Roadmap for the Chemical Industry in Europe towards a Bioeconomy

Strategy Document – Executive Summary

2019

Executive Summary

The RoadToBio project is funded by the EU under the Horizon 2020 research and innovation programme that aims to pave the way for the European chemical industry towards a higher bio-based portfolio and competitive success based on the benefits offered by the bioeconomy. The goal of RoadToBio is to create **a roadmap for the chemical industry** with the aspiration to increase the share of bio-based or renewable feedstock to 25% of total volume of organic chemicals raw materials/feedstock used by the chemical industry in 2030. Societal needs in 2030 need to be considered while aspiring for this target. The biomass used for bio-based chemicals should meet stringent sustainability criteria including on direct and indirect land use change.

The 25% target was set by the Bio-based Industries Consortium (BIC) in the 2017 Strategic Innovation and Research Agenda (SIRA). The SIRA is considered as 'guidelines' for the European biorefinery sector.

This roadmap strategy document is intended to provide an evidence-based foundation for the EU chemical industry upon which future policy can be implemented and actions delivered. The way that this report has been prepared is designed to ensure it has credibility with industry, academic, and other stakeholders and is recognised by government as a useful contribution when considering future policy. It will be successful if, as a result, the government and chemical industry in Europe are able to build on the evidence, analysis, key messages and strategic conclusions to increase share of bio-based chemicals whilst delivering significant reductions in carbon emissions, increased energy efficiency, and creating a strong competitive position for the EU chemical industry in the decades to come.

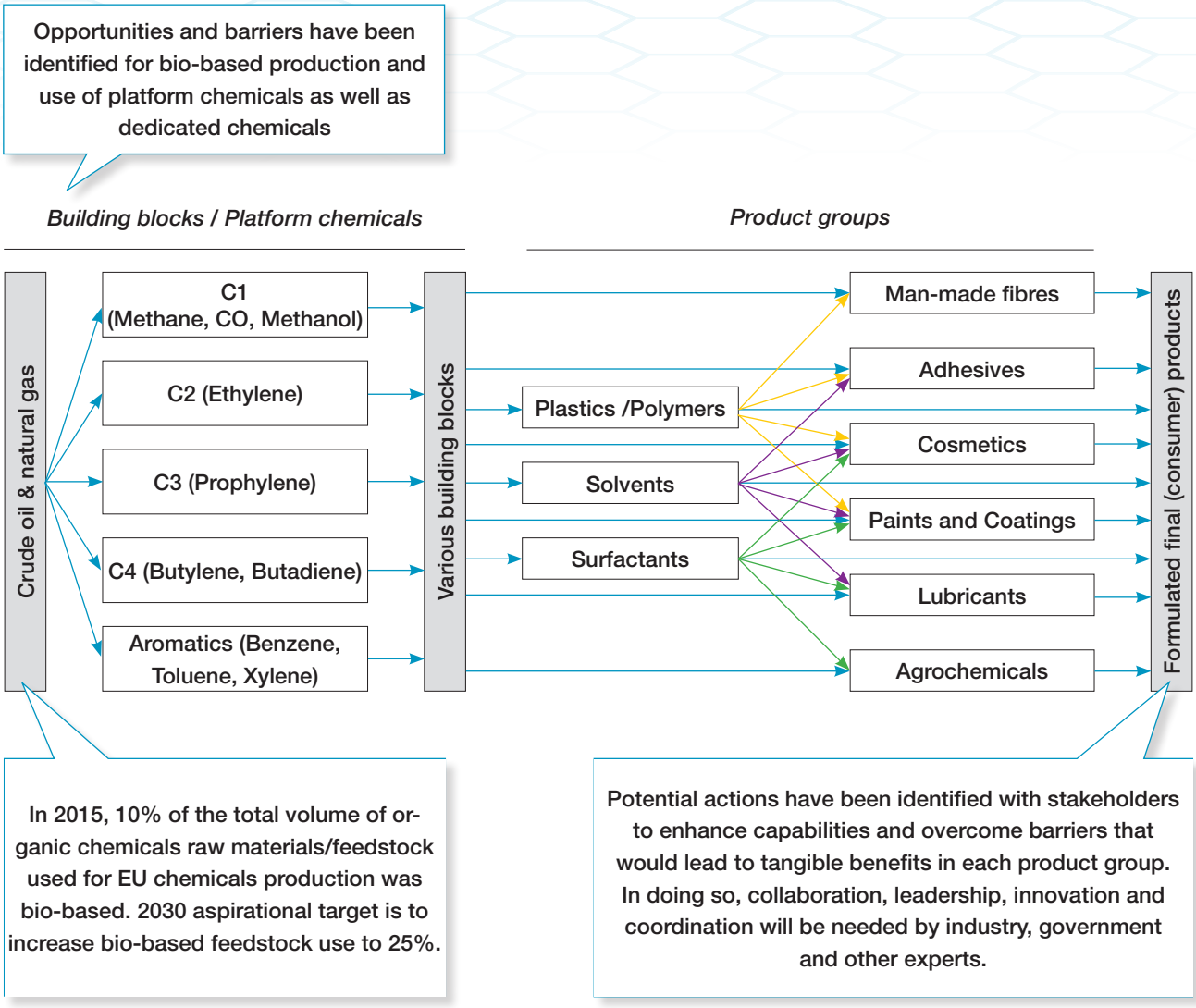


Figure 1: Brief overview of the RoadToBio project target, product groups and outcome

Product group opportunities and roadmap to increased share of bio-based chemicals in the EU chemicals industry

The strategy document includes detailed information on the drive for bio-based market growth, as well as the opportunities and barriers to increasing the share of bio-based chemicals in nine product groups:

Cosmetics, paints & coatings, agrochemicals, surfactants, lubricants, man-made fibres, solvents, adhesives, and plastics/polymers

Short term, mid term and long term actions, between 2019 and 2030, have been proposed for the barriers identified for each product group. Further, stakeholders who need to be involved to execute the actions have been identified.

Following is a summary of the product groups, opportunities and roadmap to increased share of bio-based chemicals.

Cosmetics

- The share of bio-based chemicals in cosmetics produced in the EU is about 40%, which is the highest among all product groups that are considered in RoadToBio.
- European consumers' emerging environmental awareness and a growing trend for natural products is driving the uptake of bio-based chemicals in cosmetics. Costs are less important constraints in the cosmetics segment.
- Biodegradability and low human toxicity are the main desired sustainability characteristics in the cosmetics product group. Bio-based products such as botanical extracts and vegetable oils have these key characteristics. However, bio-based solvents such as acetone are toxic and non-biodegradable, thereby presenting an opportunity for development and commercialisation of novel bio-based solvents that are safe to use and dispose.
- Functional ingredients and chemical building blocks used in cosmetics such as preservatives, solvents and surfactants are still mainly derived from fossil feedstock and therefore not sustainable.
- Low GHG emissions is a desired sustainability characteristic for building blocks such as solvents and surfactants that are used in cosmetics. The bio-based chemicals identified in the sample could lead to low GHG emissions compared to the fossil equivalents.
- By volume of use, botanical extracts and vegetable oils outweigh building blocks like lactic acid and succinic acid. In order to attain higher bio-based share in the cosmetics product group, these two subgroups will play a vital role and therefore should be the subject of further research and product development.
- Bio-based preservatives underperform in comparison to the fossil derived ones. This area of cosmetics presents an opportunity for the development and further growth of bio-based chemicals.
- European cosmetics industry is strictly regulated. Ingredients such as preservatives, UV-filters, nanomaterials or colorants are subject to long and often expensive approval procedures. Other ingredients must be safe for cosmetic use by meeting the requirements of EU legislations (cf. REACH and Cosmetic Regulation)
- Opportunities also exist in using alternate feedstocks like algae, and technology for the extraction and preservation of bioactive ingredients.

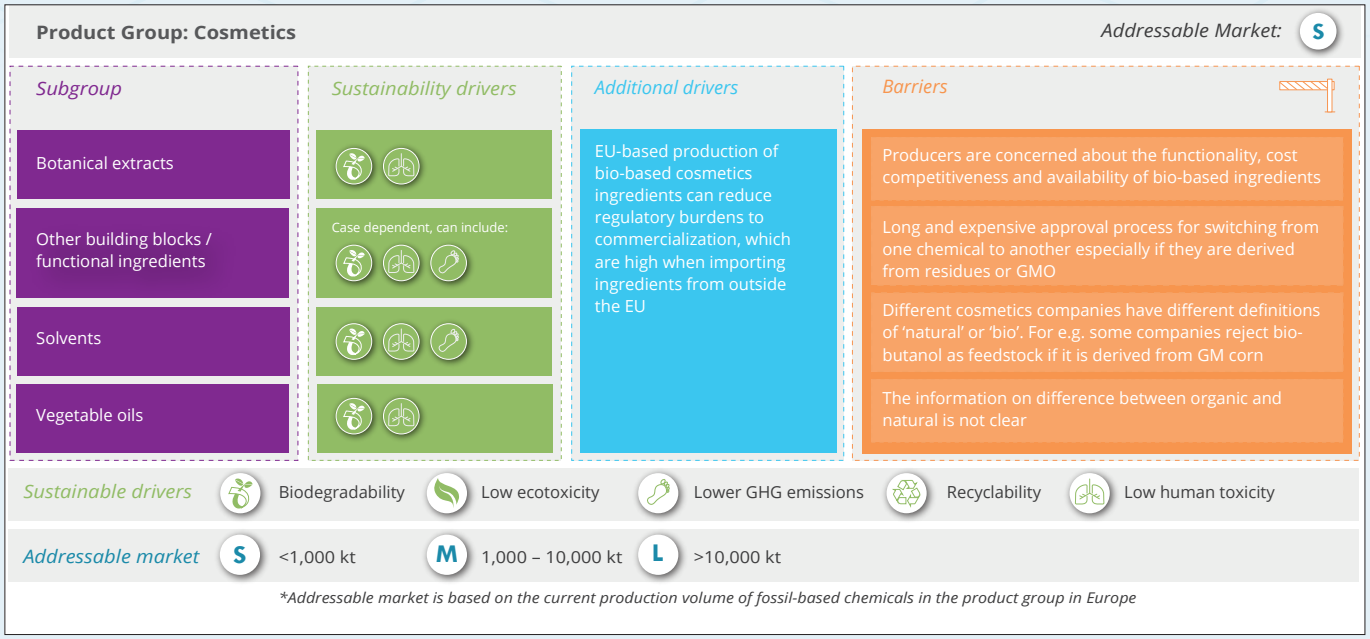


Figure 2: Pictorial summary of the cosmetics product group

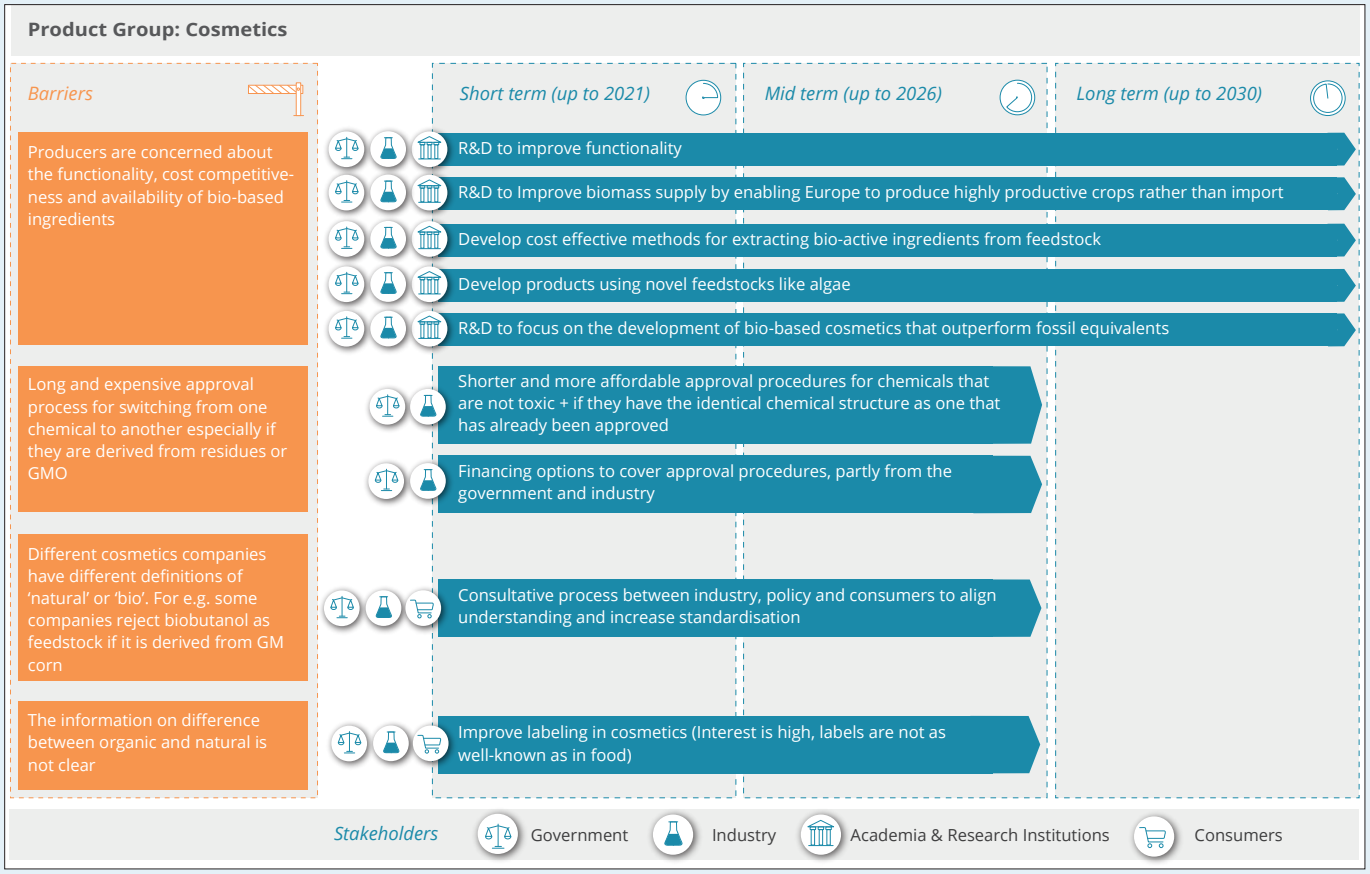


Figure 3: Roadmap to increasing the bio-based share of chemicals in the cosmetics product group

Paints & coatings

- There is a trend in paints and coatings towards more sustainable alternatives to fossil-based versions, mainly driven by producers responding to consumer demand for non-toxic, sustainable products.
- The elimination of toxic ingredients, reduction of VOCs to improve and protect indoor and outdoor air quality ("green building" movement) and reduction of carbon footprint are driving forces to an increased use of bio-based ingredients
- Bio-based production of paints and coatings in Europe is >164 kt/yr, while fossil-based production is ~718 kt/yr.
- The addressable market of paint and coatings in Europe is small (<1,000kt) in comparison to the other eight product groups.
- The performance and key parameters requirements of paints and coatings strongly depend on the area of application. Typical performance criteria include the desired appearance, ease of application, viscosity, durability, drying times etc.
- Barriers to bio-based uptake in paints and coatings result from price and performance issues; the replacement of VOC solvents usually results in shorter drying times, meaning less time to work with the products.
- Significant investment in new formulations is necessary, as well as the development of new application techniques with appropriate instruction guidelines for users.
- There are increased opportunities for bio-based materials that can be combined with functional bio-based additives such as enzymes, anti-microbial peptides, metal binding peptides and many more, to provide new enhanced paints and coatings.
- Paints and coatings are complex formulations. It is rarely possible to exchange one component for another without adjusting the whole formulation. Thus, replacement of one component often requires the development of a completely new formulation. This is a barrier, but also an opportunity for the introduction of new components with new functionalities that might not have worked in "traditional" formulations.
- Driven by the growth of the shipping industry and increasingly strict GHG and environmental regulations, companies are innovating in this space in order to find non-ecotoxic and biodegradable alternatives, such as enzyme-based compounds.

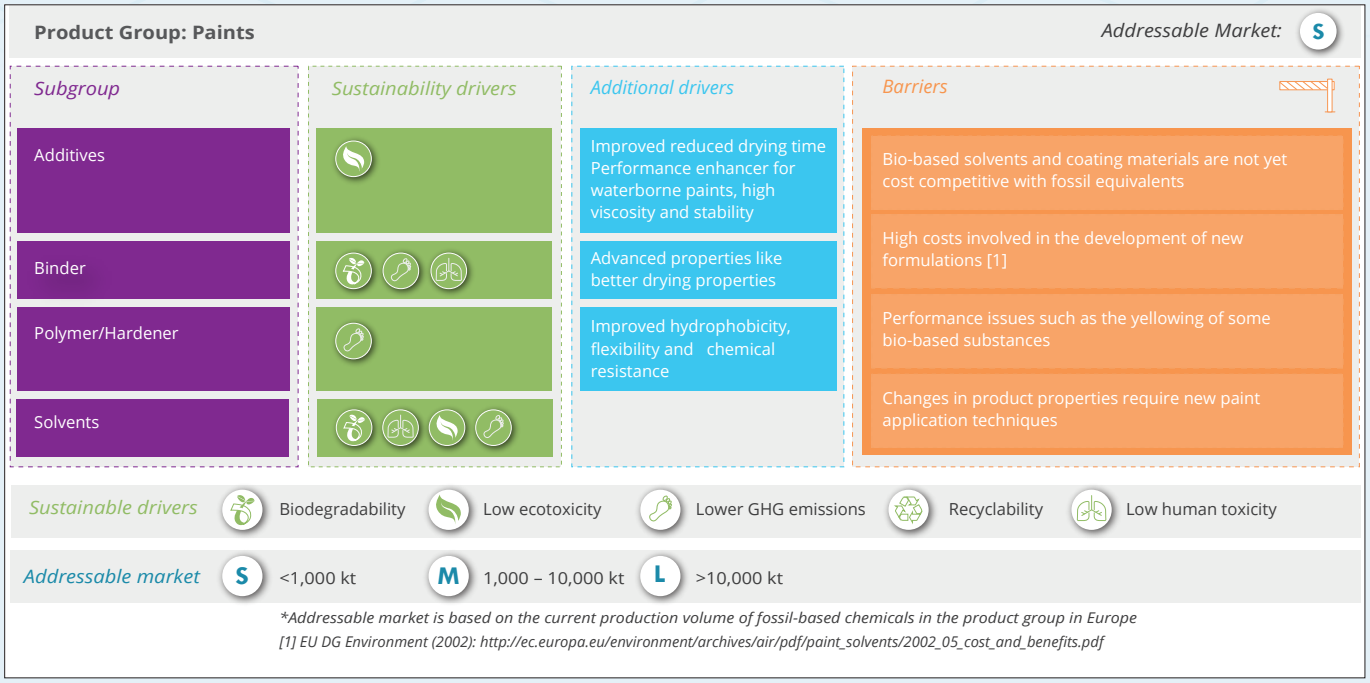


Figure 4: Pictorial summary of the paints and coatings product group

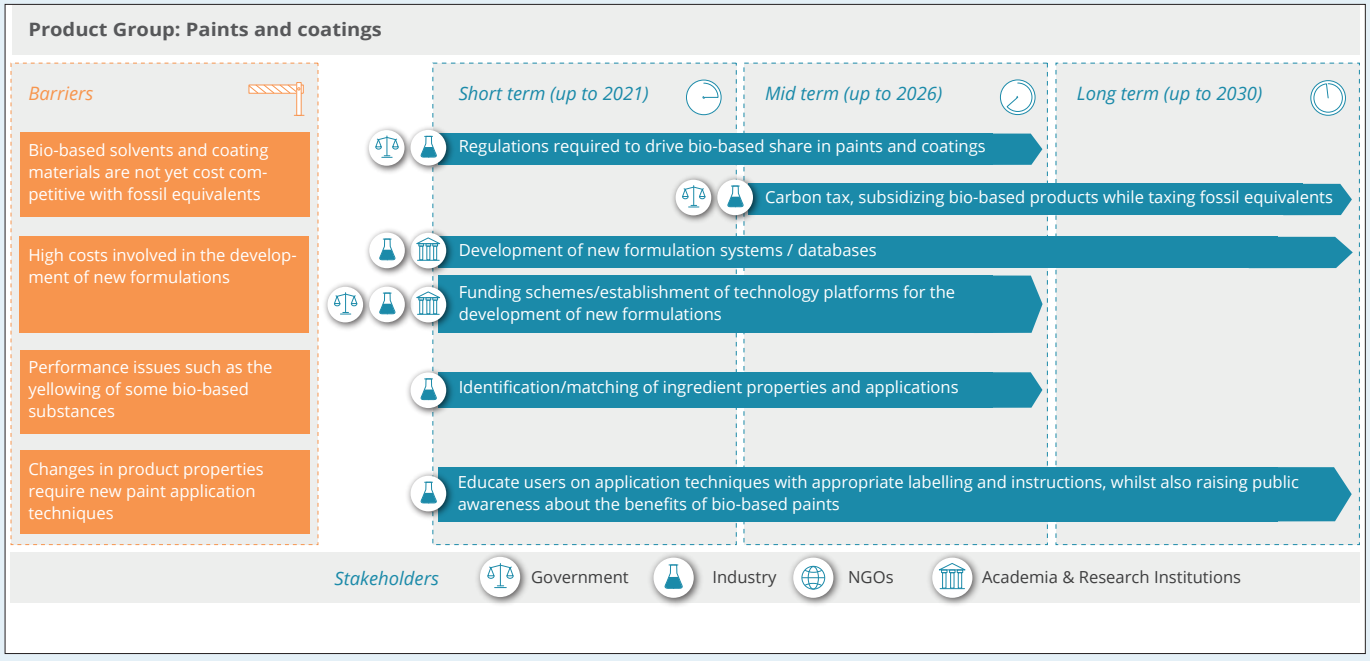


Figure 5: Roadmap to increasing the bio-based share of chemicals in the paints and coatings product group

Agrochemicals[1]

- There is a growing market for fertiliser coatings that are bio-based and biodegradable, as well as for biostimulants (including chitosan, seaweed extracts) and biological seed treatment (including botanicals).
- Biodegradability, low human toxicity and low ecotoxicity are the desired sustainability characteristics in agrochemicals. However, the bio-based chemical has to at least have the same level of performance as the fossil-based agrochemical.
- Bio-based chemical building blocks such as bio-based lactic acid, methanol and fatty alcohols present an opportunity for converting conventional fossil-based agrochemicals into partly bio-based equivalents. The performance of the latter should be, at least, at par with the fossil-based agrochemicals.
- Bio-based crop protection products start degrading soon after application resulting in little or no toxic residue. However, the drawback is that they need to be applied more frequently in order to be effective. Formulation of bio-based crop protection products can be improved to address this issue.
- New bio-based crop protection products can help address the issue of pesticide resistance in pest populations.
- European agrochemical industry is strictly regulated. Use of new ingredients in products is subject to long and often expensive approval procedures. There is a low risk category within the legislation 1107/2009 that places plant protection products on the market. This could be readily adapted for speedier approval of bio-based pesticides and is already ratified by the European Parliament. However, it is yet to be actioned by the European Commission.
- Key actors of European agrochemical industry include: Syngenta, Bayer Crop Science, Corteva (Dow Agrosciences, DuPont and Pioneer merger), BASF, Sipcam-Oxon

1 For RoadToBio, the following agrochemicals were out of scope:
– fertilisers (as they primarily contain inorganic compounds). However, coatings for Fertilisers are included in the analysis.
– Microbial agrochemicals such as microbial pesticides. RoadToBio only focuses on biochemical-based pesticides where organic chemistry plays a role.

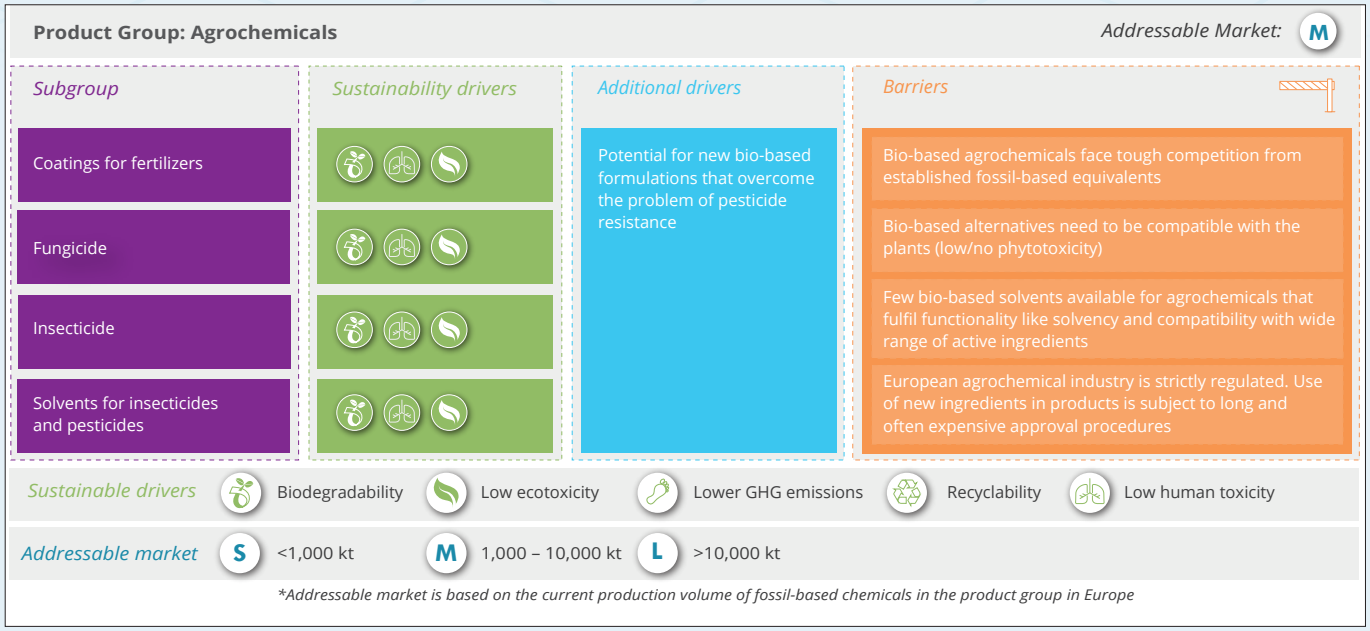


Figure 6: Pictorial summary of the agrochemicals product group

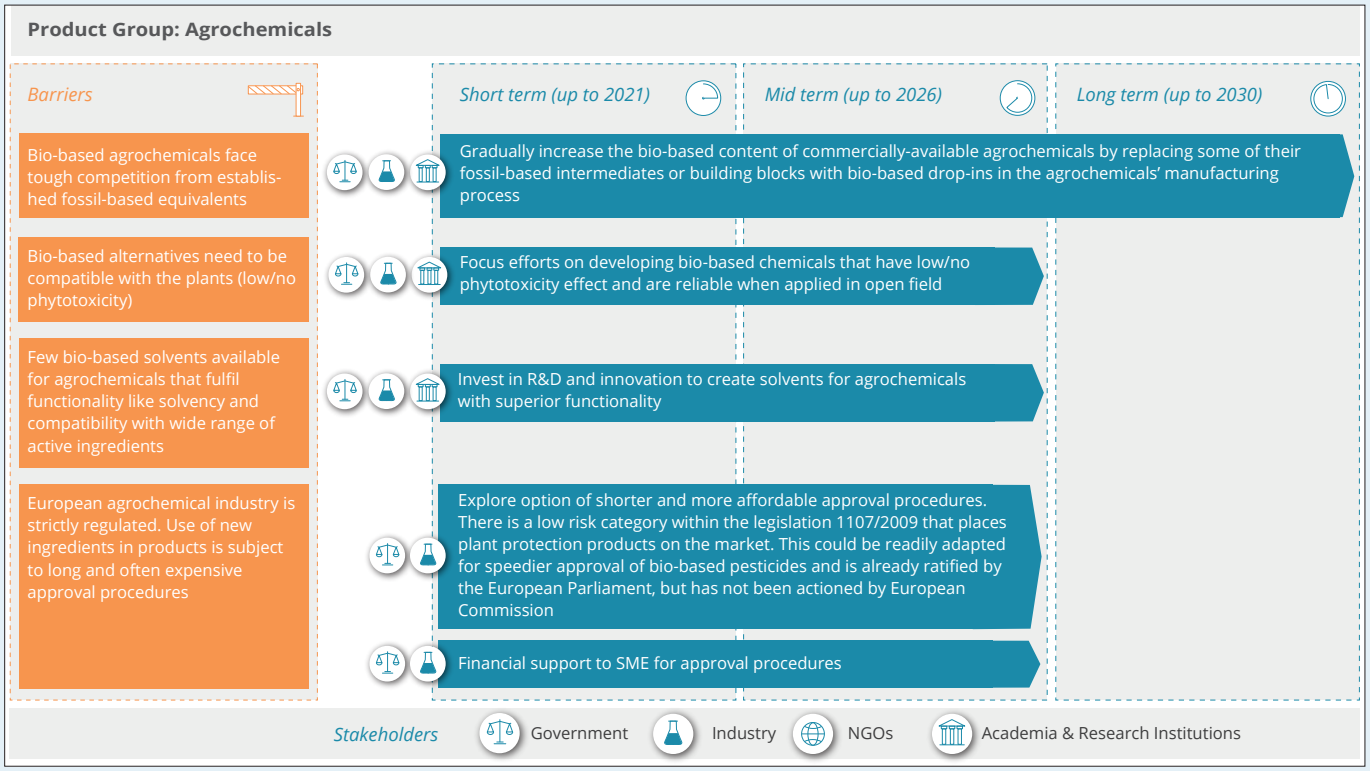


Figure 7: Roadmap to increasing the bio-based share of chemicals in the agrochemicals product group

Surfactants

- Bio-based surfactants are produced as high value products, typically for high-end customer products, such as personal care and home care products.
- Methyl ester sulfonate (MES) offers the biggest opportunity to shift from fossil to bio-based surfactants. It could be a bio-based alternative for linear alkyl benzene sulfonate (LAS) and has high potential to be used in cosmetic products.
- The demand for bio-based surfactants strongly depends on household spending.
- There is drive/requirement for clear labelling, so consumers can increasingly opt to buy product using bio-based alternatives.
- The key drivers for bio-based surfactants are their biodegradability, lower human toxicity and lower ecotoxicity, especially in environments where these sustainability characteristics are required.
- Production of bio-based surfactants in Europe is ~1,100 kt/yr, while fossil-based production is ~2,400 kt/yr.
- The addressable market of fossil-based surfactants production in Europe is medium-sized (1,000-10,000 kt/yr) in comparison to the other eight product groups.
- Besides being made from renewable feedstock, the main advantages of bio-based surfactant are possible antimicrobial properties; better performance compared to fossil equivalents which allows to use smaller quantities of surfactants; better foaming properties; higher selectivity for application at lower temperatures, higher pH and salinity; ability to achieve regulatory compliances with regard to (environmental) safety and use of low-cost feedstocks (i.e. fats and oils, sugars).
- Due to the advanced product properties the use of bio-based surfactants is possible in a wide range of product applications (cleaning, personal care, food processing, agrochemicals and textiles). However, these products remain niche due to their limited cost competitiveness compared to conventional products.
- Bio-based surfactants are usually used in end product formulations where the modification of one component has an impact on the overall composition and performance, which causes additional development costs. This cost barrier could be overcome by targeted support and funded research towards new product formulations. The clear advantage for companies is flexibility in composition, as long as a certain performance can be ensured.
- Due to the limited number of large-scale producers a secured steady supply of bio-based surfactants is uncertain which creates risk for suppliers like personal and home care producers.
- Key companies producing bio-based surfactants include Evonik, Ecover, Henkel, Saraya, Soliance, Wheatoleo and Nouryon.

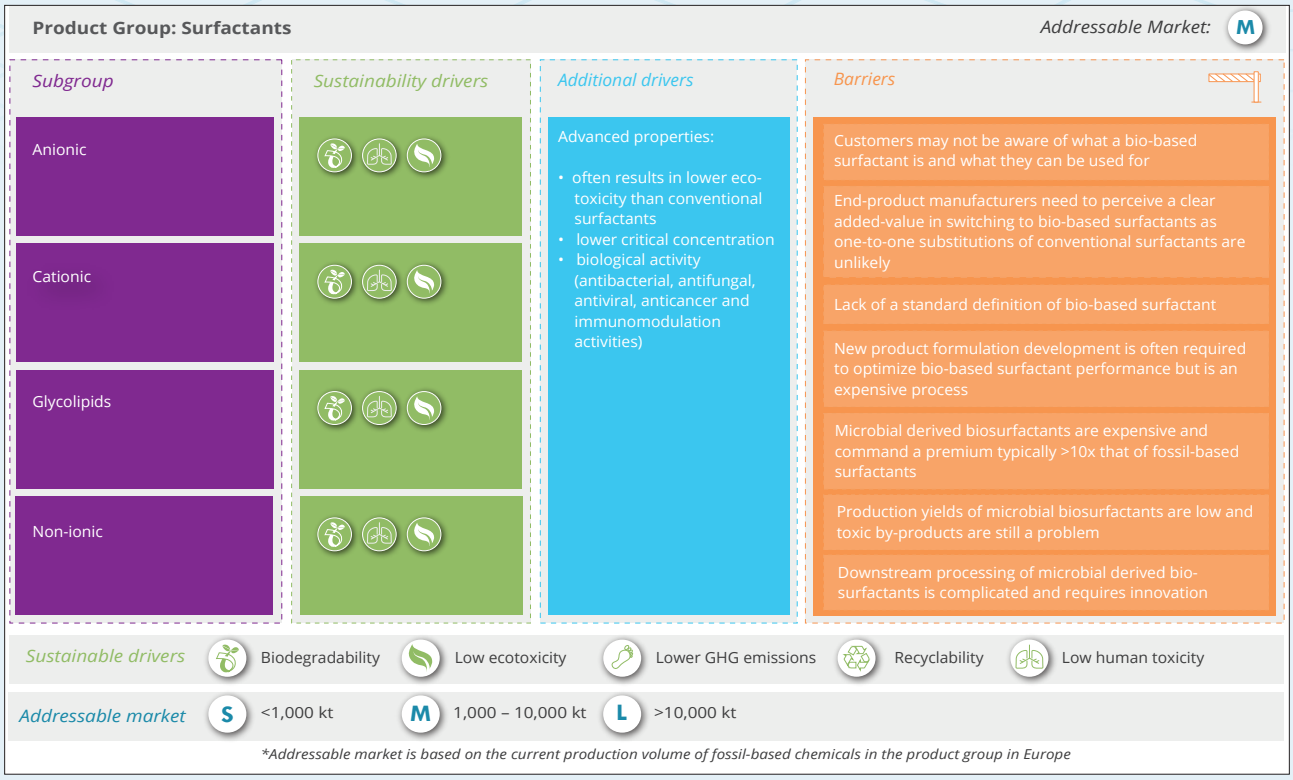


Figure 8: Pictorial summary of the surfactants product group

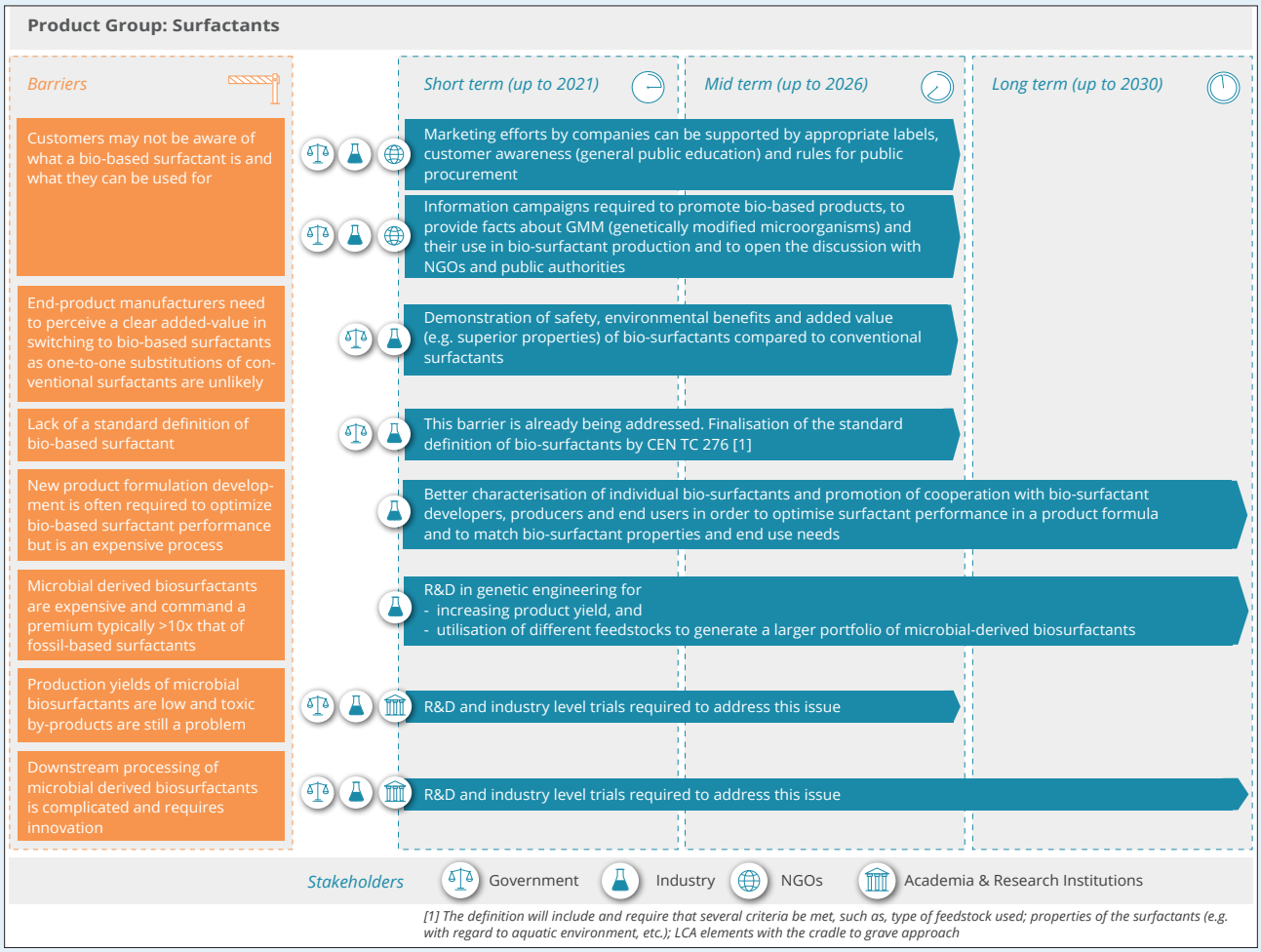


Figure 9: Roadmap to increasing the bio-based share of chemicals in the surfactants product group

Lubricants

- Environmental concerns are the leading drivers for bio-based lubricants. However, bio-based lubricants must meet the performance requirement of the application.
- In total-loss applications the trend towards bio-based lubricants is driven by regulations.
- All five sustainability characteristics (biodegradability, low human toxicity, low ecotoxicity, low GHG, recyclability) are required for lubricants.
- Most lubricating oils are mineral based and are derived from crude oils. Lubricants production costs are affected by crude oil prices.
- Bio-based lubricants have superior biodegradability characteristics compared to fossil derived alternatives.
- Bio-based drop-ins, such as succinic acid, adipic acid, propylene oxide, ethylene oxide building blocks provide an opportunity for the European lubricant industry to increase the bio-based content of its products.
- The global market value of bio-lubricants in 2025 is expected to reach 3 billion, with the major growth expected in transport and manufacturing applications.
- Some of the companies that are actively involved in bio-based lubricants market include: Total (e.g. transformer oil ISOVOLTINE BIO VE, calcium soap grease BIOMERCAN RS, textile lubricants such as LISSOLFIX APZX 225), Renewable lubricants Inc. (e.g. bio-based motor oil Bio-SynXtra™), PANOLIN AG, Environmental Lubricants Manufacturing, Inc. (e.g. ELM 85W140 Multi-Purpose Gear Lubricant), BioBlend Renewable Resources, LLC (e.g. BioFlo FG food grade lubricant)

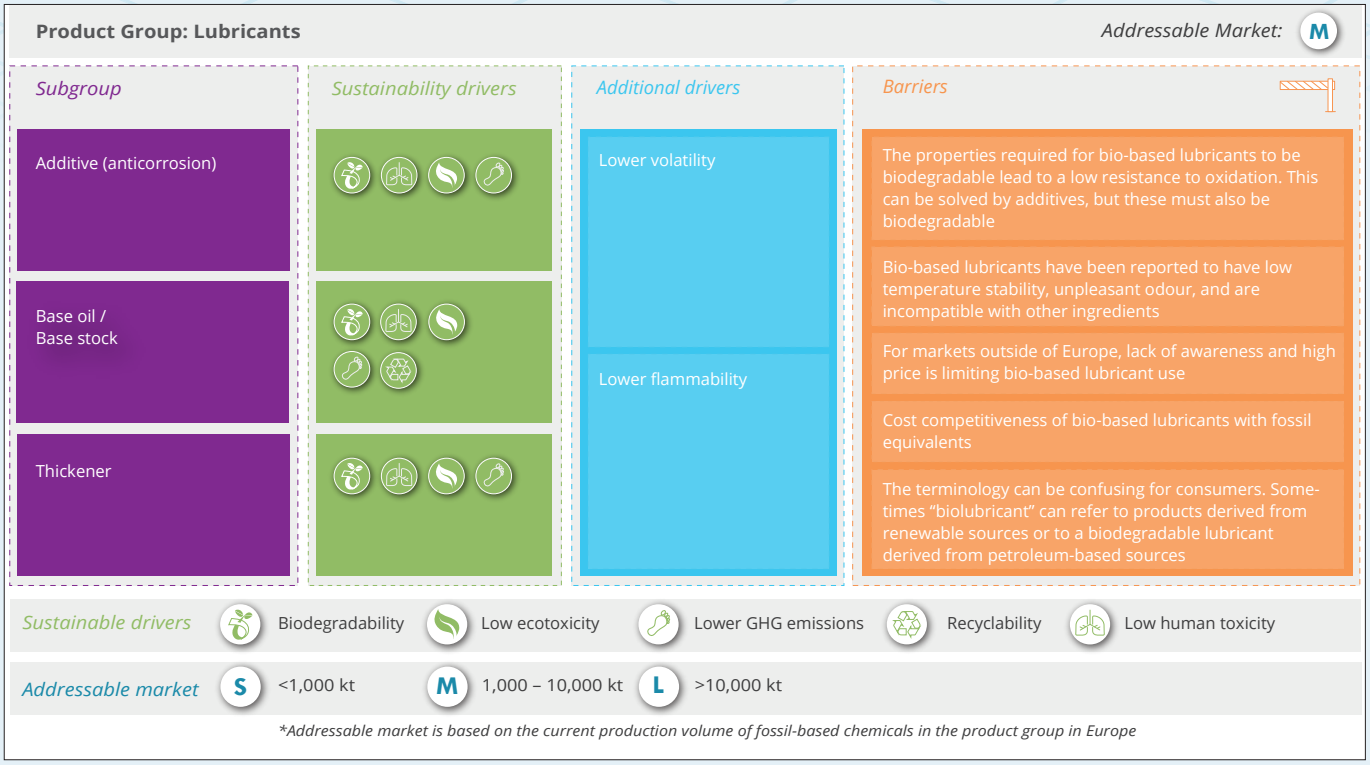


Figure 10: Pictorial summary of the lubricants product group

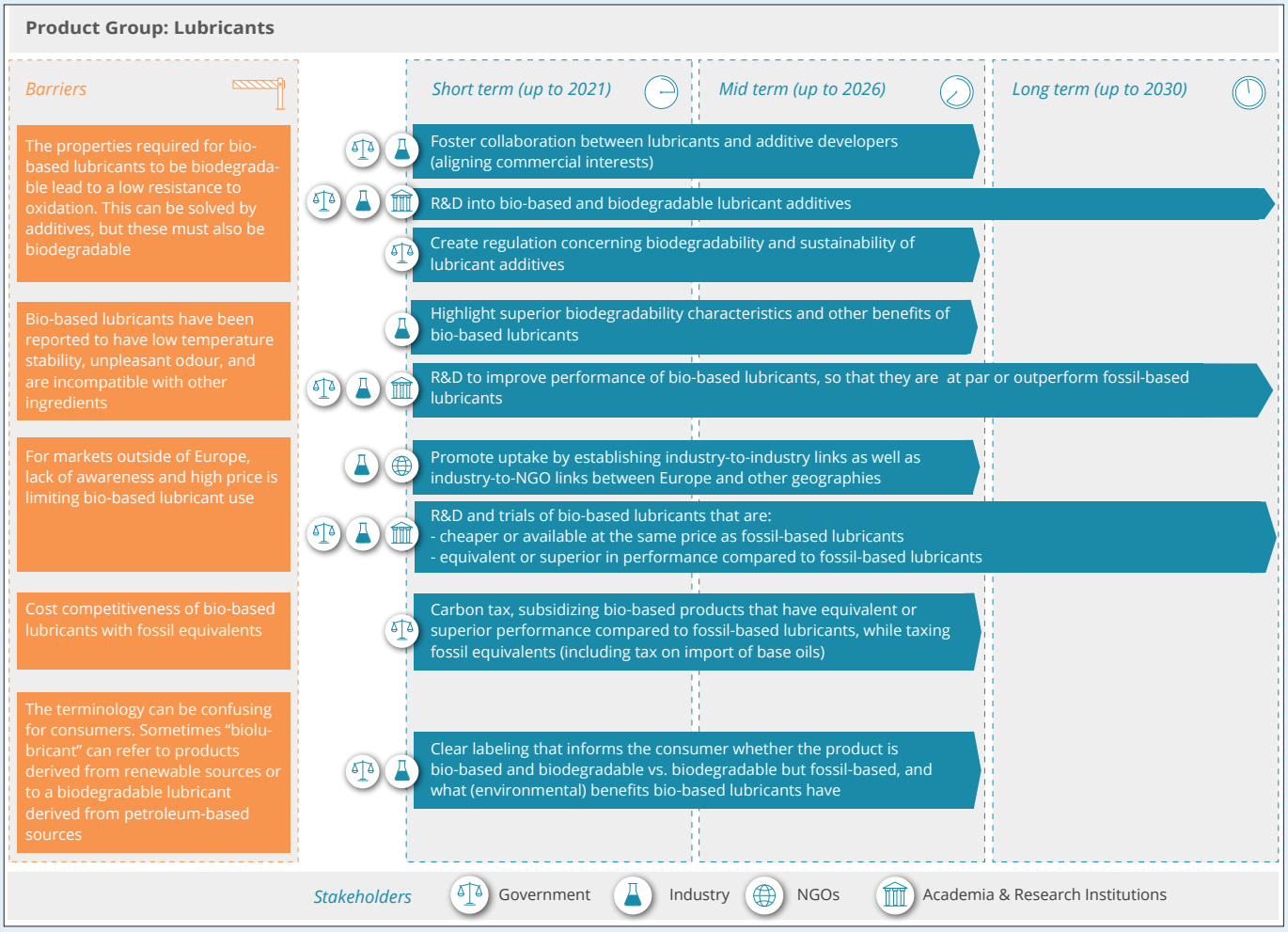


Figure 11: Roadmap to increasing the bio-based share of chemicals in the lubricants product group

Man-made fibres

- Bio-based man-made fibres production in Europe is >600 kt/yr, while fossil-based production is ~4,800 kt/yr.
- The addressable market of fossil-based man-made fibre production in Europe is medium-sized (1,000-10,000kt) in comparison to the other eight product groups.
- Consumer demand and initiatives by producers have driven the increase in the use of bio-based and recycled feedstock, as well as sustainability across the man-made fibres supply chain.
- Recyclability is the sustainability characteristic that all conventional and several bio-based alternatives have. However, recycling is not easy in case of blends such as fabric made of polyester and cotton with a small percentage of elastane. Another example is PLA which cannot be recycled with PET in established recycling infrastructure. Therefore, there is scope for further R&D in recycling techniques for different fibres.
- There is a drive to make conventional plastics such as PET and nylon biodegradable by adding 'additives'. While these additives are available on the market, the claims of biodegradation rarely pass rigorous testing and review. However, it does show that biodegradability is considered important for synthetic polymers when they approach end-of-life and cannot be recycled anymore.
- The production of some biosynthetic fibres could potentially result in low GHG emissions and some have low toxicity effect.
- Some bio-based fibres, such as bio-PTT, can be produced at lower cost compared to their fossil-based equivalents, and have properties that surpass fossil-based equivalents in fibre applications.
- There are several bio-based man-made fibres that are still at research and demonstration scale. Further R&D and industrial trials are needed to bring these fibres to commercial scale. Example of an ongoing projects in Europe is FIBFAB (H2020 project) on PLA fibre.
- Some of the companies that are actively involved in bio-based man-made fibres market include: DuPont (Sorona®), Sofila (use Arkema's Rilsan®), Aquafil, RadiciGroup (Radilon® DT 40EP25W), BASF, Solvay, Distrupol, Sateri (viscose), Lenzing (TENCEL™), AlgiKnit

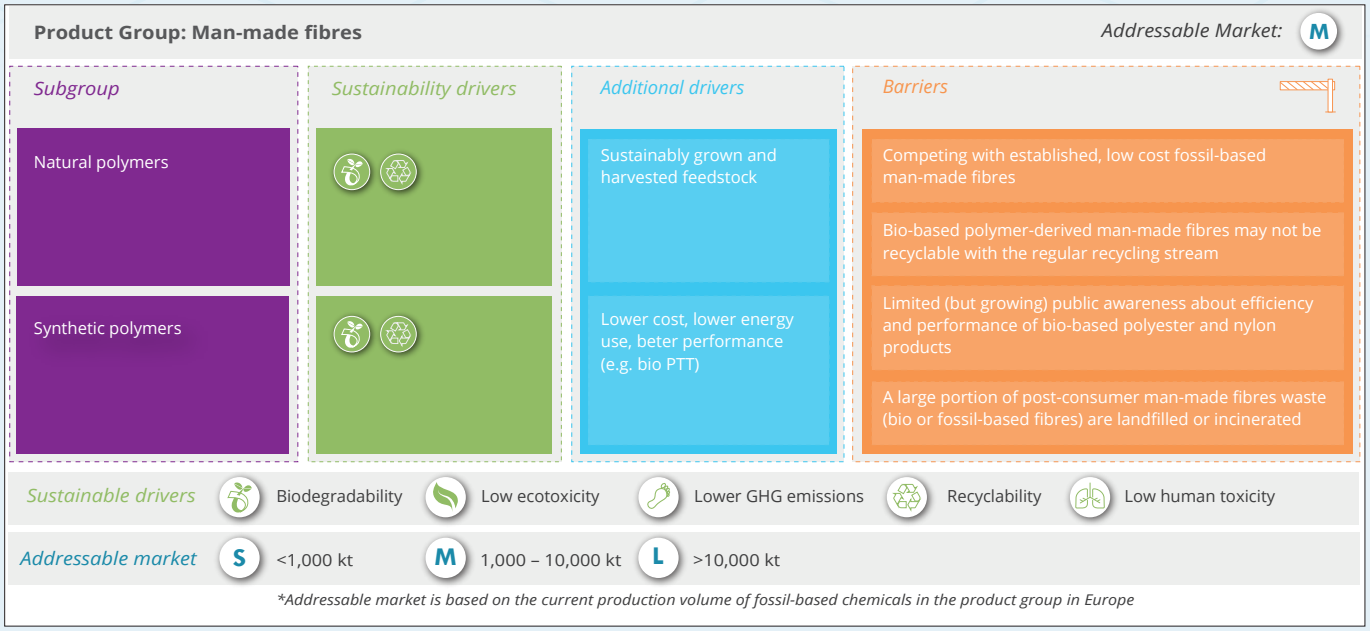


Figure 12: Pictorial summary of the man-made fibres product group

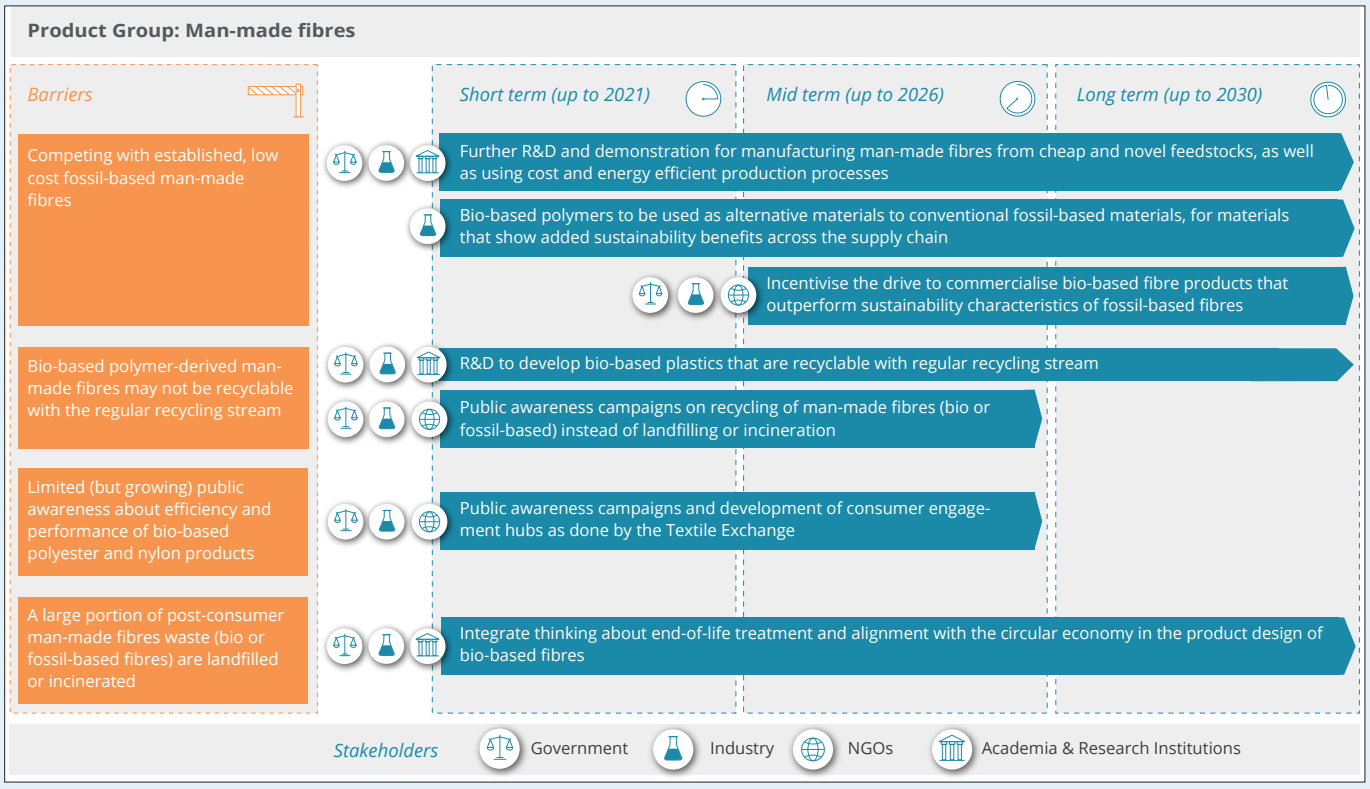


Figure 13: Roadmap to increasing the bio-based share of chemicals in the man-made fibres product group

Solvents

- Bio-based solvents production in Europe is <0.5 kt/yr, while fossil-based production is ~5,000 kt/yr. The addressable market of fossil-based solvents production in Europe is medium-sized (1,000-10,000kt) in comparison to the other eight product groups.

- The uptake of bio-based solvents is driven by the EU policy on VOC emissions and by REACH. Those bio-based alternatives which meet the criteria of low toxicity and low VOC, compared to the fossil-based counterpart, are likely to be considered as valid alternative provided that they meet the functionally requirements of the solvent in specific applications.

- Conventional and bio-based solvents identified are biodegradable (some more than others), and there is concerted effort from the industry to recover and recycle solvents where possible. This is driven by legislation that aims to reduce the adverse impact of solvents (VOCs) on human beings and the environment. It should be noted that solvents can be recovered and recycled in some sectors and applications but not in others.

- Industries are taking as many steps as possible to remain competitive, by reducing waste and recycling spent solvents. It is very important for producers, especially the ones who are using solvents for extraction, to be able to recycle and reuse the solvent. Extraction is a common processing step in chemical, food, pharmaceutical and mining industry.

- For products that are likely to end up in the environment, complete biodegradability is a relevant sustainability driver. This is the case of solvents that are typically used in formulation of cleaning products (household cleaners, personal care) or agrochemicals. However, the biggest industrial end-group in which solvents are used are paints and coatings, in which solvents evaporate after the paint has been applied, thus dissipating into the air. In such cases, biodegradability is not a relevant sustainability driver.

- Many ‘dedicated’ bio-based solvents included in this analysis claim to have low toxicity effects compared to fossil equivalents.

- The production of some identified bio-based solvents has been reported to release less GHG emissions compared to fossil equivalents.

- Bio-based solvents need to meet the functional requirement of the fossil equivalents that they intend to replace in different applications. There is significant scope for R&D and demonstration scale projects to develop a wide range of bio-based solvents and formulations that can be used in different applications.

- Some of the companies actively involved in the bio-based solvents market include: Cellulac, BioAmber, Green Biologics, DuPont-Tate & Lyle, Pennakem Europa SAS, Circa, Roquette, Cargill, Solvay-Rhodia

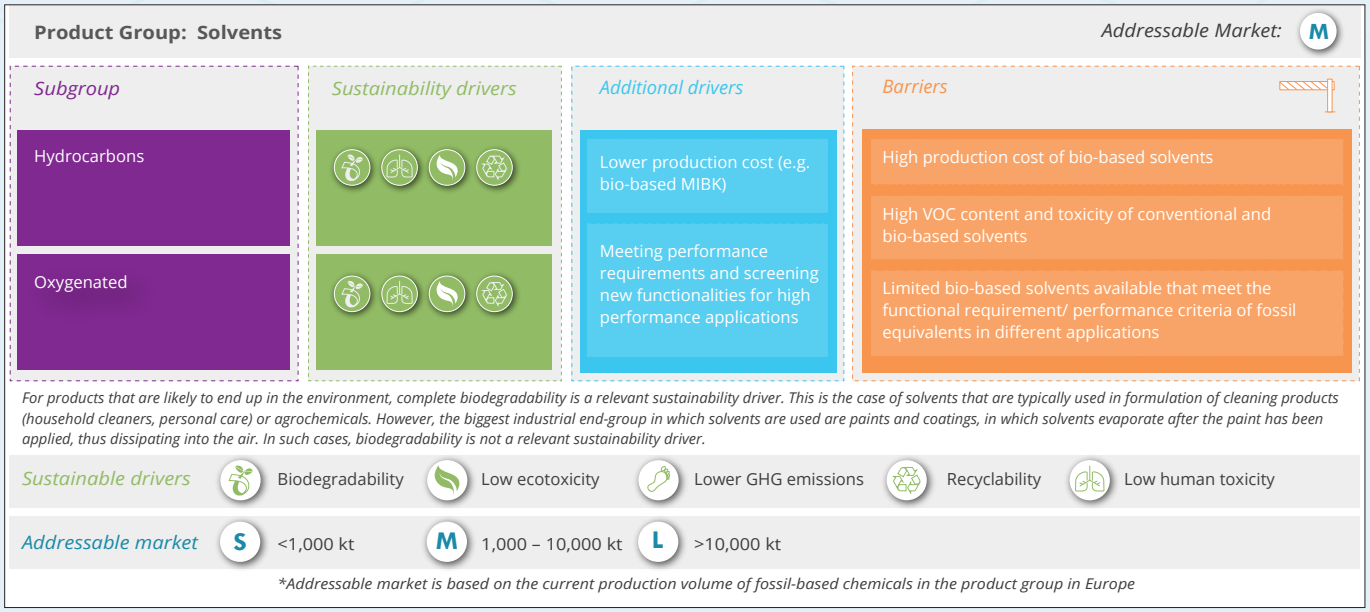


Figure 14: Pictorial summary of the solvents product group

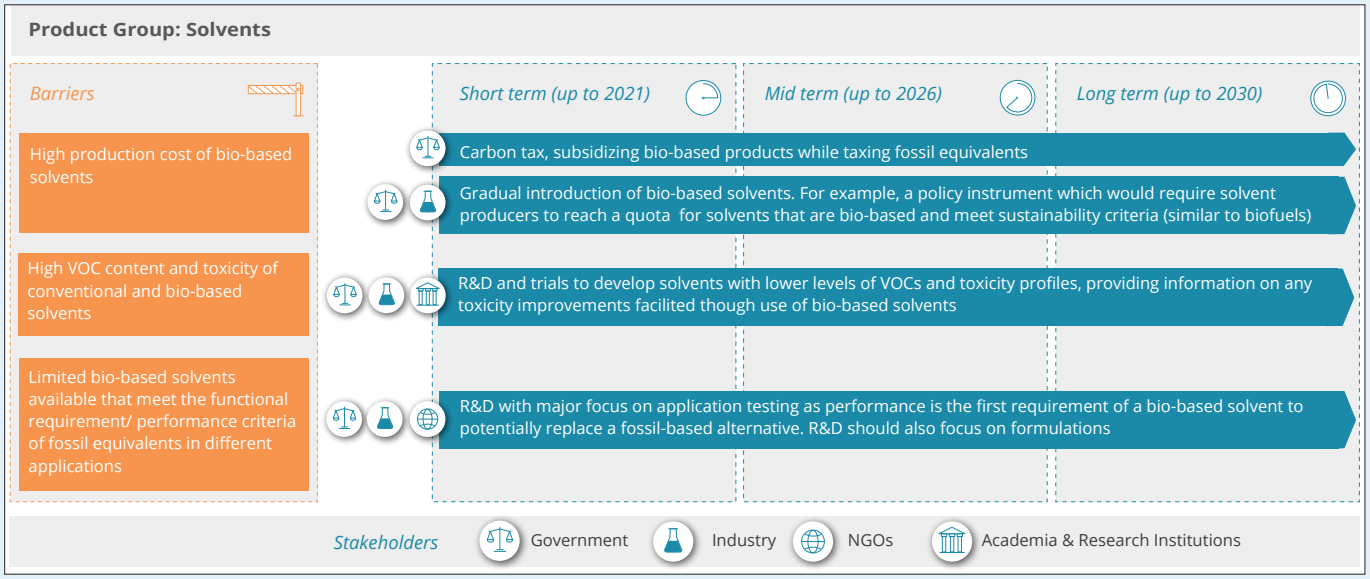


Figure 15: Roadmap to increasing the bio-based share of chemicals in the solvents product group

Adhesives

- Production cost is an important driver in the adhesives segment.
- The key sustainability driver is to reduce human toxicity by lowering VOC (especially for the wood building industry which is one of the most significant markets for adhesives).
- Environmental and health concerns related to formaldehyde create a major opportunity for the development and growth of bio-based chemicals which could replace formaldehyde. Bio-based 5-HMF and lignin derivatives are among the most promising candidates.
- A range of bio-based raw materials such as diacids, diols and natural polyols building blocks are available as a drop-in or dedicated replacement of fossil-based building blocks for adhesives and sealants.
- Keeping suitable mechanical properties while reducing the emission of VOCs is the key development and innovation trend in the adhesives segment.
- Bio-based alternatives must deliver the desired mechanical performance characteristics and water resistance requirements in adhesives. Meeting these requirements may initially rely on the development of mixed bio and fossil-based adhesives.
- Legislation may lead to accelerating the transition from synthetic adhesive to bio-based adhesives by regulating the presence of VOCs and the presence of recyclable materials, especially in the building industries.
- Some companies active in the development of new bio-based adhesives are: VTT (Finalnd), Arkema (France), Weiss Chemie + Technik (Germany) and Covestro (Germany)

Figure 16: Pictorial summary of the adhesives product group

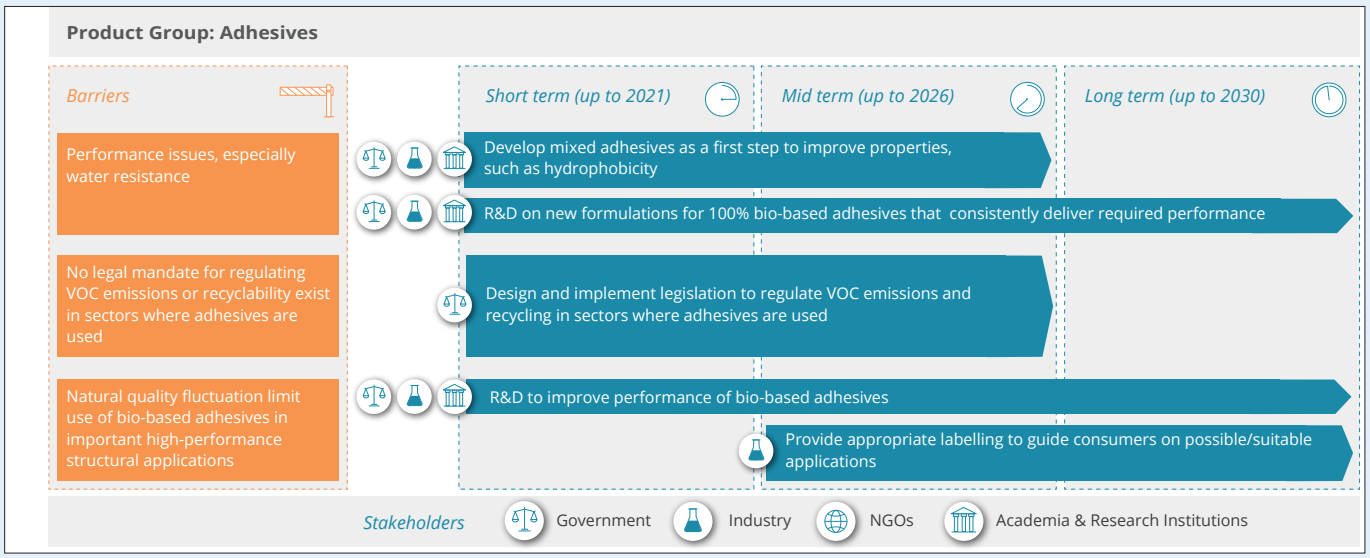
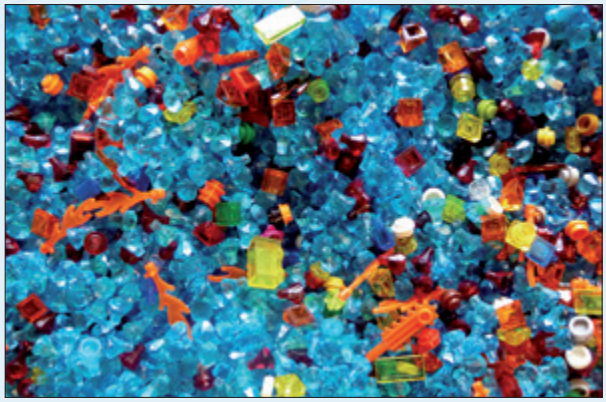


Figure 17: Roadmap to increasing the bio-based share of chemicals in the adhesives product group

Plastics/polymers



- The trend towards bio-based plastics is driven by changing consumer demands with increased awareness of environmental impacts of the plastics industry.
- To make plastic products more resource efficient and to reduce GHG emissions, the emphasis is on increasing the use of renewable feedstock using lower energy processing, while reducing the dependency on fossil resources.
- Several innovative small and large companies are responding to consumer demands towards a more sustainable plastics economy. These companies have made substantial investments in R&D for bio-based plastics designed with the circular economy in mind, e.g. PLA, PEF and bio-PTT.
- Bio-based production of plastics/polymers in Europe is >1,200 kt/yr, while fossil-based production is ~70,000 kt/yr.
- Therefore, out of the nine product groups, the addressable market of fossil-based plastics/polymers production in Europe is the largest in the nine product groups (large addressable market is considered as >10,000 kt).
- Diverse bioplastics are being developed that can be drop-ins, compostable and non-biodegradable, but few are truly biodegradable.
- Some bio-based plastics listed meet the desired sustainability characteristic for low GHG emissions, which is a key driver for thermoplastics. Low human toxicity is an important driver for some thermoplastics used in healthcare and food packaging, e.g. bio-PVC.
- Recyclability is the sustainability characteristic that most conventional plastics and their bio-based alternative plastics already possess. However, some bio-based plastics, such as PLA and PHAs cannot be recycled with current well-established recycling infrastructure and there is evidence that recyclability is a desired sustainability characteristic of these bio-based plastics. Therefore, further R&D in product development and recycling techniques is required to ensure that recyclability does not compromise performance.
- Bio-based drop-ins may not be compostable/biodegradable but would be recyclable – otherwise, biopolymers might conflict with recycling goals. Non-biodegradable biopolymers could also contribute to carbon sequestration.
- Biodegradability is considered an important end-of-life life pathway, especially when recycling is no longer technically possible. Additives are available that could increase the rate of biodegradation in treated plastic products, though claims need to be appropriately verified.
- Producers of bio-based plastic should provide adequate labelling to inform customers of types of bio-based plastics to raise awareness about bio-based plastic alternatives and end-of-life processing.
- Although TRLs for some the bio-based plastics listed are already at 9, there are some that require further R&D (including investment) and industrial trials to improve technical properties and reduce production costs to successfully grow at commercial scale.
- Some of the leading manufacturers are Genomatica, Versalis, Cargill, Synbra Technology, Novamont, BASF SE, Natureworks, Corbion, Braskem, Secos Group, Biome Technolgies, FKuR Kunststoff, Innovia Films, and Toray Industries.

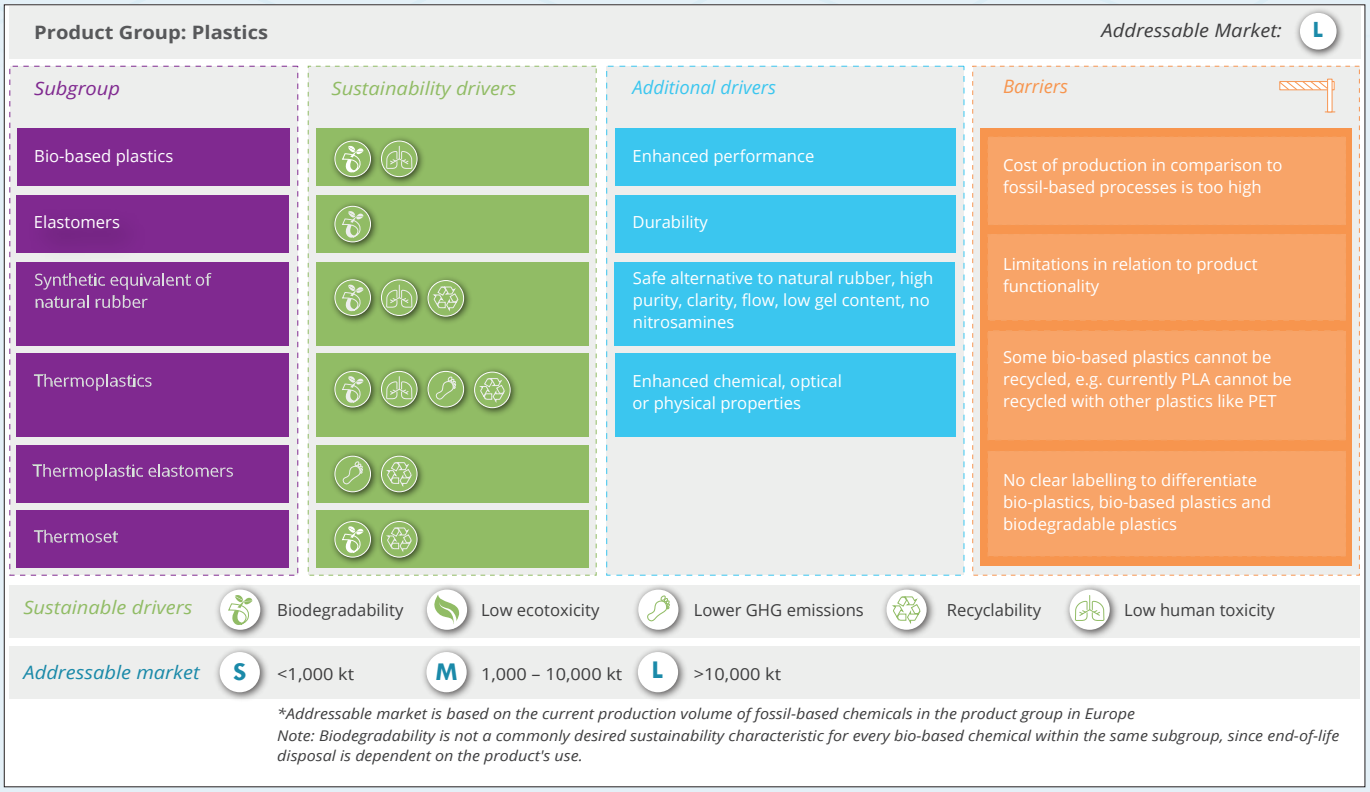


Figure 18: Pictorial summary of the plastics/polymers product group

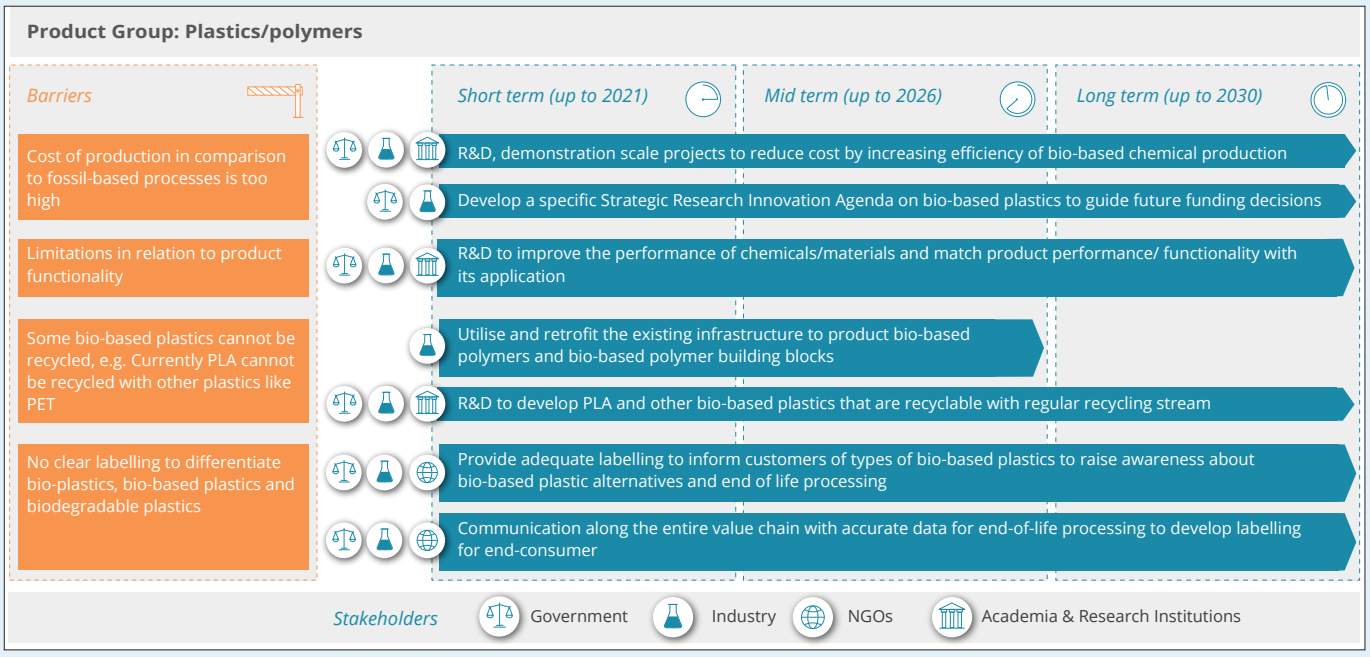


Figure 19: Roadmap to increasing the bio-based share of chemicals in the plastics/polymers product group

Besides the product-group specific analysis of barriers, some larger issues exist that concern the wider chemical industry in the bioeconomy. These are referred to in RoadToBio as general barriers. We give an overview of the most crucial general barriers and provide some recommended actions to overcome these. The collected set of actions are a mixed result of project-internal discussions, stakeholder discussions and feedback, as well as recommendations from other EU projects or strategy documents.

We classify the general barriers to increasing the bio-based share in the chemical industry into six main categories:

1. Access to feedstock
2. Competition with established fossil industry
3. Regulatory barriers
4. Societal barriers
5. Markets, Finance & Investment
6. Research & Development.

Figure 20: Summary of the general barriers and recommended actions for all six barrier

Contributing authors

E4tech: Yamini Panchaksharam, Pragna Kiri, Ausilio Bauen

nova-Institute: Christopher vom Berg, Ángel Puente, Raj Chinthapalli

BTG: Jurjen Spekreijse, John Vos, Swinda Pfau

DECHEMA: Kathrin Rübberdt, Jochen Michels, Lea König

Acknowledgement

The RoadToBio consortium would like to thank the BBI JU for funding this project under the EU's H2020 research and innovation programme. Further, we are grateful to the Industry Expert Group for their critical input and review throughout the project. We would also like to thank Lara Dammer and Mladen Crnomarković for their key input and review of the strategy document. Finally, we would like to thank all the stakeholders from diverse sectors such as industry, public and private sectors, and NGOs, for being part of this journey and for their feedback at key milestones of the project.

Disclaimer

The RoadToBio project consortium has taken due care in the preparation of this report to ensure that all facts and analysis presented are as accurate as possible, within the scope of the project. However, no guarantee is provided in respect of the information presented and the consortium is not responsible for decisions or actions taken on the basis of the content of this report.

The consortium has used an evidence-based approach for the analysis and has relied on publicly-available information in reports. However, the consortium has not verified the completeness and/or accuracy of the information contained in publicly-available reports cited in this document.

Download the full strategy document here:
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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 745623.

Bio based Industries Consortium

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