

Reflection paper

EBU vision of future Bioeconomy and the role of higher education institutions

1. About EBU

The European Bioeconomy University (EBU) Alliance is a joint commitment among eight academic partner institutions¹, aiming to take the role of a leading intellectual player in the field of the Bioeconomy to tackle the enormous environmental, economic and societal challenges of the 21st century. Since its foundation in July 2019, the EBU recognizes that European excellence in the Bioeconomy requires stronger and broader collaboration and vision. By pooling resources at both political and operational levels and by connecting with additional academic and business partners, the EBU aims to be a Bioeconomy "game changer" in the European Union (EU) and enabler for the full deployment of the Bioeconomy.

2. Why this reflection paper and the process

Taking the opportunity of its 5th anniversary, the EBU launched a reflection aimed at developing a vision for the future Bioeconomy. This exercise aims to contribute to the discussion about the Bioeconomy at the European and global levels.

This reflection paper summarises the main points of the vision. It is based on three main sources: literature on trends, strategies and gaps; input from scientists from EBU and, in particular, common EBU projects; and institutional visions by EBU members. After a preliminary collection of insights from the literature, an expert workshop was held in Vienna on 14-15 October 2024. The main outcomes of this workshop were presented and discussed at the EBU 5th anniversary event in Brussels on 19 November 2024. Finally, four rounds of internal consultation were conducted prior to this release.

The intention of the reflection paper is to frame the role of the Bioeconomy in the current processes of change and to stimulate discussion about its future. For this reason, we do not focus on its definition, but rather acknowledge that the scope of the Bioeconomy concept is evolving over time and adapting to different geographical areas. This is also intended to avoid excluding promising future options for related sectors and fields of research. For the same reason, in the following, we start from the broader picture of high-level societal objectives underlying the Bioeconomy and then narrow down attention to the specific role of Higher Education Institutions (HEI).

3. Potential role of the Bioeconomy in the economy and society

Drivers and motivation

Our vision of the Bioeconomy can be framed in the wider scope of society's aspiration to a higher quality of life. Justice and equality, self-fulfilment, freedom and health of both human and non-human nature (e.g. "One Health") are central parts of quality of life. While a common high-level framework for this ambition can be identified in the UN Sustainable Development Goals (SDGs), we also acknowledge that dealing with the Bioeconomy may require a broader and more dynamic interpretation.

The economy can be seen as a holistic mechanism mediating between societal functioning and natural resources. The Bioeconomy is the best answer to society's aspirations thanks to its integrated and systemic approach. It connects directly to sustainable production, climate change, resource efficiency, closing nutrient and water cycles, reducing environmental damages, promoting circularity and sufficiency, and moderating conflicts while contrasting the idea of unlimited growth with limited resources.

The Bioeconomy is not just about technological solutions, it's about changing how society works, our institutions and how people connect with nature. For this to happen, we need to help people to connect

¹ The partners of the alliance are: Institut des sciences et industries du vivant et de l'environnement (**AgroParisTech**), France; BOKU University (**BOKU**), Austria; Swedish University of Agricultural Sciences (**SLU**), Sweden; University of Eastern Finland (**UEF**), Finland; University of Hohenheim (**UHOH**), Germany; Alma Mater Studiorum – Università di Bologna (**UniBo**), Italy; Warsaw University of Life Sciences (**SGGW**), Poland; and Wageningen University & Research (**WUR**), the Netherlands. The associated partners are: **BIOEAST** Initiative <https://bioeast.eu/>, **European bioplastics association** <https://www.european-bioplastics.org/>; European Forestry Institute (**EFI**) <https://efi.int/>.

with nature, and cultivate a scientific worldview with which society can actively participate in this transformation (e.g. through Citizens' science). We need increasing consumer awareness and moderating consumption, support new sustainable life styles and bringing bio-innovations to replace non-renewable and fossil-based products and services.

It also means aiming at a more just and sustainable society, leaving nobody behind. This includes poverty alleviation and job creation, food security, energy for energy-poor communities, and redefinition of biobased value chains (e.g. using solutions that give opportunities to small enterprises and local actors to develop their own industries and allow a balanced distribution of profits along the value chain, including producers of raw materials).

To achieve this ambition, the Bioeconomy must be strongly interlinked with a regulatory system that allows people to participate in designing the economic system. This is part of a strategy that fosters a sense of belonging and connectedness, driven by positive imaginings and encouraging mutual respect, which is also expressed towards nature, accepting its finite capabilities through sufficiency-based approaches. Eventually, a balance between human and non-human nature can be targeted, taking into account planetary boundaries.

A key aspect of the Bioeconomy is to reduce the dependence on limited resources (e.g. fossil resources, phosphorous) and promote a transformation to a (mostly) fossil free society: a kind of economy that not only changes the way we produce and consume, but also brings development from the ground, with a focus on sustainable sources, fairness and democratization, and reduces the pressure on natural resources to allow the recovery of nature. These general principles should guide the development of context-specific and place-based solutions.

Reaching the objectives above also means dealing pragmatically with overcoming barriers, strengthening drivers and building motivations. Drivers can be attached to outer societal factors such as education, societal change, competitive pressure, geopolitical factors and ethics. Motivations can be related to inner factors affecting human behaviour, such as health concerns, but also attaching emotional, cultural and identity meaning to the Bioeconomy.

Technologies

The Bioeconomy uses a variety of technologies and emphasises technological innovation. Primary production technologies need to assess their impact on biosphere integrity (i.e. a diversity of species, from land and water and from diverse kingdoms) while improving crops (e.g. through new breeding techniques, promotion of new production systems such as vertical and precision farming and balance between local and global production). Approaches encompass boosting nature-inclusive agriculture, such as agro-ecology, conservation agriculture and nature-based solutions. Special attention should be given to emerging and niche sub-sectors, such as insects, microbes, and the blue Bioeconomy, including algae.

Processing requires speeding up sustainable technological innovation from lab to market. It needs an evaluation of the potential of different technologies, looking at novel solutions of higher economic value as well as integration with technologies producing lower value but highly demanded products to ensure full valorisation of biomass. Biotechnologies can contribute to different sectors, e.g. food, pharma and health or the production of novel products and bio-based chemicals and their derivatives.

Consumer perception is vital to technology innovation in the Bioeconomy. Consumer acceptance of technologies concerns both biomass production and processing. Disruptive innovation can have a potentially great impact, but sometimes low acceptability. Good information to the consumer and co-ownership of new technologies are needed, as well as a suitable framing of technologies (which is a main determinant of their adoption).

A whole Bioeconomy value network is needed, leaning towards a systemic approach. This includes exploring synergies in the production chain and among chains, seeking circular systems by design, benefiting of whole biomass-use crops and cascading principles, while balancing local systems with global value networks.

Services are an important part of the future Bioeconomy. Examples include ecosystem services but also more specific and innovative topics, such as nature-based therapy (e.g. augmented/virtual reality), connection with health, recreation, art, culture and design.

Convergence and synergies with other disrupting fields of technology, in particular digitalisation, artificial intelligence and robotics, are central for the future Bioeconomy development, understanding and acceptance.

Economic, policy and social innovation

Innovation systems need to be redesigned for the Bioeconomy transformation. In transformative innovation systems, start-ups and consumers play a key role as well as civil society organizations. Education in its different forms is a backbone of the innovation system. Entrepreneurs are trained in universities, new consumption behaviour is developed there, and in a bottom-up process demand and supply side dynamics come together to trigger the sustainability transformation. Vocational education and life-long learning allow adaptation to new economic and technology opportunities. In short: the desired transformation will be a knowledge intensive and a knowledge-driven process!

Complexity matters as the transformation is not a simple substitution of old technologies with new (clean) technologies. Instead, the whole economic system requires a fundamental restructuring; the interplay with the supply and demand side (i.e. new lifestyles) is of crucial importance for the Bioeconomy as it enables the technology acceptance and the market development mentioned above.

Also, uncertainty is a crucial characteristic of the system. There is no perfect foresight, and knowledge is developed in an experimental process; failure cannot be avoided but must be considered as a part of the learning process. For the public debate on the transformation, this means that appropriate communication and transparency as a paradigm of good governance is needed.

Start-up companies and entrepreneurial activities are one of the backbones of the transformation process. In research, the role of changemakers can come from different actors and their collaboration. Youth may be a focal point of attention in this respect. However, established actors and large incumbents (also) matter to unfold the transformative power of the Bioeconomy. They are necessary to provide mentorship support to youth groups and guide them inspired by best practices and mistakes/failures. For this, their awareness and absorptive capacities has to be improved and possibilities are to be made explicit about how the Bioeconomy can complement their businesses. Efficiency orientation and the exploitation of economies of scale and mass production remain important.

It is recognised that the Bioeconomy has the potential to create "green jobs" in urban areas and close to research institutions. However, the Bioeconomy also offers specific opportunities for rural regions. On the production side, the Bioeconomy is characterized by activities which are dominantly located in the countryside (e.g. agriculture, forestry, fishery). As the Bioeconomy is in many cases 'knowledge-based' the new jobs created are potentially new income opportunities in rural regions. Further, the Bioeconomy offers opportunities for marginalized groups (groups or communities that experience discrimination or exclusion) in society. These aspects of the Bioeconomy help to reduce the polarization between metropolitan areas and periphery. In the context of the EU, this can contribute to reduce geographical divide and promote regional integration.

It also requires balancing policies and better functioning markets, e.g. through education policies, better regulations (including removal of regulatory barriers) and prices on ecosystem services (environmental services, pay for pollution, pricing of nature). One of the big barriers we have seen is not the technology itself, but the framework around it. For this to be working, we need:

- Clear definitions (biobased, biodegradable, compostable, etc. – so that people and companies know what counts).
- Proper end-of-life systems (recycling, composting, recovery, etc. - so these materials actually deliver on their promises).
- Support to scale up beyond pilot projects (investment, demonstration plants, cross-sector collaboration, finance, etc. - so that ambitious visions become large-scale solutions).

Equally important is the systematic engagement of Europe's many small private forests and landowners through dedicated advisory services, peer-to-peer learning platforms and incentive schemes that underline the economic and ecological benefits they can obtain from and provide by integrating their resources into bio-based value chains.

4. Role of higher education institutions in the Bioeconomy

Research

For a resource-efficient Bioeconomy, research needs to provide technology development, increasing productivity and process efficiency, building on a strong collaboration between HEIs, research centres and industry. A renewed attention to biotechnology and biomanufacturing is vital for research and for the diffusion of Bioeconomy innovations, as well as for exploiting the potential for digitalization and artificial intelligence in the Bioeconomy.

However, Bioeconomy development also requires a comprehensive view on research that encompasses economic, societal, and environmental aspects. This approach needs to be consolidated through inter- and transdisciplinary research, fostering cooperation across social, economic, and technical disciplines. The inclusion of social sciences in particular is critical, as transformational change is a long process that requires understanding societal impacts, preferences, and expectations. Thus, HEIs can act as bridges between industry, policymakers, and citizens, helping to turn ideas into reality and building trust in the process. It is not only about new materials and processes, but also about how people use and accept them.

A critical issue in current Bioeconomy research is the lack of long-term funding structures and central research institutions that can ensure continuity and depth in research. Bioeconomy transitions are long-term visions, which must be supported by stable funding to ensure that knowledge is actionable and can address societal needs. Furthermore, a renewed effort is needed to maintain momentum through clearer narratives of the Bioeconomy, more focused terminology, and a joint understanding of the diverse perspectives within Bioeconomy research.

Environmental concerns have been only partially represented in Bioeconomy research, despite their integral role in sustainable development. Strengthening the partnership between Bioeconomy initiatives and climate, biodiversity and soil research is essential to ensure that environmental factors are adequately addressed.

On a broader level, the governance and policy systems surrounding Bioeconomy research must be adjusted to align with the evolving landscape. This includes a focus on fostering Bioeconomy research in rural and underdeveloped areas, which can contribute to the creation of green jobs and sustainable development. Moreover, there is a pressing need to invest in the infrastructure required to scale up Bioeconomy innovations.

Education

Reshaping our education systems will play a key role in fostering the Bioeconomy transition, with the overarching goal of empowering students, citizens or professionals to become agents of change, having fully embraced the values brought about by the Bioeconomy.

The implementation of a sustainable Bioeconomy needs change-makers who can drive the sustainability transition, but also experts and craftsmen with practical and technical skills.

We reckon that Bioeconomy education programmes should target a broad audience encompassing all age groups, but especially the youngest ones, to spark interest early on (for example, through practical experiments in primary schools and high schools). Master's students are another focus group, as they comprise the largest group of graduates employed by the Bioeconomy. PhD students are a pivotal group at the interface with research. At a later age, career switchers enticed by the merits of the Bioeconomy (e.g., through its reconnection with nature or sustainability agenda) are another prime target for which ad hoc Bioeconomy education could act as a career booster. Lifelong learning programs could be more dedicated to focused technical skills to deal with new bio-based resources, bioprocessing and biotechnology.

Many recent projects have investigated current skills mismatches and detailed desirable skill sets for the future Bioeconomy. We concur that training paths should put a clear emphasis on soft skills (ability to work in teams, take initiatives, communicate or exercise leadership, entrepreneurial mindset) and reflective skills (critical thinking, open-mindedness), systems thinking and multi- and transdisciplinarity (and how to facilitate it). However, a complementary development in technical skills accompanied by awareness of the transformative environment is equally needed.

Recent EBU projects have generally tested and advocated a T-shaped approach to curriculum design, combining specific sectoral skills with the above cross-cutting ones. Teaching formats engaging learners through action-oriented, learning by doing, or problem-solving, and blended learning using resources easy to share across higher education institutions are especially suitable for the Bioeconomy. As a "meta-sector" cutting across all sectors of the traditional economies, the Bioeconomy will employ a large diversity of job profiles with the ability to act as change-makers, innovation brokers or (social) entrepreneurs as a common denominator. These dynamics are especially relevant to rural or peripheral areas.

Third mission and impact

Higher education institutions are essential players and intermediaries in the Bioeconomy innovation system. HEIs need to build on a transdisciplinary approach for holistic and impactful research and technology development, and transformative science increasing visibility of potential and prospective Bioeconomy solutions. HEIs share the responsibility of raising awareness, contributing to public engagement, and providing information at economical and societal levels. They catalyse change in people's values, their consumer behaviour, facilitate participative decision making and inclusive innovations (co-creation with communities) – in other words: HEIs support people, organisations and stakeholders in experiencing (and participating in) the Bioeconomy.

The above should build on the notion that Bioeconomy is "science-based" and hence on the effort to link science, business and society through knowledge sharing, by nurturing a culture of innovation and a new generation of bio-entrepreneurs.

Operational strategies within the HEIs also entail promoting early interaction of students with the public and industry, encouraging Bioeconomy start-ups, targeting not only national, but also international markets, involving alumni and policy consultancy. Other priority actions would be to develop living labs, innovative formats for interaction with society, encourage students to create their own "sphere of collaboration", promote citizen science activities and lifelong learning models for transformation.

Furthermore, efforts should focus on scaling up and transferring already developed technologies into local contexts, particularly through collaboration with small and medium-sized enterprises (SMEs) and public institutions. HEIs can also play a wider role as advisors for policy makers and providers of direct support to policy design, implementation and evaluation. This also entails promoting a reputable public perception of HEIs in order to be credible and trustworthy.

5. Conclusion

This reflection paper presents a vision of the Bioeconomy, inspired by a positive image of the future, that enables the integration of economic, social, and environmental trajectories into a comprehensive vision for transforming behaviour, social linkages, and technologies. It aims to improve the quality of life, contributing to well-being and sustainability by ensuring the provision of a wide range of goods, from food and energy to chemicals and biobased materials, while still addressing significant long-term, concrete challenges in our society, namely climate change, depletion of non-renewable resources, and the crossing of planetary boundaries. In response to geopolitical tensions, pandemics, and climate-related crises, European policy priorities have shifted toward competitiveness resilience, security, and strategic autonomy. The Bioeconomy helps to navigate this evolving context by enhancing food security, energy independence, and supply-chain stability through sustainable solutions.

To make the Bioeconomy happen in practice, we need to:

- Give markets a boost with incentives – e.g., public procurement that favours sustainable, biobased options.
- Maintain consistent and predictable regulations – avoiding mixed signals between the EU, national, and local levels.
- Set out a clear roadmap with milestones so everyone knows what to expect and when.

As the Bioeconomy places a strong emphasis on knowledge and innovation, the role of HEIs is crucial and will continue to increase in the future. Fulfilling this pivotal role requires reflection and innovation in all areas of activity at HEIs, as well as enhanced coordination among the three traditional missions of HEIs (education, research, and societal impact), by focusing on creating a transformative system.

Knowledge sharing has the potential to help address the complexity of current challenges adequately, but this requires a more substantial involvement of HEIs in Bioeconomy innovation systems, in cooperation with economic and societal actors, and the development of a sound communication strategy for this transformative approach. A key aspect in this direction lies in the active exchange of best practices, acknowledging the diversity of solutions and leveraging ongoing experiences. By fostering the personal development of students and staff, HEIs will empower individual and institutional change-makers in the developing concept of Bioeconomy.

This vision requires a strong commitment from public policy, ranging from removing regulatory barriers to establishing a consistent long-term funding strategy that supports a European-level approach to Bioeconomy education and research. By framing the Bioeconomy as a key driver of societal resilience, HEIs can help ensure continued support and investment despite shifting EU priorities.

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