.2

[21] Cf the following publicly available sources: Henkel, Debonding-on-demand adhesives, wash-off labels, Cf the following publicly available sources for automotive headlamps and EV batteries: https://next.henkel-adhesives.com/in/en/debonding-landing-page.html?gad_source=1&gad_campaignid=22125627104&gclid=EAIaIQobChMIzObUsrHvkgMV3LCDBx0WKwnpEAAYASAAEgIdMPD_BwE, FEICA, Labelling adhesives in the context of packaging recycling, 2025, https://www.feica.eu/search_results/preview/ram-ex-o01-002-labelling-adhesives-context-packaging-recycling?id=ad7e85b1-6331-43be-ab54-6f3fc272102c&filename=RAM-EX-O01-002_Labelling+adhesives+in+the+context+of+packaging+recycling.pdf ; UPM Raflatac, UPM Raflatac Receives RecyClass Recognitions for Pressure Sensitive Labels for PP and HDPE Container Recycling, UPM Raflatac receives RecyClass recognitions for pressure sensitive labels for PP and HDPE container recycling | UPM Raflatac, 2022, https://www.upmraflatac.com/news-and-stories/news/2022/11/upm-raflatac-receives-recyclass-recognitions-for-pressure-sensitive-labels-for-pp-and-hdpe-packaging-recycling/ ; Avery Dennison, Cleanflake, 2024, https://label.averydennison.com ; Henkel, Henkel's Innovative Wash-off Adhesive for PET-Packaging Receives Recyclability Certificate by Cyclos-HTP Institute (CHI), 2024, https://www.henkel.com/press-and-media/press-releases-and-kits/2024-04-25-henkels-innovative-wash-off-adhesive-for-pet-packaging-receives-recyclability-certificate-by-cyclos-htp-institute-chi-1957120 ; H.B. Fuller, PET Beverage Labeling, 2024, https://www.hbfuller.com/en/sustainability/sustainable-packaging-solutions/pet-beverage-labeling ; RecyClass, Recyclability Approvals, RecyClass, 2024, https://recyclass.eu/recyclability/approvals/

[22] Cf. ISO (2026). ISO 21037:2026 — Adhesive bonding — Separation methods for adhesively bonded joints. International Organization for Standardization, Annex A.3.3.1

Annex II

Trade-offs between durability during use and controlled separation at the end-of-life of a product are well known in sectors such as consumer electronics, automotive applications, appliances and packaging systems. In these industries, adhesives are required to provide long-term durability and resistance to mechanical, thermal and environmental stresses during the use phase, while Debonding-on-Demand solutions are designed to enable controlled separation at later stages, such as repair, refurbishment, disassembly or end-of-life processing.

The activation mechanisms used to trigger debonding must therefore be calibrated carefully: lowering activation thresholds can facilitate easier separation but may reduce safety margins or resistance under normal use conditions. As a result, the balance between durability in use and controlled debonding inevitably depends on the specific application, operating environment, expected service life and intended end-of-life scenario.

Please find below more details for the examples illustrating inherent trade-offs in Debonding-on-Demand solutions.

Smartphones and consumer electronics

Adhesives used in smartphones and tablets must ensure high mechanical integrity and resistance to vibration, temperature changes and humidity throughout the product's use phase. At the same time, Debonding-on-Demand solutions are designed to allow controlled separation of components (e.g. batteries, displays) during repair or end-of-life disassembly, typically triggered by heat, light or specific chemical agents.

Increasing debonding sensitivity may facilitate easier disassembly but can reduce long-term resistance to thermal or mechanical stress during use, requiring careful balancing depending on device design and its intended lifetime.

Automotive interior and lightweight assemblies

In automotive applications, structural and semi-structural adhesives must meet stringent durability and safety requirements over long service lives and across wide temperature ranges. Debonding-on-Demand approaches enable selective dismantling of bonded components for repair or recycling, for example, through heat-activated or electrically triggered mechanisms. However, activation thresholds must be set high enough to avoid unintended debonding during normal operation or accident scenarios, directly affecting how easily separation can later be achieved.

Appliance repair and modular design

Household appliances increasingly rely on bonded joints to enable lightweight and modular designs. Debonding-on-Demand adhesives can support disassembly for repair or refurbishment, but only if activation conditions (e.g. temperature or solvent exposure) remain outside normal use conditions. Lower activation energy improves repairability but may compromise resistance to accidental exposure (e.g. heat from motors or electronics), illustrating the application-specific nature of the trade-off.

Multi-Layer packaging and functional assemblies

In packaging or functional laminates, adhesives must maintain barrier performance and structural integrity during filling, transport and use. Debonding-on-Demand concepts can enable layer separation during recycling. Stronger bonding improves product performance and shelf life, while

easier debonding enhances recyclability; optimisation depends on the packaging design, materials used and the targeted recycling route.

Contact

FEICA Regulatory Affairs:
Jana Cohrs (j.cohrs@feica.eu)
Maria Pulina (m.pulina@feica.eu)

FEICA is registered in the **EU Transparency Register** with ID no. **51642763262-89**

FEICA - Association of the European Adhesive & Sealant Industry
Rue Belliard 40 box 10, 1040 Brussels, Belgium
Tel: +32 (0)2 896 96 00
info@feica.eu | www.feica.eu

Publication ref. : POP-EX-P05-013