Special Issue on

Industrial Biotechnology-Made in Germany: The path from policies to sustainable energy, commodity and specialty products

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Abstract

The company Industrielle Biotechnologie Bayern Netzwerk GmbH (abbreviated: IBB Netzwerk GmbH) is a network organization in service of Industrial Biotechnology and sustainable economic growth. IBB Netzwerk GmbH manages the Network IBB. In this article, we clarify and define the relationship of Industrial Biotechnology to related areas and its relation to the goals of the bioeconomy. Second, we rationalize our commitment to Industrial Biotechnology by listing explicitly fields, for which Industrial Biotechnology is highly relevant. On this rationale, we then describe the company IBB Netzwerk GmbH and the Network IBB, their tasks, goals, mode of action and achievements so far and suggest explanations for some drawbacks of technology transfer. Finally, we attempt a bird’s eye view on cluster benefits in general, on the cluster policy of Germany as well as on an important requirement for cluster maintenance.

ABBREVIATIONS

ABV: Advanced Biomass Value; BayStMELF: Bavarian State Ministry of Food, Agriculture and Forestry; BayStMWI: Bavarian State Ministry for Economic Affairs and Media, Energy and Technology; BBI: Bio-based Industries; BIC: Bio-based Industries Consortium; BMBF: Federal Ministry of Education and Research; BMEL: Federal Ministry of Food and Agriculture; BMWi: Federal Ministry of Economic Affairs and Energy; cf.: confer; e.g.: exempli gratia; GM: Genetically Modified; GMOs: Genetically Modified Organisms; IB: Industrial Biotechnology; IBB: Industrial Processes with Biogenic Building Blocks and Performance Proteins; i.e.: id est; iLUC: indirect Land Use Change; INRO: Initiative on Sustainable Provision of Raw Materials for the Material Use of Biomass; OECD: Organisation for Economic Co-operation and Development; p.a.: per annum; R&D: Research And Development; SME: Small and Medium-Sized Enterprise; TefuProt: Technofunctional proteins; TUM: Technical University of Munich; VC: Venture Capital; ZIM: Central Innovation Program SME

There are only two kinds of science: Applied and not yet applied.

(Based on Michael Porter, Institute for Strategy and Competitiveness, Harvard Business School)

A.INDUSTRIAL BIOTECHNOLOGY

Definition, Relevant to this Article

Industrial Biotechnology (IB) utilizes biocomponents, including microorganisms, cell cultures or enzymes, as tools for technical or industrial processes. The applied processes may involve the synthesis, conversion or the degradation of industrially relevant compounds, encompassing monomers, polymers, food ingredients, drug intermediates, fuels and many other agents. The attribute “industrial” confers a specific framework upon the relationship of IB to the main colors of biotechnology. Therefore, just traditionally, there is this unfortunate, because inconsistent and artificial, differentiation of biotechnologies into different “colors”. Therefore, we attempt here an assessment of the relationship of IB to the main colors of biotechnology.

White Biotechnology

White Biotechnology is supposed to designate the Biotechnology deployed in the chemical industry or for the production of chemicals. “White” denotes the color of chemical “powders”, often just white. “White Biotechnology” used to be or still is synonymous to IB, particularly in Germany. However, IB may encompass more industries and by far more products than “only” chemicals.

Red Biotechnology

Red Biotechnology indicates the branch of drug manufacturing by biological means or based on biological intelligence. Basically, this means the production of therapeutic
as well as diagnostic) macromolecules like proteins and nucleic acids ("biologics") and other so-called "smart drugs", all designed and supposed to act selectively against a cellular target. However, when it comes to the production of rather small molecules like antibiotics or statins, the borders to the White Biotechnology blur. An example: Demand for ethyl (R)-4-cyano-3-hydroxybutyrate, the key chiral building block used to make the world's top-selling drug atorvastatin (Lipitor®; over 125 billion US$ sales volume in 14.5 years [1]), is about 200 tons p.a. and it is being made by several fine chemicals producers. This intermediate is also produced through biocatalysis [2,3] and thus clearly belongs to White Biotechnology.

**Green Biotechnology:** Green Biotechnology is reserved for genetically modified plants, which are used either as such ("optimized" for certain purposes) or as production factories for other substances, e.g. therapeutic proteins. While IB could use genetically modified plants as favorable feedstock for biotechnological conversions, it does not depend on them. In addition, due to many factors, Green Biotechnology is refused by the great majority of Germans, and has no "robust societal acceptance" [4].

**Differentiation: IB versus Bioeconomy**

IB is often considered in the same context as the term bioeconomy. However, bioeconomy only mirrors the use of renewable resources (like agricultural or forest-based material) as feedstock for the industrial production phasing out fossil resources (like natural gas and mineral oil) from industrial processes [5,6]. A direct consequence of the bioeconomy concept is supposed to be a reduced carbon footprint with its apparent climate and socioeconomic benefits. Thus, the "bioeconomy" is a visionary concept following economical-environmental and political targets. In contrast, IB is merely a technology, process or method with no political goals. The bioeconomy does not preclude a priori the application of conversion methods other than biocatalysis, like conventional chemical and physical techniques. Likewise, IB may be combined with such methods, but it still remains a cohesive approach. In addition, IB does not necessarily demand the use of renewable and/or organic materials, but also allows for inorganic substances, like carbon dioxide, carbon monoxide or hydrogen, or even mineral oil as possible feedstock for biochemical reactions. Consequently, IB overlaps and complements the bioeconomy. This may be one reason why they are – conceivably – used interchangeably by some authors and, particularly, why IB is considered a stimulus or impetus¹ for the bioeconomy. Indeed, the two approaches may develop their maximal benefit for the economy when they are combined, i.e. by initiating both product versatility and political targets. In contrast, IB is merely a technology, process or method with no political goals. The bioeconomy does not preclude a priori the application of conversion methods other than biocatalysis, like conventional chemical and physical techniques. Likewise, IB may be combined with such methods, but it still remains a cohesive approach. In addition, IB does not necessarily demand the use of renewable and/or organic materials, but also allows for inorganic substances, like carbon dioxide, carbon monoxide or hydrogen, or even mineral oil as possible feedstock for biochemical reactions. Consequently, IB overlaps and complements the bioeconomy. This may be one reason why they are – conceivably – used interchangeably by some authors and, particularly, why IB is considered a stimulus or impetus¹ for the bioeconomy. Indeed, the two approaches may develop their maximal benefit for the economy when they are combined, i.e. by initiating both product versatility and environmental protection as well as improving regional self-sufficiency (= independence from imports and transports). This benefit is exposed when domestic renewable resources are converted by cost-efficient biocatalytic processes to value adding products. To promote and catalyze just these synergies through dialog between academic, industrial and political partners is the focus of the Network IBB.

**IMPORTANCE OF IB**

What exactly is the potential of IB in combination with bioeconomy?

¹ German: “Impulsegeber”

**Relevance of IB for Enterprises (Big Industry, Small and Medium-sized Enterprises [SMes])**

There are already several enterprises which apply exclusively or partially IB in their production routes.² These enterprises may appreciate the following advantages [7]:

1) In contrast to traditional conversion methods, methods using enzymes or microorganisms usually take place at ambient conditions: they require low pressure of 1 atm (101,325 kPa) and a temperature that is 37 °C or less. An immediate consequence is a smaller amount of energy consumption and relaxed safety measures. These factors, in turn, help enterprises to save capital resources.

2) Enzymes, when used as tools for conversions of substances, are one main cost factor in IB. However, due to their unequal specificity as compared to chemical catalysts, enzymatic reactions may result in purified product streams containing less or no byproducts. This feature allows for technically simplified, cost-efficient downstream processing. This effect may compensate for high upstream process investments in biotechnology unit operations that utilize biocatalysts.

3) By using renewable biomass resources, enterprises become progressively independent of fossil feedstock. Fossil resources are not only finite but they are also linked to both supply and price volatility, which prevents solid business planning. By contrast, the sourcing of local renewable resources provides for stable feedstock supply and enables enterprises to reduce transport cost.

4) The utilization of renewable plant resources provides exploitation of nature's unsurpassed synthetic versatility. Hence, materials and products with novel chemical and physical properties can be manufactured. Consequently, companies have the opportunity for genuine innovations rather than "drop-in" solutions. This may open up new markets and enhance their global competitiveness.

At present, chemical companies apply IB to various extents. However, we think that the application of IB can be extended to other trade sectors of e.g. base materials and industrial, capital and consumer goods, food and feed production (that is, all subsections of the "Processing Industry"). Additionally, the energy, water and the building industry could also benefit from biotechnological applications to keep pace with a post-petroleum era and society [8]. This is why the IBB Netzwerk GmbH commits to promote this shift in resource and technology paradigm.

**Relevance of IB for Environment and Climate**

IB in combination with the bioeconomy strategy exerts a positive impact on environment based on the following arguments:

1) Biotechnological reactions occur mainly in aqueous solutions, not in organic solvents.³ In addition, the enzymes pose

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3 Researchers also try to find “extremophile” enzymes e.g. surviving exposure to very high temperatures, or enzymes that are able to work in organic solvents metabolizing otherwise water-insoluble substances, like e.g. intermediates of fine

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no hazard for the environment as opposed to often toxic, metal containing chemical catalysts. Certainly, all biotechnological processes must be subject to separate and thorough analysis regarding their environmental footprint according to several parameters. With some exceptions, however, most IB manufacturing is in general environmentally friendly (“Green Chemistry”, “Green Economy”, [9]).

2) IB works with foresight to prevent aftercare, that is, production should ideally yield no waste, which would have to be disposed. Currently, the integrated biorefineries represent the best model for this concept: Constituents that are not converted to the intended material and that would accumulate as waste (e.g., lignin) are used for the necessary process heat.

3) In case waste is produced, IB may provide methods for safe removal or remediation, again by use of enzymes or other biologic material. One topical example is the environmental pollution by plastic waste. Moreover, a possible solution for avoiding this problem beforehand is the use of biopolymers for the manufacturing of bioplastics [10]. One noteworthy example are the polyhydroxyalkanoates (like PHB [11]), which naturally occur as storage compounds in certain microbial systems like Pseudomonas sp. As these biopolymers are rapidly biodegradable, they cause no harm for the environment.

4) In summary, the smart combination of IB-based value chains provides for optimized use of both renewable as well as non-renewable resources. IB methods therefore promise a more efficient use of the biomass potential compared to conventional methods of material and energy use. In the context of a circular flow economy, the cascade and coupled use of biomass contributes to a complete and high-quality reutilization of raw materials. This sustainment of natural resources improves economic viability and preserves environment and climate [12].

5) In contrast to the consumption of fossil resources, use of renewable resources, particularly plant material for production of bio-fuels and other bio-based products, does not raise atmospheric CO₂ content in toto, because as much CO₂ is released as has been assimilated by the plants prior to combustion. Hence, these production processes are carbon neutral.

6) Finally, it is apparent, that the bioeconomy, combined with the environmentally compatible methods of IB, is a principal methodology to decouple economic growth from atmospheric CO₂ increase.

Relevance of IB for Agriculture and Rural Development

Until 2050, the world population will grow from seven billion to nine billion people [13]. This development puts pressure on today’s agriculture: The demand for agricultural crop land, pesticides, energy, fertilizer, food and feed – and generally for natural resources – will increase enormously. The solution to these challenges are innovations, like those offered by the IB processes, including e.g. valorization of agricultural products as well as the almost complete material and energy processing of renewable raw materials in biorefineries. Similarly, the production of second and third-generation biofuels, such as bio-Butanol, can sustainably relieve the global hunger for energy. Thus, modern technologies such as IB pave the way to a more efficient, more economical and at the same time sustainable agriculture and rural development.

IB and the “food or fuel” debate: An issue of the bioeconomy that affects IB is the discussion, whether industry is permitted to consume edibles to produce engine or jet fuels. Apparently, the obvious answer is ‘no’. However, one should be also aware of a recent study about whether food crops should be used for bio-based applications other than food and feed. The quite heretic though well-founded proclaimed view is that “all kinds of biomass should be accepted for industrial uses; the choice should be dependent on how sustainably and efficiently these biomass resources can be produced” [14]. Anyway, efforts in our Network IBB concentrate on the development of cost-efficient procedures to use plant residues and other “waste” streams in industrial processes like the sunliquid® process of Clarient. This formidable process converts straw into cellulosic ethanol, a key biofuel and chemical building block. Further, the Advanced Biomass Value (ABV) process converts algae biomass in an integrated biorefinery concept aimed at the production of renewable aviation fuels, high value bio-lubricants and CO₂-adsorbing building materials. The particularly energy efficient ABV process, which does not produce any waste streams, is further discussed in this article.

With respect to other issues regarding agriculture and bioeconomy, e.g. the feared rise in prices for foodstuff due to increasing demand of bioenergy or the ongoing so-called indirect Land Use Change (iLUC) debate, we refer to the “News” section of our website.

Relevance of IB for National Economy

IB is a key enabling technology delivering important impulses for the political and societal structural change from an oil-to-a bio-based economy. In Germany, IB product sales totaled 143 million Euros in 2010 and rose to 177.5 million Euros in 2011 (24 % increase). For comparison: the entire biotechnological industry (including the medical biotechnology) generated in Germany a turnover of 2.4 billion Euros in 2010 and 2.6 billion Euros in 2011 [16]. In fact, a study of the Organization for Economic Co-operation and Development (OECD) of 2009 predicted that by 2030 IB will add up to 39 % of the total gross added value of the output of chemicals and other industrial products that can be manufactured using biotechnology. Interestingly, the
study forecasted only a 25 % share for the health sector. Thus, the economic potential of IB is immense and steadily growing. However, in 2009 only about 2 % of the total R&D investment of the OECD biotech companies were invested in the field of IB, whereas the lion’s share of 87 % of investments flew into the health sector [17]. In Germany itself, this imbalance is even more extreme.

IB can contribute substantially to job retention and/or creation in high qualification as well as in rural sectors, can spur investments in European Economy and can strengthen the European competitiveness. However, IB still needs support and a mindset change to unfold its potentials.

**EXAMPLES OF IB CONSUMER PRODUCTS**

IB products can be found in every household and are an inseparable part of our lives. Examples are:

- **Washing and cleaning agents**: Biotechnologically produced enzymes are mixed with the detergent and decompose fats, proteins and carbohydrates at low temperatures.
- **Textiles**: the stonewashed effect on denim is achieved using cellulases.
- **Odor stopper sprays for carpets, shoes or sofa covers**: contain cyclodextrins, which absorb odors and thus neutralize them.
- **Cosmetics**: often contain biotechnologically produced hyaluronic acid for moisture regulation.
- **Many food and feed additives** are now produced biotechnologically, such as citric acid as an acidifier in beverages, natural flavors such as vanilla or strawberry flavor or phytase as a feed additive in pig breeding.
- **Vitamins**, such as vitamin C and vitamin B2, are produced biotechnologically.
- **Bioplastics** can be found in yoghurt cups and carrier bags. Recently, a toothbrush and an airbag were made from bioplastics.

Thus, consumer needs promote the advancement of IB. However, as IB production processes may involve genetically modified organisms (GMOs), there are rising concerns in the German population that these may affect health or environment. In general, there is controversy over GMOs, especially with regard to their use in producing food or additives for food and feed via IB processes. The key areas of controversy related to GM food are whether GM food should be labeled, the role of government regulators, the effect of GM crops on health and the environment, the effect on pesticide resistance, the impact of GM crops for farmers, and the role of GM crops in feeding the world population. On one side, there is broad scientific consensus that food on the market derived from GM crops poses no greater risk than conventional food. Nevertheless, opponents of GM food claim, risks have not been adequately identified and managed, and they have questioned the objectivity of regulatory authorities. Some health groups say there are unanswered questions regarding the potential long-term impact on human health from food derived from GMOs. Concerns include contamination of the non-genetically modified food supply, effects of GMOs on the environment and nature, the rigor of the regulatory process, and consolidation of control of the food supply in companies that make and sell GMOs. In the area of IB, there are three different levels, at which GMOs might come across in daily live:

1) **Substrate level**. As mentioned above, IB does not need genetically modified plant material as starting material. Conventional breeding outcomes are sufficient for IB’s purposes.

2) **Level of conversion tools (microorganisms, enzymes)**. Biocatalysts may be developed and optimized (“evolved”) by directed or random mutagenesis and selection. In fact, several companies, mainly outside Germany, apply “Synthetic Biology”, a sort of advanced genetic engineering, for the production of valuable biochemicals, biopolymers, therapeutics, and performance materials [18]. However, evolution of biocatalysts may also succeed without deliberate construction or introduction of foreign genetic material into a microorganism, so that such treatment does not result in genuine recombinant organisms. Moreover, these “evolved” tools, recombinant or not, are not used in outdoor tests but in closed containers; hence, there is virtually no risk for consumers or for nature through their accidental spreading.

3) **Level of products**. If enzymes are the manufactured item to be sold, e.g. as additives in washing powders, these may have been genetically modified; yet they cannot proliferate. Other chemicals and food/feed additives should be free of GMOs.

**EMBEDDING IB IN SCIENCE AND RESEARCH**

Innovation often commences with results of research originating from scientists’ curiosity and imagination. However, a technical problem or commercial question may also initiate research activity. In fact, given the huge challenges posed by the intended transition towards a sustainable, post-petroleum economy, such research is urgently required. Obviously, research does not only take place in academic institutions but just as well in companies themselves. On the “News” area of our website, a plethora of examples demonstrates how IB/bioeconomy may inspire research in this instance – and thus illustrates the reciprocal positive interplay of science with the economic sector.

**B.IBB NETZWERK GMBH**

**The Motive and the Genesis of IBB Netzwerk GmbH**

The German Federal Ministry of Education and Research (BMBF, Bundesministerium für Bildung und Forschung) is the main governmental institution for funding of R&D. In 2006, the BMBF announced the supportive measure “BioIndustry 2021 – Development of new products and processes in IB” aimed to awaken the interest of German enterprises and researchers in IB. This competition was supposed to selectively support strategic clusters or networks of industry and academy. Twenty-one consortia applied for a grant and the following five won a


prize money for a five years-funding of R&D projects starting in 2007/2008 (Figure 1):

- Biocatalysis2021 in Hamburg
- Biopolymers/Biomaterials in Stuttgart
- CIB Frankfurt
- CLIB2021 in Düsseldorf
- Cluster Industrial Processes with Biogenic Building Blocks and Performance Proteins (IBP) in Munich (now IBB Netzwerk GmbH)

Concerning the Bavarian cluster, by that time called “Cluster IBP”, it was reasoned by the Free State of Bavaria and the Bavarian chemical industry to create a dedicated management organization for IB as distinct company. This was considered necessary due to novel and specific duties coming up as well as a symbolic act of the recognition of the relevance and weight of IB. Accordingly, the Bavarian State Ministry for Economic Affairs and Media, Energy and Technology (BayStMWi) as well as several companies, among them the globally active specialty chemical companies Clariant AG and Wacker Chemie AG supported the establishment of such a company. As a result, the “IBB Netzwerk GmbH” was founded. Thus, the IBB Netzwerk GmbH is the product of a successful and strong public-private partnership initiated on 4 June 2008.

ASSIGNMENTS, MODE OF OPERATION

IBB Netzwerk GmbH’s objective is the transformation of valuable scientific knowledge and inventions to innovative marketable products and processes, i.e. the mediation and facilitation of the technology transfer in the area of IB.

Prerequisite: Building, Fostering and Expansion of the Network

The first requirement for technology transfer is to bring together the two ends between which the transfer takes place, i.e. scientists and businessmen. This process leads to formation of a target orientated network, at present consisting of nearly 100 members. We further expand and strengthen our network, seeking even more expertise and original ideas. The members are recruited by different ways and can see and get to know each other e.g. in frequent meetings, expert conferences and other events we organize for our network (or selected sub-groups), where the “technology push” encounters the “market pull” to inseminate each other. Accordingly, within this network, we bundle the competences and the potentials of industry and academia to realize technology transfer nation- and Europe-wide. Membership in the Network IBB is free of charge.

The Power of Intuition

Although the results of technology transfer may seem self-evident in hindsight, they do not materialize instantaneously or automatically. The lapse from an idea, even from a (patented) invention, to innovation, i.e. successful market introduction of a consumer good (or process) may be cumbersome. An extreme example is the steam engine. The power of steam to move devices was actually known and applied (as a toy turbine, called aeolipile) already by the Greek mathematician and engineer Heron of Alexandria in the 1st century AD. However, mankind had to wait for about seventeen centuries until this invention was deployed in industrial applications. The commodity “wheeled suitcase” is an even more incredible example: Although the wheel was invented six thousand years ago, suitcases only carry casters since perhaps twenty-five years. And nobody would argue that there has been no unmet need in the market the years earlier. Therefore, beside systematic, rigorous and diligent screening and scanning (academic) ideas as well as looking at the market needs and doing match-making of our members, we also train our imagination to run wild though creatively. This is a great deal of the added value we provide to the members of the Network IBB, and this is why most of the approached persons enter and stay in the network.

Core Technology Transfer Tools

Coordinated and orchestrated technology transfer can be realized utilizing the following tools:

**R&D projects:** The apparently most straightforward way to transfer technology is to draft and execute an R&D project. Starting from an idea that may lead to a new innovation in IB or bioeconomy, IBB Netzwerk GmbH teams suitable partners, usually from both industry and academy. Then, IBB Netzwerk GmbH organizes meetings, in which, together with all partners, a project with defined goal, time frame and costs is drafted. In September 2013, five years after foundation, almost 400 such meetings and negotiations have been recorded by the IBB Netzwerk GmbH. The outcomes of these meetings will be described in combination with the network chapter below.
If the R&D project is linked with technical and/or commercial risks or if the targeted products have no existing market, public grant support is sought. The IBB Netzwerk GmbH daily screens incoming information and is, thus, up-dated concerning national and European funding programs and measures with relevance for IB and bioeconomy. They are stored systematically in an own data base and are freely accessible for members of the association (see section Shareholder: The “Förderverein Industrielle Biotechnologie Bayern e.V.”). As a matter of fact, IBB Netzwerk GmbH is actively involved in the coordination and the preparing of grant proposals of its network members.

**Plant facilities:** R&D projects may pave the way but are not sufficient for the success of IB. For many products of IB/ bioeconomy, especially bulk chemicals, market entry is feasible only after the demonstration of the cost-efficient fabrication in industrial scale, i.e. several thousand tons or more. This means that, after completion of an R&D project aiming at a new product, the large scale production of the latter in a costly (pilot) plant facility is the next compulsory step. Understandably, only big industry or a strong SME can tackle and lead this endeavor. The arrangement of such big projects may also be included in the scope of IBB Netzwerk GmbH’s tasks.

**Company settlement:** The easiest way for technology transfer is to attract a company with an interesting product or process from abroad to settle down in the own region. In consequence, the value creation must occur in the new location. IBB Netzwerk GmbH has had some success in this instance.

**Start-ups and spin-offs:** The most laborious process for technology transfer is the foundation of a new company, a start-up ("spin-off" out of an academic institution), based on a (ideally: proprietary) business idea. Perhaps the main reason is that typically equity is needed (debt capital is usually out of reach due to absence of securities), and this means that a venture capital (VC) partner and/or a “business angel” must be convinced of the company’s commercial potential. Equity is lost, if the start-up fails. In fact, technology transfer via start-ups and spin-offs has been and still is a “sore spot” in Germany, inter alia due to a culture that does not accept risks as opportunities. According to a study published in 2007, in six leading European countries 5.1% of the patents gave rise to a new company. This share was larger in the UK (9.7%) and Spain (9.3%). It was smaller in Germany (2.7%) and France (1.6%). In Chemicals and Pharmaceuticals only 3.1% of the patents are used to create a new firm [19]. Today, concerning all biotechnologies this situation stays the same or similar [16].

Accordingly, and in spite of existing pre-seed and early stage federal supporting instruments (e.g. GO-Bio, Exist-Forschungstransfer, HTGF\textsuperscript{10}) as well as despite intensive scouting and efforts, start-ups and spin-offs of IB are a long time coming. To our knowledge, other “BioIndustry 2021” clusters suffer the same setback. We can spot several reasons, general ones as well as specific for IB:

- Still unfavorable political frame conditions (e.g. taxation), especially for young, innovative companies and for VCs as compared to other countries [20].
- IBB Netzwerk GmbH has not got an own seed fund to be able to support promising start-ups at its own judgment.
- Most SMEs in IB tend to become service provider (e.g. enzyme producers) due to the very high costs, if industrial manufacturing of a bulk chemical is sighted. Others target the optimization of a process. Yet service providers and process developers are in general not attractive business cases for VCs who, for example, pin their hopes on the later selling of a blockbuster.
- By and large, the German chemical industry is itself innovative. IB projects are often internally pursued. Thus, aspiring founders may imagine altogether a better life as employees in the industry than as entrepreneurs. This leads directly to the last entry.
- The “German attitude” at present: After the turbulences of the 20th century, German society sought (and largely found) the political “middle”, in which privacy, wealth, peace and freedom prevail. At the same time, however, in this middle the “statistical normal” is raised to a “good standard” to go for. Nowadays, almost everybody strives to reach this standard [21]. Therefore, people who do not quail in front of the entrepreneurial risk, not only are rare in the “middle”, they are also despised when they fail. Yet the aspired “normality” is delusive and in fact jeopardized by the steady threat of economic ruin. Therefore, we consider it essential to continue and boost every effort to promote innovative actions, also and in particular by the tool of foundation of companies.

**Supporting Measures for Implementation of Technology Transfer**

Beside the core activities for technology transfer, IBB Netzwerk GmbH does a lot of accompanying work to enable the success of IB. The activities not only serve the purpose to abolish or alleviate hurdles of market entry of products or procedures of IB but also to inform and sensitize as much as possible industry branches about their economic and sustainability opportunities within the growing family of enterprises applying IB.

**Information gathering, processing and dissemination:** IBB Netzwerk GmbH filters and processes incoming information for the network, the public, stakeholders and political decision makers. This information includes permanent documents, news from business areas and society, from science, research and education, and relevant political measures as well as announcements of events. Media of dissemination of such information comprise a monthly electronic

\textsuperscript{10} GO-Bio (www.bmbf.de/go-bio.php) and “Exist-Forschungstransfer” (www.exist.de/exist-forschungstransfer) are funding measures of the German government to encourage and support the foundation of spin-offs in Life-Science and other technical areas. Successful applicants receive, after a highly-demanding selection procedure and between three to seven years, ample financial resources from the ministries BMBF or BMWI, accordingly, with the aim to develop their business ideas to a stage, at which they may become mature and attractive for equity financing. During this period, the prospective company team may stay at the academic institution and use the existing infrastructure. So far, out of 46 funded GO-Bio projects 22 spin-offs came out. Since 2005, “HTGF” (www.hightech-gruenderfonds.de) provides VC for young technology enterprises and supports the management team by a strong network and entrepreneurial know-how.

Within the first six years, HTGF financed successfully and got off the ground about 250 high-tech companies.
PR, organization of events: IBB Netzwerk GmbH organizes expert or public events (i.e. meetings, workshops, lectures, booths in fairs and specific press conferences) single handedly or in collaboration with other partners. The goal is to demonstrate the relevance of IB and to raise its visibility and acceptance. Furthermore, we also increase the awareness level for our network members and their companies by either presenting their achievements on our website, in articles we write or in talks we give, or by placing them in conferences as speakers. Within five years, IBB Netzwerk GmbH has organized, arranged or prepared 120 events, contributions in media or press releases. The result is that the Network IBB is known and acknowledged way beyond the borders of Bavaria.

Promotion of the dialogue enterprises-politics: IB is an innovative and „disruptive“ technology. Therefore, in order to prosper, it is indispensable that the appropriate political conditions and regulatory framework be set\(^{11}\). For that, IBB Netzwerk GmbH arranges opportunities for dialogue of industry and politicians, either by organizing parliamentary evenings, workshops or other specific meeting occasions on national or European level. In five years, this exchange has been supported by more than 80 recorded meetings and discussion forums.

Educational measures: The early contact with, and engagement of scholars and students in IB is imperative, if it is to be sustained and carried further. However, operation possibilities of IBB Netzwerk GmbH on that level, e.g. co-design of academic curricula, are limited. Nevertheless, through seminars, other related events, as well as by instigating ideas and initiatives, we attempt to acquaint and familiarize this circle of persons with this fascinating field.

COMMISSIONING IBB NETZWERK GMBH

IBB Netzwerk GmbH’s service palette\(^{12}\) can be hired. IBB Netzwerk GmbH supports the implementation of every sort of innovative idea on the area of IB by experience, networking, expertise and professional competence. Upon request, IBB Netzwerk GmbH elaborates a working concept together with the client and offers a deal. Orders are always carried out in close collaboration with the client.

SHAREHOLDER: THE “FÖRDERVEREIN INDUSTRIELLE BIOTECHNOLOGIE BAYERN E.V.”

The sole shareholder of IBB Netzwerk GmbH is the Förderverein Industrielle Biotechnologie Bayern e.V.\(^{13}\). Its members include industry as well as academic institutions. Besides instructing and steering the operative work and assignments of IBB Netzwerk GmbH, members of the Association enjoy special benefits, like discount on all events organized by IBB Netzwerk GmbH and free access to the list of funding measures and other useful functionalities of our website. Every legal or natural person who is or plans to be active in the field of IB can become member of the Association. The annual membership fees differ between companies, universities and institutes and are graded according to company size and annual turn-over.

C. NETWORK IBB: A SUCCESS STORY

Members

Growth over time: By the course of actions described above, the Network IBB grew over time to almost 100 members to date\(^{14}\) (Figure 2).

The Network includes large industry, SMEs, universities, research institutions and others. It is noticeable, that the number of the enterprises (large industry and SMEs) more than tripled over 5.5 years, and that the number of SMEs therein quintupled.

Groups of enterprises: Under the umbrella of the Network IBB, there exist several sectors of industry members with the corresponding expertise (Figure 3).

SUB-NETWORKS AND SPECIALIZED ACTIVITIES

IBB Netzwerk GmbH initiated or played a major role in the formation of a number of R&D project consortia with specialized content and specific objective (cf. above). Thus, the Network IBB now represents a kind of superstructure, composed of partners who are working on one or several projects in the field of IB/bioeconomy, or have the intention to do so. From about five partners upwards involved in a project, especially if there is a common thematic focus manifesting in several related but separate projects, we speak of “sub-networks”, which are managed and/or administrated by IBB Netzwerk GmbH. Here, we summarize some examples of sub-networks and of other activities to illustrate our and the network’s accomplishments and performance.

Finalized: Cluster “Industrial Processes with Biogenic Building Blocks and Performance Proteins” (IBP)

As explicated above, the present Network IBB based originally on the cluster competition “BioIndustry 2021” of BMBF. At that time, the Bavarian network, one of the five winners of this competition, bore the name “Cluster IBP – Industrial processes with biogenic Building Blocks and Performance Proteins”. The current Managing Director of IBB Netzwerk GmbH, Prof. Haralabos Zorbas, had initiated and coordinated the Cluster IBP in his former function as project leader of the Bavarian Biotechnology Cluster.

Under the coordination of the IBB Netzwerk GmbH, a total of nine R&D projects were approved and funded within “BioIndustry 2021” by public money of the BMBF and the BayStMWi. The total project volume was 21.2 million Euros, with a total funding rate of 48 %.

\(^{11}\) Interested readers may have a look on http://www.ibbnetzwerk-gmbh.com/en/ibb-netzwerk-gmbh/dienstleistung-sangebot/


\(^{14}\) We prefer the designation „network“ rather than „cluster“ to indicate that, although Bavaria-based, the members and partners are spread all over Germany as well as over neighboring countries, like Austria, Belgium, France, Switzerland and the Netherlands. The common thematic focus and broad expertise weighs more than the localized concentration.
From today’s perspective the “Cluster IBP” was the first sub-network in the current Network IBB.

“Advanced Biomass Value“ (ABV): Sustainable Production by Energetic and Material Use of Algae Biomass

The focus of the academic and industrial consortium “ABV” is the complete valorization of algae biomass components in a waste free and energy efficient integrated biorefinery concept. Algae biomass represents a new, “third generation” biogenic feedstock, with hallmarks such as high biomass yields, low lignin content, and improved land use efficiency. Hence this biomass feedstock does not compete with food and feed production or agricultural activities in general. The absence of lignin allows simplified biomass processing and seamless integration of all biomass components in a value adding biorefinery concept for production of aviation fuels, high performance lubricants and new, CO₂-adsorbing building materials, which ultimately improve the CO₂-footprint of the entire process chain. The aim of the nine project partners under the leadership of the Department of Industrial Biocatalysis at the Technical University of Munich (TUM) is the energy-efficient production of algae biomass, its subsequent components fractionation and processing to a complementary product portfolio. Primarily, algae lipids are converted into high-performance lubricants. Then, the remaining algae biomass is further processed to bio-kerosene via a fermentative procedure employing oleaginous microbial biocatalysts. The side products accumulated in the chemical biomass conversion to renewable aviation fuels is utilized in the production of CO₂-adsorbing building materials. As a result, all resources are converted to value adding products in non-competing, synergistic commercialization strategy. ABV is funded with 4 million Euros by the BMBF and runs until 2016.

IBB Netzwerk GmbH supported the project consortium in identifying partners and in the submission of the grant application. During the project phase, the company is responsible for the acquisition of new partners and the external representation.

Strategic Alliance “Technofunctional Proteins” (TeFuProt)

The strategic alliance TeFuProt is one of hitherto five successful applicant consortia to the supportive measure “Innovationsinitiative Industrielle Biotechnologie” of the BMBF. In May 2013, the alliance was officially presented by the State Secretary Dr. Georg Schütte. 14 project partners plan to work together to gain protein isolates and modificates from agricultural plant residues. Then, the proteinaceous material shall be optimized in such a way, that it can be used as base or additive for paints, cleansing agents, building materials, lubricants, plastics etc. The partners want to launch protein derivatives on the market with properties that cannot be achieved so far by conventional materials.

The industrial partners cover the entire value chain for optimized protein products: from the supply of raw materials over purification and modification up to the technical use in numerous industrial applications. The activities of the companies are supported by research institutes.

IBB Netzwerk GmbH supported the partners in planning and structuring the alliance and the proposal and will take over the administrative project management on sub-contractual basis. In addition, IBB Netzwerk GmbH is the designated contractor for implementation-enhancing measures. After the final revision of the application and last arrangements, the alliance is expected to start this year.

ZIM Cooperation Network “BioPlastics”

At the beginning of 2014, the Federal Ministry of Economic Affairs and Energy (BMWi) approved the cooperation network “BioPlastics”. The interdisciplinary cooperation network wants to significantly increase the market share of bio-based polymers. At present, the focus of the 20 partners lies on technical projects for the development of innovative and low-priced biopolymers. These shall be used in bulk production of goods such as packaging material.

IBB Netzwerk GmbH was commissioned by the participating partners for the network management. This includes expansion of the network, promotion of the network interactions and
designing R&D projects. In addition, the IBB Netzwerk GmbH will inform the public and develop concepts to facilitate market entry. For this, the company receives a total of 150,000 Euros from BMWi and the network partners, initially for one year. After a successful first year, further funding over two to three years is possible. Funding is provided within the program “Central Innovation Program SME” (Zentrales Innovationsprogramm Mittelstand - ZIM).

The biopolymer base elaborated in the upcoming R&D projects must have the same or even better properties than conventional petrochemical plastics. In addition, the production of biopolymers and the materials themselves have to fulfill strict sustainability criteria. Thus, by this activity IBB Netzwerk GmbH is working in a field with enormous environmental relevance, since products made from petrochemical plastic are hardly degradable and pollute the environment.

**Upcoming Projects**

Besides the ongoing projects, there are also some more ideas in our network’s pipeline. E.g., based on the findings of a feasibility study about converting agricultural residues into platform chemicals (like n-butanol) and bioenergy, a new large R&D project is planned. In addition, within the sub-network BioPlastics, R&D projects on several areas like packaging articles, glues, fibers etc. are being prepared. Furthermore, the sunliquid® demonstration plant of Clarient for converting agricultural residues into climate-friendly cellulosic ethanol in Straubing, Bavaria, with an annual capacity of up to 1,000 tons of advanced biofuel, confirmed the maturity of this new and innovative technology and shows that it is, in a next step, ready for commercial deployment.

**Specialized Activity: Participation in the “Initiative on Sustainable Provision of Raw Materials for the Material Use of Biomass” (INRO)**

Another activity of IBB Netzwerk GmbH is the contribution to INRO\(^{15}\), a network for voluntary sustainability certification of material use of biomass by the industry, supported by the Federal Ministry of Food and Agriculture (BMEL) of Germany since 2011. The objective of INRO is reaching a voluntary certification agreement with companies, which are using renewable raw materials in their production process. This certification should include the dealing with biomass from the cultivation through to the primary processing. This means that the current amount of almost 3 million tons of agricultural raw materials, which the German industry processes into products at present, should be certified by INRO soon.

Until now, a catalogue of sustainability measures has been established, covering social, economic and environmental criteria, e.g. no forced/child labor, anti-corruption measures or protection of wetlands.

**Specialized Activity: Efforts in the Educational Sector**

Until now, several goals in research and education were realized. For example, a new master’s program in IB at the Munich School of Engineering of the TUM was established [22]. This program was launched in the 2010/2011 winter semester. Additionally, a Research Center for IB with a screening laboratory and a pilot station with a fermentation module of up to 1,000 liters were brought on stream [23]. IBB Netzwerk GmbH helped finding the financing of the latter.

**MOBILIZED CAPITAL**

By the end of 2013, the Network IBB has mobilized more than 100 million euros for R&D projects, plant facilities and structural measures in the field of IB (Figure 4):

- The total volume of 17 R&D projects of the Network IBB was about 47 million euros.
- 43.5 million Euros flew into the (re)construction of three different industrial plants (incl. accompanying research) and one plant of the TUM.
- 10 million Euros have been spent for technical-structural measures, such as the master’s program “Industrial Biotechnology” at the TUM or the ZIM cooperation network “BioPlastics”.

For these achievements, partners from different industries such as biochemistry, microbiology, chemistry, biochemical engineering and process engineering, mechanical engineering and plant construction worked and are still working together. Of the mobilized money, 53% were private equity and 47% were public funds from the BMBF, from the BMWi and the BayStMWi as well as from the BayStMELF for a feasibility study. As mentioned, further projects are already in the pipeline.

**D.CLUSTERS AND NETWORKS**

After this excursion in the activities of our company and our network, let us have a view on an aspect of the economic policy:

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15 Cf.: http://www.inro-biomasse.de/
The public support of clusters and networks.

Why Innovation Clusters/Networks?

Germany needs inventions and developments which must be successfully converted into marketable products and services to secure its present and future economic power and wealth. Only when new developments from research are taken up by the industry and find their way into the market, jobs and growth are created. However, much technology is tacit knowledge and cannot be easily transferred. Innovation cannot be purchased. That is where clusters or networks come into play: They are not an end in itself, but their purpose is to enable and make technology transfer verifiably more efficient.

The importance of “networks of innovators” for conducting product and process development was early recognized and questions on how network content, governance, and social structure emerge over time within the field of entrepreneurship were studied systematically several years ago [24,25]. Within networks, there are some undoubted advantages, which promote the above goal of technology transfer [26]:

- Rapid flow of information, fast access to new technologies.
- Access to external knowledge is less expensive than buying the expertise, e.g. via merger.
- Access to market- and industry-related trends.
- A particular opportunity for companies in clusters is that they can focus on their own strengths (specialization) and can additionally expand their limited resources by the integration into an overall system. That is, they may overcome insufficiency of resources and financing: one firm is dependent on the resources of another, and it is to both’s benefit to pool resources.
- Consolidation of existing and initiating new contacts with partners along a value chain.
- Increase in flexibility, fast reaction times. Networks are more “twinkle-toed” than large organizations.
- Rise in output (innovation capability, production).
- Improved image and reputation of the members’ own institution and products.

These features eventually lead to decrease “time to market” and increase of market power and competitiveness. Surely, in order to enjoy these benefits, threads that lurk must be surmounted. These threads include “lock-in” effects, separation, hidden agendas, mistrust, internal rivalry, inequity, opportunism; they all lead to instability and incoherence. Therefore, cluster managing organizations must evolve rules and confidence-building measures, but also dodges, to anticipate and appease such developments.

Conclusively, clusters are an important tool for the development of specific technologies and hence for modern economic development. They offer special services to support technology transfer and are a major link between academia, industry and politics. Companies and research institutions can easily tap the knowledge bundled in these clusters. However, whether a cluster strategy has been successful, only the cluster members can manifest at the end.

Cluster Policy in Germany

The connection of science and industry in research and development is part of the traditional strength of the German innovation system. But the federal government wanted to combine the already existing strengths in science and industry to accelerate the way from an idea to marketable products and services. In 1996, the federal government of Germany announced, that in order to better use the existing excellent research potential in Germany, an early coupling of science and industry is essential. From then on, the promotion of co-operative networks in order to improve an innovation-friendly environment should play a key role in research policy [27]. Accordingly, in Germany cluster policy measures exist on Laender and on federal level for almost 20 years now and have worked as pioneer actions of cluster promotion in Europe (Figure 5).

The involvement of SMEs is clearly in focus of this High-Tech Strategy. And all programs have in common a focus on the development of clusters/networks. These are industrially driven consortia of companies and research institutions, centrally managed by a cluster organization [29]. Their aim is to reinforce cooperation between science and industry. The resulting strengthened knowledge transfer between science and industry on the one hand leads to a significant commercial success of innovations and on the other hand to a greater scientific knowledge. This creates an added value for both sides [30].

The initiative “Biodustry 2021” of BMBF16 in 2006 has been the first cluster policy measure directly devoted to the IB in Germany. Within “Biodustry 2021”, about 60 million Euros public money was invested to let work together enterprises and institutions with expertise in disciplines like

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life sciences, chemistry, physics, informatics and engineering in interdisciplinary R&D projects [31]. With slightly different foci, the five established “policy-driven” winner clusters [32] have been working together for the overall aim: support of IB. Indeed, “BioIndustry 2021” contributed to bring ideas and research results in the field of IB to the market. Since that time, further supporting measures have also been released, particularly the “Innovationsinitiative Industrielle Biotechnologie” addressing bioeconomy in general.

You may find a selection of examples of national and international political measures and initiatives that directly or indirectly support IB on http://www.ibbnetzwerk-gmbh.com/en/industrielle-biotechnologie/industrielle-biotechnologie-und-politik/.

**Financing of Cluster Management Organizations**

A cluster organization performs the cluster management. Its central role is the coordination and administration of the cluster as well as providing goods and services. At the beginning of a clusters’ life, the cluster organization is usually financed largely by public money, because cluster members will not pay upfront. However, it is supposed to become gradually independent thereof in the midterm (to become a “private club” financed by the enterprise members themselves), or to close down upon completion of the clusters’ goal.

In an empiric study [33], a team led by Carola Jungwirth at the University Passau, analyzed, as an example, the temporary publicly funded Bavarian “Cluster Offensive”, which is expected to finance itself privately within a certain time-frame. Based on in-depth interviews with the cluster managers of the Bavarian Cluster Offensive, the authors found there is interference between the implementation of public and private goals, i.e. either to promote private enterprises and networks or to perform public duties such as infrastructure development. Hence, the planned transformation from a publicly subsidized cluster initiative into a privately financed one is difficult to succeed under the prevalent circumstances. As long as a cluster management organization is expected to perform public duties, it should still be publicly funded.

In a workshop of the cluster management organizations of “BiIndustry 2021” on 15 September 2010 in Frankfurt, Gerrit Stratmann presented the supposed life cycle of a network [34] (Figure 6). In an optimistic view, public funding of a management organization should markedly decline after about four to five years. From experience, however, one can say that the trajectory will rather follow the course of the red dashed line, i.e. public funding persists a lot longer than five years. Besides, from the age of about 5 to 8 years of the initiative, it seems public funding of approx. 30-50 % is justified and necessary to stabilize a cluster initiative as an innovation-political partner and to compensate for the provision of public goods.
In fact, after five and a half years, IBB Netzwerk GmbH was able to substantially reduce its initial rate of public support, with more anticipated decrease in the next years. According to the remarks above, it seems we are on the right way.

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