



BRYOMOLECULES

Policy brief 1

D6.4

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BRYOMOLECULES Project



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Project information

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The BRYOMOLECULES project

Liverworts, an ancient group of land plants, are a rich yet underexploited source of a wide range of biologically active compounds with high potential for the bioeconomy sector as ingredients of cosmetics/cosmeceuticals and pharmaceuticals. However, their slow growth rate in nature and the consequent difficulty in obtaining large amounts of single compounds have, until now, severely hindered the in-depth exploration and exploitation of the full spectrum of activities of liverwort secondary metabolites. Recent breakthroughs in the identification of some of the genes involved in the early steps of liverwort-specific compounds suggest that, in addition to the establishment of improved methods for growth in axenic conditions, reconstruction of liverwort metabolic pathways in heterologous systems is a promising way forth towards the practical exploitation of liverwort biochemical diversity and its industrial scale up.

BRYOMOLECULES will provide actionable knowledge on European bryophyte species and their biosynthetic genes, which can be used to produce sustainable, bio-based cosmetics and pharmaceuticals ingredients for the European market.

To do so, the BRYOMOLECULES project will use a combination of the cultivation of axenic cultures and the production of the active compounds in heterologous systems to define the most suitable production platform(s) for their large-scale production. The project will achieve a very sustainable use of the chemical diversity of wild EU bryophyte species, a largely untapped source of high-added-value natural products, without significant impacts on their biodiversity.

Besides the identification of relevant lead compounds for cosmetics/cosmeceuticals and pharmaceuticals, another major impact of the project will be the production and release according to FAIR principles of a database of metabolites and biosynthetic genes of European bryophyte species that will fuel in the years to come the development of novel bio-based products based on bryophyte-derived lead compounds, according to the concept of EU valorising biodiversity for EU bioeconomy.



Project Consortium Members









	Fondazione Edmund Mach (FEM)
	Fondazione HUB Innovazione Trentino (HIT)
	Université Jean Monnet Saint-Etienne (UJM)
	Plant Advanced Technologies Pat Sa (PAT)
	Bionos Biotech SI (BIONOS)
	Lunds Universitet (LU)
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	European Science Foundation (ESF)

Table 3 Consortium members



Summary

In this deliverable we present a preliminary policy brief outlining the policy implications directly related to BRYOMOLECULES implementation and expected outcomes. These implications are presented under different contextual groups, covering the current regulatory frameworks for the production of bioactive molecules from engineered species, the EU plans and goals for biodiversity conservation and circular economy implementation, as well as social and consumers acceptances of biotechnology-based products.

A second policy brief will be produced at the end of the project (M36) drawing from the project outcomes generated and translating them into actionable policy recommendations.



BRYOMOLECULES and the policy implications of biotechnology-based metabolic engineering processes for added-value secondary metabolite production

Introduction and background information

European bryophytes—mosses, liverworts, and hornworts—represent one of Europe’s most underexplored biodiversity resources. Despite their ecological importance and the biochemical diversity they harbour, bryophytes remain largely absent from both current bioeconomy strategies and biodiversity policies.

The EU-funded BRYOMOLECULES project seeks to address this knowledge gap by exploring the potential of bryophytes as a source of bioactive compounds (BACs) that can be sustainably integrated into pharmaceutical, cosmetic, and biotechnological value chains. The project combines biodiversity research, metabolic engineering, and circular economy approaches to create an alternative to fossil-derived chemicals and unsustainable natural resource extraction. The project aligns with EU priorities related to biodiversity and circular economy, supporting European biodiversity goals, industrial resilience, and societal readiness for bio-based innovation. The large-scale adoption of bio-based novel technology however, requires adequate policy and regulatory oversight to allow for the effective uptake of the developed technology. In the framework of BRYOMOLECULES, this means that on top of the technological objectives targeted, a number of policy implications will directly originate from the scientific activities implemented by the project.

BRYOMOLECULES: policy landscape and relevant implications

Biodiversity conservation VS sustainable use

Bryophytes are uniquely positioned at the intersection of biodiversity protection and innovation. The biochemical complexity makes them a promising source for bio-based production of BACs. On the other hand, large harvesting of wild populations could threaten the bryophyte ecosystems. To the challenge of using bryophytes as source of BACs with commercial value while at the same time preserving their biodiversity, BRYOMOLECULES responds by developing a biotechnological production platform based on axenic cultivation methods, which allow for the sustainable supply of compounds without depleting natural populations.

Policy implications: bryophytes should be more fully integrated into biodiversity frameworks such as the EU Biodiversity Strategy 2030, the Convention on Biological Diversity (CBD), and the compliance mechanisms under the Nagoya Protocol.

At the same time, measurements should be established to balance conservation and exploitation, such as ex situ cultivation and in situ protection of bryophyte-rich habitats.



Strengthening European Industrial Sustainability and Autonomy

Europe's pharmaceutical and cosmetic industries continue to rely heavily on fossil-derived reagents and globalized supply chains. These dependencies expose them to vulnerabilities linked to energy crises and geopolitical disruptions. By piloting a bioreactor-based production of BACs enabled by metabolic engineering of European bryophytes species, BRYOMOLECULES shows that Europe can build new, locally sourced bio-based pathways for BAC production, thus strengthening Europe's strategic autonomy and industrial competitiveness.

Policy implications: EU incentives for R&D investment and dedicated funding streams for natural BAC discovery and biotechnological scale-up would help translate these technological advances into market-ready applications. Public procurement could further accelerate uptake by prioritizing sustainable and innovative bio-based solutions in healthcare and consumer goods.

To ensure large uptake and broad commercialisation, traceability, reproducibility, and purity for industrial applications, quality standards for bryophyte axenic cultures should also be established.

Circular economy and biotechnology integration

The European Green Deal and the Circular Economy Action Plan call for minimizing waste and maximizing resource efficiency. BRYOMOLECULES provides a model for how synthetic biology and metabolic engineering can reduce environmental pressures by replacing chemical synthesis with eco-friendly biological production and by valorizing biomass residues through biorefinery approaches.

Policy implications: policymakers can support the uptake and transition to bio-based production methods by supporting pilot-scale platforms for BAC production, funding dedicated discovery efforts targeting rare and understudied taxa, and promoting open-access databases containing transcriptomic and metabolomic profiles of European bryophytes. Such knowledge-sharing infrastructures would catalyze further innovation across the bioeconomy.

Societal acceptance and consumer awareness

Despite the environmental benefits of biotechnology, public acceptance remains limited, particularly in the fields of cosmetics and pharmaceuticals. Concerns about genetic modification, safety, and sustainability often slow down regulatory approval and market penetration. BRYOMOLECULES dedicates effort in public engagement, education, and outreach, advocating for transparent communication informed by science-based evidence.

Policy implications: science-informed, transparent communication from EU and national authorities will be essential for fostering consumer trust. Policymakers should actively advocate for acceptance and trust-building by acknowledging and promoting the ecological and climate benefits of biotechnological production and the safety of compounds obtained from genetically modified (micro)organisms (GMOs). To complement this, EU-level eco-labeling and certification schemes for bio-based products could provide consumers with assurance of quality and sustainability, reinforcing demand for natural and innovative alternatives.

Regulatory clarity

The promise given by bryophyte-derived compounds must be matched with clear governance frameworks, to guarantee compliance to relevant legal and regulatory frameworks. Key issues include access and benefit-sharing under the Nagoya Protocol, the regulation of GMO-derived enzymes or engineered organisms, and the approval pathways for novel metabolites in cosmetics and pharmaceuticals.



Policy implications: comparative studies should be encouraged on the environmental impact of biotechnological versus traditional chemical production, ensuring that Europe develops clear regulatory approaches that favour sustainable bio-based innovation and its large-scale implementation and uptake.

Conclusion

Bryophytes are a largely overlooked resource that can play a transformative role in Europe's biodiversity conservation goals and circular bioeconomy transition. BRYOMOLECULES demonstrates how scientific innovation can unlock this potential while safeguarding ecosystems and reducing Europe's reliance on fossil-derived chemicals, effectively offering a unique opportunity to link biodiversity protection with circular bioeconomy innovation. BRYOMOLECULES demonstrates how Europe can pioneer sustainable biotechnology for high-value bioactive compounds, contributing to climate goals, industrial resilience, and societal acceptance of bio-based innovation.

Policy action will play a key role to integrate bryophytes into European biodiversity and industrial frameworks, ensure appropriate regulatory clarity and provide incentives for sustainable innovation. This would not only strengthen Europe's resilience and competitiveness but also affirm its leadership in aligning biodiversity protection with biotechnology-based circular economy solutions. By investing in bryophytes today, the European Union can turn an underexplored harbour of biodiversity into a cornerstone of its sustainable future.