Innovator's Compass: Evaluating Impactful Solutions in Bioeconomy

Triple-S

Sustainable Smart Scalable

2nd Edition, February 2025

CLIB networking biotechnology creating sustainability

Content

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Your feedback is welcome!

CLIB networking biotechnology creating sustainability

Introduction

Biotechnology is one of the key technologies to make our current century sustainable and worth living in. It enables the industry to undergo the transition from a fossil, linear economy to a circular bioeconomy. While the challenges involved may seem daunting, scientific and technological advances in biotechnology over the recent years have brought this goal within reach for the first time.

So far however, only few biotechnological innovations have been established on a large scale. What is holding biotechnology or the bioeconomy back? Of course, it takes brilliant ideas and excellent research, but in order to be applied, an idea has to mature into a product. This development from idea to product remains a major, sometimes insurmountable hurdle. Most of us can immediately cite examples of promising inventions that failed somewhere in the "valley of death".

On the other hand, **success stories** in biotechnology are reported too rarely. This is why we at CLIB asked ourselves: **What makes inventions into innovations? What characterises innovations that really have an impact?** Are there unifying criteria that almost every biotechnological invention must meet if it is to become a successful innovation?

The Triple-S project, funded by the NRW Ministry of Economic Affairs, Industry, Climate Action, and Energy, (MWIKE), has been working to find answers to these questions since the beginning of 2023. Triple-S will **identify successful biotechnological innovations** and support those biotechnological inventions **that have or may have a significant impact on a future-proof, climate-neutral and economically successful North Rhine-Westphalia (NRW).**

The aim of this project is to identify **common characteristics of successful innovations** that **can be transferred** to evaluate future inventions.

> **Invention, Innovation, Impact**
>
> **Invention** refers to the development of a new product, process, technology, or service.
>
> In the following, **innovation** refers to a novel approach (invention) that enters the application and asserts itself on the market.
>
> In the context of the Triple-S project, **impact** means that an innovation can make a significant contribution to the transformation of the economy towards a sustainable, circular bioeconomy.

Objective of the Innovator's Compass

Turning an **invention into an impactful innovation** means not only progress on the way to a circular bioeconomy, but also immense **success for everyone involved**. The target group of this Innovator's Compass is therefore all innovators who want to advance an invention to innovation, whether they work in companies, universities, or research institutions. From our point of view, the Innovator's Compass is particularly suitable for start-ups, but also for companies that are taking the first steps towards the transformation towards a circular bioeconomy. The Innovator's Compass will help these innovators to ask themselves the right questions at an early stage**, to anticipate challenges**, and to look for the right skills to answer them. Our intention is to avoid "old" mistakes, to further develop inventions according to sensible criteria, and ultimately to create more innovations with impact.

In contrast to many other guides, this Innovator's Compass takes a dedicated **biotechnology perspective**. CLIB has more than 15 years of experience in this field and has implemented numerous projects, workshops, and events for and with start-ups. At the same time, opinions, knowledge, and the input of experts from the extensive CLIB network are represented in this Innovator's Compass, incorporating expertise and experience of academia, investors, SMEs and large industry.

Taking a helicopter view, the Innovator's Compass will help to identify those inventions that can make the leap to innovation, aligning both technological and non-technological factors, and make a difference for the transformation towards climate neutrality.

The aim of the Innovator's Compass is **not** to provide innovators **with answers to all their questions**. Many of these answers depend on the individual case and need to be considered specifically for each innovation. Under no circumstances can a short document replace tailor-made advice from experts.

Furthermore, the Innovator's Compass is not all-encompassing. It does not, for example, touch on the creation of business plans or the composition of teams in the start-up. Although these points are at least as important for the success of young companies as the underlying invention, there is already a wide range of assistance available, especially in NRW. We recommend that innovators inform themselves at an early stage in these matters and avail themselves of the support available.

Reading this guide provides (future) innovators with essential questions to help their innovation succeed.

Focus on North Rhine-Westphalia (NRW)

This guide focusses especially on innovative ideas from NRW, which is why the perspective of NRW, Germany, and Europe is highlighted for the different criteria.

Methodology

The starting point for the first version of the Innovator's Compass were several projects of CLIB, which dealt with the potential of various biotechnological developments and the support of start-ups. From these findings, the **core criteria** were derived in the ongoing **Triple-S project**, which we considered essential to turn inventions into impactful innovations. These criteria were sharpened through knowledge gained at carefully selected external events and the organisation of CLIB events such as the Triple-S Kick-off Forum, pitching events, and conferences. During two co-creation workshops in November 2023 and 2024, the collected knowledge was discussed with a circle of selected experts in order to integrate as wide a range of different perspectives and expertise as possible into the Innovator's Compass.

The Triple-S Core Criteria

As initially mentioned, the Triple-S project is looking for general criteria which, if fulfilled, help innovations to succeed and have an impact.

On the one hand, these criteria are inherent to the invention/innovation itself. From our analyses to date, successful innovations are characterised by the fact that they are **sustainable, smart, and scalable**. These **Triple-S criteria** must be considered as a **triad** if the impact defined above is to be achieved: An invention can have a better CO_2 footprint, but without a perceivable improvement for the customer, it will hardly prevail in the market. Outstanding product properties are good, but if production is only on a gram scale, this will not have a significant impact on the overall system. Fossil-based processes often have gigantic scales, but do not contribute to the transformation into a sustainable and bio-based economy. Only by being all three – sustainable, smart, and scalable, can innovations truly make an impact.

By asking – and the responding to – the right questions, innovators can influence their course in these three core criteria at an early stage and help put their invention on a promising path. However, this does not mean success will be guaranteed.

In a previous project, **HiPerIn2.0**, we have shown that the success of an innovation is also influenced by a number of **non-technological criteria**. These include regulatory frameworks, other actors in value creation, and the market, but also public opinion, intellectual property (IP), business models and financing opportunities. Of these technology-independent criteria, this Innovator's Compass includes chapters on the consideration of the entire value chain, the market situation, applicable legislation and regulations, as well as skilled workers as human capital. Ultimately, the success of innovations also depends on their financing up to market launch.

Triple-S

Sustainable Smart Scalable

Identify, support, and transfer biotechnological and bio-based technologies which can make a significant difference to realise a future-proof, climate- and environmentally friendly economy in NRW.

SUSTAINABLE

Sustainable innovations make a significant contribution to economic, ecological, and social value creation. For example, they contribute to the climate goals and the *Sustainable Development Goals* (SDGs) and are building blocks of a holistic value cycle. In view of the imminent transformation of the economy, incentives by legislators, and the growing social interest, sustainability will become a strong advantage – whether as the feature of an innovation or as a feature of the company. This criterion enables inventions to assert themselves on the market in a future bioeconomy.

Exemplary questions for this criterion are:

- What is the sustainability of the invention?
- What added value does sustainability offer for innovation?
- Does the innovation meet recognised sustainability criteria or contribute to the achievement of SDGs?
- Can the sustainability of the innovation be proven, e.g. by means of a *life cycle analysis* (LCA)?
- Is there a (perspective) analysis for the areas of social, ecological, and economic sustainability?
- Are there any side effects that can contribute to or jeopardise sustainability?
- Can the innovation be scaled sustainably?
- How big is the share of innovation in the end product and thus the influence on its sustainability?
- Does the innovation help to make other parts of the value chain more sustainable?

The sustainability criterion examines how an innovation can **contribute to the sustainability of a product** in the circular bioeconomy. It covers the three dimensions of **people - planet - prosperity**, i.e. social, environmental and economic. For a viable business model to be effective in the marketplace, profitability is often the priority. However, as the transformation to a circular and sustainable bioeconomy is desired by politics, society, and industry, the other two dimensions will become much more important in the future. It will therefore be necessary for successful innovations to also make a positive contribution in the environmental and social spheres - or at least to avoid any disadvantages.

To assess sustainability, the United Nations' 17 SDGs are a good starting point. Of course, being able to make **reliable statements about the sustainability of an invention** is the next step to take. Although it can be difficult to quantify, it is an important part of determining an innovation’s value in many respects. First, sustainability presents a **marketing opportunity** and a strong driver for the success of an invention. Some consumer groups are enthusiastic about sustainable products and are increasingly willing to reward them with higher prices. But also innovations at earlier stages in the value chain benefit as brand owners increasingly demand sustainable intermediates in their supply chains. Moreover, sustainability provides a desirable purpose to the work of a company's own employees, making it easier to recruit, especially in a time of skills shortages. Ultimately, financiers are also looking for evidence of sustainability, for example to invest according to ESG (environmental, social, governance) criteria.

It is important to understand that biotechnology does not automatically mean (more) sustainable! **How can the sustainability of an innovation be reliably measured?** How can someone prove to be more sustainable than the status quo? To answer these questions, key figures on mass and energy balances as well as raw material and energy requirements need to be collected or at least estimated at an early stage. Even a preliminary LCA (life cycle assessment) can give valuable indications regarding the sustainability of an invention in its current stage and provide insight into potential for improvement. This can help to focus on hotspots, for example on improvements in process design, raw materials choice, or other factors that will have the most impact.

Sustainable in North Rhine-Westphalia

NRW has had its own sustainability strategy since 2020, which is based on the 17 UN SDGs, from which it derives 63 indicators. From the point of view of the state government, the bioeconomy represents as an important building block.

In 2023, the process of creating a dedicated bioeconomy strategy for NRW was initiated and the first key points were published.

Good LCAs require a lot of thought, good data, and possibly the involvement of experienced partners. As important as choosing the boundaries of an LCA is the choice of reference products and the selection or weighting of criteria in economic, environmental, or social LCA. While a strong LCA can answer questions, it can also raise new ones. Does the innovation have any side effects that can contribute to or threaten sustainability? Are there any unintended environmental or social side-effects?

Critical results of an LCA should be reasonably analysed and addressed if necessary. Were the data basis, metrics, and methods good enough or do they need to be improved? Can process optimisations sufficiently improve the result of the LCA? Have key issues such as synergies or scaling not been considered? In the worst case, a devastating LCA is a no-go criterion and sends the innovation back to the drawing board. In the best case, it becomes one of the most important sales arguments.

To highlight the **innovation's sustainability,** it can be helpful to rely not only on an LCA, but to add other recognised criteria. Examples are labels or certificates, which are easily recognised by customers and can increase the trust in a sustainability claim. However, they can be costly to obtain in terms of both money and time.

Sustainable **value creation** also takes an ethics review into consideration. The EU taxonomy for example comes into play, as well as exclusion criteria by financiers, which may exclude the defence industry. The social effects mentioned above are also relevant – will the innovation support sustainable working conditions in the supply chain and production, and will the required raw materials be sourced sustainably? This may need to be reassessed, particularly when scaling up to market size.

Beyond the sustainability of the innovation itself, innovators should also consider to what extent the innovation **contributes to the sustainability of the end product**. This has an impact on value creation, but also on the overall sustainability impact of the innovation. A smart, sustainable innovation that is only present in small quantities in the final product can (and should) be sustainable, but it will only have a small overall impact. Seemingly small improvements in the sustainability of bulk products, on the other hand, can mean huge improvements for entire industries.

In a circular bioeconomy, an innovation must be integrated as a **building block in a value cycle**. It is not enough to ensure a sustainable raw material supply and production, but a targeted end-of-life scenario also needs to be identified. There are several different, so-called **R-strategies** (reuse, repurpose, recycle, …) which help to understand the different stages of resource use and waste management in a circular economy and must be considered. Obviously, innovations that are at the beginning of a value chain are more difficult to assess in this regard, as an end-of-life scenario will have to be adopted by other actors further down the processing chain. We do however see increasingly stricter regulations in this area and possible incentives to establish such value cycles.

To sum it up, sustainability is a great opportunity, especially for start-ups. They can be agile, planning and scaling their processes sustainably from the outset. In addition, the sustainability of innovation can be positioned as an important building block of the value proposition.

Your feedback on this chapter:

SMART

SMART innovations bring specific, measurable, achievable, and relevant benefits in the foreseeable future. They provide a perceivable consumer benefit, for example by introducing new functionalities, making existing processes circular, or giving by-products new or additional properties. In this way, they are better able to assert themselves on the market and have a significant influence on the transformation to a circular bioeconomy.

Exemplary questions for this criterion are:

- What specific added value does the innovation offer and for whom?
- What is the intended impact, and can the innovation achieve it?
- Will the customer be an end user (B2C) or a company (B2B)?
- Can the innovation be flexibly applied to multiple, possibly changing, sectors or markets?
- How can the innovation be implemented in established value chains? Is the innovation compatible with existing market or process structures?
- Does the innovation have a place in a future bio-based/non-fossil circular economy?
- Are sustainable design and *end-of-life* part of the SMART concept?
- Does the innovation realise the greatest possible added value from the selected feedstocks?
- Is the innovation sufficiently secured by IP?

The Triple-S criterion **SMART** evaluates the **measurable relevance of an innovation**. First and foremost is the question which problem the invention is trying to solve and the new functionalities that may be introduced as a result.

The aim is to create practicable solutions with **perceptible improvements** that will prevail in the market. Especially in the chemical industry, competing solutions often have been on the market for many years and have been optimised for a linear, fossil-based economy. Smart innovations therefore achieve their success with new, smart properties, which enable additional benefits, such as the use of sustainable raw materials or better recyclability.

However, one individual innovation does not have to solve all the problems of the circular bioeconomy. A partial solution, enabling iterative progress over time, can also be effective. At the same time, there should be a clear idea what impact the innovation will have and whether it is foreseeable that this will be achieved in a reasonable time frame.

Is the invention a drop-in, a bio-similar, a bio-better, or a first-of-its-kind application? What are the advantages for potential customers? Besides additional or new functionalities, these could be, for example, energy saving, simplified regulatory measures or resource efficiency. At this point, a clear (evidence-based) definition helps to convince third parties and to clearly communicate the added value for certain target groups, opening up further application possibilities for future developments.

The above-mentioned Life Cycle Assessments (LCA*)* can provide a solid basis, and this process knowledge can also be relevant for later scaling requirements and associated financing strategies. Many funding structures have far-reaching prerequisites which should be considered.

When planning market entry, it can be helpful to identify customer groups as early as possible and to analyse their perception and expectations of the invention. This can be done in direct conversation or through information from partners who have the necessary market experience. The choice of business model can have a major influence on which unique selling points of the innovation are relevant to marketing and whether these are also reflected in public perception. In general, the focus is on affordability, availability, and sustainability, which can have different weight depending on the business model. Further market requirements and related external factors are discussed below.

In a B2B business model, the focus can be on further processing of the intermediate produced. This raises the question of whether the invention can be integrated into established value chains and market structures, or whether new process structures and markets need to be established. While **compatibility with existing structures** can make it easier to enter the market, the **exclusivity of a process or production platform** offers a strong **unique selling point**. This can create a special moment of transformation, especially when several innovative products require similar new processes and a new sector of its own can be established as a result. Such momentum can be observed, for example, in "yellow" biotechnology, where the first insect farms have just given rise to a variety of ideas for the use of the new side streams these produce.

The B2C business model usually requires a different type of marketing and can overwhelm small businesses due to the additional integration required along the value chain, including sales. Especially when introducing new functionalities, additional regulatory requirements may be added. An example from the food sector is the Novel Food Regulation.

In both the B2B and B2C business models, numerous factors influence the market, which can change abruptly and steadily. This requires constant analysis and, if necessary, adjustments to be able to **react flexibly to**

market needs. Drastic changes in demand and needs are not unlikely and influences from the international market may also necessitate a sudden change in strategies. An innovation that, at its core, is already able to meet the needs of multiple markets and sectors is more resilient to change. Initial and regular analyses can help to uncover needs and open up new markets.

In this context, the question of the **circular design of the invention** also arises. Sustainability – this aspect has already been addressed in more detail under SUSTAINABLE – is an important aspect of our future society and should be considered when designing an invention, if possible. This places special demands on potential ***end-of-life*** **scenarios** of innovations. A product might be reprocessed to a raw material at the end of its life cycle, provided that the process and demands on the purity of the feedstock allow it. Common limits in recycling processes can give an indication whether this is a feasible option. Alternatively, interfaces to other value chains may need to be identified, creating value networks. This can also be of interest for side streams that arise from the innovative process, allowing for holistic value creation, valorising even low-quality material flows. If the innovation incurs additional costs compared to the established products, the decisive factor is who bears these additional costs. Is the customer willing to pay for a green premium, or do these costs have to be saved elsewhere in the value chain?

SMART in North Rhine-Westphalia

In addition to numerous academic institutions, there are many research-based companies in NRW that invest high R&D expenditures every year. Due to the higher production costs compared to other countries in the world, NRW has always distinguished itself as a technology leader. SMEs in particular include numerous "hidden champions" in various sectors, which will also become part of a circular bioeconomy in the future.

Questions about intellectual property and the associated restrictions and opportunities are also fundamental. If the **intellectual property of third parties** is required for the innovation, the question of freedom to operate or possible licensing models must be raised at an early stage to take potential costs into account. If the innovation can be patented, this can mean a unique position in the market or make licensing a potential business model.

Your feedback on this chapter:

SCALABLE

SCALABLE innovations have realistic scaling options and can thus make a significant contribution to the transformation to a circular bioeconomy. This chapter describes the identification of relevant indicators for scale-up. These allow for the formulation of intrinsic technological requirements that a biotechnological invention must meet, in order to be scalable.

Exemplary questions for this criterion are:

- Are the key parameters for the design of the production scale known?
- At which *technology readiness level* (TRL) is the invention at the moment?
- What steps are missing to achieve market readiness?
- How, where, and by whom should the process be scaled?
- Is the raw material base scalable? Which factors will determine the price and availability of raw materials in the future?
- Is the upstream/downstream technology scalable? What are limiting factors?
- How robust is the process?
- Do the analysed mass and energy flows show that the process can be scaled theoretically? Can this be achieved in practice?
- Has the complexity been reduced to the essentials?
- Is the economic viability of the innovation evaluated in terms of production scale?
- Have costs for scale-up been determined?

Before the scalability of the invention can be considered in detail on the technological level, the goal for scale-up must first be clearly defined. Will the innovators enter production themselves, look for experienced partners, or should the innovation be licensed out later? Which market should be served first? What market share is being targeted? Of course, these goals are subject to dynamics in the interplay between the further business and market development, but first there is an initial production target (in t/a), which must be achieved after the entire process chain has been successfully scaled.

Based on this production goal, **key parameters** of the process are required to be able to define the number, volume, and design of fermentation plants (upstream) and to design the product processing (downstream) appropriately. These key parameters include the ***TRY* factors** (titer*, kg/m³;* rate*, kg/m³/h,* yield*,* $kg_{product}/kg_{feedstock}$) of the upstream process and, in addition, the respective capacity (kg/h or t/h) of the individual downstream units.

For a realistic assessment of scalability, the currently achieved ***Technology Readiness Level*** (TRL) can be evaluated in combination with the TRY factors. How do the practically determined parameters perform compared to the **theoretical maximum yield**? What yield can realistically be achieved under actual influencing factors, such as cell metabolism, by-product formation, etc.? How flexible should production be?

After estimating the required total reactor volume based on the determined quantities and the biological specifications, an initial evaluation is made on a **sensible reactor design** (e.g. stirred tank reactor, bubble column reactor), number and size. There are technological limitations, but also strategic decisions, e.g. for a centralised large-scale plant or decentralised small plants at several locations. Lock-in effects should be avoided as much as possible, such as exclusive ties to an external company or even to a technology, making changes impossible without considerable effort or costs. The availability of raw materials (quantity, regionality) must also be taken into account, as long transport routes are often uneconomical, especially for (biogenic) waste streams. These factors can influence who, where, and how an innovation scales to the next TRL. Is this done in-house or with the help of flexible scaling infrastructures?

In the overall view of the **raw material base**, it is also necessary to assess how the raw material price will change as a result of the planned scale-up. Which other stakeholders are competing for the required raw material? Are price stability and delivery reliability also ensured on a production scale? Is the raw material available all year round? Against this background, the sustainability of an invention may also have to be re-evaluated (see also Sustainability).

In order to convert the defined raw material into the purified target product, the **upstream** process steps used must be designed in such a way that they can provide or process the required material flows. In addition, a detailed analysis of the individual process steps with regard to their technological and economic scalability is required. It is very helpful to draw up an overall balance of the **mass and energy flows** of the process.

Besides biological conversion rates, other parameters are also crucial for scale-up. Heat exchange, risk of contamination, gassing, power input, mixing times, wastewater treatment, or the sensitivity to process fluctuations can all be reasons why a laboratory process works less well or not at all on a larger scale. The analysis of which factors are limiting for the large-scale process and how they can be optimised requires technical expertise and experience. Adaptations which do not require new hardware - so-called software solutions (e.g. adapted process control, changes to the organism, etc.) - are usually much easier to implement than a new reactor design.

Scalable in North Rhine-Westphalia

Access to scale-up structures remains limited in North Rhine-Westphalia. While lower TRLs can be readily scaled-up at academic locations, it is often necessary to go abroad for high TRLs. In the Trans-BIB project, CLIB is currently compiling an overview of the existing scaling infrastructure on a national level in Germany.

Downstream processing is often neglected in the early planning and development phases but represents a large share of the required capital and operating costs. Therefore, it is advisable at an early stage to develop the processing steps from the laboratory in parallel with the upstream and to test the transferability to the desired production scale. Several common laboratory methods cannot be implemented on a production scale or can only be implemented at uneconomical costs. The target market defines the permissible complexity of the overall downstream processing. The rule of thumb is: keep it as simple as possible, as complex as necessary. A scalable downstream process is often characterised by the fact that it allows a continuous mode of operation and can be individually controlled between the process steps via appropriate on- or in-line analytics. The use of soft sensors enables the simulation of process parameters, which improves process control and saves costs.

Once a holistic process concept has been drawn up for the production scale, initial assessments of the **economic viability and financing** of the developed innovation can be made. Based on a positive ratio of raw material to product costs, the developed process design can be evaluated in a techno-economic analysis (TEA). If this is also positive, the costs for construction (CAPEX) and operation (OPEX) of the final production plant, as well as the costs of the necessary scale-up steps towards industrial production can also be estimated. Depending on the level of detail, this is only possible with the help of experienced engineering companies. Under certain circumstances, the costs may be strongly dependent on whether the company's own or third-party existing infrastructure (buildings, plant components, etc.) can be used or whether everything must be purchased or newly built. It can also be useful to use scale-up plants as service providers and expert advisors. Wherever possible, costs should be minimised in order to receive positive assessments from investors or other external stakeholders.

In summary, the scalability of an invention must be tested and evaluated on many levels. Several fundamental decisions in process design have a strong influence on this evaluation. Due to the dynamic business development, scale-up must be continuously re-evaluated.

Your feedback on this chapter:

Non-Technological Success Criteria

The Triple S criteria define whether an invention in itself **can be successful** as an innovation in the market and whether it **may have an impact**. As previously described, it is primarily in the hands of the innovators themselves to meet all three Triple-S criteria. However, whether an innovation actually **has an impact** also depends on other, **non-technological factors**.

These include enablers, which contribute significantly to the success of an invention, as well as hurdles which stand in the way of its success. Even if an invention only "interacts" with these non-technological factors and even if these cannot be changed by a single company, they still need to be recognised at an early stage. Only by having a clear understanding of the relationships between an invention and the non-technological factors can innovators identify risks and address them at an early stage. In an optimal case, benefits can be derived from those enablers that help pave the way for an innovation.

This second edition of the Triple-S Innovator’s Compass will consider the following non-technological factors:

- **Value Networks**
- **Market Situation**
- **Applicable Regulations**
- **Skilled Work Force and Human Capital**
- **Financing Biotech Innovations**

Value Networks

In principle, all innovations are part of a value chain or will become part of a value chain in a circular economy in the future. It is therefore crucial not only to know or define one's own position within the value chain, but also to keep an eye on adjacent players.

- What is the availability of the raw materials or intermediates?
- Are they available locally or seasonally (especially relevant for biomass)? In what quantities are they available?
- Does their purchase affect an already existing value creation?
- What is the shelf life and quality of the raw materials?
- Is the availability of the raw material secured by several sources?
- Who are the relevant actors: the direct buyers, the users, and the end consumers? What are their respective demands on the innovation?
- Which target market will the products be introduced to, and are there special requirements or impacts on the innovation?
- Does the innovation depend on external actors to enable its circularity?
- How can innovators utilise their own side streams, possibly through other actors?
- Are innovators sufficiently networked with other players within the value chain?
- What are the logistical requirements? Does the feedstock or product have specific requirements for storage and transport?

Innovations, such as products or processes, are usually part of a value network or are intended to become so within the framework of the targeted **circular economy**. For successful innovations, actors placed before or after the innovation along a value chain in the value network need to be identified at an early stage. Many of the following considerations are part of the solid planning of the business idea but gain additional aspects against the backdrop of the abovementioned core criteria.

At the beginning of a value chain stands the feedstock, which can be **raw materials** or intermediates. Raw materials can come from primary sources, or side or residue streams – maybe from other actors in the value network. It is easier to plan with feedstocks which are available all year round and are traded globally. Raw materials from the agricultural sector in particular are often seasonal and local and must be processed, transported, or stored accordingly. Utilising side streams increases the complexity as these are usually heterogeneous, have different qualities, and often only occur very locally or temporarily. In the latter case, supply chains are often not yet fully established, so that at a pre-competitive stage, it can be helpful to **align with other players** to jointly overcome challenges, e.g. in the pre-treatment, storage and logistics of biomass streams. In principle, however, it is advisable not to be dependent on a single raw material (or supplier thereof). By using multiple sources of raw materials, the production campaign can be extended and dependence on individual suppliers can be reduced, minimising the risk of failures or process downtimes.

As already discussed under the sections **Sustainable** and **Scalable**, the required quantities are also very important. If a feedstock suddenly sees a high demand because of the innovation, this can lead to price increases but also decreased availability – which can have an impact in other areas and have a positive or negative impact on existing and extending supply chains. This can create additional sources of income for feedstock providers but can also make previous uses of the feedstock unattractive, leaving existing customers empty-handed. The extent of these distortions and their consequences also need to be part of the sustainability assessment, as mentioned in the chapter **Sustainable**.

Just like the suppliers, the **actors downstream in the value chain** are equally crucial. The earlier it is known who the direct customers, users, and also end consumers are, the better the innovation can be adapted to their specific requirements. The direct customers of the innovation may be hesitant to commit to this new process or product, fearing to become dependent on individual suppliers who can dictate price and availability. This can be a challenge for startups with exclusive products, who will need to allay these concerns and take measures to avoid shortfalls or supply issues.

Situation in North Rhine-Westphalia

With its chemical parks, NRW is an excellent example of how a concentration of local actors can strengthen individual innovations. Similar positive effects are expected for biotechnology as soon as the first large-scale processes and sites are established.

In later stages of scaling, it can be worthwhile to look further afield. Established processes often use **side streams from other stakeholders** and feed their own side streams into the value network for optimal valorisation. Such optimisation often brings the decisive economic advantage but requires networking efforts to connect with the other actors. In some cases, a side stream can even become a larger source of income than the originally targeted product. Being in close proximity to other players across the value network is helpful to realise this valorisation of each other's side streams. Such spatial networking also allows for the sharing of infrastructure, better logistical connections, and the integration of heat and energy. More dedicated biotechnology sites are currently being built at existing sites of the paper and wood industries, as well as the chemical industry. They are also conceivable, for example, in connection with food production.

Although local use of resources is a challenge, a particular strength of biotechnology is its potential to promote a decentralised approach by means of small-scale and automated solutions. This cannot be achieved by large, fossil-based network sites, and opens new possibilities for economic development across regions.

Your feedback on this chapter:

Market

Whereas in the previous section the actors were primarily considered links in a (future) value network, in a real market situation, they are in competition with each other. Actors compete directly for customers, feedstocks, and other resources (financing, human resources, infrastructure). Customers and suppliers strive to maximise their respective economic advantages in the face of competition. The end consumer can also play an important role, acting not only economically, but also emotionally.

- What is the added value of the product or service for which the customer is willing to pay?
- Who is the competition and what are they competing for?
- Which other stakeholders are relevant, and which of them could become partners?
- What is the USP of innovation? How is it protected against the competition?
- Which market is the innovation aimed at? What is the targeted sector?
- Does a market for the product exist already?
- What is the plan for market entry?
- Is public opinion and societal approval relevant for the market acceptance of the innovation?
- Does the innovation concern an emotionally charged area, e.g. genetic engineering in food?

Innovations need to succeed in the market to make an impact. It is crucial to clarify the value proposition which will raise money in the market. What communicable added value does the service or product offer? Is there a perceptible benefit for the customer?

The general development of the business model also includes the decision on the type of production: should it be manufactured in-house, in cooperation with contract manufacturers, or should the technology be licensed out?

It is also necessary to get an **overview of the competition** at an early stage. This is where the evaluation of value chain or value network, which were discussed in the previous chapter, forms the basis and gives a good indication against whom the innovation is competing, for what it competes, and how the innovation stands out from the competition. Here, the principle of *unique selling proposition* (USP) is often used for market positioning in order to differentiate one's own offer from that of the competition. The **choice of the target market** in terms of sector (e.g. cosmetics or food?) and region (e.g. in Europe or Asia?) is also decisive here. If the target market already exists, many framework conditions are clear, but an innovation still has to assert itself against established competition. If a market does not yet exist, it has to be created. This is associated with high risks, but on the other hand also promises a potential monopoly position, if successful. It is advisable to weigh up risks at an early stage and to outline alternative strategies in the case of processes that are too resource-intensive for market development.

While some innovations are intrinsically tailored to a specific target market, other innovations can theoretically serve a variety of markets. Here, the common expert opinion is to set a clear focus. Coordination with experienced experts helps to set the most promising prioritisation from an economic point of view.

Even before entering the market, the underlying **IP** should be secured to prevent a copy of the invention. Likewise, the supply of raw materials must be contractually secured, as potential suppliers may be tempted to achieve (higher) revenues what were previously considered waste streams. Existing competitors can also try to make it difficult to enter the market, whether by discounting their own products, aggressive marketing, or using established customer relationships.

The early acquisition of **reference customers** can minimise such risks. Potential customers must be persuaded to test or incorporate the innovation into their production processes or product portfolios. By this time, even small teams should have provided themselves with the necessary networking and marketing skills (see also chapter "Skilled workers as human capital"). Early contact with potential customers, but also with potential competitors, can also be used to make a valid assessment for realistic pricing.

Based on experience, it can be clearly said that the **end consumer** rarely acts as a pure *homo economicus,* especially in contact with biotechnology. If innovations offer no clear advantages, customers tend to shy away from higher costs. Therefore, successful innovations need to succeed in communicating good sales arguments.

Situation in North Rhine-Westphalia

With almost EUR 794 billion (2022), NRW accounts for around 21% of Germany's gross domestic product (GDP) and is thus already a relevant domestic market in itself, which is also very differentiated. However, due to the strong competition in the manufacturing and service industries, there is a high pressure to innovate.

Actors in the biotechnology sector should also be aware that topics around genetically modified organisms (GMOs) or novel food are emotionally charged for many end consumers and require a well-thought-out communication strategy. Other aspects, such as the use of certain raw materials, can also cause concern, aversion or even disgust. It takes a thorough knowledge and subsequent choice of the target market and the players operating in it to enable innovators to be economically successful.

Your feedback on this chapter:

Applicable Regulations

Regardless of other concerns, most markets today are highly regulated and almost all products are subject to corresponding regulations (legislation, ordinances, and other regulations). This is especially true for the chemical industry and biotechnological processes, which are subject to the far-reaching REACH regulation or more specific regulations such as novel food. Ignored, these framework conditions can slow down new innovations, make them more expensive, or simply cause them to fail if, for example, approval criteria are not met. However, certain framework conditions also allow opportunities for innovation, for example when existing markets are drastically changed by new regulations. Due to the importance, the dynamics, and the lengthy processes, this topic should be considered at early stage, involving suitable experts.

- What legislation is the innovation subject to? At what legislative level?
- How dependent is the innovation on existing or expected regulation at national or EU level?
- Will regulation have an impact on the availability of the raw material, on possible pricing, or on the incentives of buyers?
- Which certifications for the product are required by other players in the value chain?
- Who needs to deal with regulation and related questions?
- Will there be any regulatory changes in the foreseeable future, either to the benefit or the detriment of the innovation?
- How or where can an overview of the necessary approval procedures, their estimated duration, and associated costs be obtained?

Regulations include the minimum requirements that initially regulate access to the market, for example through laws and safety regulations. Inventions must satisfy these requirements in the first place, before they can be introduced on the market. Once in the market, innovations are also subject to a variety of further regulations.

In recent years, regulation has become a central issue also for biotechnology. In order to comply with the extensive regulatory requirements and thus enter the market or fall under favourable regulations, approvals, and recognition procedures are required, which are accompanied by lengthy and costly procedures. These can fatally slow down innovations or make them financially unmanageable, especially for start-ups. Regulations can, for example, restrict the availability of raw materials or create sales markets by deploying policy measures to incentivise certain ways of use.

Especially biotechnology processes using genetic resources must clearly specify where these were obtained. For example, knowledge gained from nature is subject to the **Nagoya Protocol**, which strives for a fair balance between countries of origin and users of genetic information. Moreover, the **strict regulations** on **genetically modified organisms** (GMOs) can limit the scope for action. These are currently being revised at EU level and leave (as yet) some room for manoeuvre for regional policymakers.

Innovators are often unfamiliar with legislation and regulation. For the uninitiated, this appears as a jungle of **laws, regulations, and labelling requirements**. Depending on the position in the value chain and the choice of the target market, different requirements can apply. Even the targeted production scale can be decisive. For example, the REACH regulation depends on the quantity produced and has clear gradations at the 1 t or 1000 t limit. New regulations on SSbD (*safe and sustainable by design*) will have far-reaching consequences for the development of new intermediates and materials.

In a value-added cycle, stakeholders are interdependent in terms of regulation. The area of responsibility should therefore be identified at an early stage. Innovators should be aware of framework conditions applying to their project, understand the regulatory requirements and prepare the relevant documentation. This is important to enable customers to overcome and finance the regulatory hurdles that fall their way. It is important to consult experts who are familiar with the respective target market in good time. This can be ensured by external experts or, in the medium term, by building up regulatory competencies within the company itself, especially in highly regulated markets.

Situation in North Rhine-Westphalia

The regional regulations usually have little influence, it depends on federal and EU laws. The clear feedback from the CLIB experts is that overly complex regulations, slow procedures, and legislation without a clear mission statement are currently slowing Europe down compared to other markets. A lot of work is to be done here in the coming years to keep the location globally competitive.

Another caveat: **regulations are changing**. It is of great importance to know whether there will be any changes in regulation in the foreseeable future, either in the innovation’s favour or against it. This is the only way to make necessary changes to the business idea or to take other measures at an early stage to comply with a change in regulation. For such information, cooperation in associations or directly at the political level is extremely useful. This can exceed the personnel capacities, especially in the case of smaller companies. Here, the benefits of early exchange with other actors in networks such as CLIB cannot be overestimated.

Your feedback on this chapter:

Skilled Workers and Human Resources

Every innovation depends on people to implement it. For a company, it can be crucial when and how its workforce develops. Team size, form, and qualifications, as well as growth potential, are some important aspects of human capital as a success factor.

- What expertise, skills, and experience do the innovation need, so it can be implemented?
- What perspectives need to be represented in the team?
- In what forms can and should competencies be presented in the team?
- How can cooperation be used for the successful implementation of an innovation and what risks can arise in the process?
- Which networks can the innovation benefit from?
- Are the necessary skills available on-site?
- Does the company have a recruitment strategy? Which factors make the company an attractive employer?
- How well is the company prepared for growth, change, and transformation? How flexibly can it react?

The first question for assessing resource-efficient use of human capital is the question of **which competencies are necessary for the innovator's team**. In the case of bioeconomic and biotechnological innovations, start-ups usually emerge from a founding team of scientists. However, further expertise and skills are also necessary to implement a technology. These are, for example, communication, business administration, industry and market experience, or access to relevant networks such as (future) customers or regions. Not only their knowledge, but also their diverse **perspectives** on innovation strengthen a team, drawing from a range of experiences and training backgrounds, maybe even cultural and life experience. This can be important to help the team make robust decisions and to map out paths for future development.

Once the necessary or desirable competencies and perspectives to implement an innovation have been defined, the next step is to decide **how these can be included** in the organisation.

While each team needs internal competence in a core of employees or founders, young companies often rely on external skills of advisory boards, mentors, and strategic investors. **Collaborations** with, for example, universities or the commissioning of service providers with individual projects or tasks are also forms of using external competences. When relying on such external experts, knowledge preservation and IP protection play an important role, especially in collaborations. While external service providers can be expensive, these expenses are incurred only temporary and can be requested as necessary. This can be an argument to hold off building up competences in-house, which will need to be financed continuously.

Another important resource for different perspectives are **networks or clusters**. In these, innovators can often not only meet with various experts and entrepreneurs but also address and solve hurdles together with other innovations in the market. A healthy balance between competition and collaboration is enormously important, especially in emerging markets. Networks and collaborations can also be an important source of future employees, once a company in on the path to growth.

Situation in North Rhine-Westphalia

The high density of universities, universities of applied science, and research institutions, the strong chemical industry, and multiple urban centres make NRW an attractive location for the recruitment of employees as well as for contacts to consultants with market experience.

For companies in biotechnology or those participating in the transformation to a circular bioeconomy, it can be a challenge to **recruit skilled personnel**. There are no clear, specific job descriptions and corresponding training courses at either the academic or technological level, as there is still no classic job profile for the bioeconomy. This applies not only to the innovators themselves, but also to technical personnel who can implement and operate the innovation in the market. The introduction of **appropriate training courses** is only **to** be expected in the long term. The need for skills is complex and is currently being only partially covered by diverse disciplines. The competition for skilled personnel should not be underestimated.

Therefore, start-ups need to develop a **recruitment strategy** once they plan to growth their workforce. It should give clarity about the skillsets required and the timing for recruitment, but also how attractive the offer will appear to potential candidates. Companies that clearly define their mission and live the core criteria of **sustainable and smart** can retain and motivate their employees through a joint purpose and the expected impact.

Another factor in attracting employees can be the **location of a company**. For example, the proximity to universities, conurbations or innovation hubs can be a benefit, as there is a large talent pool to draw upon. While there might be competition for employees between established industries or other young companies, the chances of attracting talent are higher. While a location might not be easily changed, a company itself can take measures to be attractive to the candidates it wants to attract. Sustainability, the external presentation, and the social responsibility of employers are becoming increasingly important when potential new employees decide for or against a company.

Once the initial team has taken the first steps towards realising its innovation and expanded its workforce, **new challenges** will emerge. The focus may shift from technology development to demonstration and business development, and human resources will need to be managed accordingly. Entirely new tasks, such as the acquisition of investments or sales, can fundamentally change the job description of the founders and be too much to handle for one or few persons. This means, founders need to move from doing everything themselves to delegating, while also building their leadership skills. This includes the skills and opportunities to integrate new competences, to manage internal changes, or to expand into new regions or sectors. The development of employees and the ability to part with employees or even members of the founding team in the event of changes in the business will also become part of the tasks during the process.

While for most start-ups, the core team starts out small, the journey to a successful innovation takes many people, both inside the company and outside. Whether to hire expertise or source it from outside, whom to work with and how to evolve throughout the stages of company development, are important decisions on the road to market implementation. It can be very helpful to build contacts with mentors and neutral confidants but also peers from the start-up ecosystem. They all can give valuable input and advice for successfully meeting these challenges.

Your feedback on this chapter:

Financing Biotech Innovations

The previous chapters dealt with how to set up an innovation for success. Most of the actions described there need not only time and knowledge, but also money: another challenge for each innovation. Entering a partnership for (co-)financing an innovation can be akin to a marriage. Finding the right financing tool and the right partner is not easy, especially as there are many different options out there. Initial enthusiasm can blur judgment; timelines, numbers, and potentially diverging aims need to constantly be aligned, relationships can sour over time, and having the right chemistry is essential for success.

- Which types of financing are available? What are their pros and cons, as they pertain to the specific innovation?
- What is the level of development of the innovation and in which environment is it being implemented – e.g. via a start-up or in an established company?
- Which information needs to be obtained and collected prior to financing?
- Which stage is the innovation at, and which financing stage does this correspond to? Pre-seed, seed, series A/B/C?
- What will be achieved with the financing?
- Does the innovation solely need money, or is there also a need for non-financial support?
- Is the founding team willing to give up part of the ownership and control of their innovation? Should the financing be non-dilutive?
- What are the financiers' aims? What are the options for return on investment? And what is the desired and viable exit strategy?
- Can the innovation match the criteria and strategic aims of the investing stakeholders, e.g. in terms of sustainability, timelines, technology, or sector? What happens if these aims diverge over time?

The wide range of funding options available to start-ups, from general funding to more impact-driven programmes, can be confusing, and not all options can be mixed and matched. While some are better suited to early-stage projects or companies, others are more useful for more mature innovations. Some can even be dead ends, preventing a start-up from accessing other funding options at a later stage. Each type of funding also has its own requirements, benefits, and challenges. It is crucial to assess and evaluate the various options to identify the **optimal fit** and the most effective route to securing the substantial funding required for scale-up. It is important to establish a solid foundation during the early stages of a business's development. This can be achieved by drawing on **supportive funding and mentoring resources**, which can then be leveraged to facilitate later stages of growth, when larger sums of capital are required and must be invested with the aim of eventual return.

For an **overview of the most common financing types for start-ups**, see pages 50-51 at the end of this chapter. This will help innovators decide which options to take a closer look at. This chapter also provides readers with important questions to ask and tips to consider prior to financing.

It is essential to be able to demonstrate one's own innovation and to understand which information is relevant for potential investors, funding bodies, banks, or other financiers. This should include an understanding of the technological details, such as scalability, smartness, and sustainability, as well as the unique selling point, the market situation, and a clear timeline for the development. Further details on these challenges can be found in the other chapters of this Innovator's Compass.

It is essential for innovators to calculate the **amount of capital required** for their next milestone. This enables them to define the stage of development of the start-up and to identify the most appropriate financing options. Furthermore, innovators should utilise this information to define the subsequent steps and demonstrate to potential financiers how their investment will contribute to achieving the desired outcome. What will the **investment be used for**: CAPEX e.g. for upscaling plants, operational costs, production campaigns, technology development, IP protection, or regulatory approval? What next milestone or value reflection point can be reached with the planned sum? It is essential to have a well-defined growth strategy in place before initiating the fundraising process.

Another strategic decision is the **kind of investment support** to look for. Do the innovators only need money or are they also looking for advice or access to a network? Many financing options offer more than cash. Business angels, for example, usually have an established network or market access they can bring to the table.

As important as drawing up the innovation's own strategy is an understanding of the investor's interests and aims. Especially in biotechnology and bioeconomy, financing options are often tied to the **sustainability aspects** of an innovation. This can be helpful, for example to secure financing from banks who invest along ESG criteria, or investors who look to invest into impact-making solutions. It goes without saying that this requires the innovation to prove its compliance with such criteria over the time of investment. The quid-pro-quo or exchange for committing investment often means giving away part of the ownership of the innovation or company (**dilutive funding**). This can be purely financial, when someone gets a share in the company. It can also involve sharing control, as investors may secure a seat on the board or influence the company's future strategy. Investors typically expect a return on their investment to offset the risks associated with supporting a young company. This often requires recovering their capital with interest, usually through a profitable exit.

While most biotech investors, business angels, or specific funding programmes understand the comparatively long scaling timelines and the need for heavy financing, the **prospective return on investment** (ROI) needs to be promising. Therefore, innovators need to show a realistic path towards an exit of an investor, or how to repay financing. This can be achieved e.g. by paying off investments with profits, going public, or by selling the entire company.

Choosing the right financing type and tool is a multi-factor decision, that can equally pave and trouble the way forward. The individual interests of stakeholders, the timelines, scopes of programmes, regional considerations, range for future possibilities, and more all have an influence on which tool is right for the specific case. To identify the right fit, it can be very helpful to **check references** – what is an investors', business angels', or competition's track record? What is the success of their previously financed innovations? What do past participants in a programme or recipients of funding from this source say?

If the long journey together is to be successful, it is important to ensure that everyone's **objectives** are compatible, that joint agreements are reached in the very likely case of potential shifts in priorities, timelines, and milestones along the way, and that everyone continues to consider the partnership beneficial.

Promotional Bank for North Rhine-Westphalia

In close partnership with its owner, the State of North Rhine-Westphalia, NRW.BANK supports people, companies, and public authorities with a wide range of promotional instruments: from low-interest loans and equity financing to advisory services and grants. It cooperates with its financing partners, in particular all banks and savings banks, on a competition-neutral basis.

The promotional fields of NRW.BANK are "Economy", "Housing", and "Infrastructure/Municipalities". To accelerate the transformation processes, the promotional bank provides effective promotional impulses – for a sustainable, climate-neutral, and digital NRW.

NRW.BANK finances its financial and advisory services largely from its own income and thus independently of the state budget. As of 31 December 2023, its total assets amounted to 161.3 billion euros. NRW.BANK has more than 1,500 employees at two locations in Düsseldorf and Münster.

Financing Options

At the co-creation workshop, we asked our experts to sort a (non-exhaustive) range of financing options for biotechnology innovations from less common to more common.

In the following overview, we sorted them roughly by early to late stage, ending with public funding.

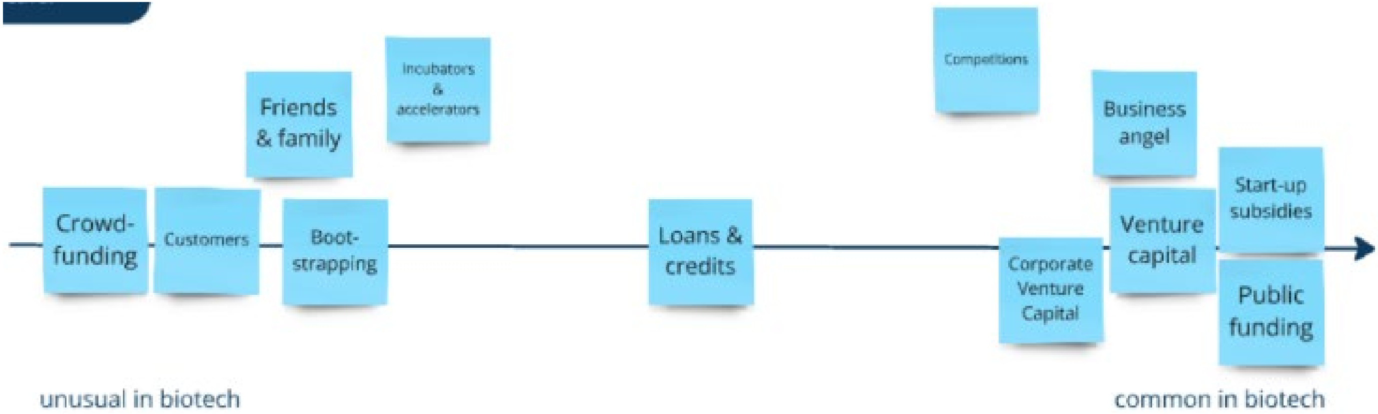

Figure 1: Different financing options sorted by our co-creation workshop experts.

Your feedback on this chapter:

Bootstrapping

- Using own money and savings (non-dilutive)
- No sharing of power or responsibility
- High personal risk, slower growth
- Usually only for early stage, heavily dependent on personal situation

Friends & Family

- Receiving money from friends and family (dilutive or non-dilutive)
- Can be a quick and easy boost
- Need for clear terms and contracts to avoid conflicts and dispute
- Amount of money depends heavily on personal situation

Crowdfunding/-investing

- Raising money from a large group of people (dilutive or non-dilutive)
- Can be a tool to build a brand and customer base
- Needs targeted and intensive marketing
- Business case needs to be clearly communicated and attractive for the target group

Incubators & Accelerators

- Programmes to support start-ups in early phase
- In Germany, many are non-dilutive
- May include lab space, offices, shared infrastructure
- May include mentoring as well as access to investors and networks

Competitions

- Participating in start-up competitions, winning prize money (non-dilutive)
- Placing high in relevant competitions can increase credibility and public awareness
- Feedback from mentors and jury can be relevant to sharpen business case
- No reliable source of money, small amounts, risk of losing focus

Business Angels

- Individual persons/small groups investing in early-stage start-ups (dilutive)
- Smaller and earlier investments compared to VC
- Decision on investment tend to be faster compared to VC
- Often serve as mentors and give access to network and markets

Venture Capital

- Investment usually in exchange for shares (dilutive)
- Different investors focus on different topics or sectors and offer support and advice
- Large range of financing, early stage to late stage
- Want to see significant growth of company, some funds are patient (aware of biotech growth times)

Corporate Venture Capital

- Venture Capital provided by a corporate (dilutive)
- Opens up contacts to large industry as customers or experts
- Some CVCs only invest in line with core business objectives
- Potentially less freedom to cooperate with other investors or industry players
- Risk for early-stage start-ups, as interests and focus on both sides can change

Start-up Subsidies

- Grants to support founders (non-dilutive)
- Often target a specific scope (e.g. region, sector, gender, …)
- Some only cover founders' cost of living, no company growth

Loans & Credits

- Classical bank loans or specific funding credits (non-dilutive)
- Project needs to be bankable, comparatively low risk
- Often fixed interest rates and timelines for repayment
- Funding credits often have more favourable rates for start-ups
- Can be relevant for established companies with innovative projects

Customers

- Financial support from customers through partnerships, investment, or upfront payments (dilutive or non-dilutive)
- Can be slow
- Only suitable if no or small invest in infrastructure is necessary
- Some customers are prepared to pay for sample material

Public Funding

- Many programmes on regional, national or European level (non-dilutive funding)
- Often targeted at ideas coming from academia
- Application process can be complex, both success rates and timelines can vary widely
- Usually, own financial contribution required
- Administration of the running project can be complex

Outlook

We hope you enjoyed reading this Innovator's Compass, and that it provided some help and food for thought. For this second edition of the Innovation Compass we have included a chapter on financing biotech innovation. The final edition is planned towards the project end and will be published at the beginning of 2026.

We are looking forward to your feedback on this Compass, anything we should include, or case studies you want to share with us.

We will finish with the last questions of this Innovator's Compass: What did you like and what was helpful? What was difficult to understand, what did you miss, what would you like to see added? Would you like to contribute and collaborate on the upcoming versions?

Scan this code to give us feedback!

CLIB
Cluster Industrial Biotechnology

CLIB is an international open innovation cluster that has been driving the development of industrial biotechnology for over 15 years. Its members are large companies, SMEs, investors, academic institutions, and universities, as well as other stakeholders from the bioeconomy. Of the more than 115 members, about 25 % come from abroad. The overarching goal of CLIB is to connect these stakeholders and create new impulses for projects, innovations, and business ideas. As a non-profit organisation, the members determine the interests and activities of the cluster, which encompass many different fields of the bioeconomy.

Throughout the calendar year, CLIB organises various events: the annual CLIB International Conference (CIC), the CLIB Networking Day (CND), webinars, and topic-specific workshops.

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