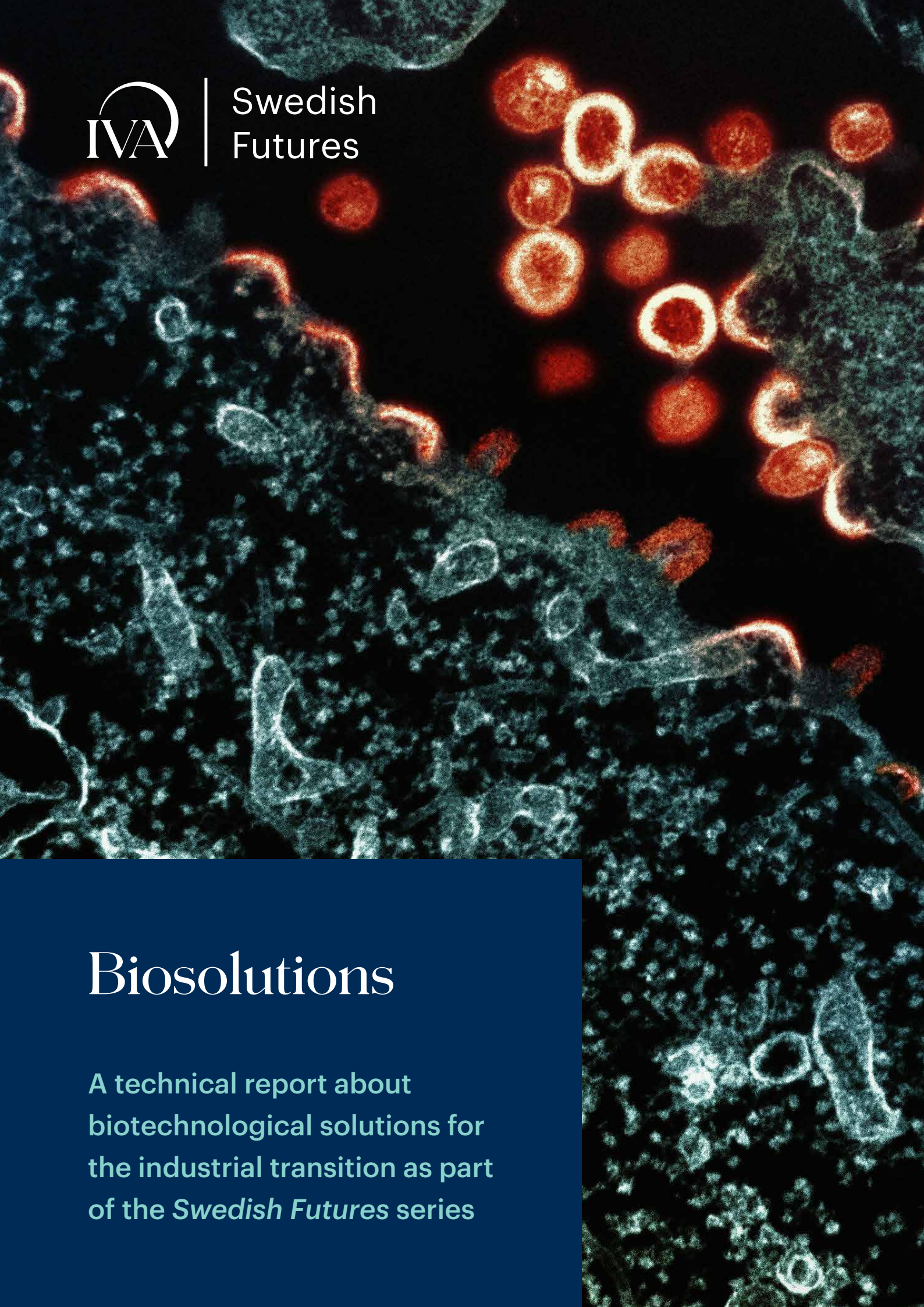


IVA | Swedish Futures

Biosolutions

A technical report about biotechnological solutions for the industrial transition as part of the *Swedish Futures* series

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Foreword



IVA is spearheading the *Swedish Futures* initiative to formulate a vision for Sweden as a leader in technology and innovation by 2035. Since autumn 2025, *Swedish Futures* has brought together stakeholders from academia, industry, and the public sector to identify opportunities, challenges and strategic directions for competitiveness and sustainable development.

Among other things, the initiative convenes working groups that quickly and systematically analyse challenges and opportunities in different technology areas and produce highly focused reports. These reports provide an overview of the status quo and outlook for the field under examination and present concrete proposals for action. They also serve as an important foundation for shaping an overarching vision for Sweden in 2035.

This report was produced by the working group on biosolutions. The group's analysis shows that Sweden has strong research, high-quality raw materials, and technical expertise in biotechnology, but lacks the capacity, regulatory framework, and funding to translate this into competitive products and companies.

As in all IVA projects, the participants have contributed in their personal capacity and not as representatives of the organisations where they work.

The report's analyses and recommendations are largely based on discussions within the working group, as well as on the experiences and knowledge contributed by its members. The working group stands behind the report in its entirety, but this does not mean that all members necessarily endorse every formulation.

The Biosolutions working group was active from April through October 2026.

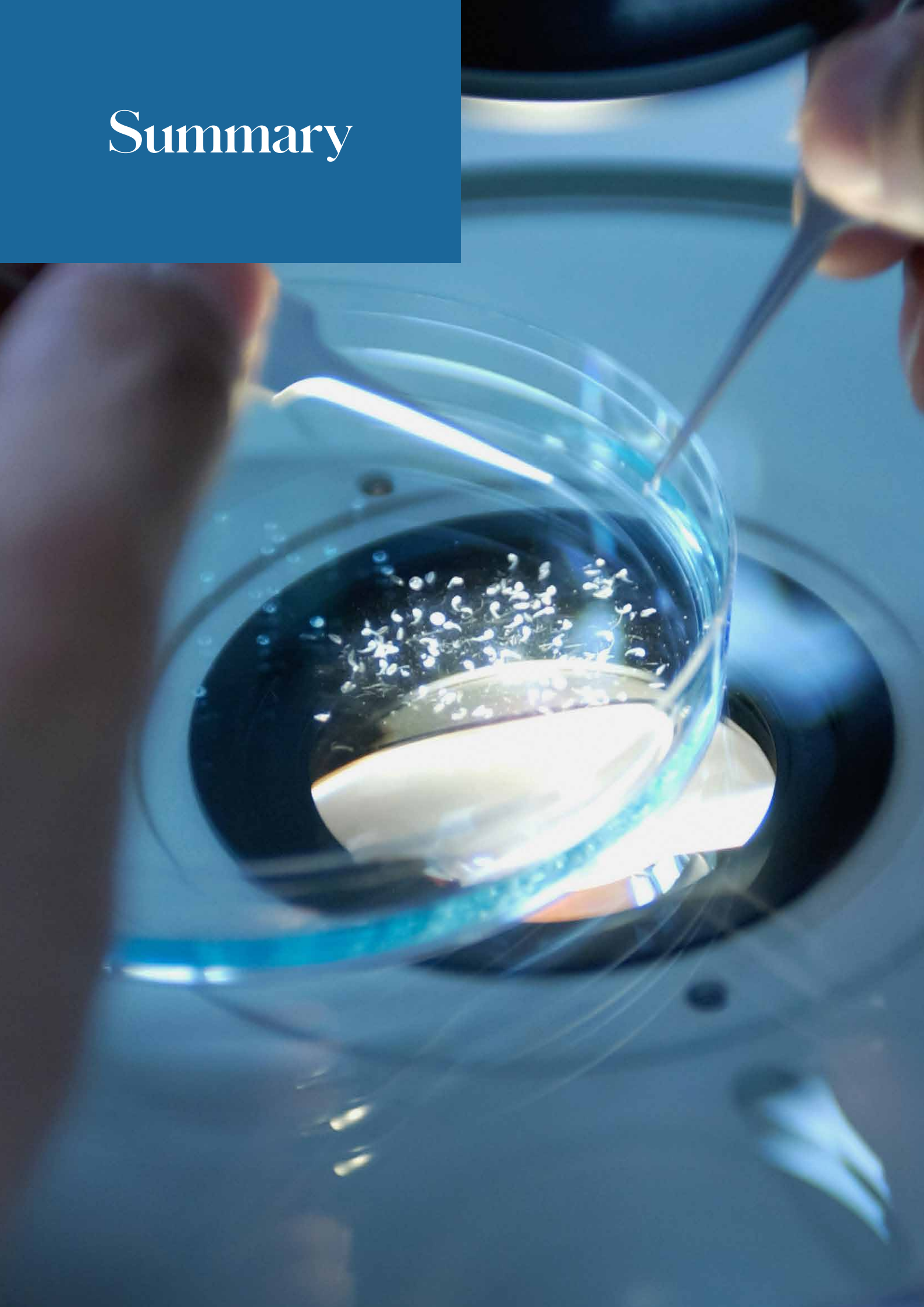
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Summary



Biosolutions use biological systems and processes to develop and manufacture materials, chemicals, and food, among other things. Key technologies include fermentation, enzyme technology, and synthetic biology. This field can contribute to new products, more efficient use of raw materials, and reduced dependence on fossil-based raw materials.

The applications are numerous. Biological processes can be used to produce new foods and ingredients, chemicals and fuels, and materials and packaging. By making use of multiple parts of the same raw material and of side streams, more value can be created from existing resources.

Sweden is well-positioned to develop this field. The country boasts strong research and biotechnology expertise, an established industry, and experience in advanced production and process technology. It also has significant biological resources, including those from forestry and agriculture. A key question is how this knowledge and these resources can be translated into new products and businesses.

The path from research to market is often long. Companies must be able to test and scale up new processes, secure capital, and gain access to the right expertise. Regulatory frameworks can also be complex and prolong the path to market. The conditions for biosolutions need to be improved throughout the entire process – from research and raw materials to production and sales.

The working group has three overarching recommendations on what Sweden should focus on to strengthen Swedish competitiveness, advance sustainability, and contribute to Swedish and global security and resilience. These are based on an analysis of Sweden's current position in the biosolutions sector, international development trends, and a review of key issues that identify obstacles and opportunities for Sweden's continued development. The recommendations summarise proposals and action items that are presented in greater detail in the report.

- Build a national scale-up facility and ensure access to Swedish test markets, enabling biosolu-tions companies to scale up in Sweden and generate growth both domestically and internation-ally.

- Simplify regulations and speed up permitting processes to reduce dependence on fossil and im-ported raw materials, attract investment, and bring products to market faster.

- Create a cohesive talent development system covering the entire chain – from undergraduate education, graduate studies, and research in collaboration with industry, to laboratory work and commercial production – so that Swedish research and innovation contribute more to the growth and competitiveness of Swedish companies.

Starting points for work on biosolutions



THE CONCEPT OF BIOSOLUTIONS

There is no universally accepted definition of the term "biosolutions," even though it is used around the world in many different kinds of texts. Authors typically define in each case what they mean by the term and how it is applied in that specific text. Therefore, it is important to be aware that "biosolutions" can have somewhat different meanings depending on the context.

The term is used, among other things, to refer to biological solutions in agriculture and the food industry, as well as more broadly in industrial biotechnology and the bioeconomy.

Some examples:
The term "biosolutions" covers goods and services derived from combining biology and technology with the ambition of accelerating the Green Transition. "Inspired by nature" is the principial concept of bioso-lutions. Through advances in technology, we can combine biology with technology to create biological, industrial green solutions – or, in short, biosolutions. *Biosolutions Glossary. The European Biosolutions Coalition.*

Biosolutions means a product, process, service or enabling technology that uses, contains, is produced by, or is functionally enabled by living organisms, biological systems, enzymes, micro-organisms, cells, microbial, fungal or algal biomass, fermentation, biocatalysis or other biological processes, and that is intended to provide a functional, industrial, agricultural, food, feed, material, circular-economy, cli-mate, environmental or resource-efficiency benefit.

Source: Working document from The European Biosolutions Coalition.

Background

In this report we use the term "*biosolutions*," encompassing solutions for the sustainable production of materials, chemicals, and food using microorganisms or their components in biotechnological processes. The term also includes resource-efficient circular flows and the potential to use microorganisms to restore damaged natural environments.

Scope of the technology report

The following limitations apply to this report:

- It is limited in scope and focused on biosolutions;
- It does not cover the prerequisites, conditions, and development opportunities relevant to the medical segment of the life sciences field,
- It does not cover the primary production of raw materials that are processed using the abovementioned technologies. This means that the extraction of biological raw materials and resources in the first stage of the value chain – forestry, agriculture, or aquaculture – is not included. The scope thus includes the production of raw materials in agriculture and forestry through cultivating and harvesting plants, crops, and forests, as well as raw materials produced in fisheries and aquaculture by catching and farming fish, shellfish, and algae.
- In this report, we do not view waste as a problem that needs to be managed. Instead, we focus on circularity and value creation from side streams.

TABLE 1: IVA's selection of topics for technical reports is based on eight criteria.

CRITERION	BIOSOLUTIONS IN SWEDEN
Global Leadership	Sweden has the potential to take a leading position in biosolutions through strong research, access to renewable resources, and a competitive industrial base.
Turnaround (opportunity to reverse current trends)	Biosolutions can become a key driver in the transition from fossil-based to renewable production systems and contribute to a more sustainable economy. Biosolutions can also create new products and production methods that change where and how goods are produced.
Positional shift	A strengthened sector can drive a shift from raw material exports to a more knowledge-intensive economy where biological resources are processed into high-value products and services.
Enabling technology	Advances in areas such as fermentation, enzyme technology, synthetic biology, and digitalisation create new opportunities to scale up sustainable products and industrial processes.
International dimension	The combination of research expertise, industrial experience, and access to renewable raw materials provides Sweden with a strong foundation for developing solutions that are in demand internationally.
Megatrends	Biosolutions address several global megatrends, such as health and nutrition, climate transition, increased resource efficiency, circular flows, and the need for sustainable production systems.
Geopolitics	Biosolutions can strengthen Sweden's resilience by reducing dependence on fossil raw materials and contributing to increased access to domestic and renewable resources.
Hot topic	The field is developing rapidly and attracting considerable international interest, driven by technological advances and growing demand for sustainable alternatives to fossil-based products and processes.

Given these limitations, it is also important to emphasise that biosolutions can be viewed as a partially overlapping, but more production- and transition-oriented, component of life sciences. We have limited our scope to those areas directly relevant to the industrial use of biological systems, processes, and organisms. The focus is on the development and production of bio-based solutions such as new materials, chemicals, food products, and industrial processes. The medical aspect of life sciences – including pharmaceuticals, diagnostics, and medical technology – falls outside this scope and is not included in this report.

Reasons for prioritising a technology report on biosolutions

IVA has conducted a data-driven analysis of patents, scientific publications, and startup investments to map Sweden's global position in 48 strategically important technology areas that are of great strategic importance to the country's future prosperity, economic resilience, and national security.[1]

Among other things, the analysis revealed that Sweden needs to adopt a more strategic approach to secure its position internationally. Against this backdrop, IVA decided to conduct an in-depth analysis of biosolutions and develop proposals for the desired future direction in this area. The selection is based on eight criteria; see Table 1.

The use of biosolutions can, among other things, replace fossil-based inputs in industrial processes, thereby reducing climate impact and fostering more circular and resource-efficient value chains.

Although the technology is widely available and demand shows signs of growing, development is not yet rapid enough, and the sector remains underinvested. Shortages of capital, infrastructure, and governance are curbing its scale-up and commercialisation. Profitability is a major challenge, as fossil-based products are often cheaper. Certain areas of biosolutions are now growing strongly, albeit from low levels. Growth in some segments is driven by high value, and Sweden is well-positioned to assume a more leading role and to achieve industrial growth.

This sector has a clear supply and security dimension. The pandemic and the war in Ukraine exposed the dependencies on imported inputs in agriculture, the chemical industry, and related sectors. Biosolutions can contribute to more diversified and regionally anchored production systems, thereby reducing vulnerability.

Global competition is intensifying due to expansive industrial policy initiatives in the US and China. Europe thus risks losing momentum in this transition. Sweden and Europe have a strong research base and favourable structural conditions but lack a cohesive approach to scaling up and industrialising the sector. This limits the impact of existing investments and development efforts.

1 IVA (2025). *Sweden's Position in Strategically Important Technologies. Investment Priorities, Strengths, and Challenges*.

Biosolutions today



An internationally growing industrial technology sector, biosolutions are based on the use of biological systems to develop new products, materials, and production processes. Several leading industrial nations have identified this field as strategically important for future investments (see the section on the international outlook). The field encompasses the use of, for example, microorganisms, cells, enzymes, and other biological mechanisms as tools in industrial production. A wide range of products can be developed and produced with biological processes, such as chemicals, materials, food ingredients, and other industrial components. Biosolutions thus contribute to the development of more resource-efficient and sustainable production systems, as biological processes can replace or complement traditional fossil-based and chemical-based production methods.

IVA has previously noted that Sweden's strength lies in a broad ecosystem of companies developing solutions in biotechnology. Examples include companies that manufacture bioprocess equipment, equipment for separating cells and biological materials, bioreactors, and solutions for purification and automation. Sweden's historically strong expertise in advanced technology and instrument development is a strategic advantage. Innovative technologies are not merely tools; they form the foundation of long-term competitiveness and development in both biosolutions and other areas of the biotechnology sector.[2]

Biosolutions differ from, but can be technically applied within, the broader life sciences field. Life sciences traditionally encompass research and innovation in areas such as pharmaceuticals, medical technology, and diagnostics, with a focus on human health. Biosolutions, on the other hand, have a primarily industrial focus and concern the use of biological processes to develop solutions in areas such as the chemical industry, materials production, food, and agriculture-related value chains. The field thus lies at the intersection of biotechnology, industrial production, and sustainable technological transition.

Biosolutions are based on modern biotechnology

Technological developments in biosolutions draw on several technical fields in which biological systems are used to develop new industrial production methods. Instead of relying solely on traditional chemical processes, companies can use, for example, microorganisms or biological molecules to produce various substances in a resource-efficient manner.

One of the most important technologies in biosolutions is fermentation. Fermentation involves cultivating microorganisms, such as yeast or bacteria, under controlled industrial conditions to produce a specific product. This technology has long been used in the food industry, for example, in the production of bread, cheese, and yogurt. Today's industrial fermentation processes, however, are significantly more advanced. Through careful control of the microorganisms' growth and function, they can be used to produce a wide variety of substances, including proteins, enzymes, vitamins, and various specialty chemicals.[3]

Another significant area is enzyme technology. Enzymes are biological molecules that act as catalysts, meaning they accelerate chemical reactions

2 IVA (2026). *Advanced Therapy Medicinal Products. A technology report within the Swedish Futures series on ATMPs.*

3 Nielsen, J., Keasling, J. (2016). *Engineering cellular metabolism*. Cell, 164(6), 1185–1197.

without being consumed in the process. Industrial enzymes are used to streamline production, reduce energy consumption, and replace or reduce the need for certain chemicals. They are used, among other places, in the food industry, detergent manufacturing, textile production, the pulp and paper industry, and the chemical industry. One example is enzymes that enable industrial processes to take place at lower temperatures and under milder conditions, which can help reduce resource consumption and lower environmental impact.[4] One example is how enzymes are used in detergents, where they break down fats and proteins in stains. This makes it possible to get clean laundry with less detergent and at lower temperatures.

Another technological area within biosolutions is synthetic biology. This concept involves designing, modifying, and optimising biological systems to create new functions and industrial applications. By modifying the genetic properties of microorganisms, biological production systems can be developed to produce specific substances with greater efficiency and precision. This technology makes it possible to produce proteins, molecules, and other substances with specific properties, creating new opportunities in industrial sectors such as food, materials, and chemistry.[5]

Continued development in biosolutions is also driven by advances in digitalisation, automation, and artificial intelligence. By combining large amounts of biological data with advanced analytical methods, researchers can identify and optimise biological production systems faster than ever before. This contributes to shorter development times, more efficient processes, and increased opportunities to develop new biologically based products for industrial applications.

Biosolutions create products through biological processes

Biosolutions are used in several industrial sectors. What they have in common is that biological processes are used as a tool to create products or improve production methods.

Biosolutions in the food industry

Biosolutions are developing rapidly in the food industry. Rather than agricultural production itself or the processing of food raw materials, the focus here is on how biological systems can be used to develop new ingredients, proteins, and other functional components. Biosolutions can also be used to develop new types of ingredients with better nutritional value, where the nutrients are easier for the body to absorb and utilise, which can contribute to better health and nutrition. For these solutions to work in practice, the foods must also taste good and have a pleasing texture. One example is the use of microorganisms as biological production platforms to make specific substances with high precision. Through these processes, proteins, fats, enzymes, and other ingredients can be produced for use in foods. Technological advancements are creating opportunities for new production systems, but widespread commercial adoption requires that the processes can be scaled up to an industrial level and that production costs can compete with established methods. At the same time, the products must meet safety and quality requirements and be accepted by consumers.

Biosolutions are also used for the production of established food ingredients. Enzymes, vitamins,

4 Kirk, O., Borchert, T., Fuglsang, C. (2002). *Industrial enzyme applications*. Current Opinion in Biotechnology, 13(4), 345–351.

5 Stephanopoulos, G. (2012). *Synthetic biology and metabolic engineering*. ACS Synthetic Biology, 1(11), 514–525.

PRECISION NUTRITION

Precision nutrition means tailoring diet and nutrition to an individual's needs, rather than applying the same solution to everyone. For humans, this might involve, for example, tailoring their diet to differences in metabolism, health, and gut flora. In agriculture, the same principle can be applied to animals, for instance by adjusting feed to meet the individual cow's needs and milk production. Biosolutions can contribute new ingredients, proteins, and other biological components that make a more personalised diet possible.

amino acids, and other functional components are already produced industrially today through biological processes. These applications contribute, among other things, to improved product quality, more efficient production processes, and reduced resource use.

Biosolutions in the chemical and fuel sectors

The chemical and fuel industries are key areas for biosolutions. Development in this field primarily involves using biological processes to produce chemicals, fuels, and other molecules that are currently often derived from fossil raw materials. Biosolutions can thus provide alternatives to fossil-based production and new ways to manufacture both existing and new chemicals.

Through fermentation and other biotechnological processes, microorganisms can help produce organic acids, alcohols, solvents, and other chemical building blocks, for example. These substances can then be used to make plastics, paints, and laundry and cleaning products, among other things. Biological processes can also enable the production of certain substances more efficiently and with less energy and fewer fossil raw materials.

Biosolutions are also used to produce renewable fuels. Biological processes can help convert biomass or other renewable raw materials into ethanol, biobutanol, biogas, and other fuels. Another area of development is advanced biofuels, which utilise side streams from food production. This focuses on developing fuels compatible with existing engines, transportation systems, and industrial processes.

This development also includes more advanced chemicals and fuel components with specific properties. Through synthetic biology, for example, microorganisms can be modified to produce tailored molecules. This can create new ways to produce substances that are difficult to manufacture using traditional chemical methods. For wider use of these solutions, production processes must be scalable, suitable raw materials must be available, and costs must be competitive with established fossil-based processes. For fuels, additional requirements include energy content, sustainability, infrastructure, and compatibility with existing engines and systems.

Biosolutions in packaging and materials

The packaging industry is an important application area for biosolutions, where development primarily involves creating new materials and production processes that can reduce dependence on fossil-based raw materials and contribute to more circular material flows. The focus is not on the primary production of biological raw materials, but on the industrial processes in which biological components are refined into advanced materials with specific properties.

BIOTECH PRODUCTS IN OUR EVERYDAY LIVES

Materials and products developed using biosolutions are part of our everyday lives.
Below are three examples.

Alternative proteins are made from biological material and serve as a complement to animal-based proteins, such as those found in meat, fish, and dairy products. They can also be used as animal feed. There are many different ways to produce and improve these proteins, including through the use of enzymes in fermentation. The challenge lies not only in creating protein-rich food from biological materials, but also in achieving the right taste and texture so that consumers actually choose to buy the products.

It is difficult to predict how large the market for alternative proteins will be in the future. It depends not only on price, but also on taste, texture, and consumer preferences.

Biofuels are those made from biological materials that can replace fossil fuels such as oil, coal, and natural gas in transportation, heating, electricity generation, and industry. They are often classified into different generations based on the level of technological development. First-generation biofuels are produced from edible plant parts, such as corn. Second-generation biofuels are produced from non-edible materials, such as organic waste and wood. Even newer generations are based on microorganisms, genetically modified crops, and a technology called pyrolysis – a method of heating materials in the absence of oxygen to break them down into fuel.

Today, most of the world's liquid biofuel for transportation is produced using the oldest technology, which relies on crops such as corn. In the future, newer generations of biofuels are expected to become more important. One objection to first-generation biofuels is that they compete with food production for agricultural land. The newer generations require less land, which makes them particularly promising for the future. Overall, they are more resource efficient. However, all types of biofuels are expected to help reduce greenhouse gas emissions.

Fermentation is an ancient method of preserving food over long periods of time and is used, for example, in the production of bread (where fermentation is referred to as leavening), cheese, and wine. The technology is widely used in today's food system, to produce everything from animal feed to yogurt.

Fermentation can help make the food system more sustainable and safer by reducing food waste and the risk of harmful bacteria. The technology can also make food more nutritious and extend its shelf life, which in turn reduces food waste.

The text in the fact box is based on Box 4 in the report, "The Potentials of Biosolutions". Copenhagen Economics (2022). Alliance for Biosolutions, Denmark.

This area is closely linked to the development of a more circular economy, where the origin, use, and recyclability of materials are becoming increasingly important.[6]

Bio-based plastics are a key aspect of this. Plastics consist of polymers, which are large molecules that form the fundamental building blocks of the material. While traditional polymer production is

6 European Commission. (2018). *A sustainable bioeconomy for Europe: Strengthening the connection between economy, society and the environment*. Swedish Environmental Protection Agency (2025). *The Swedish Environmental Protection Agency's Roadmap for Sustainable Plastic Use*.

largely based on fossil-based raw materials, biosolutions are developing alternative materials that use biological components as building blocks. These materials can be tailored for various industrial applications by optimising properties such as strength, flexibility, and barrier functions.[7]

Development efforts include, among other things, materials based on cellulose, lignin, and other biological molecules. Through advanced processing methods, these components can be transformed into functional materials for applications such as packaging, composites, and other industrial products. Cellulose is an established material platform, while lignin has garnered increased attention as a basis for the development of new polymeric materials and chemical products.[8] [9]

Biosolutions can contribute to a higher-value and more comprehensive utilisation of forest raw materials. With the help of enzymes, microorganisms, and other biotechnological processes, hemicellulose, lignin, bark, and their molecules can also be processed. Cellulose can be used in more advanced applications than paper, such as textiles, functional materials, and chemicals.

For new materials to be used commercially, they must meet high standards in areas such as sustainability, food safety, barrier properties, cost-effectiveness, and recyclability. Development therefore requires collaboration across various fields, such as materials science, biotechnology, and industrial process engineering. In Sweden, research institutes such as RISE, along with companies in the materials and packaging industries, are helping to develop and scale up new bio-based material solutions.

Biosolutions in relation to agriculture

Agriculture is closely linked to biosolutions through the development of industrial technologies and products related to agricultural value chains. Agricultural production itself – such as crop cultivation, livestock farming, and the production of biological raw materials – is not, however, included in the issues addressed in this report. Instead, the report focuses on the processes and solutions in which biological systems are used to develop new products or improve the efficiency of existing production methods.

One area of application is biological inputs in which microorganisms or biological molecules are used to develop alternatives or complements to traditional chemical solutions. Examples include microbial products and biologically based crop protection solutions. Work in this field focuses on the development, production, and commercialisation of these technical solutions, rather than on their actual use in agriculture.[10]

Another area are biological processes that help transform existing biological side streams into new products. Industrial processes can help convert biological components into, for example, ingredients, chemicals, or materials. This can contribute

7 Nakajima, H., et al. (2017). *The recent developments in biobased polymers toward general and engineering applications: Polymers that are biobased and biodegradable*. Polymers, 9(10), 523.

8 Klemm, D., et al. (2005). *Cellulose: Fascinating biopolymer and sustainable raw material*. Angewandte Chemie International Edition, 44(22), 3358–3393.

9 Upton, B., Kasko, A. (2016). *Strategies for the conversion of lignin to high-value polymeric materials: Review and perspective*. Chemical Reviews, 116(4), 2275–2306.

10 Philp, J., Winickoff, D. (2019), *Innovation ecosystems in the bioeconomy*, OECD Science, Technology and Industry Policy Papers, No. 76, OECD Publishing, Paris.

to circular resource flows and the increased use of existing biological resources.[11] Biosolutions thus serve as enabling technologies for new industrial applications linked to agricultural value chains, without encompassing primary production itself.

An ecosystem built on collaboration

The Swedish biosolutions ecosystem is based on close collaboration between industry, academia, research institutes, innovation programmes, and public sector actors. Development in this field requires collaboration among actors with a variety of expertise and roles. The path from technical development to commercial application often involves several steps, ranging from research and testing to scaling and market introduction. A well-functioning innovation system is therefore a key prerequisite for the development and industrial establishment of new biologically based solutions.

In the Swedish collaboration model, researchers contribute new knowledge and technical solutions. Research institutes support applied development and provide opportunities for demonstration, while industry is responsible for commercialisation, production, and international market presence. The OECD has highlighted this type of collaboration structure as a competitive advantage within bioeconomic innovation systems, where the ability to coordinate different actors contributes to the development of new value chains.[12]

Research institutes focused on industrial transition can provide access to infrastructure for the development and verification of new technologies. Test beds, pilot environments, and demonstration facilities can make it possible to test biological processes and materials on a larger scale before they are introduced commercially. Within biosolutions, they play an important role, as the transition from laboratory results to industrial production often involves significant technical and economic challenges.[13]

The academic foundation consists of several Swedish universities conducting research in areas such as biosolutions, materials development, biological production systems, and circular processes. Together with industry and research institutes, these institutions contribute to new knowledge, expertise, and the development of new technical solutions.

The business sector encompasses both established industries and emerging technology companies. Large companies in the process, forestry-based materials, chemicals, food and packaging industries contribute industrial experience, production capacity, and opportunities to scale up new solutions. Smaller and more research-intensive companies develop specialised technologies in areas such as biological production platforms, advanced materials, and circular processes. The interaction between established industry and new technology companies is crucial for developing and bringing new solutions from research to market.

National innovation programmes and collaboration platforms bring together various stakeholders. By funding joint research and innovation projects, they foster networks, knowledge exchange, and collaboration among academia, research insti-

11 European Commission. (2018). *A sustainable bioeconomy for Europe: Strengthening the connection between economy, society and the environment*.

12 Philp, J., Winickoff, D. (2019), *Innovation ecosystems in the bioeconomy*, OECD Science, Technology and Industry Policy Papers, No. 76, OECD Publishing, Paris.

13 Vinnova (2023). *Nine-Year Evaluation of Strategic Innovation Programs: BioInnovation*. VR 2023:18.

tutes, industry, and the public sector. In this way, they help bring research closer to industrial application and build long-term collaboration around a bio-based industry.[14]

The public sector contributes primarily through funding, strategic direction, and by creating the conditions for innovation. Various government agencies play roles in research, industrial transition, energy, the environment, and regional development. Public funding is particularly important in early development phases, as new technologies often involve high risks and require investment before commercial viability can be achieved.

Biosolutions are governed by several regulatory frameworks

Biosolutions are regulated through a multi-level system in which Swedish legislation interacts with directly applicable EU regulations and international agreements. The aim is to ensure that bio-based innovations are developed and used in a sustainable manner, taking into account human health, the environment, and biodiversity. At the same time, the aim is to promote innovation and a sustainable bioeconomy. See also the fact box on regulatory sandboxes in Key Issue 4 later in this report.

Since this is a cross-sectoral field, it is not regulated by any single Swedish law. Instead, activities within the biosolutions sector are governed by several laws and regulations, depending on the type of product, process, or organism used. In Sweden, the Environmental Code serves as the central legislation for activities that may impact the environment. It contains provisions regarding chemical products and biotechnological organisms, environmentally hazardous activities, waste management, and the general rules of consideration, in which the precautionary principle serves as a fundamental starting point.[15] The Environmental Code is supplemented by a regulation that, among other things, governs the handling, supervision, and control of chemical products and biotechnological organisms.[16]

Depending on the area of application, other Swedish legislation may also apply. Biosolutions in the food sector are regulated by the Food Act.[17] The handling of biological agents or chemical substances are also covered by the Work Environment Act, which sets requirements for a safe work environment and for risk prevention measures.[18]

The EU's regulatory framework is of great importance, as many provisions apply directly to the member states. The most important are a regulation on the registration, evaluation, authorisation, and restriction of chemicals[19] and a regulation on the classification, labelling, and packaging of substances and mixtures.[20] Depending on the application, EU regulations governing biocidal products, plant protection products, genetically modified organ-

14 Vinnova (2023). *Nine-Year Evaluation of Strategic Innovation Programs: BioInnovation*. VR 2023:18.

15 Environmental Code (1998:808). Swedish Code of Statutes.

16 Regulation (2008:245) on Chemical Products and Biotechnological Organisms. Swedish Code of Statutes.

17 Food Act (2006:804). Swedish Code of Statutes.

18 Work Environment Act (1977:1160). Swedish Code of Statutes.

19 European Parliament & Council. (2006). *Regulation (EC) No 1907/2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)*. Official Journal of the European Union.

20 European Parliament & Council. (2008). *Regulation (EC) No 1272/2008 on classification, labelling and packaging of substances and mixtures (CLP)*. Official Journal of the European Union.

isms, and food may also be relevant. In addition to binding legislation, biosolutions development is also influenced by the EU's bioeconomy strategy, which aims to strengthen a sustainable and competitive bioeconomy.[21]

International regulations also apply. The Cartagena Protocol on Biosafety regulates the transboundary movement of living genetically modified organisms,[22] while the Nagoya Protocol regulates access to genetic resources and the equitable sharing of benefits arising from their use.[23] International trade in bio-based products is also influenced by the World Trade Organization's rules, particularly an agreement specifying how countries may protect people, animals, and plants without unnecessarily hindering trade.[24]

International outlook

The countries highlighted in the international outlook are examples of different approaches to biosolutions and relevant international initiatives. The selection is not exhaustive.

The EU is transitioning to a circular economy

The EU is committed to transitioning to a more circular and bio-based economy. This refers to an economy where materials and products are manufactured to a greater extent from renewable biological raw materials rather than fossil-based ones, and where resources are reused in a closed-loop system rather than discarded. A key initiative is *the Circular Bio-based Europe Joint Undertaking*, a partnership between the EU and the private sector with a total budget of 2 billion euros.[25] The partnership funds research and innovation projects designed to help European companies develop and disseminate new bio-based solutions, while reducing the industry's environmental impact. The industry side of the partnership is represented by *the EU Biobased Industries Consortium*, an association of companies working to strengthen the competitiveness of European bio-based industries.

The goal of the collaboration is to reduce the EU's dependence on fossil raw materials while building a more sustainable and circular economy, in line with the EU's long-term climate goal of net-zero emissions by 2050. About ten companies headquartered in Sweden are members of the organisation. Some of them are large, such as Tetra Pak, Nouryon, and Södra Skogsägarna. Most, however, are small startups that are primarily active in the forestry and paper industries, but also in the food, materials, and energy sectors. There are also associate members who have an interest in the organisation's activities but are not themselves part of the bio-based industry. For example, Chalmers, KTH, and Lund University are associates, as are RISE and Skogfors.

21 European Commission. (2025). *Bioeconomy Strategy*. Government Offices of Sweden. (2026). *Communication on a Strategic Framework for a Competitive and Sustainable Bioeconomy in the EU* (Fact Sheet 2025/26: FPM51).

22 United Nations (2000). *Cartagena Protocol on Biosafety to the Convention on Biological Diversity*.

23 United Nations (2010). *Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the Convention on Biological Diversity*.

24 World Trade Organization. (1995). *Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement).*

25 European Union. *Circular Bio-based Europe Joint Undertaking (CBE JU).*

The Netherlands sets goals for a circular economy

The Dutch government has adopted a long-term strategy to transition to a circular economy, aiming to achieve a fully circular economy by 2050.[26] [27] Biosolutions are part of this transition. Through biological processes and renewable raw materials, new materials, chemicals, and fuels can be developed as alternatives to fossil-based products.[28]

The Netherlands also has a strong research and innovation environment in this field; for example, Wageningen University conducts research on bio-based materials, bioprocesses, biomass processing, and circular production systems.

Denmark's success is closely linked to the country's innovation system

Denmark has established itself as an international leader in biosolutions, primarily through its strong position in enzyme technology and fermentation. This development has been built on longstanding collaboration between research, public initiatives, and a competitive industry where companies have developed biological solutions for global markets. Danish companies have built up global expertise in the use of enzymes and microorganisms to streamline industrial processes and replace fossil-based solutions.[29]

Denmark's success in biosolutions is closely linked to the country's innovation system, where research, industry, and public sector actors collaborate to develop and scale up new biological technologies. The Danish model is based on strong specialisation in knowledge-intensive fields, where research can be rapidly translated into industrial applications. This has created a competitive sector in areas such as industrial enzymes, microbial processes, food technology, and sustainable production solutions. The combination of research expertise, industrial experience, and commercial capability has enabled Denmark to develop global exports in this field.[30] Denmark has a major private funding source in the Novo Nordisk Foundation, which funds research, innovation, and companies in fields such as biotechnology. The foundation complements public funding by financing development from research and early-stage business ideas through to new companies and commercial operations.

From a Nordic perspective, Denmark is a clear example of how smaller countries can achieve international competitiveness in biosolutions through strategic specialisation. The Nordic countries share several strengths, such as robust public research systems, high innovation capacity, and close collaboration between academia and industry. Denmark, however, has distinguished itself by establishing commercial applications of biosolutions early on and building global value chains around biological solutions.

26 Government of the Netherlands (2023). *National Circular Economy Programme 2023–2030*.

27 The Platform for Accelerating the Circular Economy (2020). *The circularity gap report. Closing the Circularity Gap in the Netherlands*.

28 OECD (2021). *Policies for a Carbon-Neutral Industry in the Netherlands*, OECD Publishing, Paris.

29 Carus, M., Dammer, L. (2018). *The circular bioeconomy—Concepts, opportunities and limitations*. Industrial Biotechnology. 18(2).

30 Næss-Schmidt, H.S. et al (2022). *The potentials of bio solutions. Climate and sustainability potentials, barriers to growth, and Danish strongholds*. Copenhagen Economics.

The United States holds a strong position and is focused on creating companies

The United States holds a leading position in advanced biotechnology, synthetic biology, and bio-based production. The country's strength is rooted in the synergy between world-leading research environments, extensive investments in research and development, and a robust commercial sector that enables the rapid development and scaling up of new technologies. The US bioeconomy has long been developed through strategic investments in the biosciences and the commercialisation of research-based innovations. In particular, the US bioeconomy strategy has emphasised the importance of strengthening research, innovation, and the industrial application of biological technologies in areas such as food, energy, and environmental protection.[31]

Another advantage is that the US regulatory framework is more product-based and less complex than Europe's, which can lead to shorter processes and lower barriers to bringing new biotechnology products to market.[32] The links between academic research, venture capital, and entrepreneurship in the US have created an innovation system in which new technologies in fields such as synthetic biology can rapidly progress from research to commercial products. The US position is therefore based not only on cutting-edge technical expertise but also on the ability to create companies and industrial applications around new biological solutions.[33]

China has significant production capacity and can scale up quickly

China's position in biosolutions is based on the country's large industrial capacity, extensive manufacturing sector, and growing investments in biotechnology. Developments in the bioeconomy are closely linked to national strategies for technological self-sufficiency, industrial upscaling, and the development of new applications in agriculture, health, and materials. China's national plan for the bioeconomy highlights biological innovation as a strategic area for future economic development and competitiveness.[34]

One of China's key strengths in biosolutions is the combination of research investments, large-scale production capacity, and the ability to rapidly scale up new technologies. The fact that the Chinese government largely controls development in the sector means that national priorities and long-term investment programmes are the main driver of progress.[35]

Europe and China have different approaches to organising production and innovation. For example, China has a long-term industrial policy with government initiatives in strategic areas.[36] The five-year plan for 2026–2030 highlights, among other things, new materials and biomanufacturing.[37]

31 The White House Office of Science and Technology Policy. (2012). *National Bioeconomy Blueprint*. Executive Office of the President of the United States.

32 Barraza-Botet, C. et al. (2026), *A comparison of the innovation and regulatory environments for biotechnology and biosolutions across the European Union and the United States*, OECD Science, Technology and Industry Working Papers, No. 2026/02, OECD Publishing, Paris.

33 National Academies of Sciences, Engineering, and Medicine (2020). *Safeguarding the Bioeconomy*. Washington, DC: The National Academies Press.

34 Zhang X., et al (2022). *The roadmap of bioeconomy in China*. Eng Biol. 2022 Nov 30;6(4):71–81.

35 Philp, J., D. Winickoff (2019), *Innovation ecosystems in the bioeconomy*, OECD Science, Technology and Industry Policy Papers, No. 76, OECD Publishing, Paris.

36 IVA (2026). *Advanced Manufacturing: A technical report within the Swedish Futures series on complex discrete manufacturing*. See in particular the section "Europe and China Have Different Approaches," which contains several references.

37 The State Council of the People's Republic of China. (2026). *The 15th Five-Year Plan for national economic and social development of the People's Republic of China*, 2026–2030.

TABLE 2: Overview of global competition in biosolutions, broken down by three major regions.* Note that the table does not show data specific to biosolutions, due to the availability of data and supporting information that can be compiled in a clear and comprehensive manner. Biotechnology is a broader concept that also encompasses other areas. Some of the data in the table pertains to biotechnology in general and therefore cannot be directly interpreted as a snapshot of the state of biosolutions. There are no reliable statistics on the size of the biosolutions market in Europe, the US, and Asia. The table therefore compares the regions based on three metrics: patents, companies' commercial strength, and production capacity. Patents provide the best picture of trends over time, but the data presented in the table does not describe biosolutions alone (the measurement also includes medical biotechnology).

REGION	PROGRESS TO DATE	CURRENT STRENGTHS	OUTLOOK
United States	Has long been a leader in commercialisation, venture capital, and biotechnology patents. Its lead has grown since the early 2000s.	Held approximately 40% of the world's biotechnology patents in 2020 and accounts for about 60% of the global market value in biotechnology.	Expected to remain strong in synthetic biology, startups, and high-value products. Limited food production capacity and high costs for new facilities could slow development.
Europe/ EU	Has extensive experience with enzymes, food ingredients, chemistry, and process technology. The biotechnology sector has grown rapidly, but scaling up has been slower.	Accounted for approximately 18% of the world's biotechnology patents in 2020. Germany and Denmark are particularly strong in biosolutions.	Has strong potential in enzymes, specialty chemicals, and sustainable processes. Progress may slow if funding, permits, and approvals are not improved.
Asia	Has transitioned from cost-effective production of amino acids, vitamins, and other products to increased research and more advanced production. China has closed the gap with the West.	China accounted for approximately 10% of the world's biotechnology patents in 2020. China and Japan are relatively strong in biosolutions. There are estimates that a large share of global production capacity is located in China, but the data supporting this is uncertain. In China, the statutory processing time for new food ingredients is 20 business days.[1] In Singapore, the processing time for applications for novel foods is 9–12 months.[2] [1] National Health Commission of the People's Republic of China. *Application guide*. [2] Singapore Food Agency. *Guidelines on Applying for Pre-Market Approval for a Novel Food*.	Asia is expected to see the fastest growth in production capacity. China is particularly strong in large-scale fermentation. Japan, South Korea, and Singapore are strong in equipment, advanced processes, and research.

* McKinsey & Company (2025). *Ingredients for the future: Bringing the biotech revolution to food*. Article published March 13, 2025.

Carnegie Endowment for International Peace, "A Competitive Analysis of the Biomanufacturing Strategic Landscape and Technology Stack," July 23, 2026. https://carnegieendowment.org/research/2026/07/a-competitive-analysis-of-the-biomanufacturing-strategic-landscape-and-technology-stack

European Commission Joint Research Center (2024). *Building the Future with Nature: Boosting Biotechnology and Biomanufacturing in the EU*. COM(2024) 137, March 20, 2024.

European Commission Joint Research Center (2024). *The global landscape of biotech innovation: state of play*. News announcement. Published March 20, 2024.

Fluegel, L. (2026). *A Competitive Analysis of the Biomanufacturing Strategic landscape and Technology Stack*. Carnegie Endowment for International Peace. July 2026.

Germany builds on a strong process industry

Germany has a well-established process industry and is one of Europe's strongest players in biosolutions, with particular strengths in advanced manufacturing, the chemicals industry, and integrated industrial processes. The country combines an established industrial base with the ability to develop bio-based alternatives to fossil-based chemicals and materials.

The German National Bioeconomy Strategy emphasises the importance of using research and innovation to develop a competitive and sustainable industry based on renewable resources and biological processes.[38] A key strength is the synergy between industrial expertise, technological development, and established value chains in the chemical and manufacturing industries. By integrating biological processes – such as the use of biomass, enzymes, and bio-based raw materials – into existing industrial systems, new opportunities are created to develop more sustainable production methods. The industrial bioeconomy thus serves as an important tool for strengthening both sustainability and long-term competitiveness within German industry.[39]

Overview of global competition among three major regions

Tabell 2 provides an overview of the differences between three major regions. To complement the table, the working group's experience is that attitudes towards novel foods and new technologies vary between countries and regions. Within the EU, for example, there are differences between northern and southern Europe, as well as between different parts of the United States. In China, national decisions and priorities can have a greater impact across the entire country. These differences influence how new solutions are received and how quickly they can be introduced in different markets.

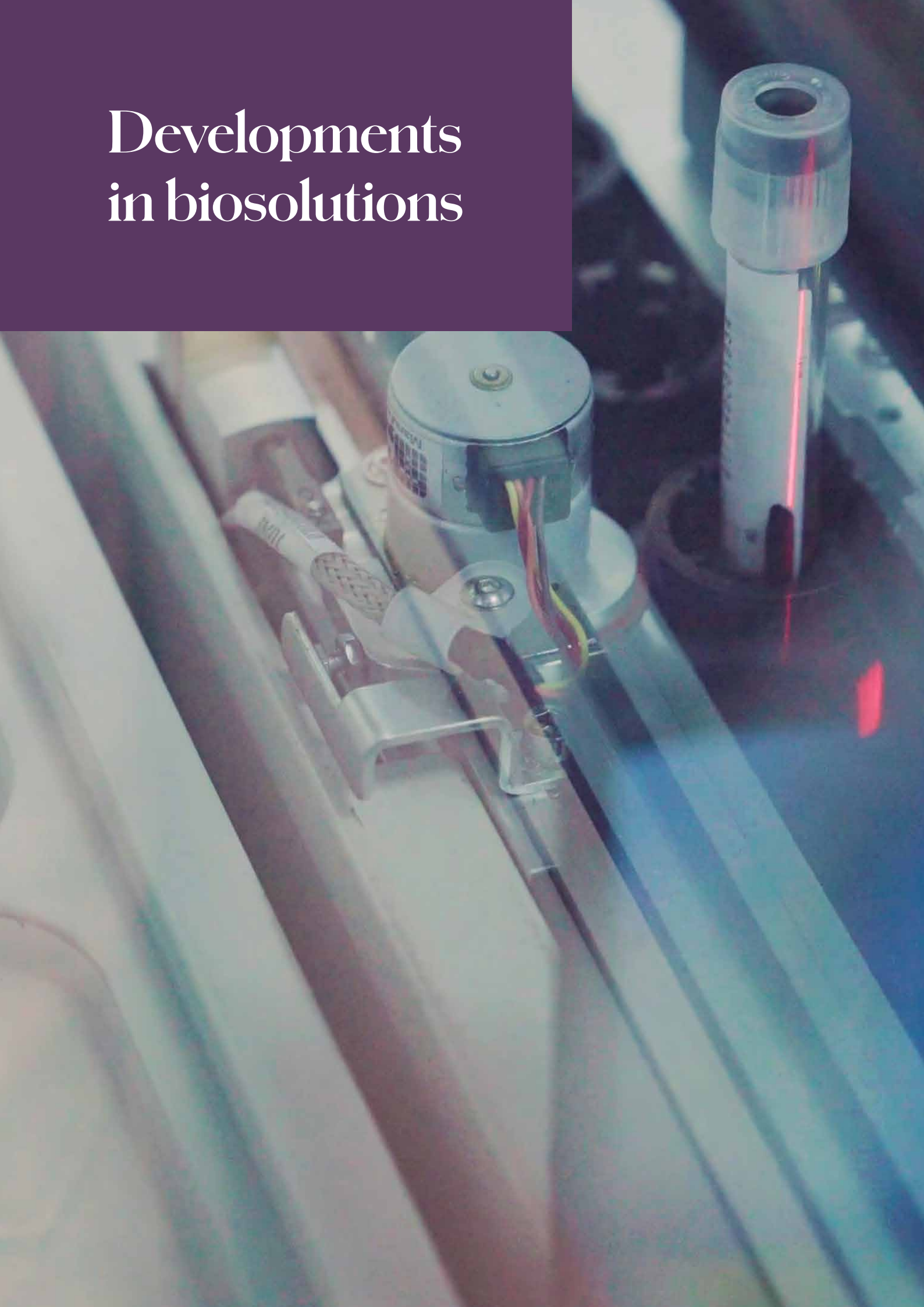
One analysis is that there are great opportunities to use fermentation in new ways, but that the pace of development will vary around the world. It is unlikely that fermentation will quickly replace today's methods of producing food and chemicals; rather, its use will likely increase step by step. First in the production of enzymes and certain particularly valuable ingredients, then in certain chemicals and materials, and later on, even for producing larger quantities of proteins and chemicals.

It is therefore not just a question of which region has the strongest research capabilities. The ability to secure funding, obtain the necessary permits, and build large factories capable of producing goods at a competitive cost is equally important. The US currently has a lead in research, start-ups, and investments. Europe has strong research and industry but finds it more difficult to transition from research to large-scale production. Asia, particularly China, is rapidly building up its capacity to produce biosolutions on a large scale.

38 Bundesministerium für Bildung und Forschung (2020). *National Bioeconomy Strategy*.

39 Bundesministerium für Wirtschaft und Energie (2023). *Positionspapier der Dialogplattform Industrielle Bioökonomie*.

Developments in biosolutions



Biosolutions contribute to a better world

Reduced greenhouse gas emissions

Bio-based solutions have the potential to help reduce greenhouse gas emissions across several major industries. They will not be able to eliminate all emissions, but they serve as a tool for curbing emissions by replacing fossil-based raw materials with renewable biological alternatives.[40]

A large part of today's industry relies on fossil raw materials such as oil and natural gas, not only as fuel but also as raw materials in the production of, for example, plastics, chemicals, paints, textiles, and other materials. In some cases, biosolutions can replace these with biological raw materials from, for example, forests, agriculture, and side streams. Through fermentation, enzyme technology, and other biotechnological processes, these raw materials can be converted into molecules and materials needed by industry. Sugar, starch, and cellulose, for example, can be used to manufacture plastics and chemicals that would otherwise be oil-based. Biological side streams can also be used as raw materials in new products, which reduces the need for primary raw materials and can contribute to more circular material flows.

Some bio-based solutions can also completely replace plastic. One example is bio-resin, a binder that holds natural materials together to form strong fibres. Such materials have already been tested in the manufacture of wind turbine blades, cars, clothing, and food packaging.[41]

Biosolutions and land use

Land is a limited resource that must meet competing needs, including food production, forestry, nature conservation, and other ecosystem services. When fossil-based raw materials are replaced with bio-based raw materials, land use must therefore also be considered. If biomass is grown specifically to produce chemicals and materials, competition for land may increase. If available side streams from agriculture, forestry and other raw materials are utilised, more products can be manufactured without requiring additional land.

Protein made with biosolutions can contribute to the world's food supply because it does not require as much land, a factor that is increasingly important in the face of population growth and climate change that affects agricultural land.[42]

The global protein market is expected to grow through 2050. Traditional protein sources, such as meat, fish, milk, and eggs, are expected to account for nearly the entire market during this period. The market for fermented and cultured protein – that is, protein produced using microorganisms or cell culture – is currently very small but is expected to grow slightly through 2050. These products would then comprise around 6 – 9 percent of the global protein market.[43]

40 Copenhagen Economics (2022). *The potentials of biosolutions. Alliance for biosolutions*, Denmark.

41 IRIS Group (2021): *Biosolutions in Denmark*.

42 Valin, H., et al. (2014). *The future of food demand: understanding differences in global economic models*. Agricultural economics, 45(1), 51–67.

43 The assessment is based on data from Sweden Food Area.

LONGER SHELF LIFE MEANS LESS WASTE

Biosolutions help bakeries use raw materials more efficiently and get more product out of each batch. This makes it possible to produce more types of bread and baked goods with high and consistent quality. Biosolutions can also contribute to bread with higher protein content, better taste, and longer shelf life, which reduces food waste.

For dairies, biosolutions offer new opportunities to develop a broader range of yogurts and cheeses with consistent quality and a good, well-balanced flavour and texture. Biosolutions can also be used to increase protein content, reduce sugar and fat, and extend product shelf life. This results in products that last longer and maintain their quality over time.

This example is taken from Novonesi's 2025 Annual Report.

Less food loss and waste with biosolutions

In the EU, an average of 130 kilograms of food are thrown away per person per year.[44] Food waste leads to the production of more food than necessary, which accounts for an estimated 6 percent of global greenhouse gas emissions.[45] Most of this waste occurs in households, during food production, and in stores. This drives up both production and emissions within the European food sector.

Beneficial bacterial cultures used in food production can extend the shelf life of many foods – ranging from dairy products and meat to seafood and prepared meals – by slowing the growth of microorganisms that cause food to spoil or pose health risks. Similarly, food waste can be reduced by using fermentation in the production of animal feed, such as silage.

In 2022, global plastic waste production was estimated at 400 million metric tons per year.[46] Bioplastics made from starch can be biodegradable and can help reduce the amount of plastic that remains in nature and the oceans for long periods of time.[47] Furthermore, certain enzymes can rapidly break down specific types of plastic. If such enzymes were used on a large scale, plastic waste could be reduced significantly. Biosolutions can also be used to convert plastic waste into new raw materials for industry.

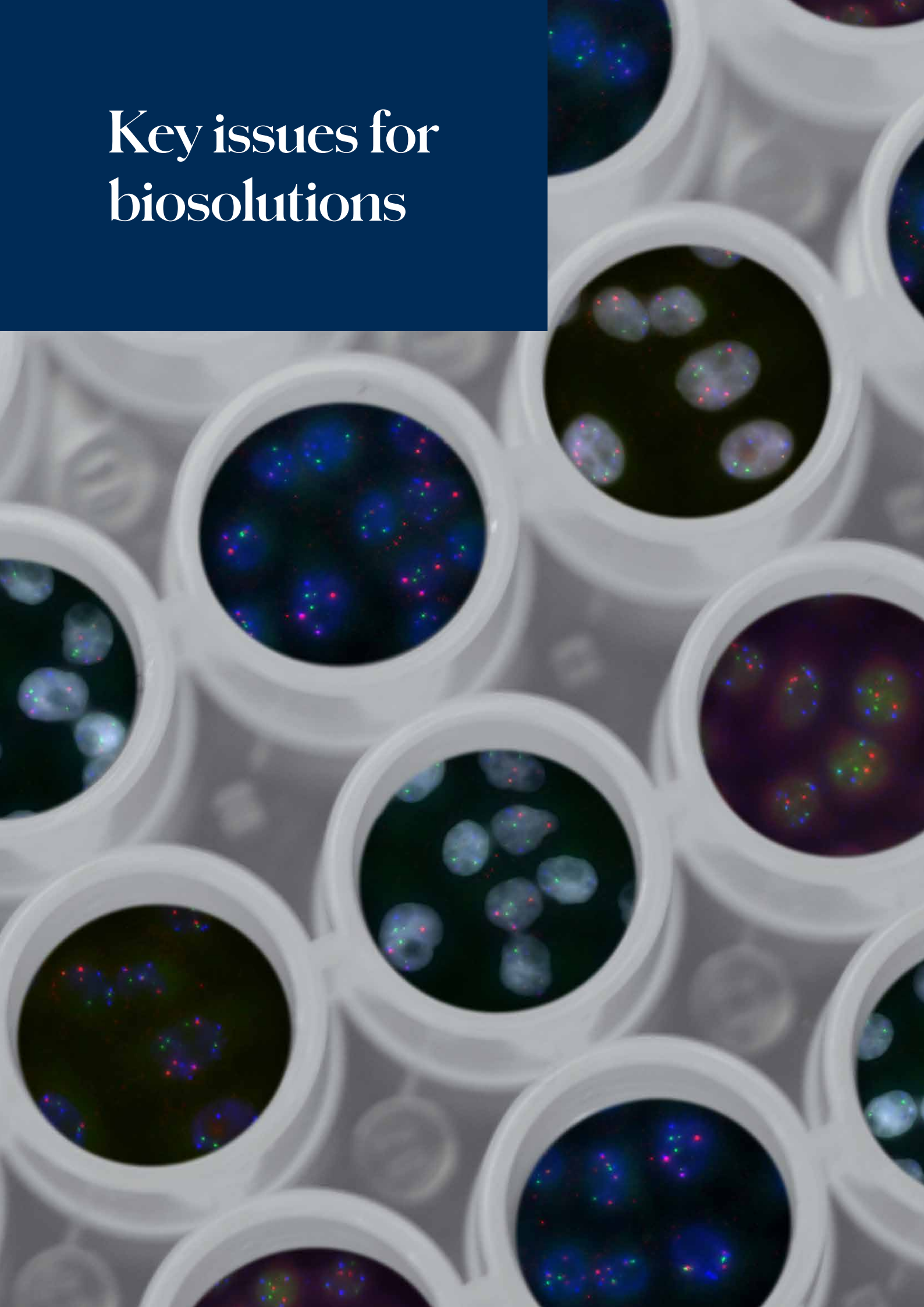
44 Eurostat. *Food waste and food waste prevention – estimates.* Information retrieved on August 18.

45 Hannah Ritchie (2020). *Food waste is responsible for 6% of global greenhouse gas emissions*. Published online at OurWorldinData.org. Information retrieved on August 18.

46 Cook, E. et al (2026). *What a Waste 3.0. Global Snapshot of Solid Waste Management toward Circularity until 2050*. World Bank Group.

47 van den Oever, M. et al (2016). *Bio-based and biodegradable plastics – Facts and Figures. Focus on food packaging in the Netherlands*. Wageningen Food & Biobased Research number 1722.

Key issues for biosolutions



Key Issue 1: Demand-driven production and value-added raw materials processing

This issue concerns responsibility throughout the entire value chain, from raw materials to finished products. It also addresses how demand for bio-based products can be developed and established. Today, it is unclear where in the chain responsibility for the products actually lies – with the raw-material grower, the manufacturer, or the end-product seller. Conditions vary greatly between different industries, such as the food and chemical sectors. This can lead to competing priorities regarding how raw materials are used and which products are prioritised.

Challenges

Demand for products and materials based entirely or partially on biological raw materials remains uncertain. This applies not only to food but also, for example, to plastics, packaging, chemicals, and other industrial products. For many of these products, the cost is currently higher than that of fossil-based alternatives, making it difficult to persuade customers to switch to more sustainably produced products. Therefore, the value that biosolutions create must be clear. For example, such values could be better functionality, higher quality, health benefits, or greater resilience to disruptions in supply chains. Sustainability can be an important part of the value, but it is rarely enough on its own to convince customers to choose a more expensive alternative.

A broader view of demand is also necessary. The market can drive development, but policy instruments and public procurement may be needed to create demand for solutions that cannot yet compete with established fossil-based alternatives.

Margins are low in the materials, food, and basic chemical product sectors, where goods are manufactured in large volumes, making it difficult to recoup investments. Furthermore, the value chains are fragmented, meaning that players in different industries rarely collaborate.

Certain smaller markets, such as cosmetics, sports nutrition, or food served in healthcare settings to patients with special dietary needs, may be willing to pay more for these products. However, such markets can be difficult for manufacturers to identify and reach. There is also a risk that the industry focuses too much on the technology itself rather than on the problem the product actually solves for the customer. Another risk is failing to consider economies of scale – that is, the cost per unit can be much lower if production occurs on a large scale.

Many of today's processes are not efficient enough. In many cases, only about one-third of the biomass is converted into the desired product, while the remaining material becomes by-products or side streams. Biomass here refers to biological material that can be used as a raw material in industrial processes, such as materials from agriculture, food production, and the forestry industry. A significant portion of the resulting side streams can currently be used by other companies or operations, but regulations and technical limitations mean that some of it is not fully utilised.

There are also conflicting priorities between different applications and industries. Better guidelines are needed to determine which raw material provides the greatest benefit in various processes. For example, a raw material can be used for food, fuel, or new materials, and the choice of application affects both resource efficiency and value creation. Allocation is also driven by the market, where

the actor willing to pay the most gains access to the raw material. The raw material will be directed towards the use for which people are willing to pay more: biofuels, food, or new materials. The market price therefore does not necessarily reflect which use provides the greatest benefit to society.

Opportunities

Sweden is well-positioned to become a test market thanks to good access to high-quality bio-raw materials, expertise, and technology providers. A key question is how actors in the value chain (from raw material producers and the processing industry to product companies, brand owners, and retailers) can collaborate to create sufficiently large and predictable demand. This can be achieved, for example, through joint development projects, multi-year purchase agreements, or joint orders. In this way, the players can share the initial risk and generate the volume required to develop and scale up new products and production solutions. For raw material producers, this creates a more secure market; for the process industry, a clearer basis for investment; and for product and trading companies, an opportunity to develop and test new products in a real-world market. Sweden already has an established process industry capable of developing and producing bioreactors and other equipment needed to develop and scale up operations in the field of biosolutions.

The retail sector can play a special role in creating demand by making new bio-based products visible and understandable to consumers. For example, grocery retailers can use specialised product lines, prominent displays, and marketing to highlight new and more sustainable products. In this way, the retail sector can help *build* demand, rather than merely responding to demand that is already established.[48]

There is also an opportunity to clarify what is currently referred to as waste, by-products or side streams and to view these as resources with economic value. There is significant interest in gaining access to such materials, sometimes based on the assumption that they should be available for free. In practice, however, even residual materials have a value and a cost – including the cost of collecting, sorting, and processing them. The question, therefore, is how these materials can be used in a way that is both resource-efficient and commercially viable. Not all side streams are suitable for new products. In some cases, they are so complex that the energy consumption and cost of processing them exceed the value of the product that can be produced. In such cases, energy recovery, for example, may be a more reasonable alternative. Creating value from all raw material streams is a prerequisite for building profitable bio-based value chains.

Biosolutions can contribute to better resource utilisation by enabling the extraction of multiple valuable components from the same raw material for use in different products. For example, a raw material can first be used to manufacture a high-value product and then further utilised in other products or processes. In this way, the same raw material stream can give rise to multiple applications, which can reduce waste, lower costs, and decrease the need for new raw materials. Such resource-efficient utilisation can be achieved through both process optimisation and cascading. Process optimisation involves extracting more of the desired product from a given amount of raw material. Cascade utilisation means that different parts of the raw material are used in multiple

48 Deconinck, K. et al. (2025), *How do consumers interact with environmental sustainability claims on food? Evidence from 40 countries*, OECD Food, Agriculture and Fisheries Papers, No. 218, OECD Publishing, Paris.

stages and for different products, with each part used where it is most beneficial.

However, the theoretical potential of various raw materials and by-products is greater than the potential that can actually be realised. This is due, among other things, to the quality and availability of the raw material, the cost of collecting and processing it, and the ability to develop efficient processes. To build competitive bio-based value chains, therefore, both the technical potential and the commercial conditions must be considered.

By linking raw material production, processing, and product development, we can better identify where the real demand lies. Such a value chain perspective can also help ensure that questions regarding customers, the market, and willingness to pay are addressed early in the development process. In this way, demand and shared commitments within the value chain can provide a clearer basis for investments in production capacity (see Key Issue 2, below).

Strengthening the circular approach is another opportunity. Circularity is about using resources more efficiently and keeping materials and products in use longer. In the field of biosolutions, for example, this could involve processing side streams, reusing process water, recycling chemicals and nutrients, or designing products and processes so that materials can be used in multiple stages. In this way, resource use can be reduced while new value is created.

Key Issue 2: Multi-technology scale-up facility for commercial production

This question concerns the need for a larger facility where various biotechnology-based methods can be tested and scaled up to commercial production. Sweden currently has laboratories, small pilot plants, and other biotechnology infrastructure, but largely lacks open capacity to scale up biosolutions from the pilot stage to a relevant industrial scale.

Challenges

Needs vary significantly between different types of products and raw materials. It is unclear which raw materials and applications have the greatest potential in Sweden – for example, forest-based raw materials for fuels, chemicals, and materials; agricultural byproducts for food and feed; or marine byproducts.

Investments in both facilities and operations are costly, and few players have the capacity to build such infrastructure on their own. This makes it nearly impossible for smaller companies to take an idea all the way to industrial scale. The demonstration facilities that already exist internationally are often limited in scope and are sometimes owned by private companies, making them difficult for others to access.

Sweden also lacks a comprehensive overview and coordination of existing resources, making it difficult for smaller companies to know where to turn.

Opportunities

From a broad, interdisciplinary perspective, Sweden needs to find the financial resources to build,

operate, and maintain the infrastructure that future engineers will need to receive training, conduct research, and develop new solutions.

Specifically in the field of biosolutions, the technology itself is already considered mature enough for a large-scale facility. However, for the facility to be flexible and capable of handling multiple technologies, several reactors are needed, which means that the individual reactor volumes will be smaller. A future facility should be able to handle several different stages of production – such as dewatering, extraction, and purification – across multiple parallel production lines. It should be as flexible as possible to meet the needs of various industries, from food to materials.

A shared facility could enable multiple companies to share investment and operating costs, thereby lowering the barrier for smaller companies to scale up new products to industrial levels. One option is to use a public-private financing model in which public entities contribute to the basic infrastructure while private-sector companies pay for access and production at the facility. With a facility of sufficient size, many different companies could scale up their production and develop new products at a lower cost. However, this requires sufficient demand from companies and other users. It is important to understand shared needs and commitments (see Key Issue 1) in order to assess the business case for investing in a facility and ensure that it operates at adequate capacity. A facility for upscaling, demonstration, and early-stage production can also contribute to increased resilience by strengthening national production capacity and reducing vulnerability in value chains.

Nordic collaboration is likely necessary to achieve sufficient scale and funding. Previous Swedish national collaboration platforms in other research areas are cited as models.

Key Issue 3: Knowledge and expertise in biosolutions

Knowledge of biosolutions is currently limited. This applies to politicians and decision-makers, young people choosing their field of education, and the general public. The question is how the technology can best be explained in a way that different target groups truly understand and engage with. It is also about building the expertise needed to develop, scale up, and apply the technology in industry.

Challenges

There is a lack of clear sources of information and concrete examples – such as products – that demonstrate what biosolutions can actually be used for. The concept is often conflated with other topics, and there is widespread misinformation and outright misunderstanding. Negative historical experiences, such as the earlier debate over genetically modified crops, have created lingering doubts.

The societal benefits are unclear to most people, especially an understanding of the consequences if the transition to new production methods fails to happen and fossil fuels, chemicals, and materials continue to dominate. Investors also show little interest, partly due to this lack of knowledge.

Sweden also lacks a clear ambition for biosolutions at the national level. There is neither a cohesive political vision nor sufficient government investment in research and development. A lack of knowledge and visibility makes it harder for the technology and its potential to gain traction and attract investment. Furthermore, the industry is not doing enough to highlight its successes.

Securing a skilled workforce is also a challenge. Research must be strengthened throughout the entire chain, from basic research to practical application and commercialisation. Both public and private investments in biosolutions are insufficient. While enrolment in biotechnology programmes at the university level is strong, interest is weaker at the high school level and among doctoral students.

Opportunities

The benefits will become more tangible if it is clearly demonstrated which problems biosolutions can actually solve – for example, how applications based on biological processes can replace or streamline today's use of fossil raw materials. It is important to demonstrate these benefits through applications that people can relate to, such as the production of materials, chemicals, and packaging that many use in their daily lives.

Several major countries, such as India, China, and the United States, are already investing heavily in biosolutions. This can be an argument for Sweden needing to keep pace so as not to fall behind in research and innovation. One approach would be to compare biosolutions with already well-known technological initiatives – such as the development of solar cells, artificial intelligence, or electric cars – to make the field more accessible.

Concrete comparisons between the climate footprint of bio-based production and that of traditional production could help demonstrate the benefits more clearly. Similarly, clear examples of products and companies can show how the technology works in practice and what benefits it can generate.

Communication needs to be tailored to different audiences, from consumers and students to decision-makers and politicians. It needs to clearly demonstrate the benefits that biosolutions can provide for society, for individuals, and for Sweden as a whole. Role models and concrete success stories can also help spark interest in educational programmes and careers in this field.

More funding is needed for research and innovation in biosolutions, with targeted initiatives throughout the entire chain – from basic research to upscaling, commercialisation, and skills development. Better collaboration between education and industry can be fostered, for example, through an increase in the number of industry-sponsored doctoral students and educational programmes with practical components.

An assessment of the skills industry demands compared to what the education system offers can provide a basis for developing educational programmes. Practical experience is important, as it gives students a better understanding of how knowledge is applied in industry. There are already examples of high school programmes conducted in close collaboration with industry that provide students with both opportunities for direct employment and a pathway to higher education.

In the life sciences, biotechnology is developing rapidly, with major advances being made in areas such as precision medicine, diagnostics, drug development, and advanced therapies. This has led to significant progress in research, technology, and expertise in the field of biotechnology. Much of this can also be applied to biosolutions, for example in fermentation, cell culture,

enzyme technology, and the development of biological production processes. Technology transfer and increased mobility of expertise between these fields can therefore help accelerate the development of biosolutions. Closer collaboration between the life sciences, industry, and biosolutions can also lead to new applications and business opportunities and make it easier to leverage the biotechnology expertise that already exists in Sweden. Communication, education, research, and the business sector must therefore be viewed as parts of the same chain. To build the biosolutions sector in Sweden, we need both a broader understanding of the technology's potential and the expertise required to translate that potential into products and businesses.

Key Issue 4: Simplifying and streamlining regulatory frameworks

Regulatory barriers refer to the laws, rules, and approval processes that govern which bio-based products may be sold and used. The question is how these rules can be simplified and streamlined without lowering safety standards.

Challenges

The EU's regulatory framework is perceived as extensive and complicated, with decision-making processes that are often slow and sometimes politically driven rather than purely evidence-based. In some cases, regulations are entirely lacking; for example, there is uncertainty about which enzymes are covered by which provisions. Regulations and their application sometimes differ between member states, making it more difficult for companies to establish themselves and sell their products on the European market.

This is in line with the analysis conducted by the *European Bioeconomy Coalition* (EBC), a European coalition of organisations and companies working to develop the bio-based economy. The EBC argues that Europe has strong research capabilities and many companies in the biosolutions sector, but that regulations and other structures make it difficult to bring innovations to market. Regulatory frameworks are often designed around conventional products and may therefore not be well suited to bio-based solutions. Lengthy and unpredictable approval processes, differences between EU countries, and a lack of clear definitions increase costs and risks for companies. At the same time, the link between regulation, financing, and the ability to scale up production is weak. The EBC therefore believes that Europe needs simpler and more predictable regulations, faster approvals, and better opportunities to move from research and testing to large-scale production. The goal is to enable more solutions to be developed and produced in Europe, rather than having companies and investments move to other markets.

The US has an advantage here due to its large, cohesive market with uniform regulations. European fragmentation makes it more complicated for companies to grow and can also make it

TESTING AND DEVELOPING REGULATORY FRAMEWORKS

Internationally, in Sweden, and not least within the EU, there is increasing discussion of regulatory experiments, sometimes referred to as "regulatory sandboxes". The purpose is to study, for example, new working methods within public administration, existing or amended regulations, or new organisational structures, before their full-scale implementation.

There are several reports and research studies that demonstrate why a forward-looking and innovative public administration is needed and what benefits it can bring.

One example is a 2022 communication from the European Commission on a new European innovation agenda. It highlights that innovation should be facilitated through better conditions and regulatory frameworks. Innovation can also be supported by using so-called regulatory sandboxes – that is, defined test environments where new solutions can be tested before the rules governing them are fully in place. In September 2026, the Commission presented a proposal for a new *Innovation Act*. At the same time, the Commission published a recommendation on common principles for regulatory sandboxes, where new solutions can be tested in a controlled environment. The proposals will now be considered further.

Another example is a declaration on innovation in public administration that the OECD and its member countries developed in 2019. The purpose of the declaration is to give innovation in the public sector greater weight and legitimacy. About forty countries have signed it, including Sweden.

harder to attract investment, since companies and investors must navigate different regulatory frameworks and market conditions across countries. This can undermine the competitiveness of European companies relative to countries where regulatory processes are faster and more uniform.

Opportunities

There is a need to map out the entire approval process for biosolutions in Sweden, clearly outlining which authority is responsible for what. In addition, there should be requirements for prompt response times for permit applications. Singapore is viewed as an international role model in this area.

Sweden should swiftly implement upcoming European regulations for biotechnology. Another option would be to formally join Denmark's so-called regulatory sandboxes – controlled testing environments where new regulations can be tried out on a small scale before wider implementation.

By joining forces with other countries – such as Denmark, Finland, the Netherlands, Belgium, Germany, and Austria – Sweden can gain greater influence in its efforts to shape EU policy. There is also a call for clearer Swedish representation that actively advances these issues within relevant EU forums.

Key Issue 5:
Attracting capital and keeping companies in Europe

At issue is how Sweden can attract more capital and companies to the biosolutions sector and how to prevent Swedish and European companies in this field from relocating abroad. It involves both creating the conditions for new Swedish companies to grow and making Sweden attractive to international companies that wish to establish operations, research, or production here. One important aspect is that Sweden could become vulnerable in the event of war or another serious crisis if it lacks its own Swedish or European production capacity.

Capital is needed not only to start new companies, but also to invest in existing companies, new production capacity, and new technologies. This applies both to growth capital for startups and to investments that enable established companies to develop new products, processes, and production solutions.

Investments in the biosolutions sector can therefore be relevant for companies that do not themselves develop various types of biotechnology but that supply equipment, materials, and services to the industry. These could include, for example, companies that manufacture stainless steel components and process equipment for production facilities. A growing biosolutions industry thus has the potential to generate demand in other sectors of the economy as well.

Challenges

Sweden is certainly in a relatively strong position from a European perspective when it comes to attract-ing capital to sectors such as energy, materials, and artificial intelligence. The food sector, however, is particularly vulnerable because profitability is often low while risk is relatively high, which can make investments less attractive.

There is a lack of large-scale development environments where the entire value chain – from idea to fin-ished product – can be tested before it becomes commercial. Both Sweden and the EU are described as relatively small and fragmented markets compared to the US and China, which makes it more difficult to test production on a truly large scale. Furthermore, venture capitalists in Sweden and the EU often have limited knowledge of biosolutions specifically, which means the field is easily overlooked even though Sweden has strong companies in the biosolutions equipment sector. Slow regulatory processes, as de-scribed above, also deter investors.

The entire process for applying for EU funding – from the call for proposals to the application – must be improved and simplified. Agencies such as Vinnova should support both companies and universities in applying for such funding. There is a need for a designated government agency to provide strategic direc-tion and coordinate initiatives in the field of biosolutions.

Opportunities

One way to increase interest is to actively seek out investors who already understand the challenges and opportunities in this field. Another is to involve large, well-established industrial companies, which often take a more long-term view of their investments than pure venture capital firms.

There is also a need for meeting places – both digital and physical – where new companies and investors can connect.

The future of biosolutions in Sweden



Vision

By 2035, Sweden will have strengthened its international competitiveness in biosolutions by translating robust research, high-quality biological raw materials, and technical expertise into products, companies, and large-scale production. Biosolutions have become an established part of Swedish industry, creating added value, boosting exports, generating new companies and jobs, and enabling more resource-efficient production. Sweden has built on its strong foundations in research, innovation and raw materials and can now develop, scale up, and commercialise new solutions.

Sweden's competitiveness in this field is based on close collaboration between research, industry, and raw materials-based sectors, as well as a well-functioning digital infrastructure. Strong research across the entire biotechnology sector – including synthetic biology, enzyme technology, and fermentation – is combined with a competitive process industry, expertise in bioprocesses, strong technology suppliers, and access to high-quality biological raw materials. Forests, agriculture, and marine resources form an important part of Sweden´s raw material base. Sweden has strengthened its ability to process these resources into high-value products, and it has increasingly shifted from exporting unprocessed or minimally processed raw materials to producing materials, ingredients, chemicals, and other higher-value products. Side streams and byproducts are no longer regarded as waste, but as resources that can be integrated into new value chains. Access to bio-based raw materials has become a clear competitive advantage. Nordic cooperation in the field of biosolutions has been strengthened and helps attract global markets.

A crucial change is that Sweden has improved its ability to translate research into industrial applications and commercial production. It has reduced its former weakness in transitioning from research to industrialisation and commercialisation by strengthening the development chain – from basic and applied research to pilot testing, scale-up, and digitalised production. Companies have access to the expertise, funding, and production capacity required to develop new processes and products. A national upscaling facility has created the capacity for both large and small companies to test and demonstrate various types of biotechnological processes. The facility makes it possible to conduct longer production runs and scale up new technologies from laboratory testing to commercially viable production. As a result, more companies can grow in Sweden and without having to look abroad for the production capacity needed to develop and scale up new solutions.

By 2035, AI is an integral part of Swedish biotechnology production and is used to analyse process data and control and optimise, for example, fermentation, dosing, and temperature in real time. Deviations can be detected early, and production can be adjusted before problems affect the outcome. This has transformed the industry's way of working. Processes that previously required a great deal of manual labour and lengthy testing can now be monitored and optimised automatically, resulting in more consistent quality, lower raw material and energy consumption, and fewer production stoppages. The development and scale up of new biotechnological processes are progressing more rapidly, shortening the path from the laboratory to production and making it easier to manufacture new products in smaller batches. AI is an asset in the development of new products and processes in synthetic biology by making it possible to better link microorganisms' DNA to their ability to produce various molecules and materials. This makes it significantly faster to develop and adapt microorganisms for specific purposes and production processes.

The ecosystem for biosolutions has also become more cohesive. There is close collaboration between large and small companies, startups, uni-

versities, research institutes, investors, and public sector actors, with each complementing the others' expertise. Raw materials, research, technology, production, and the market are linked together in stronger value chains. It has become easier to identify where Swedish strengths can provide international competitive advantages and to concentrate resources on areas where the conditions for world-leading operations are particularly favourable.

The conditions for attracting capital have improved. The biosolutions sector is no longer viewed primarily as high-risk, low-return, but rather as one with clear potential to create economic value through sustainability, health, resource efficiency, and increased resilience to crises. Investors in Sweden and the EU have gained a better understanding of the sector's opportunities, and more long-term industrial companies are participating in financing. This has strengthened companies' opportunities for growth and reduced the risk of operations relocating to other parts of the world. Access to competitive production environments, capital, and expertise has made Sweden and Europe more attractive as a base for new companies and technologies.

Regulatory frameworks and permitting processes have also become more predictable. Companies can understand at an early stage which requirements they must meet, which agencies are responsible for different parts of the process, and how long the approval process is likely to take. New products can be tested in controlled environments and developed in close dialogue with the relevant authorities. Swedish stakeholders have become more active in the EU's regulatory work and are collaborating with other countries (primarily Denmark, Finland, and the Netherlands) to influence the development of regulations that create better conditions for bio-based solutions.

The supply of talent has evolved from a limitation to a strength. More young people are pursuing degrees in biotechnology, and more are aware of the opportunities the field offers. The connection between schools, universities, and the business community is stronger, with more practical components, industry-sponsored doctoral students, and other forms of industry-linked education. Education and research are better aligned with the needs of society and industry, ranging from biotechnology research and process development to production and commercialisation. Decision-makers have also gained a better understanding of the field, which has paved the way for more long-term and well-informed decisions.

We have also become better at demonstrating the value that biosolutions create. A clearer and more concrete picture of products, companies, and societal benefits has contributed to greater understanding among consumers, investors, and policymakers. Previous scepticism and misconceptions have largely been replaced by an understanding of how biosolutions can be used in our daily lives. This has strengthened Sweden's reputation as a leader in biosolutions and helped make the field attractive to both talent and capital.

Part of the potential in biosolutions lies in what we do not yet know. As new microorganisms, enzymes, and biological processes are explored, entirely new properties and applications may be discovered. This could lead to products and production processes that we cannot foresee today and, in the long term, transform how we produce food, materials, and chemicals. For Sweden, it is therefore important not only to develop solutions that are already known, but also to create space for research and entrepreneurship that can lead to the unexpected. By 2035, Sweden will have a strong and clear position in selected areas where Swedish raw materials, research, industrial expertise, and technology can be combined in ways that are difficult for other countries to compete with. We have strengthened our competitiveness in precision nutrition by developing new ingredients, proteins, and other biological components for

more personalised diets for humans and animals. We have also strengthened the country's food security and reduced dependence on fossil raw materials and imported inputs, while simultaneously creating new products, companies, and jobs. Biosolutions is thus not only part of the transition to a more sustainable economy, but it is also a growing industry that creates economic value and constitutes an important part of Sweden's long-term competitiveness.

In ten years, Sweden will have strengthened its international competitiveness in biosolutions by combining biotechnological expertise with the efficient use of biological raw materials. Sweden holds a strong position in food, materials, and chemicals and has developed production processes in which multiple products can be extracted from the same raw material and side streams from one process are used in another. This enables Swedish companies to extract more value from each raw material, reduce resource costs, and develop high-value-added products for a growing global market.

Five proposals for the development of biosolutions in Sweden

In the previous section, we identified five key issues surrounding biosolutions. To address these, we present five overarching proposals, which in turn consist of a number of concrete action items. The proposals do not correspond one-to-one with the key issues. Several proposals address multiple issues, and together they cover the entire scope of the topic.

The proposals focus primarily on the coming years and on building the capacity to develop, scale up, and commercialise more biosolutions. However, they must be viewed from a longer-term perspective. A full transition from fossil-based to bio-based raw materials and products is significantly more complex and will require changes in production, markets, and regulations. For many products, it is currently difficult to achieve profitability with bio-based alternatives when compared to established fossil-based products. Factors such as costs, access to raw materials, the scale of production, demand, and policy instruments influence the conditions, and all of these parameters can change over time.

The proposals should be implemented as part of the same development chain rather than as five separate initiatives. The first involves getting research, industry, and capital to work together throughout the entire development process. The second creates the physical capacity to scale up new processes. The third reduces regulatory barriers to market entry. The fourth secures the expertise for building and operating these businesses. The fifth strengthens demand and gives companies the opportunity to test their products commercially.

In parallel with implementation, Sweden needs to monitor how the conditions for the long-term transition are evolving domestically, within the EU, and in other parts of the world. Different future paths are possible, depending on how energy prices, climate policy, trade, access to fossil-based and biological raw materials, and demand for bio-based products – among other factors – develop over time. These factors influence which solutions will be competitive and what investments will be needed. The question of how to achieve a transition towards reduced fossil fuel dependence and what policy instruments are needed is already widely discussed in Sweden and across the EU.

Comprehensive coordination should be built into implementing the four other initiatives. The government needs to designate the organisations responsible and ensure that Formas, Vinnova, RISE, universities, the business sector, investors, and relevant authorities are working towards the same priorities. Sweden should regularly benchmark its

progress against leading countries in biosolutions to assess whether it is narrowing the gap tions.

Short-term progress must therefore be combined with preparing for different long-term scenarios.

In this way, the goal for 2035 will not be merely to build a strong ecosystem for biosolutions, but to strengthen Sweden's actual ability to transform biological knowledge and raw materials into competitive products, companies, and production.

Proposal: Create a cohesive path from research to commercial production

Sweden has strong research in biosolutions and several areas with significant industrial expertise, but its ability to take new knowledge all the way from research to a commercial product is weaker. There is currently a gap between research and industrialisation. The need for change in this area is not just about access to research funding, but about the current fragmentation of the development chain among different actors and funding systems. A project may be successful in the research phase but lack the funding, industrial partners, or expertise needed to progress to pilot testing, scale-up, and market entry.

To strengthen its competitiveness, Sweden therefore needs to create a more cohesive development chain. The starting point should be to identify areas where Sweden has strengths that could form the basis of internationally competitive value chains. This could, for example, involve areas where Swedish research, biological raw materials, the process industry, and technical expertise can be combined. Prioritisation should be based on both technical potential and actual demand. It is essential to ask early on which product should be developed, who the customer is, and what value it creates.

Implementation should therefore be based on a clearer link between research, industry, and capital.

Public research funders need to view the development chain much more as a whole, while larger industrial companies should be involved at an earlier stage. For smaller companies, it is particularly important to receive assistance in finding industrial partners, developing business models, and seeking international funding.

Another aspect is that it is significantly easier to move from academia to industry than the opposite direction. More researchers move to companies than those working in industry move to universities and colleges. As a result, knowledge about industry's needs and working methods does not find its way into academia to the same extent. For example, a researcher who works for a period of time at a company can gain experience in how a new technology is tested, developed, and scaled up for production, while the company gains access to cutting-edge research knowledge. Similar models exist in the US (so-called *sabbaticals*) and within the Swedish Foundation for Strategic Research, which runs a program that covers the salary costs for individuals who, for a period of time, wish to move between the private sector, government agencies, and hospitals, or between academia and research institutes.

There is a need for better opportunities for people from industry to enter academia. Industry-based

doctoral students are one example, but there could also be fixed-term professorships and other academic positions for people with experience from the business sector. An engineer moving from industry to academia, for example, can contribute knowledge the issues faced when a technology is put into practice, the skills companies need, and the most relevant research questions. In this way, experience from industry can contribute to both research and teaching and give students a better understanding of how knowledge is applied in the workplace.

Concrete action points

- The government should task Formas, the Swedish Research Council, and Vinnova with jointly developing a coordinated funding model for biosolutions. Private funders and foundations could also help complement public funding by prioritising biosolutions. The model should cover the entire pathway, from basic research and applied research to pilot testing, scale-up, and commercialisation. The aim is to reduce the risk of projects falling between the responsibilities of different funders as they move from one development phase to another.

- Vinnova should establish a dedicated funding program for companies and research organisations that wish to take a biosolutions research from the laboratory to industrial application. This support should not only finance technology development but also be used to build consortia, identify industrial partners, develop business models, and prepare applications for major Swedish and European funding programmes. The support should therefore bridge the gap between national and EU funding.

- Larger industrial companies should be involved from the earliest stages of research and development. These companies can contribute knowledge about markets, customers, and production processes and identify which technical solutions actually have the potential to be scaled up. Companies should also be involved in the design of calls for proposals, so that research questions better reflect industry needs. The companies' perspectives should also be taken into account in the evaluation of applications. In this way, development can become more demand-driven, reducing the risk that technically promising solutions are developed without a clear market. Inspiration can be drawn from various funding tools within European innovation, such as *the European Innovation Council* and *the Circular Bio-based Europe Joint Undertaking*, where industry stakeholders participate in designing calls for proposals and conducting evaluations.

- Business Sweden, together with relevant public sector actors, should build a targeted network of investors interested in biosolutions. The network should be linked to specific Swedish companies and projects and used to connect companies with both Swedish and international capital.

- Every two years, Sweden's capacity to develop and scale up biosolutions should be benchmarked against that of leading countries across research, access to capital and expertise, production capacity and regulatory frameworks. The comparison should also show whether researchers and companies have access to the infrastructure they need and where Sweden needs to strengthen its resources.

EXAMPLES OF INFRASTRUCTURE IMPORTANT FOR BIOSOLUTIONS

Sweden has several national research infrastructures relevant to biosolutions. These include advanced equipment, laboratories, and other resources for research and development. For biosolutions, this may involve, for example, investigating biological material, developing biological processes, and testing new methods.

Biotech Heights in Lund has research laboratories and test environments for fermentation and bioprocess technology. Among other facilities, it houses the Lund University Prepilot Plant, which provides access to laboratories and process engineering equipment where processes in the food, biotechnology, and chemical engineering sectors can be developed and tested on a pilot scale.

RISE Bioeconomy Arena in Örnsköldsvik has an open technology infrastructure for industrial biotechnology, including equipment for developing microorganisms, bioreactors of various sizes for cultivation and fermentation, and equipment for separation and purification. The facilities can be used to develop and scale up biological processes, from laboratory to pilot scale. This makes it possible to test and develop processes for, for example, food, chemicals, materials, and other bio-based products.

Tetra Pak's facility in Karlshamn is a pilot plant where both startups and established companies can develop and test new fermented foods and ingredients, and assess how production performs a larger scale.

Treesearch is a national collaboration platform for research and capacity building focused on developing new materials from forest-based resources. The platform brings together academia, industry, foundations, and the government and is open to researchers at Swedish universities.

SciLifeLab provides access to advanced equipment and expertise for studying cells and microorganisms, such as bacteria and yeasts. *The National Genomics Infrastructure* at *SciLifeLab* focuses, among other things, on genomics – that is, the analysis of an organism's genome. Such information can be used to identify and develop microorganisms with properties suited to industrial processes.

Implementation and timeline

The first step should be to identify where in the development chain the largest funding and capacity gaps exist and which Swedish areas within biosolutions are best positioned to develop into internationally competitive value chains. This should be done immediately and serve as the basis for a coordinated effort.

Within two to three years, the coordinated funding model should be established, and the first priority projects should have access to support through multiple development phases. At the same time, industrial partners and investors should be involved earlier in the projects.

By 2035, there should be a functioning pathway from research to commercial production in the priority areas. By then, more Swedish companies should have been able to grow from research projects into commercial operations and, to a greater extent, retained both expertise and production in Sweden.

Impact assessment

Above all, the proposal can reduce the gap between research and commercialisation identified by the working group. If more projects can navigate the critical steps from research to scale-up, Swedish research is more likely to lead to new companies, products, and production in Sweden. It can also help ensure that public research investments are translated to a greater extent into economic value and international competitiveness. When more projects reach a level where they can compete for European funding, Sweden can also secure a larger share of the funds the EU allocates to research, innovation, and industrial development.

Proposal: Establish an open national upscaling facility

The transition from the laboratory and pilot scale to industrial production is one of the most significant bottlenecks in this field. The working group highlights the need for an open-access scale-up facility where companies can conduct longer production runs. This would allow them to demonstrate that a process works at a commercially relevant scale and test new products in a defined market. A facility with a total reactor volume of approximately 100,000–200,000 litres is considered appropriate for handling a variety of processes. Since the facility must be flexible, capacity needs to be distributed across multiple reactors.

The problem is that such a facility requires significant investment, while individual companies often find it difficult to bear the cost before a product is commercially established. Therefore, the capacity should be built as a shared resource rather than as a facility for a single company. Companies should be able to use the facility on a pay-per-use basis when they need to scale up and demonstrate their processes.

For the facility to become a competitive advantage, it must offer more than production capacity. It should be linked to research, process development, and expertise, and be capable of use across multiple stages of development. It should also be designed based on actual industry needs. A cross-industry model could make it possible to utilise the facility's capacity for various types of biosolutions, for example in the food and materials sectors. Since different products have different quality and safety requirements – such as food versus materials – the facility must be designed to meet these requirements.

The design can draw inspiration from existing facilities such as the Testa Center but should cover the entire process – from testing and development to large-scale production – specifically within the biosolutions sector.

Implementation therefore requires industry involvement as early as the planning stage. The required process equipment, capacity, and post-processing capabilities should be identified before any investment is made. This would ensure that the facility is designed around the technologies and products with the greatest potential, rather than a general level of technical ambition.

It should be noted that an initiative to establish an open national upscaling facility in the field of biosolutions does not replace the need for access to other major infrastructures, such as Biotech Heights and the RISE Bioeconomy Arena in Örnsköldsvik.

Concrete action points

- Biotech Heights, in collaboration with industry and a broad range of stakeholders from academia and research institutes, should conduct a feasibility study and develop an investment and implementation plan for an open-access national scale-up facility. This work should also involve the construction industry and stakeholders with experience in developing and scaling up biotechnological processes. The framework should adress capacity, technical focus, location, investment requirements, ownership, financing, and a model for user access.

- A steering group comprising large industrial companies, SMEs, start-ups, universities, research institutes, and public sector organisations should identify shared capacity needs across industries. This should guide which functions and technologies are incorporated into the facility. The steering group should also monitor developments and ensure that the facility continues to meet the industry's needs. The steering group should assess the need for fermentation, separation, purification, and other downstream processing, and recommend when capacity should be expanded over the long term. Its members should be well-established and enjoy a high level of trust within the biosolutions sector.

- The government and private investors should design a public-private financing model in which the state assumes part of the initial investment risk, while private actors contribute capital and long-term user commitments. Companies should primarily pay for the capacity they use.

- Stakeholders and academic institutions should link the facility to education and research so that it becomes a shared environment for developing, testing, and scaling up new processes. Companies should be able to use it to generate data for customers, investors, and future industrial production decisions.

Implementation and timeline

The upscaling facility can be expanded in stages. A long-term capacity of approximately 100,000–200,000 litres can provide sufficient flexibility for several types of biosolutions, while the first phase can have a lower capacity and focus on food and ingredients. In these areas, there are already products, companies, and an established market to build upon. This makes it possible to start with a limited-scale facility, gain experience in large-scale production, and simultaneously test technologies and business models in practice. Once the operation is established, capacity and applications can be expanded to include, for example, materials. In this way, an initial, limited-scope initiative can develop into a significantly larger facility over time. Initially, an assessment of industrial demand should be conducted; based on this, the scope and function of the facility can then be planned. In parallel, investment costs and the financing model should be analysed. This work should begin immediately. The facility should primarily be built as a national resource but should be usable by – and, in the long term, linked to – corresponding capacity in other Nordic countries.

Within two to three years, the operating entity, location, financing, and technical focus should be decided, and construction should have begun. Companies should be able to submit project proposals and long-term user needs as early as the establishment phase.

By 2030, the facility should be established as a central resource for Swedish biosolutions. It should be able to accommodate both Swedish and international companies and help make Sweden an attractive location for upscaling and early-stage commercial production.

Cost assessment

A scale-up facility for biosolutions – that is, production using microorganisms – costs between 0.7 billion and 1.5 billion Swedish kronor. This estimate is based on the assumption of a 200,000-litre production capacity. The cost of a commercial production facility, with a capacity of one million litres, is in the range of 1.9 billion to 3 billion kronor. A very large-scale facility, with a capacity of 10 million litres, costs between 5 billion and 9 billion kronor. The calculations assume that the facility is built entirely from the ground up, while retrofitting an existing facility could reduce the cost by 20 to 30 percent.

It should be noted that investments in a scale-up facility for manufacturing biosolutions are associated with several uncertainties. The most significant of these are access to raw materials over time, price volatility in the market, long-term agreements for product sales, and regulatory barriers.

Three international examples can be cited for comparison. In the Netherlands, 60 million euros (approximately 660 million Swedish kronor) has been invested in precision fermentation, a technology in which microorganisms are used to produce specific substances. In Finland, the government agency Business Finland has invested the equivalent of approximately 100 million Swedish kronor in a company that manufactures protein powder. In the United Arab Emirates, an American company is investing in the Middle East's first large-scale bioreactor.[49]

Impact assessment

An open-access scale-up facility can directly lower one of the most significant barriers between research and industrial production. Companies do not have to bear the entire investment in advanced production capacity themselves before the market is established. This can make it easier to attract capital and customers and increase the likelihood that upscaling will take place in Sweden. The facility can also serve as a shared infrastructure that strengthens several parts of the Swedish biosolutions ecosystem.

Proposal: Make the Swedish path from innovation to market faster and more predictable

Regulatory frameworks and permitting processes are a key competitive factor, as new applications in biosolutions often fall in the grey area between established categories. There is a perception of complex EU regulations, lengthy processes, and a lack of clarity regarding responsibilities and interpretations. Companies may also encounter different applications of the same European regulations in different countries.

49 Cost assessments and international examples are based on data from Sweden Food Area, which in turn has drawn on information from McKinsey & Company.

To strengthen competitiveness, Sweden therefore needs to do more than just work towards simpler regulations. It is equally important to make the process understandable and predictable for companies. A company developing a new product needs to be able to understand early on which regulations apply, which authority to contact, which requirements must be met, and approximately how long the process might take.

A review is needed of the entire path from development and testing to an approved product. The starting point should be the actual path companies take through the system, rather than the authorities' current organisational structure. If multiple authorities are involved, responsibilities and points of contact must be clear.

Sweden also needs to work more strategically at the EU level. If regulations are crucial to companies' competitiveness, Swedish authorities, companies, and researchers must jointly identify the issues in which Sweden has particularly strong interests and build alliances with other European countries.

Concrete action points

- The government should task the Swedish Agency for Economic and Regional Growth with mapping out the path companies take from development to an approved product in the field of biosolutions. This should be done in collaboration with relevant sectoral agencies such as the Swedish Food Agency, the Swedish Board of Agriculture, and the Swedish Chemicals Agency. The mapping exercise should identify which agencies and decisions are involved, where the processes take the longest, and where companies face the greatest uncertainty. This assignment can build upon the existing government mandate given to the Swedish Agency for Economic and Regional Growth and Vinnova to improve funding for groundbreaking innovation and so-called deep-tech companies, which also includes the possibility of utilising EU funding instruments.[50]

- The government should clarify the division of responsibilities among agencies and establish a clear point of contact for companies developing new solutions in the field of biosolutions. Companies should be able to obtain guidance early on regarding applicable requirements and which agencies need to be involved.

- Relevant agencies should set clear targets for response and processing times. Companies should be able to estimate how long time the process will take from the early stages of product development.

- The Government Offices and relevant agencies should explore the possibility of using regulatory sandboxes, taking into account experience from Denmark. The aim should be to create controlled environments where new products and processes can be tested, allowing agencies and companies to develop a shared understanding on how existing regulations apply across different areas of responsibility.

- The Government Offices should establish more systematic cooperation between Swedish companies, government agencies, and researchers in preparation for EU regulatory

50 The Government (2026). *Mandate to the Swedish Agency for Economic and Regional Growth and the Swedish Agency for Innovation Systems to investigate capital supply for knowledge-intensive companies*. Reference number: KN2026/01433.

developments. Sweden should work with other countries to identify areas of common interest and build coalitions to influence both new regulations and their implementation. Sweden should actively influence the EU Circular Economy Act[51] so that the regulations create better conditions for circular and bio-based products and enable Swedish companies to develop and scale up new solutions.

Implementation and timeline

Efforts should begin with the areas where regulations have the greatest impact on biosolutions and where companies face the greatest uncertainties. An initial process mapping should be conducted immediately.

Within two to three years, new channels of communication, clearer responsibilities, and targets for processing times should be established. Regulatory sand boxes should be used for specific development projects, with lessons learned incorporated into the agencies' standard operating procedures.

By 2035, a predictable and business-friendly regulatory process should be an established part of Sweden's competitive advantage. Sweden should also have developed a stronger capacity to influence European regulations relevant to biosolutions.

Impact assessment

A more predictable process can reduce time, costs, and risks for companies developing new solutions in the biosolutions sector. This is particularly important for smaller companies with limited resources.

Furthermore, if Sweden becomes more effective at influencing EU regulatory development, the impact could extend far beyond the Swedish market, which could make Sweden a more attractive location for the development, production, and establishment of new companies in the sector.

Proposal: Build the expertise needed to scale up Swedish biosolutions

Access to people with the right expertise is a long-term prerequisite for Swedish competitiveness. The working group considers enrolment in biotechnology programmes at universities and colleges to be strong in Sweden, but notes that interest is weaker at earlier stages of the education system. Companies need better access to expertise in areas such as bioprocesses and industrial applications.

The challenge, therefore, is not merely about training more biologists or civil engineers in biotechnology. It is about ensuring the right expertise throughout the entire process, from research to industrial

51 European Commission. (2025). *Circular economy*.

production. This requires knowledge of biological processes as well as production, technology, economics, quality, regulations, and commercialisation.

The link between academia and industry therefore needs to be strengthened. Industry-based doctoral students, internships, and industry-oriented education can help develop expertise directly aligned with industry needs. Educational models such as technical colleges can also be used to strengthen a broader skill base. The national graduate school in bioeconomics aims to strengthen the supply of expertise by bringing together higher education institutions and the business sector around graduate education and the development of expertise to meet the future needs of the bioeconomy.[52] This is an important step that can be further developed by linking it to industry's needs for long-term expertise and to the development of educational programmes at the undergraduate and graduate levels.

Another key aspect of implementation is a long-term approach. The education system cannot be quickly adapted once a skills shortage has already arisen. Needs must be identified several years in advance and monitored regularly.

Concrete action points

- The Government Offices, in collaboration with higher education institutions and the business community, should develop a long-term skills profile for biosolutions through 2035. It should identify the skills that will be needed in research, systems analysis, process development, production, quality, commercialisation, and business management. This framework should then serve as the basis for the development of educational programmes, with a broad foundation of knowledge in undergraduate education and opportunities for specialisation later on. The needs of the business sector are important in this work but should not steer educational programmes towards overly narrow or short-sighted competency requirements. A broad foundation makes it easier for students to develop new knowledge and adapt as technology and industry needs change.

- Higher education institutions and companies should expand their capacity for industry-based doctoral students, internships, and industry-oriented thesis projects. Industry should be involved from the very beginning, when the content of educational programmes and research questions are being formulated, so that the development of skills better meets actual needs.

- Ensure access to infrastructure where students and future engineers can gain practical experience with the technology, equipment, and production processes used in industry. Companies should contribute equipment and technology, identify real-world problems and development tasks, participate in teaching, and offer internships or project work. They can also provide engineers and other experts to serve as mentors. In this way, students gain experience during their education with the technology and work methods they will later encounter in industry.

- Higher education institutions, schools, and the business community should develop initiatives to increase interest in biosolutions earlier in the education system, for example by including biotechnology as a subject in relevant high school programmes. Concrete information about companies, products, professions, and

52 The initiative is described in the bill *"Research and Innovation for the Future, Curiosity, and Benefit"* (Bill 2024/25:60)).

career paths should be used to raise the profile of the field.

- RISE and higher education institutions should develop continuing education opportunities for professionals. As technologies and production processes evolve rapidly, existing staff must also be able to acquire new skills without leaving the industry.
- The business community and higher education institutions should regularly access skills needs and identify skills gaps. This assessement should be linked to the international comparisons of Sweden´s competitiveness, making skills provision part of strategic decision-making.

Implementation and timeline

The work should begin with a joint assessment of skills needs and educational offerings. This should cover both current gaps and the skills required as production scales up. At the same time, companies and higher education institutions should identify which educational programmes and research environments can be developed quickly.

Within two to three years, more industrial doctoral students, internships, and industry-oriented training programmes should be established. At the same time, continuing education should be offered to professionals in the industry.

By 2035, Sweden should have a broader skills base covering the entire chain from research to industrial production. Companies should be able to recruit the talent needed to develop and scale new biosolutions in Sweden.

Impact assessment

A stronger talent pool reduces the risk that companies will be forced to seek critical expertise outside Sweden as their operations grow. It can also strengthen the link between research and industry, thereby contributing to faster commercialisation. In the longer term, this expertise is essential for Sweden to be able to maintain and further develop the value chains being built within biosolutions.

Proposal: Establish Sweden as a test market that helps biosolutions companies enter international markets

Technical development alone is not enough to create competitiveness; there must also be customers willing to pay for the products. The working group points out that demand for products based on biosolutions is uncertain and that development therefore needs to begin with clearer questions regarding customers, products, and value.

Sweden has the opportunity to use its own market as a testing ground for new products. Swedish consumers have high expectations regarding, for example, quality and sustainability, as evidenced by established certifications such as KRAV. There is also a perception that Swedish consumers are relatively open to new prod-

ucts, which can facilitate the introduction of new solutions. Although Swedish households do not necessarily have higher disposable incomes than households in other European countries, there are still reasons to view Sweden as a suitable and appropriately sized initial market. By testing new products in Sweden, companies can gain experience that facilitates a broader launch in Europe.

A stronger Swedish test market can help bridge the gap between technological development and commercial success. Companies can gain the opportunity to test products in real-world environments, gather feedback from customers and consumers, and improve the product before an international launch. This is particularly relevant for new foods, materials, and other products where it is difficult to assess demand based solely on laboratory tests.

For this to work, demand needs to become a more active part of the innovation system. Larger companies and retailers can contribute by articulating specific needs and serving as early adopters. Public sector actors can contribute where possible by creating opportunities for testing and using new solutions. This is not about guaranteeing a market for new products, but about creating better opportunities to test whether they actually solve a problem and create value.

The proposal therefore complements the proposed initiatives in research, scale up, and skills development. If Sweden can offer both development capacity and a market where new solutions can be tested, companies will have better conditions for moving from technology to a commercial product.

Concrete action points

- Retailers in the grocery sector should work with producers – and possibly also in collaboration with researchers – to identify areas where new biosolution technologies can be tested in real-world environments. The focus should be on specific products and needs rather than on the technologies themselves. For each product, there should also be a clear description of the benefits it offers consumers, its features, and the expected impact compared to existing products.

- Larger companies should develop models to serve as early-stage customers or testing partners for smaller companies. For example, a startup should have the opportunity to test a new product or process in a real-world industrial or commercial environment before a full-scale launch.

- Vinnova should develop funding programmes for projects that combine technical development with early customer validation. From the very beginning, companies should be required to describe the customer, use case, value, and willingness to pay – not just the technical solution.

- Explore the possibility of introducing a phased authorisation model where companies can start with small, controlled tests and gradually move on to larger-scale use. The first step could involve limited, low-risk tests with simpler authorisation and documentation requirements. If the test is successful, the company can move on to larger volumes and broader use, with stricter requirements for safety, documentation, and follow-up. The full requirements should apply only upon full-scale production and market launch. In this way, safety can be maintained while companies are given the opportunity to develop and test new products more quickly.

- The national upscaling facility (see above) should also be used for commercial validation. Production runs should provide evidence both of whether the process works technically and of whether the product meets the quality, cost, and scale requirements necessary to be attractive in a market.

- Business Sweden should link the Swedish test market to international market entry. Companies that have tested and validated a product in Sweden should be able to use the results to identify international customers and markets and prepare for export.

Implementation and timeline

The first step should be to identify specific product areas where Sweden has both industrial expertise and the potential to serve as a test market. Companies and potential customers should be involved as early as the product development phase.

Within two to three years, models for testing and early-stage customer collaborations should be established in priority areas. At the same time, the available scaling-up capacity should be used for projects requiring both technical and commercial validation.

By 2035, Sweden should be an attractive test market for new biosolutions. Swedish companies should be able to use the domestic market to develop, test, and improve products before expanding internationally. This should help more products transition from technical innovation to commercial success.

Impact assessment

A stronger test market can reduce the risk of companies investing significant resources in products that work technically but lack sufficient demand. It can also make Sweden more attractive to companies that want to develop new products close to customers and users. The combination of Swedish research, scaling-up capacity, and a functioning test market can thus strengthen the entire journey from idea to international market.

Recommendations

The working group has three overarching recommendations regarding what Sweden should focus on to build Swedish competitiveness, achieve sustainability, and contribute to Swedish and global security and resilience. These are based on an analysis of Sweden's current position in the field of biosolutions, international development trends, and a review of key issues that identify obstacles and opportunities for Sweden's continued development. The recommendations summarise a number of proposals and action items that are described in greater detail above.

- Build a national scale-up facility and ensure access to Swedish test markets, enabling biosolutions companies to scale up in Sweden and generate growth both domestically and internationally.

- Simplify regulations and speed up permitting processes to reduce dependence on fossil fuels and imported raw materials, attract investment, and bring products to market faster.

- Create a cohesive talent development system covering the entire chain – from undergraduate education, graduate studies, and industry-collaborative research to laboratory work and commercial production – so that Swedish research and innovation can contribute more to the growth and competitiveness of Swedish companies.

Appendix



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Glossary

Biomass

Material from plants, animals, and other biological sources. Biomass can be used as a raw material to produce fuels, materials, and chemicals, for example.

Enzymes

Enzymes are substances that help accelerate chemical reactions in living organisms. They can also be used to control and optimise various industrial processes.

Fermentation

In fermentation, microorganisms are used to convert one substance into another product – for example, when yeast converts sugar into alcohol.

Fossil raw materials

Raw materials formed from plants and animals over millions of years, such as oil, coal, and natural gas.

Renewable raw materials

Raw materials derived from sources that can be replenished within a relatively short period, such as plants, wood, and side streams from agriculture and forestry.

Innovation system

An innovation system is a network of companies, researchers, government agencies, and other stakeholders who work together to develop new ideas and solutions and put them to practical use.

Input product

A product used to manufacture another product. Inputs can include, for example, raw materials, chemicals, or various types of components.

Carbon footprint

The total amount of greenhouse gases emitted by an activity, product, or person. The term is used to describe how much something contributes to climate change.

Microorganisms

Microorganisms are very small living organisms, such as bacteria, yeast, and moulds. They can be used to produce various substances and products.

Nutrition

Literally, nutrition means providing nourishment. The term is often used in contexts related to how the body absorbs and uses nutrients from food.

Reactor

In the field of biosolutions, the term is used to describe a container in which biological processes can be carried out under controlled conditions. A reactor is used, for example, to cultivate microorganisms or to produce various substances.

Sabbatical

A limited period during which a person temporarily leaves their regular position to work, conduct research, or pursue professional development in another setting. The term is used primarily in academia and is common in the United States, where researchers, for example, may spend a period at another university or in the private sector.

Side stream

A material generated during a manufacturing process that is not the main product but can be used as a raw material in another process.

Synthetic biology

This term refers to the design, modification, and optimisation of biological systems to create new functions and industrial applications.

Teknikcollege

Teknikcollege is a quality certification for high school and adult education programmes in technology and industry in Sweden. This educational model is a collaboration between schools, the business community, and municipalities or regions, whereby programmes that meet certain quality criteria can be certified under this name. The idea is for the education to closely align with what industry actually demands, including through internships, collaboration with local businesses, and regular updates to the curriculum, so that students are well-prepared to enter the workforce directly or continue on to higher education.

Test market

A market where new products can be tested in real-world use before being launched in a larger market. This gives companies the opportunity to gain experience and receive feedback from customers.

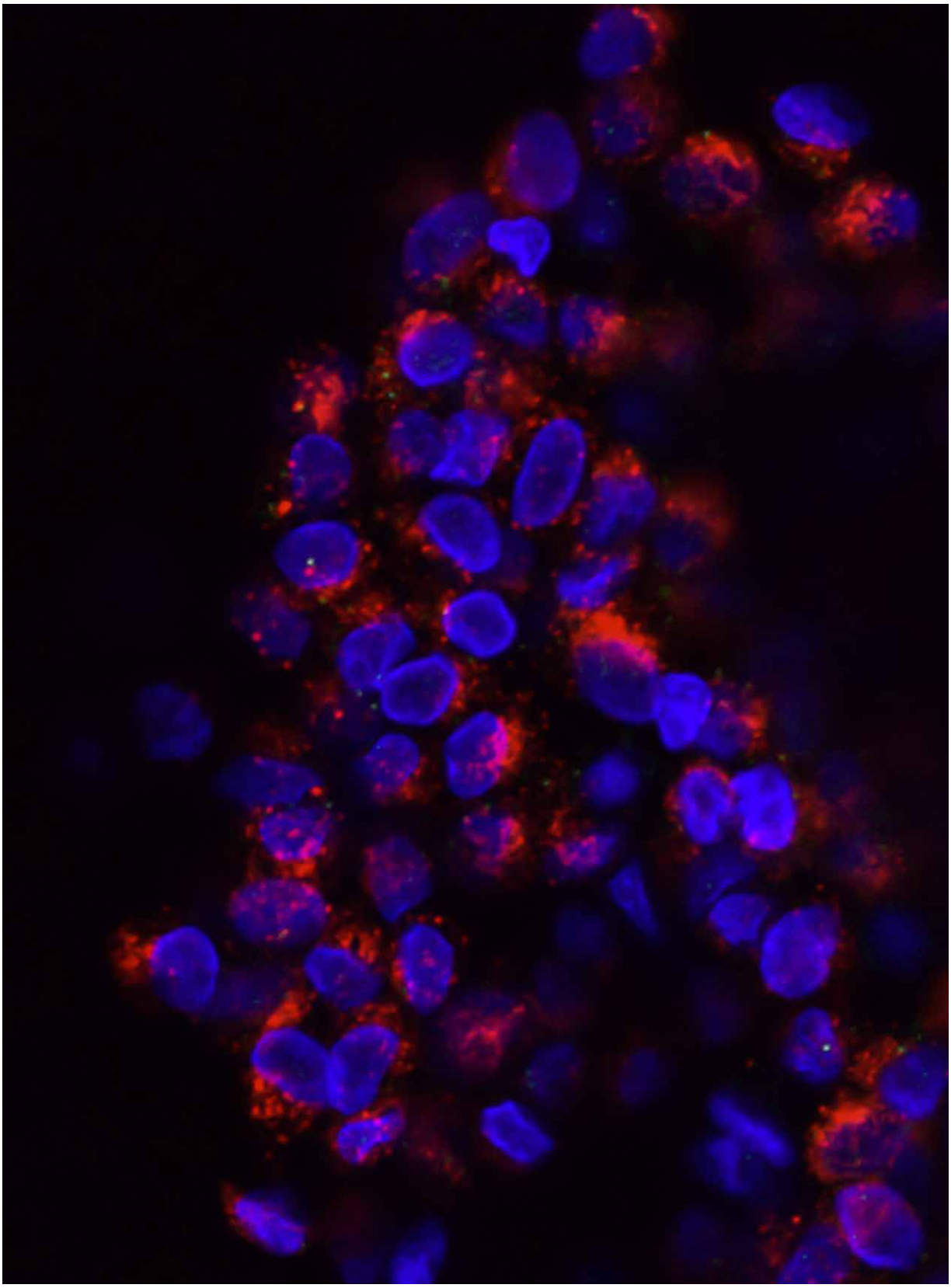
Greenhouse gases

Gases in the atmosphere that contribute to global warming. Carbon dioxide, methane, and nitrous oxide are examples of greenhouse gases.

Scaling up

Scaling up means moving from manufacturing or testing something on a small scale to producing it on a larger scale. This often requires larger equipment and adjustments to the process.

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