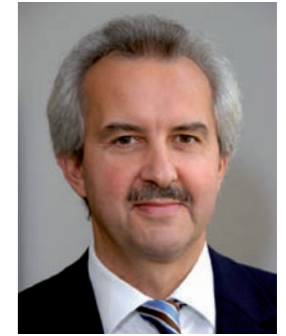


**Combine disciplines, improve parameters,  
seek out international partnerships**

First recommendations for research into the bio-economy in Germany

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## Foreword

With the establishment of the Bio-economy Research and Technology Council, which has its headquarters at acatech – the German Academy of Science and Engineering – the BMBF (German Ministry of Education and Research) in conjunction with the BMELV (German Ministry of Food, Agriculture and Consumer Protection) has broken new ground in policy advice. For the first time a scientific council has been established by a national academy for an innovative field: the bio-economy. This means that the Council does not only benefit from the greatest possible expertise, but also enjoys the greatest possible independence in the production of its findings. The Bio-economy Council is conscious of the particular importance of the tasks it faces. Tasks which stand at the top of the political agenda are helping to safeguard global nutrition and energy provision, and assisting adaptation to the regionally specific effects of climate change. Knowledge and technological development are absolutely vital to solve these problems. In addition, the bio-economy has great social significance. In Germany, Europe and across the globe the bio-economy offers economic possibilities which, particularly in these times of stagnation and the accompanying labour market problems, are of special relevance. In these circumstances, the Bio-Economy Council decided, six months after it was founded in January 2009, to deliver its first recommendations, in order to highlight ways to exploit these possibilities. The recommendations outlined here should provide a framework for possible political but also economic decisions, as well as for the necessary processes of social acceptance. This will also entail specialist academic debate of the bio-economy as a subject area in so-called round-table talks on green gene technology or similar communication factors.



(Prof. Dr Reinhard F. Hüttl, Chairman of the Bio-economy Council)

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## Summary

The need for climate protection, the increasing purchasing power and demand for foodstuffs in emerging nations with growing populations, as well as rising crude oil prices have meant that agricultural raw materials are now more in the spotlight, both economically and with regard to sustainable production. New markets for biologically based products have also developed. At the same time, progress in biotechnology and gene technology have opened up completely new possibilities in the food and feed sectors, which may provide clear answers to the social, economic, cultural and climatic changes we are currently facing. In the future, foodstuffs with a proven potential for disease prevention will, for example, be a key component of healthcare, and thus also represent a significant factor of the economy and growth.

Given the global challenges in food production and water and energy provision, these are extremely strong reasons why the political, scientific and business communities must engage immediately with the bio-economy.

With its many different branches the knowledge-based bio-economy already represents a prominent economic sector in Germany and the European Union, which in the future will also gain in importance globally. Currently in Europe it produces an annual turnover of around 1.7 trillion Euro and employs 22 million people. In Germany the figures are two million people producing an annual 300 billion Euro. In scarcely any other branch of research and technology is economic prosperity linked to the goal of ecological compatibility. For this reason the bio-economy is more than 'just' a growth sector. It is a new and highly integrative concept uniting science, business and society in a dialogue about sustainability and global issues of the future.

With this in mind, the Bio-economy Council is presenting here its first recommendations for strengthening the bio-economy in Germany. They focus on the creation of better structures for research and technological development, and the introduction of products and processes to the market. Correspondingly, this paper will address the legal parameters in the sphere of green gene technology, as well as the securing of strategically important international partnerships and student development. It will also suggest a better social dialogue on opportunities and risks.

**The Council makes the following particular recommendations:**

- 1 Establishing of high-level research structures in the field of the bioeconomy.**
- 2 Creating of reliable parameters and the elimination of legal uncertainties, for example in the field of green gene technology.**
- 3 Increasing research funding even in times of economic crisis, as well as creating incentives to attract more private investment.**
- 4 Ensuring that knowledge transfer takes place on both a national and international level.**
- 5 Improving student education and development.**

## 1. Note

The scientific and economic sectors that fall under the concept of the bio-economy – also termed the knowledge-based bio-economy – are some of those with the strongest growth not only in Germany, but in Europe and across the globe.<sup>1</sup> They reconcile economic prosperity with the goal of ecological harmony as scarcely any other branch of research and technology can. For this reason the Bio-Economy Council has set itself the tasks of raising the public profile of the potential of the bio-economy, optimising the parameters of research policy vis-à-vis the bio-economy, as well as improving the cross-linking between science, business, politics and society in order to attain an efficient knowledge and technology transfer on the basis of a broad acceptance of the bio-economy. The Bio-economy Council's recommendations set out here to create better structures for research, technological development and the introduction of products and processes into the market are the first steps in this direction.

<sup>1</sup> With regard to the definition of the term 'bio-economy', the Bio-economy Council has followed that of the European Commission. According to this the concept of the bio-economy includes all industrial and economic sectors and their associated services which produce, process or in any way use biological resources (plants, animals, micro-organisms). These sectors include: agriculture and forestry, the food industry, fisheries, aquacultures, parts of the chemical, pharmaceutical, cosmetic, paper and textile industries, as well as the energy industry. In English these sectors are commonly referred to as the 'four Fs': Food, Feed, Fibre and Fuel, although the use of materials is much more than 'fibre'. The Cologne Paper produced in 2007 under the German EU Council presidency, 'En-route to the knowledge-based bio-economy' defines the bio-economy as the application of knowledge in the life sciences to new, sustainable, environmentally friendly and competitive products. The paper also emphasises another important aspect: the concept of the bio-economy does not only involve the supply side in the sense of what is scientifically and technologically possible, but also has an eye to the demand side, which at the 2007 climate research summit the German government emphasised was essential for attaining climate protection goals on a global level. Another important publication on this subject is the OECD study 'The Bioeconomy to 2030: Designing a Policy Agenda'. The EU Commission has also underlined the significance of the life sciences because the findings in this field will form the basis for all further steps taken in the bio-economy and thus for their implementation.

## 2. Global challenges – and the situation in Germany

All the major challenges of our time have a global dimension and cannot be solved by sectoral approaches alone. Population growth, climate change, water shortages, urbanisation, starvation, global health issues, as well as poverty, the unequal distribution of resources and other challenges can only be tackled by a joint effort from the community of nations with the aim of a long-term global perspective and effective regional implementation. Besides technological innovations, solving global problems requires innovation within institutions and within the existing political and economic parameters.

The current economic crisis highlights that we live today in a 'Global Community' which has direct effects on regional and local structures in our part of the world, too. Rural communities ceased a long time ago to be self-contained entities functioning independently of global processes; they are affected by developments at a wider geographical level. The shortage of natural resources is, therefore, a challenge not only to international but regional and local policy. In the field of biomass production for energy and material use, for example, an overlap between global trends and the development of rural areas has been visible for years.

Even if biomass can only provide a portion of our energy provision in the future, its use represents an important step along the path towards an age of energy post fossil fuels. Especially for agricultural production in the rural areas of eastern Germany this has opened up a new economic perspective.<sup>2</sup> Although these areas are frequently affected by economic stagnation, the demand for natural resources has led to an improvement in the economic situation.

Besides other benefits, the increasing importance of biofuels has helped create greater value in the agricultural sector, and led to rising prices for land and agricultural raw materials.<sup>3</sup> Areas of innovation to ensure that land use is oriented towards the future include the optimisation of existing and new farming systems (e.g. agroforestry systems) and the cultivation of plants with new characteristics (ingredients, better use of water, nutrients and CO<sub>2</sub>). Optimising the use of biomass, for example maximising the energy and material value that can be derived from it, or sustainable livestock husbandry in a way that is in harmony with local conditions, are other features of a sector which is increasingly attracting attention, economically as well. Today, the production of biomass for energy already has the largest share of the renewable energies industry in Germany, employing 100,000 people.

<sup>2</sup> Research and enterprise in the bio-economy can be seen as an important example of development in the new German Länder, also with regard to the fading away of the solidarity tax. Five out of 11 projects which were supported by the BMBF as part of the second tender for the programme 'Top-level research and innovation in the new German Länder' have links to the bio-economy (INFLUINS, ProNet-T3, Dt. Energie-Rohstoffzentrum Freiberg, Light2Hydrogen, PROGRESS).

<sup>3</sup> The total area of farmland dedicated to renewable raw materials has risen from around 300,000 ha in 1990 to more than 2 million ha today (total area under cultivation in Germany: 11.8m ha).

Throughout Europe the entire bio-economy currently employs 22 million people and produces an annual turnover of 1.7 trillion Euro.<sup>4</sup> It thus represents one of the largest economic sectors of the EU. The 2007/2008 corresponding estimates for Germany were an annual turnover of 300 billion Euro and around 2 million people employed.<sup>5</sup> This means that the bio-economy has considerable scope for development, but also there is a need to improve the general parameters:

- An increase in research and technological development will lead to a further rise in growth rates and thus employment. This may make a significant contribution to attaining the Lisbon goal of investing three per cent of the Gross National Product in research and development by 2010.
- The intensification of research and technological development in the bio-economy can help master the global challenges of food, feed, water and energy provision on the principle of sustainability. The material use of biomass also needs consideration here.

Beyond the national strategy of biomass use, Germany, as one of the leading players in the field of renewable energies, has the opportunity to develop innovative technologies and, via export, particularly to emerging nations, to combine economic and ecological benefits. It is several years ago now that the European Union decided to increase the proportion of energy from renewable sources to 20 per cent by 2020.

In the meantime the new US government has also announced it is prepared to invest 150 billion dollars in environmentally friendly technologies by 2019. It is intent on raising the proportion of primary energy consumption from renewable sources to 10 per cent by 2012. In spite of all the intensive efforts towards using biomass for energy and materials, the main topic of the bio-economy remains the profitable, but resource and environmentally friendly, and (with regard to animal husbandry) humane production of food and feed by means of organic production. Foodstuffs with a proven potential to prevent diseases and illnesses will be an element of future healthcare, and thus also represent an important economic and growth factor. To avoid competition for farmland between different types of land use, the supply of biomass must be fundamentally increased. A large amount of research is needed to achieve this, as are new systems of farming.

Many organisations such as the Food and Agriculture Organization (FAO) have given their opinions on these subjects. In the run-up to the G8 meeting in Treviso, the Humboldt Forum for Food, Agriculture

<sup>4</sup> EU Commission, 2009.

<sup>5</sup> The importance of industrial biotechnology and agro-biotechnology, for example, as far as turnover and employment are concerned, is hard to identify. This problem is also true for other areas of the bio-economy. Statistics for biotechnology only show figures for dedicated biotechnology businesses. These are firms whose primary business objectives are the application of biotechnological processes to create products, to provide services, or to carry out biotechnological research and development. Industrial biotechnology and agro-biotechnology are dominated by large integrated companies, however. Source: Die Deutsche Biotechnologie, 2009.

and Nutrition also issued a statement from Berlin. Entitled 'Food First', it emphasised this particularly important side of the bio-economy. It predicts that, despite recent price decreases for foodstuffs, rising prices are to be expected in the medium and long term. This offers the great opportunity of a broad-based stimulation of agricultural and food activities in developing and emerging nations, in which a further worsening of food shortages would have particularly drastic effects.

The growth in biomass production is constrained by a limited availability of the geo-resources land and water, as well as the lack of plant varieties with a high efficiency in exploiting resources. In addition, it is expected that soils will continue to suffer increasing processes of degradation (including the effects of climate change). This means that existing land must be used as effectively as possible without neglecting the principle of sustainability.

To be in a position to best meet these challenges, science, agriculture, the food, chemical and energy industries, as well as politics on the one hand, and producers and consumers on the other, must in the future be as closely united as possible.

### 3. The bio-economy – a growth sector

The bio-economy thrives on the interplay between knowledge generation (invention) and the successful transfer to the market (innovation). Over the past few years the Excellence Initiative, cluster development and the Science–Business Innovation Alliance under aegis of the German Ministry of Education and Research (BMBF) have come up with the effective idea of linking pure research more closely with practice to create synergies. It is an idea which is particularly relevant to the bio-economy. A glance at the statistics shows that the research areas relating to the bio-economy are many and varied. Bio-economic research takes place in almost all of the scientific disciplines identified by the German Office for National Statistics. While the agricultural (agriculture, horticulture, veterinary medicine), forest and food sciences are wholly relevant to the bio-economy, within the natural sciences biology, physics and chemistry are also important. The humanities, as well as social and economic sciences meet the bio-economy with cross-cutting topics such as legal parameters, the question of behaviour, and the acceptance of new technologies and their socio-economic valuation. The role of engineering and the technological sciences is also key in the fields of nanotechnology and information technology. The knowledge-based bio-economy is thus a good example of the need for interdisciplinary and transdisciplinary research and for a better appreciation of hitherto under-represented areas of research by means of new challenges. An innovation and qualification offensive for the agricultural, forest and food sciences, as well as all other areas of the biomass economy is thus a key challenge. One consequence of this multi-disciplinary approach, however, is that it is almost impossible to organise clearly all the fields which belong to the bio-economy using existing methods of classification. Any audit, therefore, of research, funding volumes and turnover in this field gives only a pretty rough estimate. With the restructuring of departmental research within the Ministry of Food, Agriculture and Consumer Protection (BMELV), the government has already taken an important step towards streamlining the research structure in the bio-economy. Another indication of the importance of this subject is the adoption of plant research as a priority in the high-tech strategy, as well as the funding of networks of excellence in biotechnology, agricultural and nutrition research by the BMBF, for example Bio-industry 2021 and Bio-energy 2021. The BMBF's Foresight Process is also giving special priority to bio-economic topics such as bio-refineries, the efficiency of resource use, biological production platforms and the linking of technological research and socio-economic research topics.

### 4. Gaps in the current research landscape

A detailed examination of the research landscape and the funding of bio-economic topics shows that, similar to German energy research, where the responsibility for devising a provision strategy lies with several different federal ministries, in the bio-economy there is also a great need for a distinct identity and structural consistency. In addition there is the well-known federation–Länder problem. The fragmentation of research structures and topics in Germany, as well as the diversity of funding mechanisms and institutions, lead to a similar diversity in setting priorities. Frequently these are uncoordinated, giving rise to redundant work in research projects and an unnecessary diversification of activities.

A reason for this is the inherent classification within the research system by subjects rather than by the challenges outlined above. The field of bio-economics is highly complex, interdisciplinary and transdisciplinary, but also determined by the state of development of applied research. Given this situation the consequences of fragmentation are particularly serious, as it means that important efficiency potentials, synergies and the formation of critical masses are inevitably lost. Therefore an integrated, systematic approach, which includes the dismantling of old research structures to create new, efficient units, is essential to exploit the potential of the bio-economy. The importance of integrative bio-economic research and the need to establish new forms of coordination and research structures can also be seen in many current developments and projects. For example, in four of the networks of excellence in agricultural and food research approved by the BMBF, the expertise of partners from science and business has in each case been united in an interdisciplinary cluster and, by means of a close linking of research, theory and development, ought to lead more quickly to marketable products and processes. The selected projects contain innovative structures which can help develop the knowledge-based bio-economy. On the other hand, the overall findings of the tender process reveal much more widespread gaps in targeted research funding in the areas of agriculture, forestry and food sciences. There is also room for improvement in the overall coordination of biomass research in Germany. In a paper on the 'Coordination in the area of bio-energy/the bio-economy between the Helmholtz Community and the DBFZ with the participation of the BMELV, BMU (Ministry of the Environment) and BMBF' (February 2009), the authors criticised a lack of coordination within biomass research in Germany and called for this to be rectified. With the establishment of the German Biomass Research Centre (DBFZ) as well as other existing agricultural departmental research institutions such as the Julius Kühn Institute (JKI), the Johann Heinrich von Thünen Institute (vTI), the Helmholtz Association 'Sustainable Bio-economy', or the Fraunhofer seminar groups 'Industrial Biotechnology' and 'Food Chain Management', the first steps have been taken to initiate a national, inter-institutional coordination of research activity in the sphere of biomass. The focus of ministerial research is on the production side and that of the DBFZ on bio-energy technology. These institu-



tions are insufficiently integrated into the general research landscape for bio-economic research, however.

At the Jülich research centre a plan is currently being developed in conjunction with the university there for a so-called Bio-economy Science Centre, which by combining and integrating scientific expertise and technologies should make a substantial contribution to bio-economic research. First of all, they will bring together at a regional level the relevant research disciplines from local colleges and non-university institutions to create a scientific centre of expertise. This integrative concept should produce synergies capable of overcoming disciplinary obstacles and of giving rise to new knowledge and innovative solutions for the development of new products and technologies for a bio-economy.

Notwithstanding this, it is still necessary to develop further the bio-economy and the integrative and collaborative research to enable this, to intensify the exchange of information, and to improve partnerships and cross-linking between the existing initiatives, bodies and structures in science, business, politics and society at a broader level.

As part of the structural adaptation of the German research landscape, therefore, infrastructure centres with specific project topics should also be developed in which institutions can enter partnerships corresponding to allocation of tasks within the German research landscape. Examples of such groups or activities are a future energy council, the Bio-industry 2021 Cluster, the Fraunhofer Society's Bio-refinery Centre (Chemical–Biotechnological Process Development Centre/CBP Leuna), which is funded by the federal government and the Länder in central Germany, as well as current plans for the use of microalgae.

## 5. Five recommendations for the bio-economy in Germany

For overall coordination, Germany's science and technology needs a regionally anchored research structure, but one which also is active internationally, and in which non-university research institutions, universities, ministerial institutions and business collaborate closely. In the opinion of the Council, therefore, there is a fundamental need for structural change to make possible the interaction on a broad level of all areas pertaining to the bio-economy as if they were a single unit.

### **First recommendation: Understand that the bio-economy is a systemic field of research – establish overriding research structures**

The bio-economy encompasses a broad spectrum of topics which need to be considered as a whole, and require a close interlinking of all areas and actors. Intensive transfers between science, business, politics and society which break with conventional structures and the autonomy of individual academic disciplines, are absolutely crucial for the successful development of a knowledge-based bio-economy.

At present the research landscape in Germany, which is still mainly oriented towards individual academic disciplines, is insufficiently developed to achieve this. Therefore, either new agendas which transcend individual disciplines and institutions need to be developed, or existing efforts in this direction must be supported. A change in research structures in Germany towards national centres is also necessary along the lines of the cluster development that is already in motion.

The federal structure of the university system obstructs the formation of national centres of research and education. Better coordination between institutions funded by central government and those by the Länder is, therefore, a permanent challenge.

The Council also believes that there should be a greater pooling of research funding, so as to ensure that the funds are used more efficiently. Bio-economic research funding ought to come 'in a single chunk', so as to determine the priorities and distribution of monies for research as closely as possible along the lines of agreed performance criteria or benchmarks. The setting up of an inter-ministerial working group would be an important first step towards achieving this.

Finally, there are several possible models for a suitable pooling of research areas relevant to the bio-economy, from a partial to a complete consolidation of all areas (as with the EU Commission, for example).

### **Second recommendation: Create reliable political parameters – eliminate legal uncertainties, for example in the areas of green gene technology**

The current debate on green gene technology highlights the fact that a social outlook open to research and innovation as well as reliable legal parameters are necessary to increase Germany's chances in international competition with regard to these technologies – particularly given the very

high level of plant research in Germany. This does not only concern universities and research centres, but small, medium as well as large enterprises in the private sector, for whom investment decisions are substantially dependent on the corresponding legal regulations. Reliable legal regulations are essential to preserve the long-term survival of development processes in many areas of the bio-economy. Only a high level of social acceptance can create the right conditions for a bio-economic research landscape in Germany.

The Council therefore supports the establishment of legal certainty and reliable parameters from the research stage to licensing and marketing, including transparent consumer information, so as to enable the responsible development and application of new technologies. As in comparable areas of the life sciences or energy research, political decisions should be made on the basis of independent scientific evaluations and with a long-term perspective.

Green gene technology is only one example here. Others are tissue engineering, animal cloning, stem cell research, genome analysis, as well as the issue of humane animal husbandry and the establishment of sustainability criteria for the importing of biomass. On a more general level, an assessment should be made as to whether there ought not to be a study undertaken in Germany, along the lines of the European Commission's Lead Market Initiatives, to find out where there are institutional, legal and other obstacles impeding the advancement of the bio-economy, for bio-based products for example. Such a study should also make suggestions for overcoming these obstacles. To improve the level of dialogue, another of the Council's suggestions is that the topic of the bio-economy should be given consideration at so-called round tables on green gene technology or other communication factors, to ensure harmony on issues of acceptance with closely-related topics.

**Third recommendation: Increase research funding in times of crisis as well – offer incentives for more private investment**

The tax system for funding the bio-economy must become more innovation friendly, and be developed into a funding scheme open to all fields and in businesses of all sizes. In this respect, the Bio-economy Council welcomes the BMBF's eight-point plan of May 2009 for innovation and growth. The Council believes that the new coalition pact should adopt the basic measures necessary to increase innovation, and lower the tax and contributions burden.

Besides amendments to corporation tax and to the law on the modernisation of the parameters for capital investment in venture capital, a tax-based research and development funding scheme should be adopted. Freeing innovative startups from social security contributions – as encouraged by the Expert Commission for Research and Innovation – can help to accelerate the growth of new firms. A reliable legal framework is necessary for the survival not only of small and medium businesses. Just as important as strategies for implementing the bio-economy in the current economic climate by means of investment incentives (funding instruments oriented to small and medium businesses, flexi-

ble funding criteria), are the current legislative processes. Only these can create long-term planning security for investment decisions in the private sector.

Despite, and indeed because of the current difficult economic situation, public funding of the bio-economy as an important field of the future, should be gradually expanded. The reasoning behind this anti-cyclical research funding is the positive effects that targeted measures will have on sales and employment. In the current economic crisis important sectors of the bio-economy have already shown that they can act as a buffer, and in the long term create jobs that are safe from economic crisis. Developing those bio-economic research institutions that receive central government funding should also be looked at.

**Fourth recommendation: Ensure knowledge transfer at both a national and international level**

Many countries and regions of the world are actively working on the concept of the bio-economy. Globalisation has particular significance for bio-economic markets, production and research. The global distribution of biological resources, research activity and markets for the varied products, but ones that are closely linked in the networks of value chains, is a prominent feature of the bio-economy. The international division of labour in research, production and market access is fundamentally important in the bio-economy.

The global challenges we face today and the consequent development of a knowledge-based bio-economy, as well as the integrative research that accompanies this, urgently require the intensive exchange of information on an international level. In the long term, Germany also needs to create targeted funding instruments for joint research in international partnerships examining the bio-economy. There must, therefore, be a strengthening of cooperation and cross-linking between existing bio-economy-related bodies, structures and initiatives in science, business, politics and society, while a plan for strategic partnerships at international level must be developed. Cooperation should not only be intensified with the BRIC countries, but with selected African as well as other Asian and South American nations which play a key role in production and processing or which are a market for German goods.

In view of the finite nature of global resources, or of those that are dwindling ever more rapidly, many large countries have oriented their international trade strategically. Because of its dependence on raw materials, Germany has also sought closer contacts and cooperation beyond the borders of the European Union.<sup>6</sup> These partnerships are in Germany's interest and should be seen as investment in innovation.

<sup>6</sup> Germany is a net importer of foodstuffs and feed, which is why the amount of farmland that can be planted with energy crops is restricted. Moreover, biomass is the only regenerative source of carbon with a material use (e.g. in the chemical industry). Most importantly, however, unlike in tropical countries (large land reserves), the biotechnological transformation of biomass into ethanol cannot be carried out at present in a profitable way. This is another factor which calls for sober judgement vis-à-vis the cultivation of energy plants, despite the euphoria over growth.

Up till now, cooperation between Germany and the BRIC<sup>7</sup> countries, for example, has tended to be regional, institutional or project-related. In this respect the high level of confidence in the German research landscape is manifest. It is the Council's recommendation that this confidence should be developed towards international strategic partnerships on a national level. The coming legislative period should also see the institution of a series of workshops involving Germany and the BRIC countries, the results of which could form the basis for such agreements. Models of public-private partnerships should also be discussed.

European and global knowledge transfer must, therefore, be an integral part of international partnerships in which Germany is involved. Also of great importance are links with developing countries. Here the aim should be, by means of efficient development, to support mechanisms for overcoming key challenges such as sustainable economic development, climate protection and an improvement in nutrition through bio-economic processes and products. The incentive for cooperation with German partners should be increased by funding instruments which, at least for the entry phase into common projects, should also enable significant funding of partners in BRIC countries and others. The establishment of scientific centres by the German Foreign Office and the BMBF as part of the 'Foreign Science Policy Initiative' breaks new ground and must be developed further. In view of the high potential for innovation and the need for strategic partnerships it is recommended that certain scientific centres should be linked to centres dealing with bio-economic topics in specific continents or countries.

#### **Fifth recommendation: Enable more excellence in student development**

The initiative to create internationally competitive parameters for public research institutions must be consistently developed. This is not just a case of setting up professorships and student research groups. Universities and research institutions must also be encouraged to work efficiently and in a more business-like fashion. Incentives for developing a lively and dynamic culture of innovation should be offered, which also focus more on potential economic applications. For this they should also make use of business and political know-how of business and politics. Businesses for their part ought to include scientists more on their advisory boards. In addition, innovation transfer between science, business and politics should also be intensified at the labour level through regular exchange. This approach implies more permeability between the areas concerned.

To ensure the development of a first-rate cadre of students, educational structures must be set up that reflect the systemic character of the bio-economy. This includes the creation of interdisciplinary study programmes. At the Weihenstephan Centre of Science at the TU in Munich, this has already

been realised, at least to some extent. The reform should include simplifying collaboration across Land (regional) boundaries. The 'Doctoral Certificate Programme in Agricultural Economics' is an example of a long-term, national institution for a structured educational programme in agricultural and food economics in Germany. The cooperation of a number of faculties and research institutes means that a comprehensive range of courses can be offered, providing access to all relevant research areas in agricultural, forest and food economics, across Land and institutional boundaries, thus laying the foundation for the bio-economy.

To enable these sorts of developments, the natural sciences must be strengthened within schools by adapting the curriculum and pedagogical agendas, something that has long been recommended in a variety of initiatives from the political arena, science academies, public bodies and foundations. Targeted funding of top students through cooperation with schools, universities and businesses is absolutely vital to ensure that the bio-economy continues to develop successfully in Germany.

#### **Conclusion**

The Bio-Council hopes with these recommendations to help illustrate the importance of the bio-economy particularly given the current economic climate and the increase in global challenges.

In the future it sees itself as a closer partner of the political community, the wider public, as well as of science and business, so that together we can look for ways of using our natural resources more efficiently and sustainably.

<sup>7</sup> Brazil, Russia, India and China.

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For his help in drafting these recommendations we should also like to offer our warmest thanks to Dr Andreas Möller, Berlin.

### PUBLISHER'S NOTE

#### Published by

The Bio-Economy Research and Technology Council (BÖR), Berlin (2009).

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#### Production and design

psz Kommunikation, Patrick Imhof

#### Printed by

LASERLINE Druckzentrum, Berlin

ISSN 1869-1404, ISBN 978-3-942044-15-8 (print edition), ISBN 978-3-942044-16-5 (online version)

The German National Library has registered this publication in the German National Bibliography; detailed bibliographical data can be found online at <http://dnb.d-nb.de>.



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ISBN 978-3-942044-15-8