

Priorities in Bio-economic Research

Recommendations of the Bio-economy Council

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Summary

In this paper, the Bio-economy Council defines the priorities with regard to relevance and urgency of the research topics identified in its report “Bio-economy Innovation” and makes recommendations with regard to time scales and financial backing. The primary objectives are to increase the volume of biomass available for various applications and to use the limited natural resources efficiently in order to fully exploit potential and to reduce the likelihood of newly competing demands arising, as for example, between those of the bio-energy and foodstuff industries.

In its report “Bio-economy Innovation” the Council identified research topics that it considered should form part of a knowledge-based bio-economy. In its initial report, it defined three interdisciplinary recommendations and provided a detailed structural guideline. At the time of the publication of the report in September 2010, the Council was already planning a further prioritisation review of the identified research topics for 2011. The results of its prioritisation review are set out in this paper. The Council also herewith brings its research recommendations into line with the “National Bio-economy Research Strategy 2030” (Nationale Forschungsstrategie BioÖkonomie 2030) of the Federal Government.

Of the total of 35 topics, the Council has identified 14 that are of particular relevance and should be initiated as a matter of priority. These include four of particularly urgent relevance:

- A basic prerequisite needed to establish a sustainable bio-economy and thus a research project that must be implemented with primary priority is the targeted breeding of crop plants and livestock to increase yield or output and to provide these with specific characteristics, and the corresponding adaptation of production systems so as to realise the full genetic potential.
- The development of innovative technologies, improvements to processes and increasing economic efficiency along value creation chains should form the second focus of efforts. These will help reduce high losses along value chains and make the bio-economy more consumer-orientated.
- Innovations in biomass-based energy production, conversion and storage are a third essential concern, whereby it is important to ensure that competition with the production of food and animal feeds is reduced to minimum.
- The fourth focus must be on research into soil as a resource: in view of the increasing demand for biomass, ever greater reliance is being placed on soil productivity. Research into the long term preservation of agricultural land in sufficient quantity and quality must thus receive priority support.

The Bio-economy Council wishes to make it clear at this point that it considers all 35 topics as relevant. In this paper, the individual urgency and extent to which they require funding are defined. In addition, the Council concludes that there are certain fundamental projects, such as research into artificial photosynthesis and synthetic biology, which have strategic and long-term importance and that must be implemented as a matter of urgency. This also applies to multidisciplinary topics which can be expected to generate major synergistic effects, such as the promotion of quantitative economic analyses and scenarios towards an adequate science policy counselling in the domain of the bio-economy.

In order to ensure that the groundwork for the realisation of the required research and innovation is in place, the Council expressly recommends that existing structures and framework conditions be modified to the new requirements of the bio-economy. The Bio-economy Council thus recommends that a **National Bio-economy Platform** be set up to carry out the coordination work and to provide impetus for the corresponding conversion processes with the relevant actors.

I. Background – The thematic recommendations of the Bio-economy Council in its report “Bio-economy Innovation”¹

In its 2010 report, the Bio-Economy Council provided a detailed and extensive review of the bio-economy, and defined the term as follows:

The bio-economy encompasses all those sectors and their related services which produce, process or use biological resources in whatever form.

The bio-economy combines highly research-intensive economic activities in agriculture, forestry and the food sector with the innovative use of renewable raw materials for material and energy use. Because of this integrative function, the bio-economy will be important to Germany’s future as a centre of business and technology.

The bio-economy’s potential for innovation, which needs to be strategically harnessed by the scientific and business communities, lies in the development of new types of products and production techniques, the creation and exploitation of synergies as well as in raising the resource efficiency of the various interrelated value chains: from the production of biomass in agriculture and forestry to the end products in the food and energy sector and areas of industry such as the chemical, textile, paper and pharmaceutical sectors. This is all to be based on the most up-to-date knowledge about the fundamental processes within plants, animals and microorganisms.

The greatest challenges of our time can only be addressed and translated successfully into economic and social value if we manage to combine more closely the key technologies of the 21st century in the biological and life sciences with the agricultural sciences² and engineering and turn these into successful innovations. More than ever, business and science now need to act together as a unified “system”. By bringing together the various areas within science and business, which today still operate for the most part within their own sectors, Germany will become more competitive, and her leading position as a centre of business and technology will be reinforced. A better economic database to record the rapidly developing bio-economy is also needed to underpin this strategic alignment.

¹ This overview is based on the summary of the Council’s report 2010 “Bio-economy Innovation – Research and technological Development to ensure food security, the sustainable use of resources and competitiveness”.

² The recommendations made with regard to agriculture and agricultural sciences in this report are to be in general understood to also apply to forestry and forestry science.

To help formulate such a research strategy, the Bio-economy Council outlined three key recommendations in its report, organised by subject area, thereby providing each of the research fields with detailed recommendations for a programme. These are followed by a further recommendation on structural issues.

The following measures are specified:

1. Development of efficient value chains, processes and products
2. Ensuring global food security, promoting health and assumption by Germany of its responsibility for global issues
3. Sustainable use of natural resources
4. Appropriate integration of the bio-economic approach in the system.

Re. 1. Development of efficient value chains, processes and products:

It is essential for the optimal development of all technologically feasible and economically relevant value chains that the processes and the resulting high-value products and energy sources are resource-efficient and cost-effective. One of the key innovations of bio-economic research will be not only to develop individual innovative value chains but also to link these chains in the system.

The breeding of plants and animals with higher yields/capacity and specific characteristics, including the ingredients for healthy nutrition, are central to a bio-economic research strategy seeking to optimise value chains.

Sustainable economic activity is dependent on adequate provision and the efficient management of biomass in a way that also protects resources. Research into how the material uses of biomass can be extended by a combination of biotechnological and chemical conversion processes, as well as the use of improved enzyme systems to digest biomass and waste products, will deliver important contributions to efficiency. The field of industrial biotechnology must also focus on further developing its underlying research in order to maintain – and, where necessary, improve – the high level of innovation that currently exists. Innovative biotechnological processes can reduce the consumption of raw materials and energy, and decrease the generation of undesirable by-products, secondary products and emissions.

Strategic development in the bio-economy should have a sound scientific basis and be geared towards the long term. To this end, the necessary socio-economic research and analytical basis must be strengthened. For example, dynamic system models should be used to investigate alternative scenarios to the bio-economy taking into account socio-economic perspectives.

Re. 2. Ensuring global food security, promoting health and assuming Germany’s responsibility for global issues:

Important value chains of the bio-economy can be found in the food sector. Our ability to feed the world’s population is dependent on the efficiency and the sustainability of these value chains, while their product and processing quality correlates directly with human health and the quality of life. In this context, German research also has the responsibility to provide support to emerging and developing nations to secure sufficient volumes of good quality food for their populations and to counter the volatility of food prices. Local analyses of production systems that draw international comparisons are needed, especially in the sector of small farmers in developing and emerging nations, as this sector plays a key role in feeding the world’s population.

To meet the growing need for food, feed and raw materials for productive or energy use, and to strike a balance in the competition for biomass, there must be a substantial increase in the yields of food and feed plants, as well as in the productivity of livestock farming. Research geared towards increasing the health-boosting properties of foods and the awareness of healthy nutritional lifestyles must also be prioritised.

Re. 3. Sustainable use of natural resources:

The geo-resources of soil and water, nutrients and the biological diversity of plants, animals and microorganisms form the basis for bio-economic value creation. As the availability of these resources is limited, it is vital that we conserve them and use them sustainably. There must be better understanding of sustainable land use, soil quality and ecosystem services, and new verified findings must be translated more quickly into practice. Technological solutions must be found to cope with changes in water availability and to improve the use of fertilisers and nutrients. This means developing optimised farming techniques and more efficient crop varieties that are more drought-tolerant and efficient in their use of nutrients. There must also be consideration of the regionally specific effects of climate change.

On the basis of the principle of resource efficiency, all potential uses of biomass must be prioritised and optimised. There is no doubt that a greater use of bio-based products can help the world meet climate targets as well as the aim of “combating hunger and poverty” as defined by the UN Millennium Goals.

For the strategic orientation of this bio-economic research, there needs to be greater focus on the economics of resource use, including institutional regulations.

Re. 4. Appropriate integration of the bio-economic approach in the system:

Existing structures and parameters must be adapted to the new requirements so that the topics listed in the three research areas can be worked on effectively and put into practice.

It is important that research funding be interlinked more closely and overall funding volumes increased: the research infrastructure must continue to be adapted accordingly. Recent studies indicate that greater investment in research and development is absolutely essential if important agricultural resources are to be available in sufficient quantities, and that this must contribute towards ensuring global food security.

It is essential that future research funding is allocated not just to research in the natural sciences and engineering, but also to the economic and social sciences as well. The maximum potential of the bio-economy can only be realised by means of these interdisciplinary approaches. On the one hand, we need to establish an economics of technological development, which can deliver as rapidly as possible an assessment of the competitiveness of and suggestions for sustainable technological approaches. On the other hand, socio-economic research needs to analyse how the efficiency of the bio-economy can be improved by innovative control and incentive mechanisms.

Taking into account the points outlined above, the Bio-economy Council thus strongly recommended the **establishment of an interdepartmental national bio-economy research programme** to allow the pooling and better coordination of research funding from the Federal Government. This recommendation has been adopted by the Federal Government and was given form in November 2010 as the “National Bio-economy Research Strategy 2030” (Nationale Forschungsstrategie BioÖkonomie 2030). In the following proposals for prioritisation, the Council has thus also organised its recommendations in line with this national research strategy.

Another prerequisite for the successful development of the bio-economy is the close linking of private research activity with that in the public sector. Legal uncertainties which hinder the commercial use of new research findings must be resolved. Cooperation and the synergy between public research institutions and industrial firms of different sizes and in the various business sectors are essential. New types of structures such as clusters and innovation alliances, e.g. open innovation projects and ‘unusual’ alliances between sectors that have seldom collaborated in the past, will play an important role here. In its recommendations, the Council also indicates those research areas in which larger private sector involvement can be expected and, conversely, those in which contributions from the private sector will be less pronounced.

The bio-economy and its related research are not restricted to the national level. Particularly when international, primary objectives or global resources are at stake, Germany must act in conjunction with other countries. The Bio-economy Council believes that the **German bio-economy and national bio-economic research must make greater efforts to integrate themselves strategically and work as partners on the international stage.** Also important here are uniform, transnational principles, e.g. for the import of biomass and licensing of corresponding crops for farming. In technological decision-making, such as over the use of genetically modified crops, scientific assessment should not only consider the risks of use, but also those of non-use.

There needs to be more openness towards and communication with the public as far as the subjects of bio-economic research and its potential to secure sustainability, innovation and employment within Green Growth strategies are concerned. Ultimately, it is up to the business community to introduce new products and processes, and to ensure that markets develop positively. In this area, there must be greater use of existing market knowledge to shape the strategic orientation of research programmes. Any system of government incentives and funding instruments ought to be no more than temporary.

A fundamental requirement of the bio-economy concept is extensive collaboration across disciplines and sectors. It is thus necessary to bring together the various scientific communities with the involvement of the business sector in order to achieve the desired enhancement of our knowledge base. In conclusion, the Council thinks it is crucial that the political, scientific and business communities cooperate more closely than in the past and agree on the measures that need to be taken in the pre-competition stage. The Bio-economy Council thus recommends that a **National Bio-economy Platform** be set up to implement the necessary tasks of coordination. It is hoped that the prioritisation recommendations presented here will prove to be of help in this task.

II. Description of the prioritisation procedure

In order to prepare its prioritisation recommendations, the Council formed an internal ad hoc work group consisting of four of its members.³ The work group was also able to call on the expertise of the spokespersons of the work groups Soil, Plants, Animals and Biotechnology and other members of the Bio-economy Council in the initial review phases.

The prioritisation review was undertaken in the following stages:

The Council first discussed and agreed to the **prioritisation criteria** (see Table 3 in the Appendix). The scale used to evaluate the individual research topics ranged from 1 (low significance) to 5 (high significance) for each of the four criteria – economic, environmental, socio-cultural and scientific dimensions.

Working on the basis of this matrix, the spokespersons of the various work groups prepared initial prioritisation assessments with the help of their work groups, which were reviewed and thus taken into account by the ad hoc work group.

At the same time as the spokespersons were preparing their prioritisation proposals, the research topics were evaluated using the same criteria independently by each individual member of the ad hoc work group in an anonymous procedure. Each topic was subjected to an overall review and was ranked in groups from I to IV by relevance. Relevance group I represents topics with a particularly high priority, group II consists of high priority topics, group III of moderate priority topics and group IV of low priority topics. However, it must be borne in mind that even those topics allocated to group IV are still relevant over the long term and require support in the view of the Council.

Those topics that received divergent gradings were assigned a priority in a mutual consultation process conducted within the ad hoc group. The results of the **proposed prioritisations by subject** were discussed in detail by the Council during its sittings on 7 March 2011 and 10 June 2011 and subsequently approved with minor changes (see Table 2 in the Appendix).

The Council also decided to outline in more detail time scales for the implementation and the financial requirements for the realisation of the topics specified in the report “Bio-economy Innovation”.

³ Joachim von Braun (coordinator), Thomas Hirth, Stefan Marcinowski and Alfred Pühler

II. Description of the prioritisation procedure

The public sector **funding** required for each research topic was categorised as small (up to €3 million annually), medium (€3 – €10 million annually) or large (€10 – 30 million annually). None of the research topics was assigned to an originally proposed category - “very large” (i.e. greater than €30 million annually), although the Council believes that the research topic “biomass-based energy sources” requires funding on this scale. The Council has appointed a new work group that will be considering this topic area and will propose further details of the research required here. The estimated contributions that can be expected to be made by the private sector towards these projects were also assessed as small, moderately large and large.

With regard to **time scale**, the research projects were classified as short term (requiring funding for up to four years), medium term (requiring funding for four to ten years) and long term (requiring funding for more than ten years). In addition, certain projects were earmarked that need to be undertaken and funded as a matter of urgency.

The Bio-economy Council once again emphasises that it considers that all research topics that were recommended in its report are of relevance, and differ only with regard to the weighting of aspects, such as the required volume of funding and urgency of implementation. The Council has explicitly taken this factor into account in presenting these proposals.

In addition to the topics outlined in the report “Bio-economy Innovation”, the Council has also considered the areas of activity defined in the “**National Bio-economy Research Strategy 2030**” of the Federal Government (see Table 2 in the Appendix) in its prioritisation review and has consequently revised some aspects of the Council report that required clarification.

III. Prioritisation results and interpretation

The research topics that are considered to be of “primary” importance and that need to be initiated as a matter of urgency are listed in Table 1. These “primary” research topics are those that were allocated to relevance group I or II on a prioritisation by subject scale of I to IV.

Table 1: Primary and most urgent research topics

| Recommendation (R) 1: Develop efficient value chains, processes and products required for a successful bio-economy | Evaluation by topic area |
|--|---|
| R1-2 New and improved processing techniques to produce the desired products in greater volumes and purity, but also alternative processes, such as the integration of separation processes at the reaction stage, to reduce production costs (process-integrated processing) | II |
| R1-3 Breeding of crops and livestock for greater yields or output and specific characteristics (including plant ingredients for healthy diet) and adapting production systems to exploit the genetic potential | I* |
| R1-5 Methods and techniques of multiple use and coupled use, development and establishment of biorefinery plants; greater emphasis on pilot and demonstration plants from the perspective of sustainability | II* |
| R1-8 Development and production of new high-value products (e.g. pharmaceuticals, cosmetics, nutritional supplements, special chemicals) | II |
| R1-12 Consumer-related aspects | II* |
| R1-14 Innovations in agriculture and forestry (precision farming, satellite- and computer-controlled distribution systems for water, nutrients and crop protection products; harvesting technologies, innovative animal husbandry techniques) | II |

Evaluation by topic area:

I = Particularly high priority, II = High priority, * = funding required as a matter of urgency

III. Prioritisation results and interpretation

| Recommendation 2: Ensure global food security, promote health and assume global responsibility | Evaluation by topic area |
|--|---|
| R 2-1 Localised analyses of production systems in their international context (with particular focus on small farmers), evaluation of their sustainability and strategies for improvement, including the reduction of losses in the marketing and consumption system | II* |
| R 2-4 Development of higher-yielding crops that are more resistant to stress (with particular focus on wheat and legumes); use and further development of marker-assisted selection (MAS) and automated high-throughput techniques | II* |
| R 2-5 Optimisation of plant ingredients and animal products for health purposes (e.g. improvement of micronutrient contents and reduction of heavy metal uptake, mycotoxins, predictive breeding) | II* |
| R 2-6 Selection and propagation of productive, robust and disease-resistant livestock | II |
| R 2-7 Improvement in animal health and development of efficient strategies for combating animal epidemics (zoonoses); human animal husbandry and feeding methods | II |
| R 2-8 Development of high output organisms by targeted manipulation of entire metabolic pathways using modern technologies (system biotechnology, genomics, proteomics, metabolomics, metabolic pathway engineering, fluxomics) | II* |
| R 2-9 Innovative technologies and improved methods for reducing post-harvesting losses in the value creation chain | I* |

Evaluation by topic area:

I = Particularly high priority, II = High priority, * = funding required as a matter of urgency

| Recommendation 3: Ensure global food security, promote health and assume global responsibility | Evaluation by topic area |
|---|---|
| R 3-1 Soil quality, land use, ecosystem services (prioritising land use; national and international regulations on land and water rights; progress in agricultural technology; improving monitoring and data; soil aspects of organic farming) | I* |
| R 3-2 Water use, water efficiency, water quality (locally adapted schemes for water storage and irrigation; agronomic adaptation measures, soil analysis and information systems; plant breeding), biological approaches to water purification on the ground | II |
| R 3-3 Targeted use and recovery of nutrients (interactions between plant roots, soil and microorganisms; optimisation of cultivation techniques and fertilisation; closing material cycles; recovery of phosphorus in particular; development of plant systems that reduce ecological footprints, e.g. phytase maize as an animal feed) | II* |
| R 3-5 Adaptation to climate change (plant and animal breeding; climate-friendly animal husbandry and crop cultivation; weather forecasting; agronomic measures, e.g. mixed cropping, agro-forestry systems), adaptation of forestry (REDD), carbon storage in soils and incentive mechanisms | II* |
| R 3-7 Quantitative analysis of genotype-environment interaction at the mechanical level, in the high throughput situation and its application in the field (breeding nursery); sensor and concept development; expansion of the German plant phenotyping network | II* |
| R 3-8 Sources of bio-energy (conversion processes, demonstration plants, biogas concepts, storage concepts, use of biomass without competing with food security needs) | I* |
| Recommendation 4: Appropriate integration of the bio-economic approach in the system | |
| R 4-1 Implementation of structural measures (network formation, competence centres) | II* |
| R 4-2 Research into communication options | II |

Evaluation by topic area:

I = Particularly high priority, II = High priority, * = funding required as a matter of urgency

III. Prioritisation results and interpretation

An overview of prioritisation results, time scales and funding requirements is provided in Table 2 in the Appendix. In conclusion, the contents can be summarised as follows:

1. In its prioritisation review, the Bio-economy Council considered a total of 35 topics. It has assigned a particularly high priority to four of these topics and high priority to 17 topics (Table 1). Ten topics are categorised as having moderate priority while four have low priority (Table 2 in the Appendix).
2. The Council estimates contributions of the private sector will tend to be low in the case of 14 topics, moderately large in the case of eight topics and large in the case of 13 topics (see Table 2 in the Appendix).
3. In addition, the Council concludes that there are certain fundamental aspects that have strategic and long-term importance and that must be considered as a matter of urgency. This applies, for example, to research into artificial photosynthesis and synthetic biology.
4. This also applies to multidisciplinary topics which can be expected to generate major synergistic effects. During the prioritisation review and a comparison with the National Research Strategy (whose primary strategic aims are largely in conformity with the recommendations of the Bio-economy Council), the Council identified certain topics that it considers to be of generalized interdisciplinary significance (see Table 2 in the Appendix).
5. In order to ensure that future prioritisation reviews can be evidence- and results-based, there must be greater focus on research into strategy and foresight modelling and the generation of a corresponding statistical database.

In order to put in place the groundwork for the realisation of the required research and innovation, the Council recommends that existing structures and framework conditions be modified to the new requirements of the bio-economy. The topics relating to institutional and organisational innovation (recommendation 4: "Appropriate integration of the bio-economic approach in the system") have a high priority, but with the exception of the topics that require additional research or funding, these have not been considered to the same extent here as were the topics involving research. The Bio-economy Council is considering the initiation of a separate implementation policy for these in cooperation with the relevant actors.

Appendix

Table 2: Prioritisation of research topics specified in the report “Bio-economy Innovation” and details of time frames and funding

| Recommendation i: Develop efficient value chains, processes and products required for a successful bio-economy | Evaluation by subject area | Time scale | Funding | Conformity with areas of activity defined in the NRS |
|--|----------------------------|------------|---------|--|
| R1-1 Expansion of the material uses of biomass using a combination of biotechnological and chemical conversion processes; new and improved enzyme systems to convert biomass (including the use of waste) | III | M | L1 | 4 |
| R1-2 New and improved processing techniques to produce the desired products in greater volumes and purity, but also alternative processes, such as the integration of separation processes at the reaction stage, to reduce production costs (process-integrated processing) | II | M | L1 | 4 |

Evaluation by subject area:

I (particularly high) to IV

Time scale:

Duration (years): S = -4 | M = 4 -10 | L = >10 | Commencement.* = to be initiated as a matter of urgency

Funding:

Total volumes (approx. € million per annum): S = -3 | M = 3 -10 | L = 10 -30 | V = >30

Private sector involvement: s = small | m = moderately | l = large

Conformity with areas of activity defined in the “National Bio-economy Research Strategy 2030” (NRS):

- 1 = Ensure worldwide food security
 - 2 = Make agriculture sustainable
 - 3 = Produce healthy and safe foodstuffs
 - 4 = Use renewable resources for industrial purposes
 - 5 = Extend the use of biomass as a source of energy
- I = Interdisciplinary activities
GT = Generalised topics with interdisciplinary relevance

| Recommendation 1: Develop efficient value chains, processes and products required for a successful bio-economy | Evaluation by subject area | Time scale | Funding | Conformity with areas of activity defined in the NRS |
|---|----------------------------|------------|---------|--|
| R1-3 Breeding of crops and livestock for greater yields or output and specific characteristics (including plant ingredients for healthy diet) and adapting production systems to exploit the genetic potential | I | L* | L1 | 2 |
| R1-4 Further development of energy conversion processes | IV | M | M1 | 5 |
| R1-5 Methods and techniques of multiple use and coupled use, development and establishment of biorefinery plants; greater emphasis on pilot and demonstration plants from the perspective of sustainability | II | M* | Lm | 4 |
| R1-6 Synthetic biology: expanding the application range of synthetic genes and genomes, genome engineering (genetic modification of many genes at the same time), design of new metabolic pathways; design of adapted minimal cells for industrial uses | III | L | Lm | GT |
| R1-7 Research into the basis of alternative energy sources such as algae (optimisation of organisms, process techniques and use) and artificial photosynthesis systems (biobatteries) ⁴ | IV | L | Ms | 5 |
| R1-8 Development and production of new high-value products (e.g. pharmaceuticals, cosmetics, food supplements, special chemicals) | II | S | L1 | 4 |
| R1-9 Integrated biological production systems (agro-forestry systems, combination of crop production and aquacultures) | IV | M | Ms | 2 |
| R1-10 Sustainability of various production techniques (comparative analyses of socio-economic and ecological factors at different locations; improving sustainability of production systems) | III | S | Ms | 2 |

⁴ In the case of research into artificial photosynthesis in particular, dovetailing with other clusters of the high-tech strategy is necessary (nanotechnology, catalysis, organic electronics, materials science).

| Recommendation i: Develop efficient value chains, processes and products required for a successful bio-economy | Evaluation by subject area | Time scale | Funding | Conformity with areas of activity defined in the NRS |
|--|----------------------------|------------|---------|--|
| R 1-11 Strategy development (e.g. development of dynamic system models) and research into institutional measures to increase the competitiveness of the bio-economy | III | S | S s | GT |
| R 1-12 Consumer-related aspects | II | M* | M m | 3 |
| R 1-13 Standardisation and certification | III | S | S s | GT |
| R 1-14 Innovations in agriculture and forestry (precision farming, satellite- and computer-controlled distribution systems for water, nutrients and crop protection products; harvesting technologies, innovative animal husbandry techniques) | II | M | M1 | 2 |

Evaluation by subject area:

I (particularly high) to IV

Time scale:

Duration (years): S = -4 | M = 4 - 10 | L = >10 | Commencement.* = to be initiated as a matter of urgency

Funding:

Total volumes (approx. € million per annum): S = -3 | M = 3 - 10 | L = 10 - 30 | V = >30

Private sector involvement: s = small | m = moderately | l = large

Conformity with areas of activity defined in the “National Bio-economy Research Strategy 2030” (NRS):

1 = Ensure worldwide food security

2 = Make agriculture sustainable

3 = Produce healthy and safe foodstuffs

4 = Use renewable resources for industrial purposes

5 = Extend the use of biomass as a source of energy

I = Interdisciplinary activities
GT = Generalised topics with interdisciplinary relevance

| Recommendation 2: Ensuring global food security, promoting health and assumption by Germany of its responsibility for global issues | Evaluation by subject area | Time scale | Funding | Conformity with areas of activity defined in the NRS |
|--|-----------------------------------|-------------------|----------------|---|
| R 2-1 Localised analyses of production systems in their international context (with particular focus on small farmers), evaluation of their sustainability and strategies for improvement, including the reduction of losses in the marketing and consumption system | II | M* | Ms | 1 |
| R 2-2 Analyses of options for ensuring global food security and limiting the volatility of food prices, including regional and global storage | III | S | Ss | 1 |
| R 2-3 Increase in the health benefits of foods (e.g. processed foods); promotion of healthy diets | IV | L | Ll | 3 |
| R 2-4 Development of higher-yielding crops that are more resistant to stress (with particular focus on wheat and legumes); use and further development of marker-assisted selection (MAS) and automated high-throughput techniques | II | L* | Ll | 2 |
| R 2-5 Optimisation of plant ingredients and animal products for health purposes (e.g. improvement of micronutrient contents and reduction of heavy metal uptake, mycotoxins, predictive breeding) | II | M* | Mm | 3 |
| R 2-6 Selection and propagation of productive, robust and disease-resistant livestock | II | M | Ml | 2 |
| R 2-7 Improvement in animal health and development of efficient strategies for combating animal epidemics (zoonoses); human animal husbandry and feeding methods | II | M | Ml | 2 |

| Recommendation 2: Ensuring global food security, promoting health and assumption by Germany of its responsibility for global issues | Evaluation by subject area | Time scale | Funding | Conformity with areas of activity defined in the NRS |
|---|---|-----------------------|----------------|---|
| R 2-8 Development of high output organisms by targeted manipulation of complete metabolic pathways using modern technologies (system biotechnology, genomics, proteomics, metabolomics, metabolic pathway engineering, fluxomics) | II | L* | L l | GT |
| R 2-9 Innovative technologies and improved methods for reducing post-harvesting losses in the value creation chain | I | M* | M m | 1 |

Evaluation by subject area:

I (particularly high) to IV

Time scale:

Duration (years): S = -4 | M = 4 - 10 | L = >10 | Commencement: * = to be initiated as a matter of urgency

Funding:

Total volumes (approx. € million per annum): S = -3 | M = 3 - 10 | L = 10 - 30 | V = >30

Private sector involvement: s = small | m = moderately | l = large

Conformity with areas of activity defined in the “National Bio-economy Research Strategy 2030” (NRS):

1 = Ensure worldwide food security

2 = Make agriculture sustainable

3 = Produce healthy and safe foodstuffs

4 = Use renewable resources for industrial purposes

5 = Extend the use of biomass as a source of energy

I = Interdisciplinary activities

GT = Generalised topics with interdisciplinary relevance

| Recommendation 3: Sustainable use of natural resources in the bio-economy | Evaluation by subject area | Time scale | Funding | Conformity with areas of activity defined in the NRS |
|--|----------------------------|------------|---------|--|
| R 3-1 Soil quality, land use, ecosystem services (prioritising land use; national and international regulations on land and water rights; progress in agricultural technology; improving monitoring and data; soil aspects of organic farming) | I | L* | Ms | 2 |
| R 3-2 Water use, water efficiency, water quality (locally adapted schemes for water storage and irrigation; agronomic adaptation measures, soil analysis and information systems, plant breeding), biological approaches to water purification on the ground | II | L | Ms | 2 |
| R 3-3 Targeted use and recovery of nutrients (interaction between plant roots, soil and microorganisms; optimisation of cultivation techniques and fertilisation; closing material cycles; recovery of phosphorus in particular; development of plant systems that reduce ecological footprints, e.g. phytase maize as an animal feed) | II | L* | Mm | 2 |
| R 3-4 Safeguarding the genetic resources of plants, animals and microorganisms, and efficient use of these (biodiversity, cell factory systems; systems biology, synthetic biology); metagenome banks | III | L | Mm | GT |
| R 3-5 Adaptation to climate change (plant and animal breeding; climate-friendly animal husbandry and crop cultivation; weather forecasting; agronomic measures, e.g. mixed cropping, agro-forestry systems), adaptation of forestry (REDD), carbon storage in soils and incentive mechanisms | II | L* | Ls | 1 |
| R 3-6 Economics of resource use (competition between uses for land and water, 'virtual water', ecobalancing), institutional arrangements for supporting innovations (including collective action for water use and ecosystem services); and adaptation through action | III | M | Ms | 1 |

| Recommendation 3: Sustainable use of natural resources in the bio-economy | Evaluation by subject area | Time scale | Funding | Conformity with areas of activity defined in the NRS |
|--|----------------------------|------------|---------|--|
| R 3-7 Quantitative analysis of genotype-environment interaction at the mechanical level, in the high throughout situation and its application in the field (breeding nursery); sensor and concept development; expansion of the German plant phenotyping network | II | M* | Ms | Ü |
| R 3-8 Sources of bio-energy (conversion processes, demonstration plants, biogas concepts, storage concepts, use of biomass without competing with food security needs) | I | L* | L1 | 5 |
| R 3-9 Integrated plant protection systems | III | M | L1 | 2 |

Evaluation by subject area:

I (particularly high) to IV

Time scale:

Duration (years): S = -4 | M = 4 - 10 | L = >10 | Commencement: * = to be initiated as a matter of urgency

Funding:

Total volumes (approx. € million per annum): S = -3 | M = 3 - 10 | L = 10 - 30 | V = >30

Private sector involvement: s = small | m = moderately | l = large

Conformity with areas of activity defined in the "National Bio-economy Research Strategy 2030" (NRS):

1 = Ensure worldwide food security

2 = Make agriculture sustainable

3 = Produce healthy and safe foodstuffs

4 = Use renewable resources for industrial purposes

5 = Extend the use of biomass as a source of energy

I = Interdisciplinary activities

GT = Generalised topics with interdisciplinary relevance

| Recommendation 4: Appropriate integration of the bio-economic approach in the system | Evaluation by subject area | Time scale | Funding | Conformity with areas of activity defined in the NRS |
|---|----------------------------|------------|---------|--|
| R 4-1 Implementation of structural measures (network formation, competence centres) | II | S* | S s | I |
| R 4-2 Research into communication options | II | S | S s | I |
| R 4-3 Research to identify and remove barriers to innovation | III | M | S m | I |

Evaluation by subject area:

I (particularly high) to IV

Time scale:

Duration (years): S = -4 | M = 4 -10 | L = >10 | Commencement: * = to be initiated as a matter of urgency

Funding:

Total volumes (approx. € million per annum): S = -3 | M = 3 -10 | L = 10 - 30 | V = >30

Private sector involvement: s = small | m = moderately | l = large

Conformity with areas of activity defined in the “National Bio-economy Research Strategy 2030” (NRS):

1 = Ensure worldwide food security

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4 = Use renewable resources for industrial purposes

5 = Extend the use of biomass as a source of energy

I = Interdisciplinary activities

GT = Generalised topics with interdisciplinary relevance

Table 3: Prioritisation criteria

| |
|--|
| <p>Economic dimensions</p> <ul style="list-style-type: none"> - Value creation for Germany - Employment - Growth/leapfrog effect - Competitive situation (overheads, strength, structures) - Outlay versus probability of realisation (market readiness) |
| <p>Environmental dimensions</p> <ul style="list-style-type: none"> - Contribution to climate protection - Contribution to resource conservation (raw materials and energy) - Effects on ecosystems and biodiversity |
| <p>Socio-cultural dimensions</p> <ul style="list-style-type: none"> - High value, long term jobs - Effects on geographical locations (rural areas/urbanisation) - Consideration of global responsibility and global effects - Ethical values - Knowledge and education |
| <p>Scientific dimensions</p> <ul style="list-style-type: none"> - Competitive situation (overheads, strengths, structures, international partners) - Leapfrog effect for innovation - Viability and feasible duration, technical practicability/implementation |

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With particular thanks to the Federal Ministry of Education and Research (BMBF) for its funding support and acatech (the German Academy of Science and Engineering) for its administrative help.

The Bio-economy Council's work is supported by an administrative office:

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Dr. Andrea George (academic research assistant)

Dr. Katja Leicht (academic research assistant)

Thordis Möller (academic research assistant)

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Dipl.-Biol. Elke Witt (academic research assistant)

We should also like to thank the following students for their work at the administrative office:

Julian Braun and Adrian Luncke.

Thanks also to Christoph Uhlhaas for his editorial input.

PUBLICATION DETAILS

Published by

Bio-economy Research and Technology Council (BÖR)

© BÖR, Berlin (2011)

Design and layout by

Oswald + Martin Werbeagentur, Berlin

Printed by

Brandenburgische Universitätsdruckerei

ISSN 1869-1404, ISBN 978-3-942044-17-2 (print version), ISBN 978-3-942044-20-2 (online version)

The German National Library has registered this publication in the German National Bibliography; for detailed bibliographic information, go to <http://dnb.d-nb.de>.



Issued by

Bio-economy Research and Technology Council
(Forschungs- und Technologierat Bioökonomie) BÖR
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