Bioökonomierat

Global Visions for the Bioeconomy – an International Delphi-Study

Background

The German Bioeconomy Council, an independent advisory body to the German Federal Government (see www.biooekonomierat.de/en/) has been discussing so-called flagship projects with experts from all over the world. The aim of this exercise is to recommend to the German Government where the most important fields for further innovation support and new policy may be found. Flagship projects have been defined as “new ideas, large breakthrough innovations or even ‘visions’ with a cross-sectoral and convincing aim. They should be realistic and evoke a big change during the next 25 years.”

The Fraunhofer Institute for Systems and Innovation Research (ISI) in Karlsruhe coordinated this Delphi study on behalf of the German Bioeconomy Council. The Delphi survey was performed in two “rounds”: After the survey had been answered by bioeconomy-related experts, the aggregated but anonymous answers from the first round were provided to the experts. In the second round, the participants were given the option to change their evaluation or stick to the first assessment. Moreover, three new flagship projects were formulated on the basis of participants’ feedback and recommendations received in the first round. These new flagship projects were then added and assessed in the second round. The survey was performed online, in English only, and the questionnaire was designed jointly with the members of the Bioeconomy Council.

Content

1 Executive Summary

The German Bioeconomy Council, an independent advisory body to the German federal government (see www.biooekonomierat.de/en/) has been discussing so-called flagship projects with experts from all over the world. The aim of this exercise is to recommend to the German Government where the most important fields for further innovation support and new policy may be found. Flagship projects have been defined as "new ideas, large breakthrough innovations or even 'visions' with a cross-sectoral and convincing aim. They should be realistic and evoke a big change during the next 25 years."

Four draft flagship projects were formulated at a workshop during the 10th meeting of the Bioeconomy Council. These flagship projects were assessed, discussed, improved, and new projects were added within the framework of a classic Delphi survey in two rounds.

The Fraunhofer Institute for Systems and Innovation Research (ISI) in Karlsruhe coordinated this Delphi study on behalf of the German Bioeconomy Council. The data collection and analyses for this report were the sole responsibility of the Fraunhofer Institute.

A Delphi questionnaire typically consists of open questions and statements about future issues that should be assessed by criteria or direct questions. In the case of the Bioeconomy Delphi survey, not only short statements but also a more comprehensive vision of each flagship project – similar to a scenario – was provided in the first round for assessment and comments. Experts were asked to evaluate both the relevance (from very high to not relevant) and desirability (yes or no) of the flagship projects, and to add and describe additional flagship projects that were seen as very important for the development of the future global economy. In all cases, comments were welcome and analyzed qualitatively. After this initial survey, the aggregated but anonymous answers from the first round were provided in the second round where participants were also given the option to revise their first judgment. Three new flagship projects were derived from participants' feedback and recommendations from the first round and were added for assessment.

In the first round, 2,274 experts from all over the world with bioeconomy-related expertise from a broad range of disciplines were invited to take part

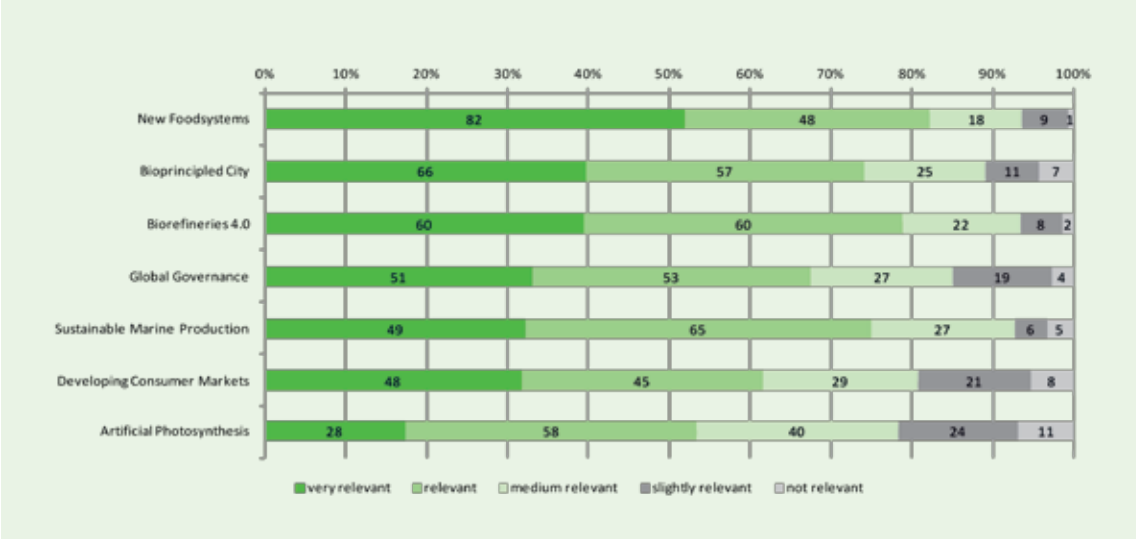

Figure 1–1: All seven flagship projects in comparison – Relevance

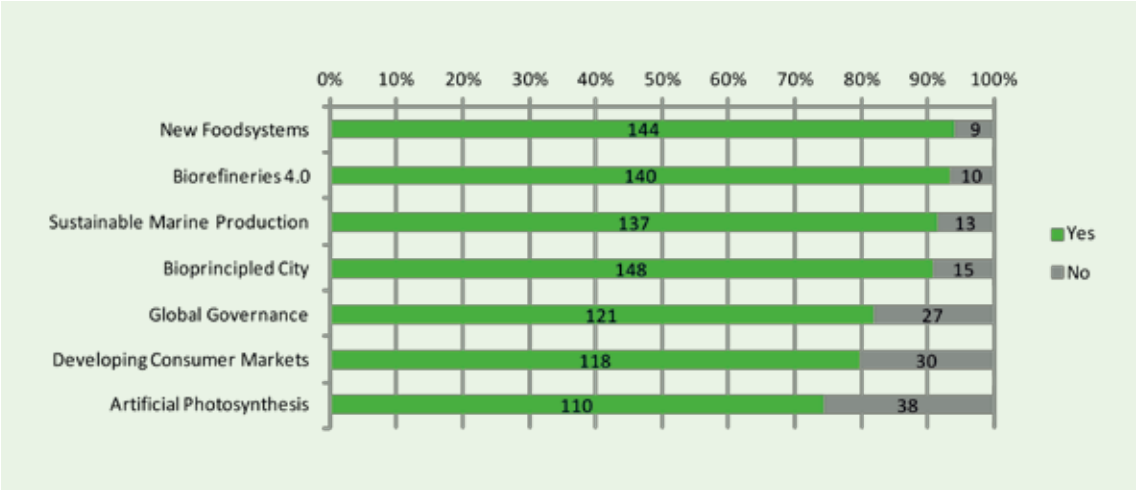

Figure 1–2: All seven flagship projects in comparison – Desirability

in the Bioeconomy Delphi. 492 experts opened the survey, 292 participants completed the first survey round and 24 gave only a few responses but were included in the analysis..In the **second round**, of the 292 invitations sent, 149 participants completed the Delphi survey and 18 gave only a few responses but were included in the analysis.

Assessment of Flagship Projects

The four flagship project candidates predefined by the Bioeconomy Council were **Bioprincipled City, New Foodsystems, Artificial Photosynthesis** and **Global Governance**. They were all rated as **"relevant"** (see figure 1-1) or even "very relevant" by the majority of participants in the survey. Artificial Photosynthesis and Global Governance got slightly lower ratings.

The "new" flagship projects that were derived from comments received in the first survey round were **Sustainable Marine Production, Biorefineries 4.0** and **Developing Consumer Markets**. They were also rated as very relevant or relevant, with a lower approval rate for Developing Consumer Markets.

The **desirability** of the projects was rated positively (see figure 1-2) in all cases but Artificial Photosynthesis, Global Governance and Developing Consumer Markets had a lower approval rate. Artificial Photosynthesis was commented as being very specific and having alternatives that appear to be more economic. Global Governance was commented as having severe limitations.

The **major results** assessing the single flagship projects are:

1. Bioprincipled City

Concerning the **relevance** of this flagship project, about 40% of participants (135 in the first, 66 in the second round) rated the relevance as very high, around one third of participants considered Bioprincipled City as relevant. The results for the two rounds are nearly identical (note: participation in the second round was lower). The majority of participants estimated that the project could be realized by 2040. Asked for single aspects, the participants considered the following most relevant: closing material loops in cities (e.g. by collecting rainwater, cleaning wastewater and establishing cascading use, purifying the air or substituting non-recyclable with recyclable and renewable materials so that "waste" is effectively abolished), design solutions adopting biological principles (design solutions and functional materials make use of energy depots, natural lighting, waste water systems and strategic planting to achieve energy and water autonomy) as well as biobased materials and "green" industrial production in cities.

2. Artificial Photosynthesis

The Artificial Photosynthesis flagship project was considered less important than the other projects but more than 50% of participants still judged it as relevant or highly relevant. Artificial Photosynthesis scored high on average desirability – but more experts than in the other cases rejected the

candidate. Accordingly, estimation of the time horizon shows a lot of variance. Considering specific aspects, the participants were on average rather sceptical regarding the future competitiveness of hydrocarbons produced via artificial photosynthesis. Hydrogen as an energy source was rated as more relevant. The technical challenges were commented as being high – which also explains the larger number of experts estimating that the project would be realized after 2040 or "never", compared to the other flagship projects.

3. New Foodsystems

The results regarding relevance and desirability provide a clear indication, with more than 80% of the respondents in the second round considering New Foodsystems as relevant and more than 90% as desirable. The majority of participants expected New Foodsystems to be realized by 2030. Looking at single aspects of this Flagship candidate, the participants considered the following issues as very relevant "Food value chains are designed in such a way that virtually no more waste occurs", sustainable principles in globally operating agriculture with lower emissions, "all people on earth consume balanced diets and stay healthy" and alternative protein sources. Microstructured foods and personalized nutrition were considered less important on average.

4. Global Governance

The majority of participants thought that this flagship project was relevant and desirable. However, nearly 20% rejected the idea of a flagship project in the field of global governance. Furthermore, the estimations regarding feasibility varied a lot. Single aspects like *sustainability criteria, mechanisms for monitoring and ensuring food security* or *protecting eco-system performance* as well as a *"green growth" strategy* scored highest on relevance but the average evaluations of the single aspects of the global governance flagship project were relatively similar.

5. Sustainable Marine Production

Sustainable Marine Production was assessed by a majority as very relevant or relevant. Most of the experts also regarded this flagship project as desirable. Realization by 2030 was regarded as realistic by the largest group of participants, many estimated that the project was feasible by 2040.

6. Biorefineries 4.0

A majority of participants also assessed Biorefineries 4.0 as very relevant or relevant. Moreover, Biorefineries 4.0 was also judged as highly desirable with a more than 90% approval rate. A majority of participants believed in realization by 2030 with other participants estimating a later time for realization.

7. Developing Consumer Markets

Developing Consumer Markets for the bioeconomy of the future was assessed slightly weaker than the other new flagship projects. Around 20% of respondents rejected this flagship project which was a rather high percentage compared to the other projects. The assessment of the time horizon for realization showed a classic bell curve and indicates a high degree of uncertainty among experts.

Is there a priority?

The proposed flagship projects envisaging the bioeconomy of the future were largely regarded as relevant and desirable with differences in nuances. Some were rated as "idealistic" but on average all of them were regarded as feasible (only few experts said "never realisable"). Nevertheless, experts pointed out the fact that they could foresee a lot of challenges and technical problems. The technical challenges seem to be highest for Artificial Photosynthesis, for example. However, the majority of participants stressed that the directions taken were correct. In the case of Bioprincipled City and New Foodsystems, a paradigm shift or at least a culture change and a change in consumer behavior was defined as necessary – but participants identified early signals for this.

Comparing the different flagship projects, there was a preference for Bioprincipled City and New Foodsystems in the first round (investment units, approval rates). Artificial Photosynthesis was viewed as being very specialized and Global Governance as very difficult to achieve. But the distribution of investment funds in the second round – when all seven flagship projects had to be considered - was fairly equal, there was no longer any clear preference (see figure 1-3). The reasons for this are not clear: it could be a statistical arte-

fact – people tend towards the average or mainstream in the second round (consensus principle of Delphi surveys) – or the more critical experts failed to participate in the second round. Without further analyses, it is difficult to derive any conclusions from the participants' investment behavior in the survey.

All flagship projects will definitely need time (more than 15 years minimum) for their realization, they will include a lot of work, need effort to convince policy-makers and citizens but were regarded as a worthwhile trial. A participant's comment summarized it like this: "I think you have picked the most important ones in agriculture, forestry and aquaculture. Go on!"

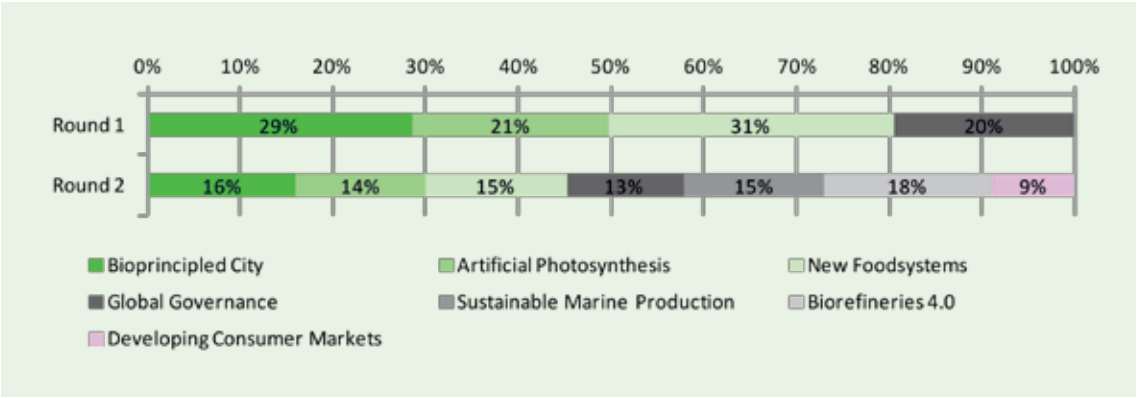

Figure 1-3: Distribution of 100 units of future investment

2 Methodology

A classic Delphi survey (see References) was performed in two rounds. The questionnaires used in both rounds are attached in the Annex of this report.

The aim of the first round was to ask the experts about their ideas for flagship projects and to assess the four candidate flagship projects proposed by the German Bioeconomy Council.

The advantages of a two-round Delphi survey are that the participants can judge twice, find new information between rounds and change their opinion without losing face or having to defend this change of opinion. Thus, group dynamics are different from workshop discussions. Anonymity is a very important characteristic of a Delphi survey: Only the administrators know the experts. Comments are possible at every step and the first-round results serve as "psychological anchors" because nobody "knows" the future.

The Delphi questionnaire typically consists of statements about future issues that are formulated in the present tense and have to be assessed by criteria or direct questions. In the case of the Bioeconomy Delphi survey, both short statements and a more comprehensive vision of the flagship project were provided in the first round for assessment and comments. The first four candidate flagship projects were developed at a workshop of the German Bioeconomy Council during the 10th Council Meeting in November 2014. They were discussed, improved and the formulation was refined by a subteam of the Council and Fraunhofer ISI.

2.1 First Round

The survey was designed and conducted using a professional survey tool (EFS). The participants were invited by e-mail. The questionnaire was accessed via a password-protected direct link in the e-mail.

In the first part of the survey, the participants were asked for their own ideas for flagship projects to realize a future bioeconomy. Flagship projects were defined as "new ideas, large breakthrough innovations or even 'visions' with a cross-sectoral and convincing aim. They should be realistic and evoke a big change during the next 25 years." In the second part of the survey, the participants were asked to assess the four candidate flagship projects proposed by the German Bioeconomy Council. For each flagship project presented, the participants were prompted to rate the following aspects[1]:

- **Relevance:** Relevance in this case means that the flagship project bears some importance, that it is significant for the future global bioeconomy or that the participants personally regard its quality as being important. The relevance of the reflected flagship project should be rated on a scale from 0 (not relevant) to 100% (very relevant). The scale was translated into not relevant, slightly relevant, medium relevant, relevant, very relevant.
- **Desirability:** In this case, desirability means that it would be worth having this flagship project realized, that the participant would seek it, regard it as being useful, advantageous or pleasing. Participants were directly asked if they wanted this flagship project to be realized. They could provide a "yes" or "no" answer.
- **Time horizon:** "When do you regard this flagship project as feasible?" Here, the participants could choose on a timescale from 2015 up to 2040, later than 2040, or never.
- **Additional ideas** and **comments** were welcome.

In the third part, the survey prompted participants for a general assessment of priority-setting. "If you

1 Forced decision: The participants had to provide an assessment to carry on.

should invest 100 units of investment capital for the next 20 years, how would you distribute this amount among the 4 flagship projects?"

The survey concluded with personal questions, specifically the self-rated degree of proficiency concerning the single flagship projects (from "no expertise" to "high expertise"), as well as demographic information regarding the "country of residence", the professional background "I work in: science/research, politics, industry, non-government organization, etc.", and the age group. The personal questions were not programmed as forced decisions.

2.2 Second Round

With regard to the four existing flagship projects, the survey tool was programmed to present graphics of the aggregated results of the first round for each project. Furthermore, the description of the four **existing flagship projects** was partly revised to consider participants' feedback regarding lack of clarity. In the second round, the participants were prompted to reassess each project. They had the opportunity to align their assessment with the average valuation or to judge differently. Information on the personal ratings of the first round was intentionally not provided to make the experts really reconsider their valuation.

In the second round, the participants were additionally presented with **specific aspects** or "subvisions" of each flagship project. These specific aspects were derived from the ideas collected during the German Bioeconomy Council meeting and from the numerous comments received for each flagship project in the first round. The aspects were presented in statement form in the questionnaire. The participants were asked to assess the relevance of each aspect on a scale from 0 (not relevant) to 100% (very relevant).

Moreover, three "new" flagship projects were identified and formulated by the German Bioeconomy Council team and Fraunhofer ISI on the basis of the participants' ideas for bioeconomy flagship projects as well as their additional comments provided after assessing the four flagship projects. In order to decide and formulate the new flagship candidates, the study team first clustered similar project ideas that were mentioned several times. The clusters with the highest volume of contributions were given a title and described by using and cross-checking with the original comments in the questionnaire (ideas, comments and other feedback). The new flagship projects were added to the questionnaire and assessed in the same way as the four other candidates. The criteria were again: **relevance** of the flagship project, **desirability** and the **time horizon** (all with a forced decision).

The participants again had the opportunity to provide further **ideas or comments** for all seven flagship projects.

The third part of the survey again presented the decision on "**future investment** of 100 units of investment capital for the next 20 years" but this time the participants were asked to distribute the amount among all seven flagship projects.

Finally, personal **proficiency** or **expertise** had to be indicated; this time for all seven flagship projects. In the second round, the participants were asked to specify the location of work ("Where do you work?").

2.3 Analysis

The results of the first and second round were analyzed qualitatively. New ideas and comments collected in the first round were integrated on the one hand into the "new" flagship projects of the second round, on the other hand they were used to describe the specific aspects of the flagship projects and to refine the descriptions of the flagship projects themselves. Participant comments are further used in this report to document interesting aspects or arguments raised by the participants.

For the purpose of this report, simple descriptive statistics, i.e. frequency distributions and sample means, were calculated with regard to the relevance, desirability and time horizon assessments for each flagship project and survey round. The data collection and analyses for this report were the sole responsibility of the Fraunhofer Institute. More sophisticated statistical analyses, e.g. regarding changing assessments and differences in assessments by geographic location and expertise, will be performed and published in the coming months.

3 Sample Description

The study team aimed to have a stable sample of about 100 valid answers in the first round and 60 valid answers at the end of the second round. As the dropout rates in internet surveys are rather high, it was estimated that at least 500 experts from G7 states and other countries, where bioeconomy experts were identified, should be selected and approached.

Bioeconomy-related expertise spans many topics and disciplines. To construct the sample, the following knowledge areas were specifically considered as bioeconomy-related: biosciences, agriculture, forestry, marine, biotechnology, biobased chemistry, green building, food & nutrition, conservation, biodiversity and sustainable consumption. The sample was built first by considering members of bioeconomy councils, official advisory bodies and dedicated bioeconomy clusters. In a second attempt, Fraunhofer ISI conducted a bibliometric analysis to identify authors of scientific publications classified under the keywords (bioeconom* OR „bio-econom*“). 981 persons were identified via this search. Additionally, the office of the Bioeconomy Council in Germany searched for relevant experts and leaders in science, industry and civil society organizations, who had participated in bioeconomy-related events and fora. In cases where it was impossible to find personal e-mail addresses, the general contact e-mail address of the organization was used.

Finally, in the **first round**, 2,274 experts were invited to participate in the Bioeconomy Delphi. Their professional backgrounds were in science and research, in industry, non-profit organizations, associations, clusters, policy-making and consultancy. From the thematic background, the selection was very broad and the experts were therefore asked to estimate their own proficiency with regard to the individual flagship projects. 492 experts opened the survey in round one, 292 participants completed the questionnaire and 24 gave only a few responses but were included in the analysis.

For the **second round**, 292 invitations were sent out and 148 participants completed the questionnaire. 18 participants answered some questions but did not finish the survey. These answers were included in the analysis.

The **age** distribution of the participants reflects that the sample was drawn from people with a certain level of professional experience: few respondents were younger than 30 (6 persons) or older than 69 years (4 persons). The largest age group was between 50 and 59 years. This question was only asked in the first round.

Experts living in 49 different **countries** took the survey in the first round. The majority indicated that they lived in Europe, most of them in Germany (see Figure 3-1). For the second round, the question was adapted slightly to specifically ask for the workplace. The participating experts indicated that they worked in 38 different countries distributed all over the world. In the first round, the participants were asked about their professional background (Figure 3-2). Two thirds of the participants worked in science and research.

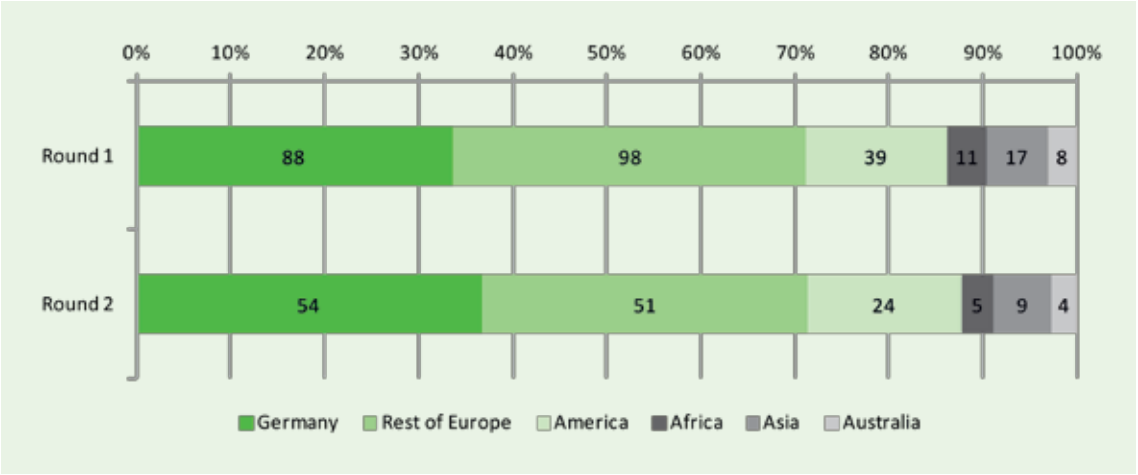

Figure 3-1: Distribution of residency (round 1) and workplace (round 2). for round 1: n=261; for round 2: n=147

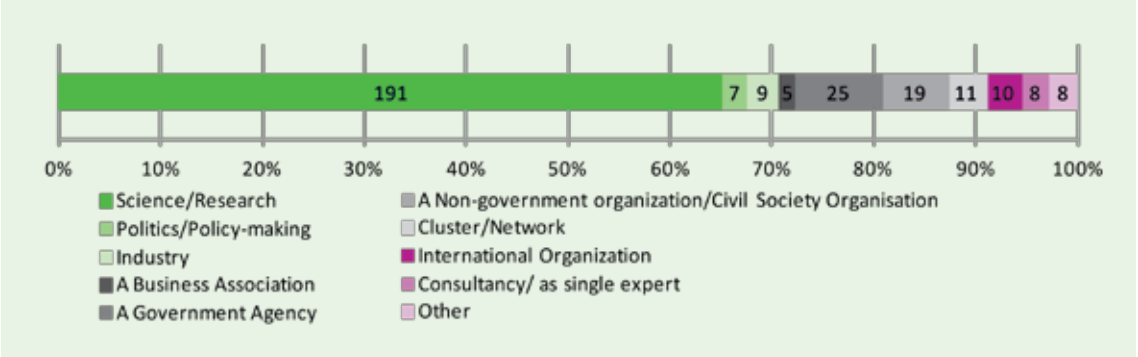

Figure 3-2: Background (affiliation) of the participants. All participants n=293

4 Proficiency of the Participants

The **proficiency** of the participants differed according to the thematic issue of the flagship project. The distribution of the self-evaluated **proficiency** (on a scale from 1 to 5) is shown in the following figures (4-1 and 4-2). In the **first round**, the participants rated their proficiency on average higher for New Foodsystems (Figure 4-1; 40 percent of responses for high and above average expertise, mean 3.16) than for the other three flagship projects. In contrast, in the area of Global Governance nearly 25% considered themselves as experts (high or above average rating, mean 2.64), for Bioprincipled City, there were nearly 24% (high or above average rating, mean 2.65) and for Artificial Photosynthesis 23% that considered themselves as experts (high or above average rating, mean 2.45). Artificial Photosynthesis was regarded as very specific field of expertise (see comments below).

In the second round, the expertise for the new flagship project candidates was found to be on average lower than for the flagship projects proposed by the German Bioeconomy Council (see figure 4-2). With regard to Biorefineries 4.0, 40% of participants considered themselves as experts (high or above average, mean 2.96). For Sustainable Marine Production 20% were experts (expertise above average or high, mean 2.4) and for Developing Consumer Markets 17%. In both cases, more than half of the participants indicated that they had low or no expertise. Regarding the Flagship Projects proposed in the first round, average proficiency rates were highest for New Foodsystems and Global Governance and lowest again for Artifical Photosynthesis (18% experts, mean 2.33).

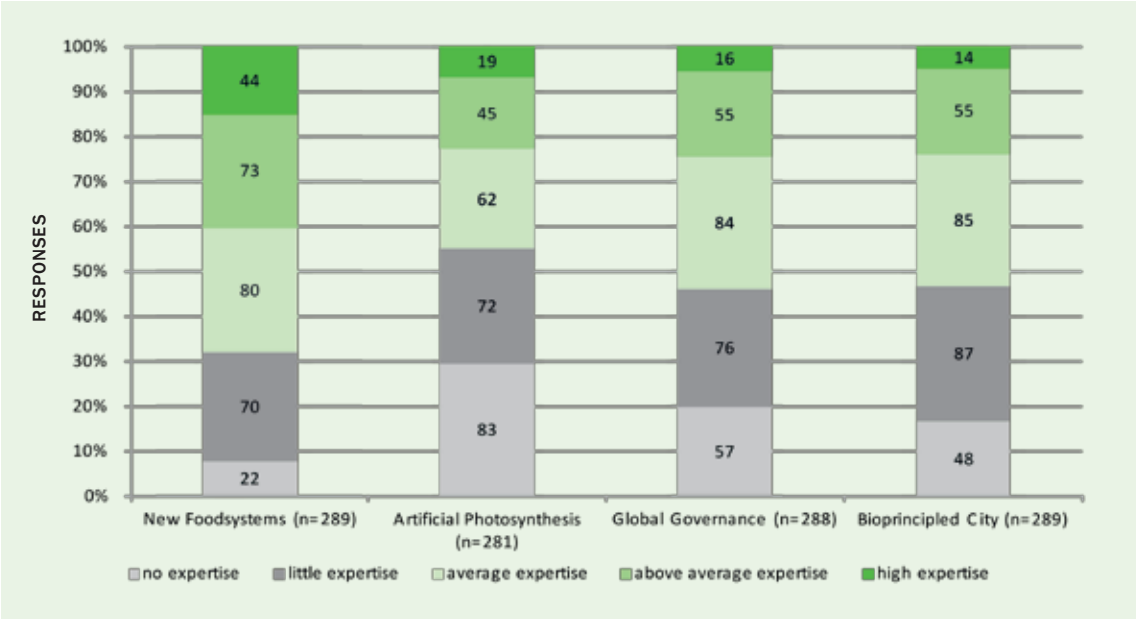

Figure 4-1: Proficiency of the participants in the first round

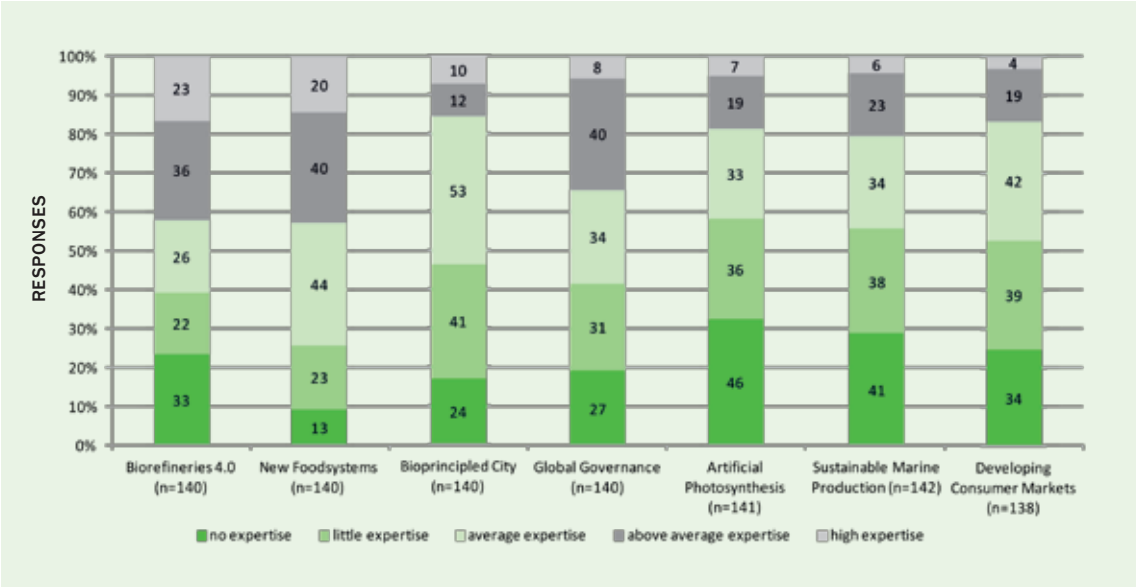

Figure 4-2: Proficiency in the second round

5 Assessment of the Flagship Projects proposed by the Bioeconomy Council

The following section introduces the four flagship project candidates of the Bioeconomy Council – **Bioprincipled City, New Foodsystems, Artificial Photosynthesis** and **Global Governance**. The participants were asked to rate and comment these projects in both Delphi rounds. The report first presents the description of the flagship project in the questionnaire, followed by the results concerning the assessments of relevance, desirability and the time horizon.

About 40% of participants rated the relevance of **Bioprincipled Cities** as very high and around one third of participants considered the project to be relevant (Figure 5-1). The distribution of results for the two rounds looks quite similar (note: participation in the second round was lower). On average, the project received a rating of 74% relevance (on a scale from 0 to 100%) in the second round. When asked to judge the desirability of Bioprincipled Cities, about 90% of participants answered favorably in both rounds (see figure 5-2).

The majority of the respondents estimated that Bioprincipled Cities will be realized by 2040. In the first round, the estimations were distributed rather broadly. Nearly 20% believed in realization by 2020 and 25% thought it would be possible only after 2040. In the second round, the ratings were more conservative on average. Whereas only 7% of participants considered Bioprincipled Cities to be feasible in the short-term, about one third of the participants believed in realization by 2030 and by 2040 respectively. In both rounds, only a few participants could not imagine this project becoming a reality (see figure 5-3).

Asked to rate the relevance of single aspects related to this flagship project in the second round, the participants considered closing material loops, using design solutions that adopt biological principles as well as biobased materials as most relevant (see figure 5-4).

5.1 Bioprincipled City

Background:
In 2045 about 2/3 of the world's population are expected to live in megacities with more than 10 million inhabitants. In the coming 30 years, urban development and construction may require more resources than in the entire human history. Innovative solutions are needed in order to enable these mega cities to function in a sustainable way, to provide quality of life for their inhabitants and for a multitude of (endangered) living organisms.

Flagship Project:
The integration of biological principles into urban planning and city life has become a key element for the achievement of greener cities with high levels of self-sufficiency and quality of life. Locally coordinated production, provision, use and recycling systems ensure that mega cities function on the basis of closed material and energy cycles. Emissions, waste and losses are minimized. Renewable resources, cropping techniques and biotechnology play a major role in closing the loops. Value-chains are based on the cascading use of natural and renewable resources, e.g. water. Urban (vertical) farms are economically and ecologically efficient high-tech production centres. Spaces for recreation, production, services, work and living are integrated and decentralized in city districts. Mega cities innovate sustainable building designs and construction techniques by referring to biological principles and renewable resources. Green areas, and especially the green belts of big cities, are recognized as important retreats and contribute to biodiversity, water regulation and filtration, air cleaning, halting soil erosion and desertification, mitigating temperature extremes (saving energy consumption) and human recreation.

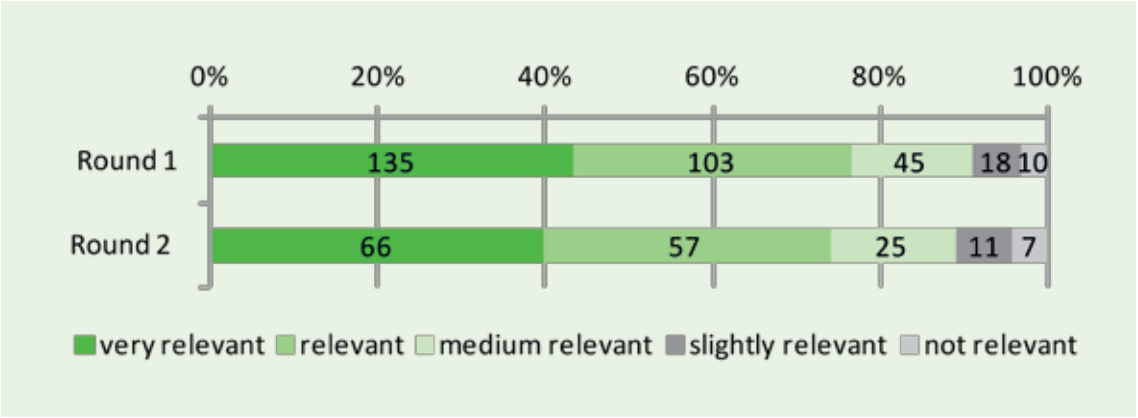

Figure 5-1: Relevance. All participants round 1: n=311; round 2: n=166

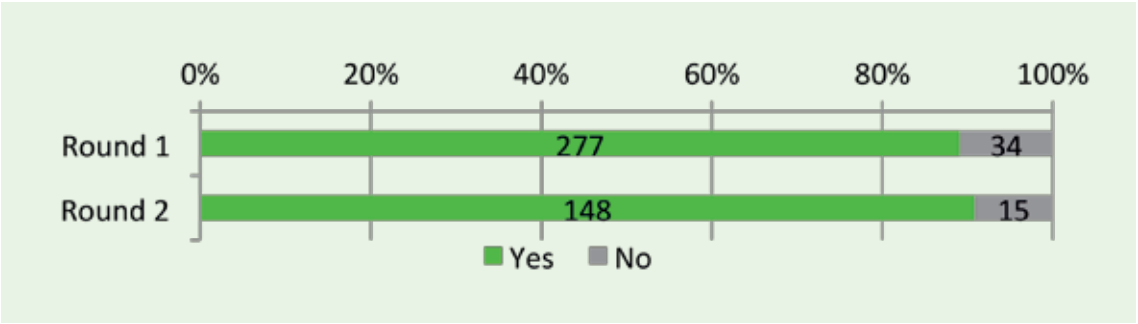

Figure 5-2: Desirability. All participants round 1: n=311; round 2: n=163

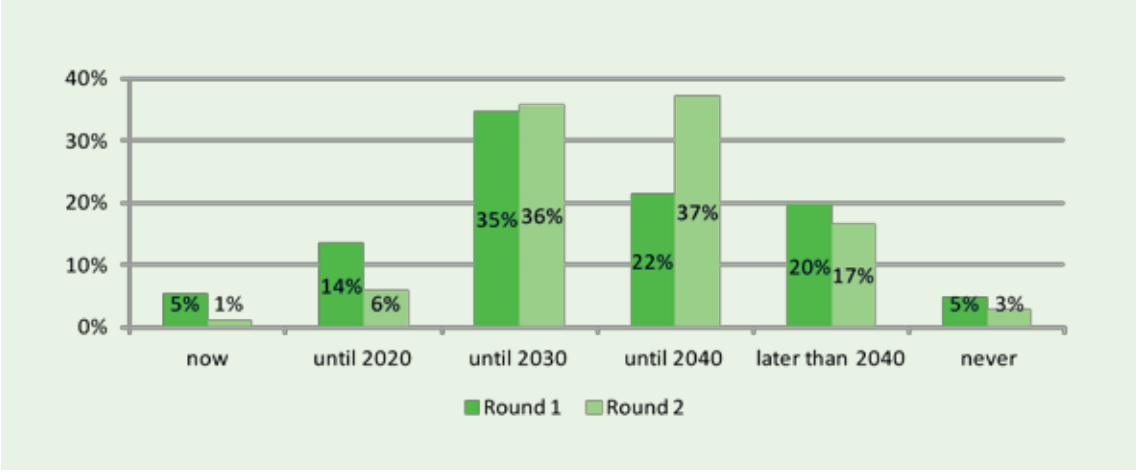

Figure 5-3: Time horizon. All participants round 1: n=310; round 2: n=167

The Bioprincipled City was widely regarded as feasible but with limitations. Some participants doubted its validity in megacities (comments: *"I still really struggle to see this happening in megacities with millions of people living in a very high population density. Smaller towns have a better chance of pulling this off."*). Others saw it instead embedded in a regional context. The dilemma is summarized in the following comment: *"In developing such projects, politics and land prices are going to be the real drivers of reform, therefore there also has to be adequate social policies to protect and rejuvenate run down areas in a socially sustainable manner. Also the closed cycle concept of a city will never*

truly work, as there is not enough natural land (i.e. non-concreted) in the urban area to deliver food, to support biomimicry concepts and recycling. It has to be acknowledged that other areas of land will be needed and of course depending on the size of the city, such area could be massive, in order to supply such cities with food and ecosystem services for recycling nutrients."

Vertical farms and urban farming in general were regarded with skepticism and, if participants argued in favor of urban farming, they stressed the limitations of crops and scale. Comments were, for example: *"Vertical farms are and will probably be non-sense."* or *"Urban farming should focus on the production of plants and vegetable food rather than livestock husbandry and animal production!"*

Transport by bicycle to the extent proposed was also doubted *("I regard the idea that everybody (majority of population) should bicycle as not realistic. Families with 2–3 children and also the aging population, people in their 80–90ties are an increasing part of the population pyramids."*).

Many participants mentioned the regional embedding of Bioprincipled Cities and that they cannot exist in isolation. There were also participants who saw the whole flagship project as having similarities to or overlaps with "Green City" concepts. This was articulated in comments like: *"I do not see this project as an element of bioeconomy. This is green city concept."* The way it is communicated therefore has to be considered carefully (*"Bioeconomy has a problem with communication it´s content due to the broad range of aspects linked into bioeconomy. Many of the aspects mentioned in that flagship idea – (...) – have nothing to do with bioeconomy or would extend the concept into a even wider space. Though I fully support cities and city development as an important aspect of sustainability and sustainability research (...) – linking all these aspects to bioeconomy might further blur the concept and thus finally kill all activities to somehow give bioeconomy a profile!"*). Accordingly, industrial production and Bioeconomy Cities were seen as ambivalent (*"I think industrial production needs to be clean, I just don't think it needs to coexist with residential living. They can be located at a reasonable distance."*)

To realize the flagship project, the different surroundings, regions, existing infrastructure, situation and size thus have to be considered. To have only nice small places as Bioeconomy City enclaves was not regarded as enough. Participants mentioned several times that the whole idea is very much linked to food, on the one hand, and to the change in education and people's behavior, on the other (*"Education and campaigns for sustainable consumption, engaging people for changes in social practices"*). The last three aspects mentioned above were mainly considered in the additional flagship project Developing Consumer Markets.

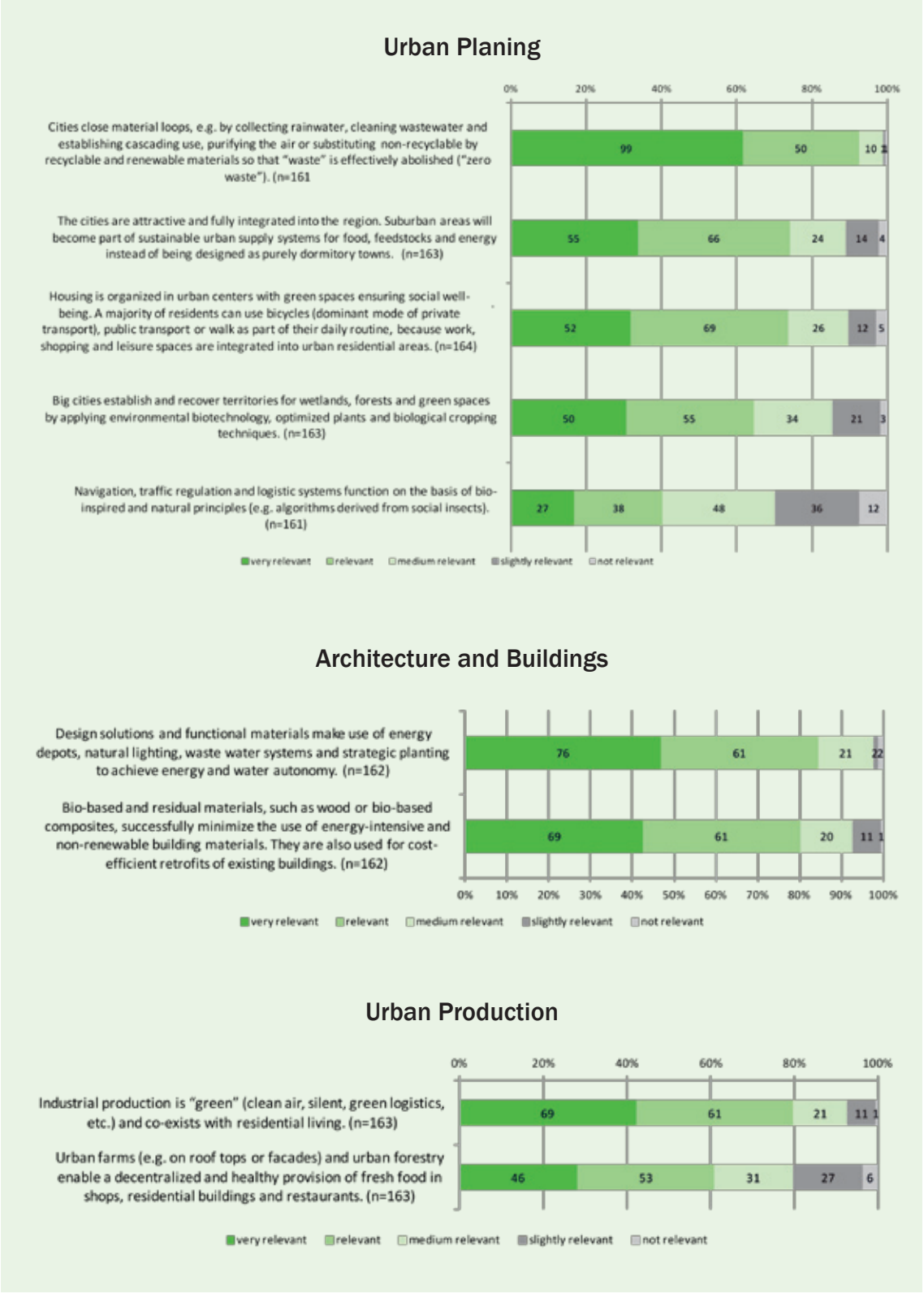

Figure 5-4: Relevance of specific aspects

5.2 Artificial Photosynthesis

Background:
Photosynthesis, i.e. the production of carbohydrates from water, CO_2 and sunlight in plants, algae and bacteria, is the basis of life on earth. When people implement this process in plant-independent systems, carbohydrates, such as sugar or starch, are available in every part of the world, regardless of environmental conditions and in any amount desirable. This can revolutionize the production of foodstuffs and make an important contribution to fighting world famine.

Flagship Project:
Aided by the renewable production of carbohydrates, people are no longer dependent on the use of fossil fuels, thus protecting the environment and nature. This can contribute to the decarbonization of the atmosphere. Artificial photosynthesis is superior to the plant-based systems or the solar cells common in 2015 in terms of sustainability and efficiency. Understanding and applying the photosynthetic process in man-made systems facilitates further steps that produce biofuels or primary energy.

The flagship project targeting **Artificial Photosynthesis** achieved an aggregated score of 61% in the second round (on a scale from 0 to 100%) and was on average considered less important than the other projects. Nevertheless, more than 50% of participants in both rounds judged it as relevant or highly relevant (see figure 5-5). About three quarters of participants in both rounds considered Artificial Photosynthesis (see figure 5-6) a desirable project – but more participants than in the other cases considered it as not desirable.

The time required to realize the outcomes described for Artificial Photosynthesis (see figure 5-7) was estimated on average as rather long. A solid majority of respondents in both rounds estimated that it would be realized after 2030 – if at all. 12% of participants in the first round and 8% in the second round did not believe in its feasibility.

As reasons for late realisation, participants mentioned technical barriers in the comments field but also indicated a lack of competitiveness compared to other solutions for producing sugars or transforming solar energy.

Various participants commented on the fact that Artificial Photosynthesis is very specific compared to the breadth of topics covered by the other three flagship projects. This might explain why relevance and desirability were rated less positive on average than for the other flagship project candidates.

Considering specific aspects (Figure 5-8), the participants were rather skeptical on average as regards the future competitiveness of hydrocarbons produced via Artificial Photosynthesis. The use of Artificial Photosynthesis for energy generation and fuel production was assessed more positively, with more than 60% of participants considering it as relevant or very relevant (see Figure 5.8).

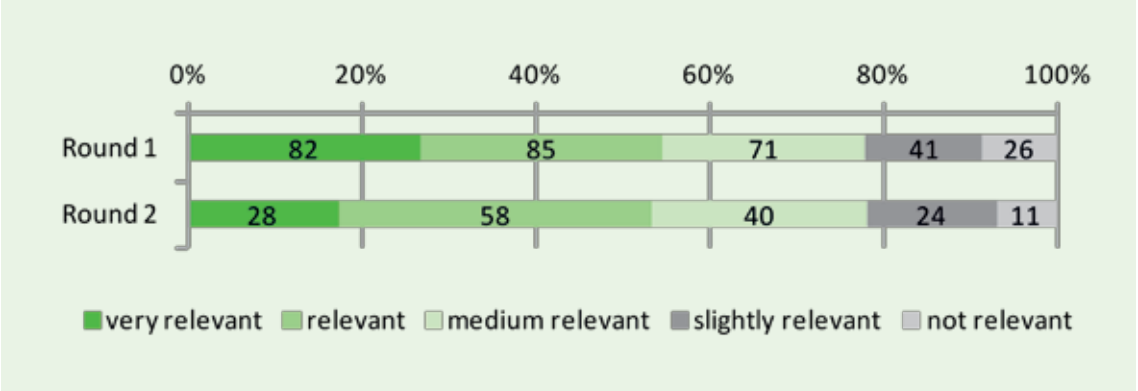

Figure 5-5: Relevance. All participants round 1: n=305; round 2: n=161

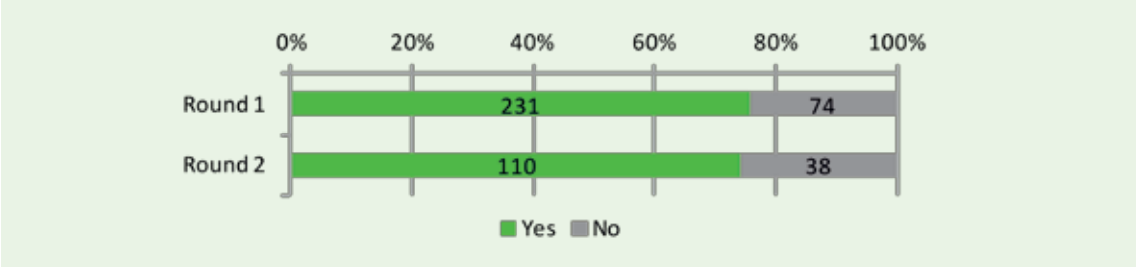

Figure 5-6: Desirability. All participants round 1: n=305; round 2: n=148

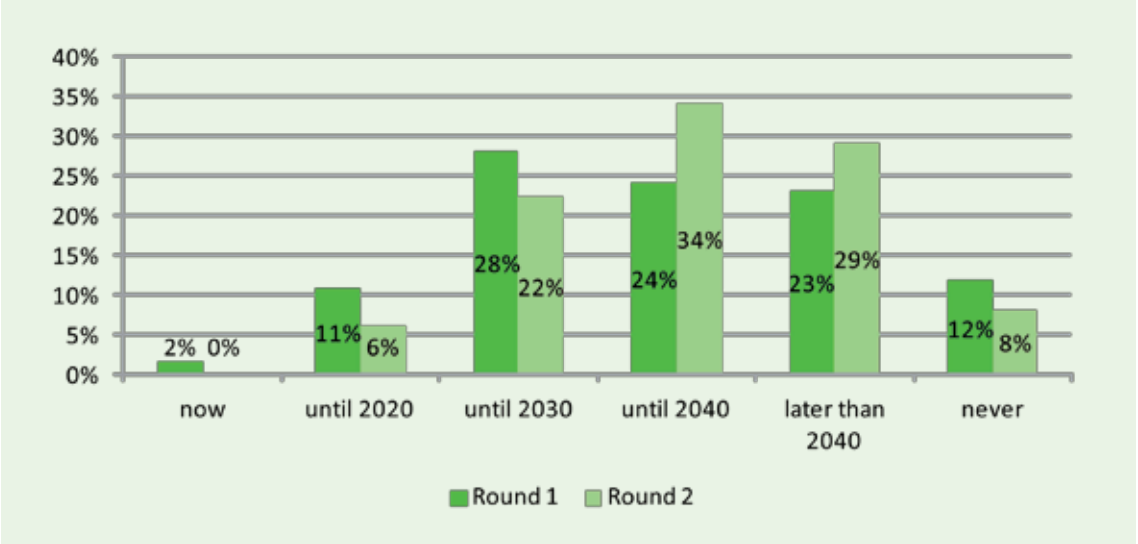

Figure 5-7: Time horizon. All participants round 1: n=305; round 2: n=161

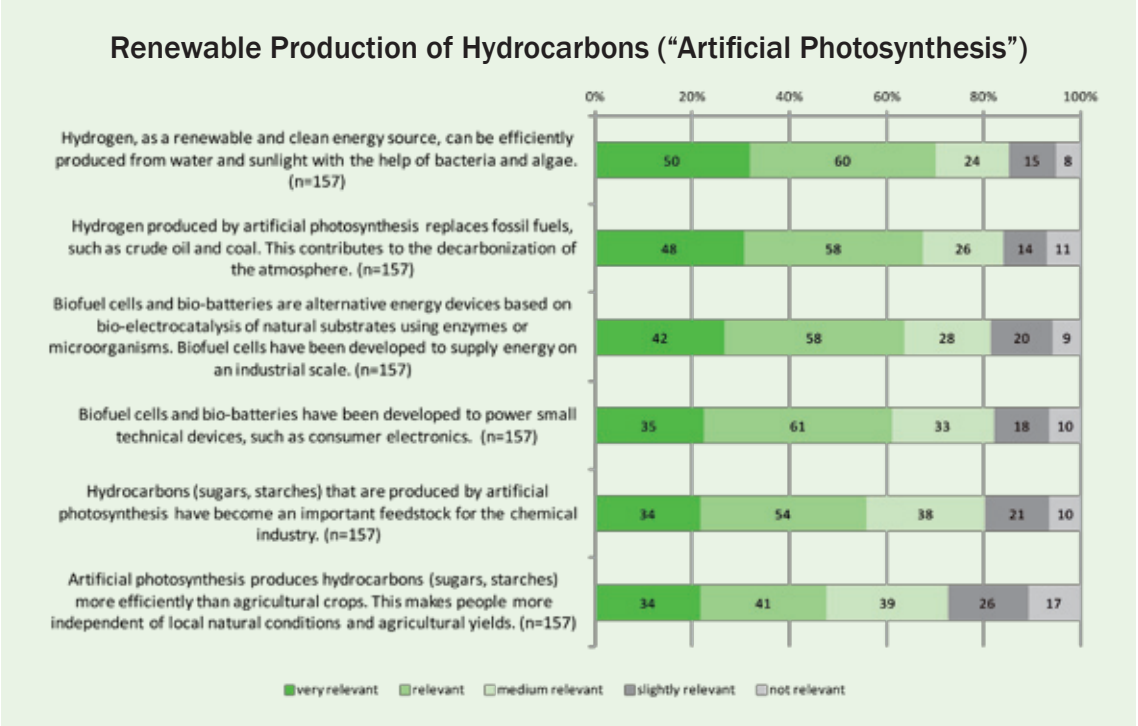

Figure 5-8: Relevance of specific aspects

The comments revealed perceptions of technical challenges, e.g *"The technical difficulties are enormous."; "While I agree photosynthesis is important and this would be a wonderful technology to crack, I am not sure about the materials they intend to employ for such a technology, or the environmental costs of producing, developing and expanding a market on such a technology."* In addition, Perceptions of a lack of competitiveness compared to other solutions were given. *"Why artificial photosynthesis for hydrogenization when water electrolysis is available and could easily be improved much cheaper and faster - and even in future with NO competition for biomass (only seawater and sun...)?"*; *"While this is a fancy topic – it is rather unlikely that such an approach will really be competitive against other technological solutions already much further advanced"*. Perceptions of ambiguity and unclear impacts were also mentioned. *"We cannot copy exactly the energetic production and interactions of nature and we will need to keep in mind the side effects of biophotosynthesis too."*

Some participants just regarded the attempt as a threat or as "crazy" ("*This is techno-hubris to the maximum. It proposes to replace green plants, which nature has developed to harvest solar energy, recycle water, provide oxygen to us air-breathing organisms and feed not only humankind but animals, insects and birds with some sort of concoction of steel and plastic and silicon that may give us a bit more energy per hectare but if widely adopted would be the end of life on earth. (...) Artificial photosynthesis is just crazy."*)
Others considered it only feasible in specific settings and rather on a decentralized level as part of a larger solution ("*Replacing fossil-fuel based products by artificial photosynthesis can only be a part of a larger solution as energy is not the only resource that is limited, e.g. minerals, phosphor etc. are also limiting resources."*). One reason for the more critical assessment of the project might lie with the interpretation of the term "artificial" in this context ("*It should be more clearly defined, what artificial photosynthesis really means. I consider using bacteria and algae for hydrogen production is not artificial but natural."*).

5.3 New Foodsystems

Background:
One of the bioeconomy's key objectives is to feed everyone on earth adequately and healthily. Although the number of people suffering from hunger in developing and emerging countries has been greatly reduced, it still remains at around 800 million people (status: 2014). The demands of the world's growing middle class, which is investing its rising income mainly in consumption, especially meat consumption, are increasing at the same time. As in many industrialized countries, emerging societies are confronted by the rise of lifestyle diseases which are caused by poor diet and lack of exercise. The increasing global meat consumption is leading to an increase in resource consumption and CO_2 emissions, while the complex processing and packaging of food contribute to this and the volume of generated waste increases.

Flagship Project:
Sustainable consumption is implemented in new food concepts. Low-emission agriculture which sustains biodiversity contributes to this. The food industry offers products that represent an attractive alternative to resource-intensive meat consumption based on new sources of protein in plants, algae, fungi or insects. Individually tailored foods ensure that people receive a varied and healthy diet within the scope of new supply concepts. Efficiency gains lead to losses being prevented or re-integrated into the material cycle along the entire value chain. Regional approaches are implemented where appropriate.

The results regarding relevance (Figure 5-9) and desirability (Figure 5-10) of the flagship **New Foodsystems** give a clear indication: more than 70% of respondents in the first round and more than 80% in the second round considered New Foodsystems as very relevant or relevant. In the second round, the mean relevance rating was 79% (on a scale from 0 to 100%). Nearly 90% of experts considered it as desirable.

The majority of participants in both rounds regarded the flagship project as being feasible by 2030 (see figure 5-11). In the first round though, the participants seemed more optimistic, nearly a third thought that the project could be realized by 2020. In the second round, there was a peak in responses for the category "until 2030".

Looking at the assessments of detailed aspects of the flagship project, the picture is a bit more differentiated (see figure 5-12). On average, participants considered it important for food losses to be prevented along global supply chains and for agriculture to work in a sustainable way. The consumption of more healthy and environmentally-friendly diets, such as alternative proteins, also scored high in average relevance. Personalized nutrition and microstructured foods received lower average importance ratings.

Whereas in general, the New Foodsystems were assessed as desirable and relevant, even as a "must" (*"The importance of this project is very high. However, today we face challenges that impede the fulfillment of the basic ideas of the project: - poor coordination of control systems for food at the global and national levels; – a large number of standards for the production and sale of food products; – inequality in access to quality food due to their value; – insufficient dissemination of the values of a healthy diet; – the risks of new biotechnologies for food."*), the formulation of the flagship project as such was slightly criticized for having too many different aspects, conflicting objectives and integrating too diverse pathways: *"This flagship project appears to start with several objectives that are not well accepted by the public and which seem to think they can displace the economic system across a large number of countries. A more fruitful approach is to determine how to work within a market context to achieve objectives that are well support by the public". "You are mixing too many too diverse pathways (3D-food-printing – zero waste)."* or *"There are some conflicting ideas in the topics outlined above, how can you have global markets for food, yet major amount of food is produced within a 100km from a particular demand sink?"*

Some participants regarded it as "idealistic" and missed the very concrete solutions to achieve it *"The second point is slightly idealistic, unless they can establish farm equipment and systems that eradicate the need for monocultures, this point will*

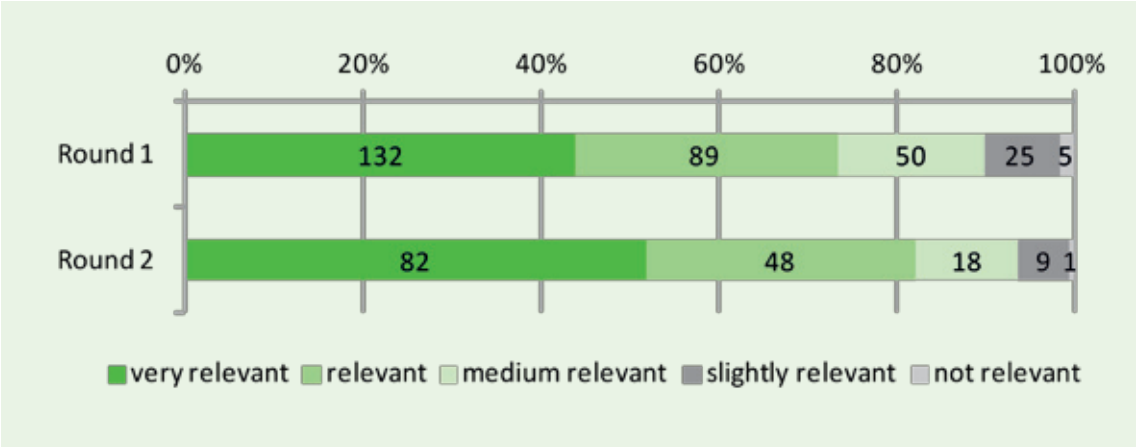

Figure 5-9: Relevance. All participants round 1: n=305; round 2: n=158

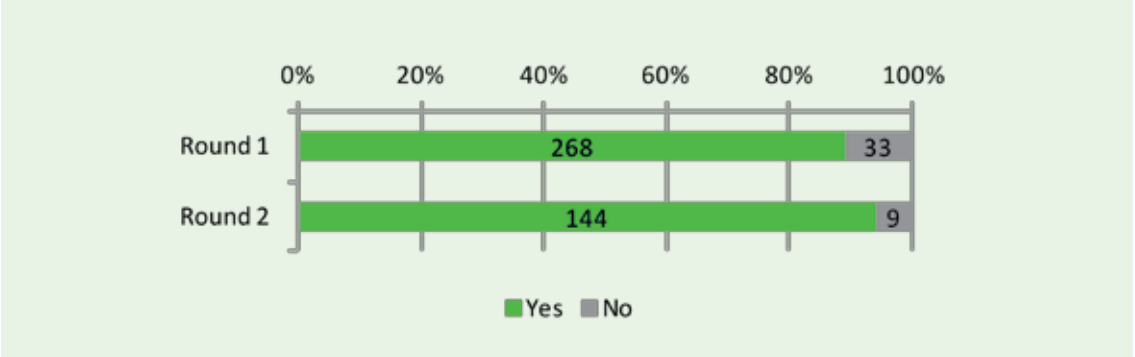

Figure 5-10: Desirability. All participants round 1: n=301; round 2: n=153

never be realised, the fundamental core of modern agriculture is monoculture and mass production at the expense of diversity. What about meat consumption – how do they envision tackling the issues related to massive meat production industries, i.e. if the production capacities are reduced, what are the alternative solutions? They outline all the idealised situations, but provide no insight into potential solutions for achieving them."). Others made additional proposals, e.g. white lupins for protein production which is already available, for example, in German vegan milk products.

Reducing the consumption of meat seemed to be welcomed by many experts although current trends indicate a further increase. While this is a global issue, regional issues relating to Foodsystems were also mentioned. One is that some participants doubt the 100 km principle (*"All parts of the world need to be linked on food/protein production. The 100 km rule for food does not work in all parts of the world." "To foster vibrant rural spaces and avoid a further growth of mega cities and their surroundings, food should be grown even further away than 100km. In addition, food should be grown where the natural ecosystems are apt for this type of production to reduce environmental effects, input use and resource exploitation (e.g. water) as much as possible. Food imports are good when they foster trade with low- and middle income countries who have enough agricultural resources to feed their own population and export that helps them to further develop (...)", "Again, the ability to feed a city from the solar energy captured in a given radius is quite constrained."*

Other concerns included regulation and food policies because decisions on nutrition should remain personal and *"The role of religious beliefs or esoteric/anti-scientific beliefs has to be critically discussed. Moreover, the food supplies (production of food) are not the main obstacles, but uneven food distribution (extreme poverty vs. unempathic consumption by affluent people)."*

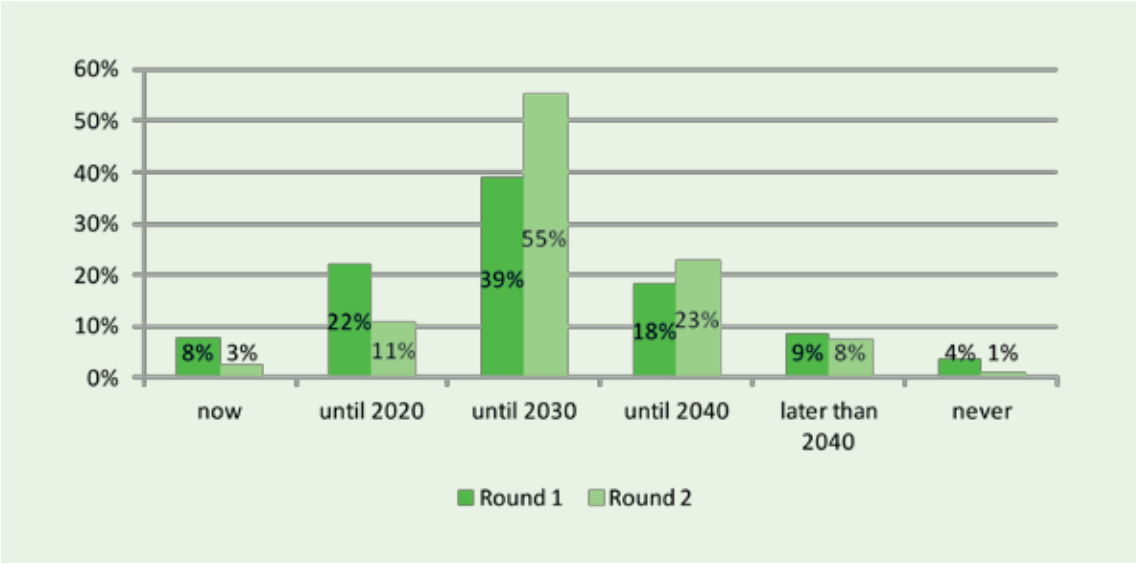

Figure 5-11: Time horizon. All participants round 1: n=301; round 2: n=158

Figure 5-12: Relevance of specific aspects

5.4 Global Governance

Background:
The bioeconomy is also based on the international division of labour, foreign investments and international trade in feedstock, services, technologies and biobased products. Experience shows that international exchanges in the bioeconomy do not automatically ensure sustainable development. Recent examples are land grabbing, rising food prices due to speculation and industrial uses or monoculture plantation of economically interesting crops.

Flagship Project:
To take full advantage of the positive potential of the bioeconomy, a global policy framework has been adopted by most countries active in the bioeconomy. The framework defines the guiding principles of fair exchange, specifically respecting the sustainable development goals (ending hunger, ensuring eco-system performance, maintaining biodiversity). Mechanisms for monitoring and ensuring food security, protecting biodiversity and the eco-system performance are in place. This includes principles for knowledge sharing and intellectual property rights.

The vast majority of participants thought that the **Global Governance** flagship project was relevant (see figure 5-13) and desirable (see figure 5-14). It received an average relevance rating of 70% in the second round. However, nearly 20% of experts were sceptical and considered it as "not desirable".

Concerning the time horizon for realization (see figure 5-15), the results of the two rounds indicate some degree of uncertainty in the estimate. On average, the evaluation differed between the first and the second round. Overall, there was a slight shift towards a later time for realization (which might be due to the sample composition in the second round). In the first round, the assessments were rather broadly distributed. In the second round, more than one third of respondents believed in realization between 2020 and 2030. However, still half of the respondents estimated that Global Governance was only feasible later than 2030. 15% in the first and 14% in the second round even regarded this flagship project as not realizable. Looking at different aspects of the Global Governance flagship project, all of the proposed issues received positive relevance ratings from more than 60% of respondents (see figure 5-16). Sustainable development of the bioeconomy, specifically sustainability criteria and ensuring food security, were among the aspects with the highest average relevance ratings. However, differences in the ratings seem rather small and it is therefore not possible to single out Global Governance issues that are clearly more important than others.

Irrespective of the positive ratings, there were some critical comments about the flagship project hinting at existing barriers and specific aspects (see figure 5-16), e.g. *"This proposed flagship seems doomed to failure because it proposes to replace the current market economy within countries and international trading regimes across countries rather determining how to work within that system to achieve a set of goals."*; *"It is all fine, but what is at stake here regarding the international division of labour, foreign investments and international trade is a fundamental shift of the running system – and not an additional global policy framework adopted by most countries active in the bioeconomy, supposingly based on voluntary but in no way binding guidelines/principles. Whatever positive potential of the bioeconomy will end in a dead lock, if there will be no paradigm shift and globally we stick to the current growth-orientated economic system."* or *"The question – is trade part of the problem or the solution?"* One expert even regards it as *"greenwashing for biotechnology approaches?"* (but intentionally with a question mark).

On the other hand, experts mentioned in their comments that risk policies have to be dealt with, and the project was seen as contradictory to the current market economy which is only growth-oriented.

Others thought that the idea did not go far enough: *"I would like to see some grassroot initiatives and social media elements integrated to this flagship project. (...) Citizen-based monitoring with mobile phone applications will be used to check and ensure adoption of sustainable practices in certificated production systems etc"*

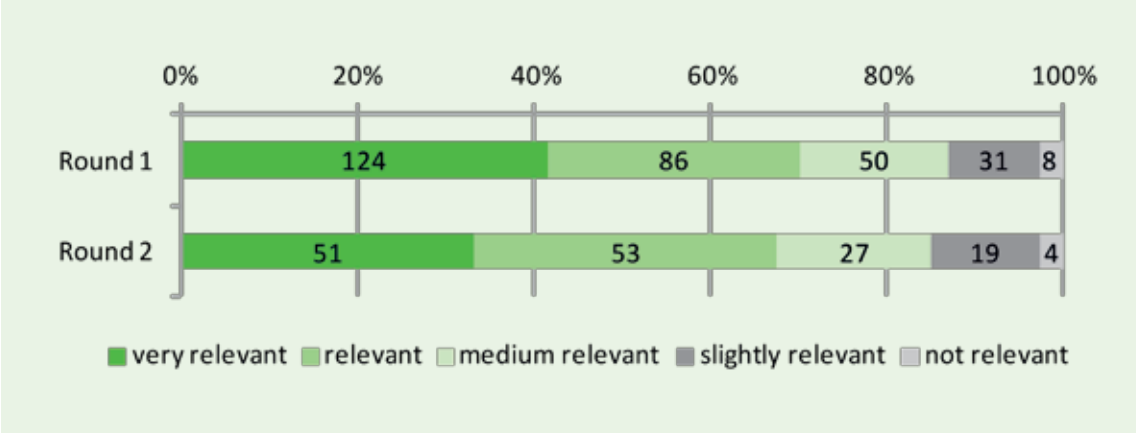

Figure 5-13: Relevance. All participants round 1: n=299; round 2: n=154

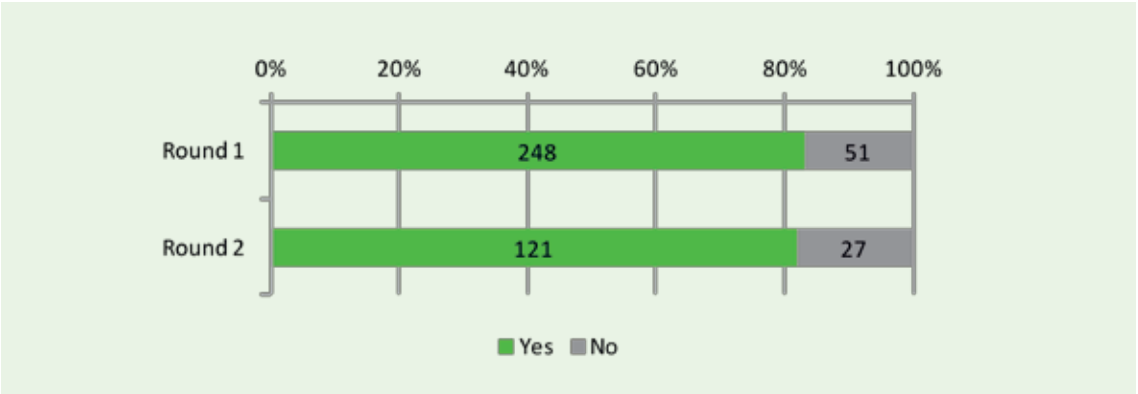

Figure 5-14: Desirability. All participants round 1: n=299; round 2: n=148

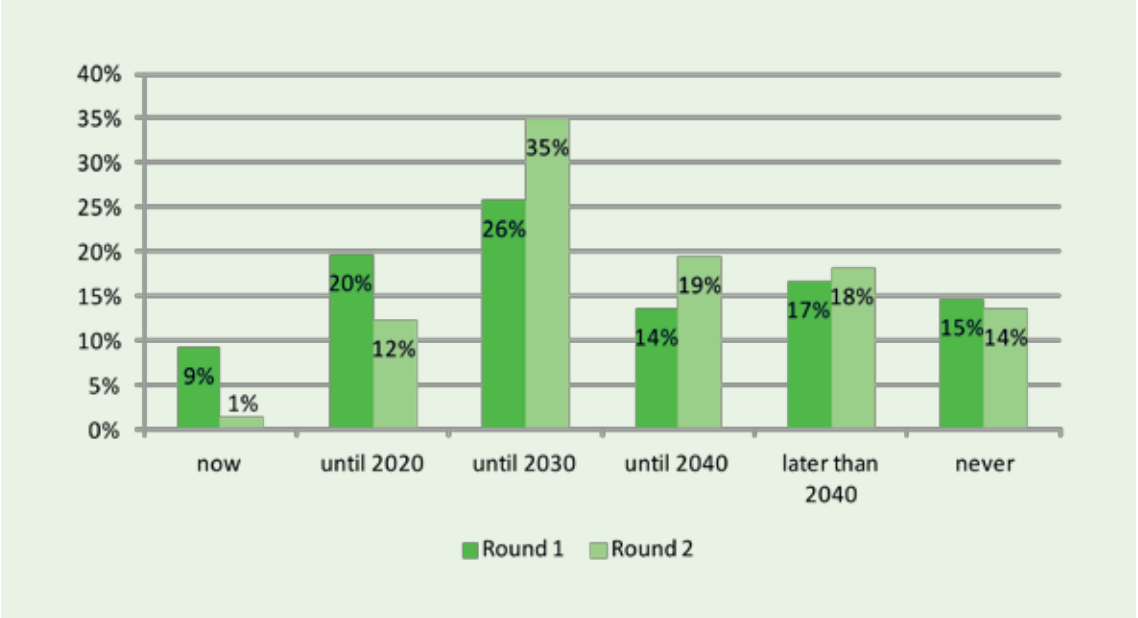

Figure 5-15: Time horizon. All participants round 1: n=299; round 2: n=154

And some experts did not see people well-prepared for Global Governance: *"This project presupposes a degree of wisdom and selflessness in humankind that I see no evidence for in the world around me. (...) I like these standards for local or regional application. I think they would be used as tools to oppress and manipulate on a global level."* or *"Principle obstacles lie in the nature of human beings which are organized in societies and nations/ states. The interests of these will not converge into insights as history has shown too often."*

Figure 5-16: Relevance of specific aspects

6 Assessment of the "New" Flagship Projects derived from Participant Ideas and Feedback

The following section describes the "new" candidates for flagship projects that were derived from participants' ideas and proposals collected in round one. The project team formulated the following projects: **Sustainable Marine Production**, **Biorefineries 4.0** and **Developing Consumer Markets**. Although many participant comments were considered when detailing the existing flagship projects and when formulating the new project candidates, it was not possible to integrate all proposals and ideas received.

6.1 Sustainable Marine Production

To meet the needs of a growing population and an expanding bioeconomy, sustainable aquatic cultivation of marine organisms has gained importance. New methods not only complement fading yields of non-sustainable fishery. They bear new potential to grow and harvest algae, mussels, krill, plankton and other marine organisms in seafarms that are operated environmentally friendly (e.g. avoiding antibiotics, preference for plant-based protein). Algae for example serve as a source for food and food supplements (e.g. omega 3 fatty acids), feed as well as fine chemicals (e.g. oils). Algae and marine plants are exploited to produce hydrogen and biomass for the production of energy (biofuels). Marine production is carried out sustainably by applying bio-principles and bioeconomic modeling and simulation tools. The cultivation processes are associated with additional positive effects for the environment e.g. treating marine littering (e.g. plastics), filtering harmful substances out of the water or protecting the seashore.

A majority of participants in round two assessed the flagship project envisaging **Sustainable Marine Production** as being very relevant or relevant (see figure 6-1). The average score was 73% (on a scale ranging from 0 to 100%). About 90% of respondents considered the project as desirable (see figure 6-2).

The flagship project which was formulated on the basis of ideas and comments collected in the first round was considered by a majority of respondents as feasible in the mid-term (see Figure 6-3).

Comments showed that Sustainable Marine Production was appreciated as a good idea (*"This is a very good idea. However, now we already have aquatic cultures for fish, etc., which are not environment-friendly - therefore the technology in this area has to be improved very much"*; *"Very important short term project"*), especially if it is possible to *"balance production quantity (which seems easier) and quality of fish etc."*.

But the participants also pointed to constraints: *"The main question is, if Germany would be the country to drive this. There is already a lot on its way in this direction in Northern countries and in Asia."* Environmental damage and problems like those in agriculture were feared (*"I don't like the idea of additional industrial production of food in the sea, which will cause the same problems as our conventional agriculture. We have to live better with what we have."*) and overall realization is commented as between very short-term and completely unrealistic (*"Looks too much like a 'ideal' scenario. Doesn't look feasible. (...) Everything seems to be driven from a human perspective."*). The aims mentioned in the description of the flagship project were regarded by some commentators as too broad, and experts warned of technical challenges of different kinds.

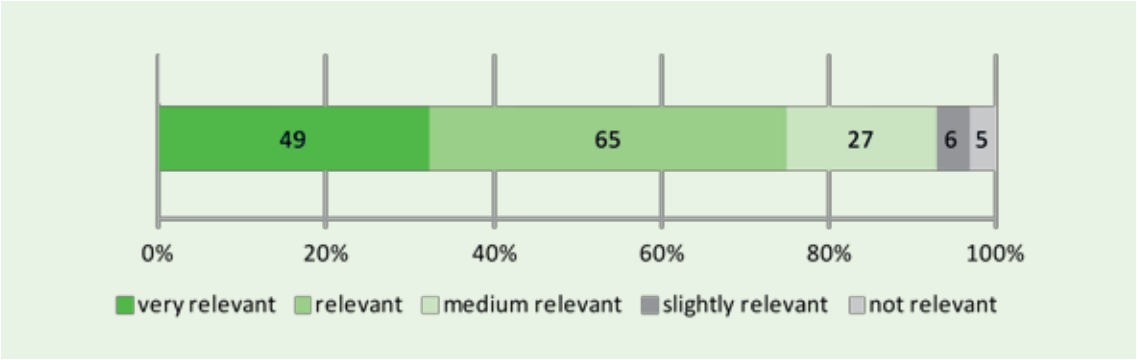

Figure 6–1: Relevance (n=152)

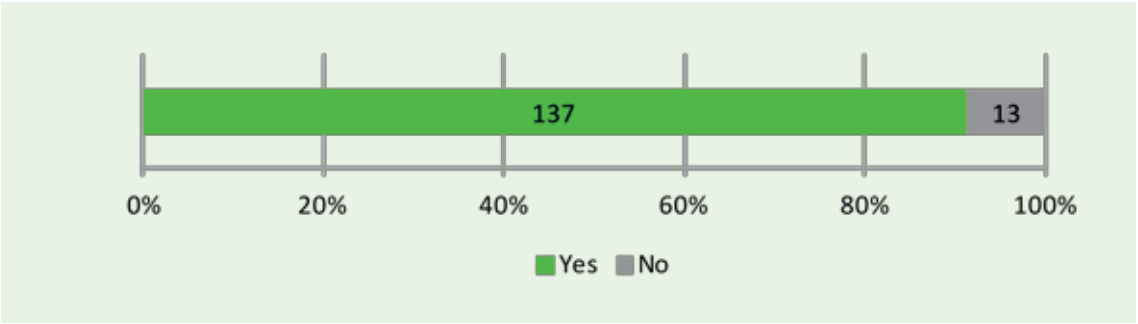

Figure 6-2: Desirability (n=150)

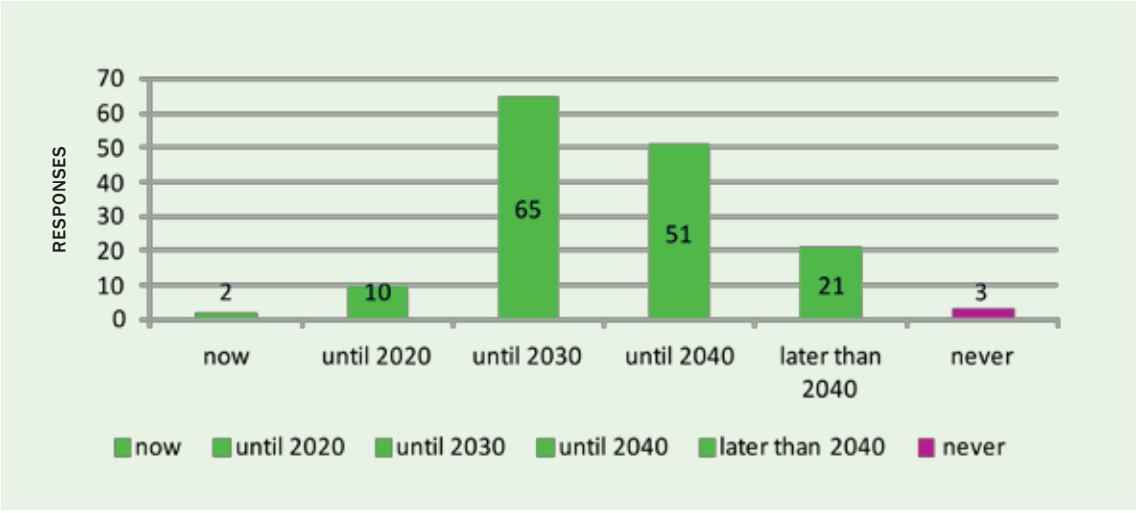

Figure 6-3: Time horizon (n=152)

6.2 Biorefineries 4.0

Biorefineries of the fourth generation have gained large economic importance and form an own industrial sector. The basis of which are multi-purpose concepts converting lignocellulose-containing feedstocks (wood, straw etc.), algae, food and even plastic waste efficiently and flexibly into energy, fuels, bulk and fine chemicals. Biomass is an established source for active pharmaceutical ingredients which are produced in energy-efficient biocatalytic downstream processes. Overall, any carbon-containing waste can be transformed via gasification or enzymatic biotransformation. The production capacity of all biorefineries makes up 10 to 20% of the chemical and petrochemical industry. The dimension and number of agricultural monocultures has been reduced. The dilemma "food vs. fuel" is solved. The new biorefineries fit elegantly into the landscape and do not produce "waste" anymore: a zero-waste circular economy is a reality.

Biorefineries 4.0 were assessed as being very relevant or relevant by nearly 80% of the experts, with an average score of 75% (on a scale ranging from 0 to 100%) (see figure 6-4). Biorefineries 4.0 were also judged as highly desirable, with more than 90% approving the project (see figure 6-5).

Biorefineries of a new generation were largely regarded as feasible. About half the respondents indicated they believed in realization by 2030 and nearly a third by 2040 (see Figure 6-6). This is backed by some comments: *"This is an achievable target." "The project is important. We must pay attention to the safe use of biowaste in food production."* but also *"This project is really desirable! However, Germany often suffers from the fact, that the industrial sector is not willing to adopt new production strategies, because they live well with their old, established strategies..."*

Interestingly, the target market share of 10–20% for Biorefineries proposed in the flagship project was even regarded as too low by one commentator: *"The number of 10–20% is too low, a number of 30–50% should be envisioned."* New biorefineries should not only replace fossile-based products with biobased ones but experts should also go a step further and think of new concepts (circular) which was recommended in the comments. Biorefineries might be able to contribute to waste reduction but again zero-waste was doubted: *"I do not think zero-waste is realistic. Minimized, yes, zero, no. Moreover the cellulose still has to come from somewhere, and I think we should carefully consider what we put in there."*

Technologically, the participants mentioned some new possibilities, e.g. *"Modern genetic technology allows a more diverse use of the microbial world than just the well-known production strains, which are often very inefficient in producing specialist products (...)" "The sustainable, low energy biorefinery will depend on novel catalysts, designed enzymes and functionally expanded cells. Cells have the advantage, that they are biocatalysts which can be grown and easily been scaled up. Thus a focus on such systems is important."* It was regarded as even more interesting, if different feedstock could be used – this was one of the opinions.

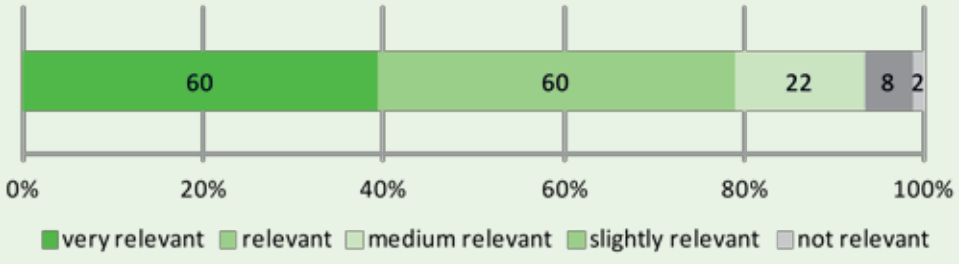

Figure 6-4: Relevance (n=152)

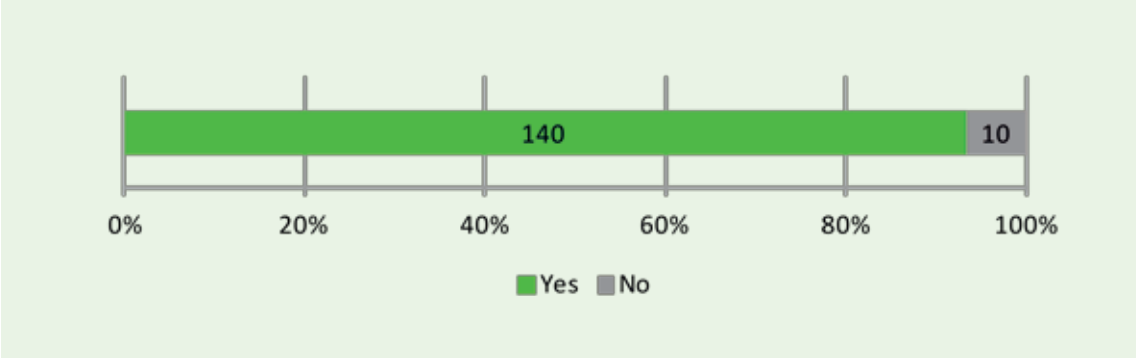

Figure 6-5: Desirability (n=152)

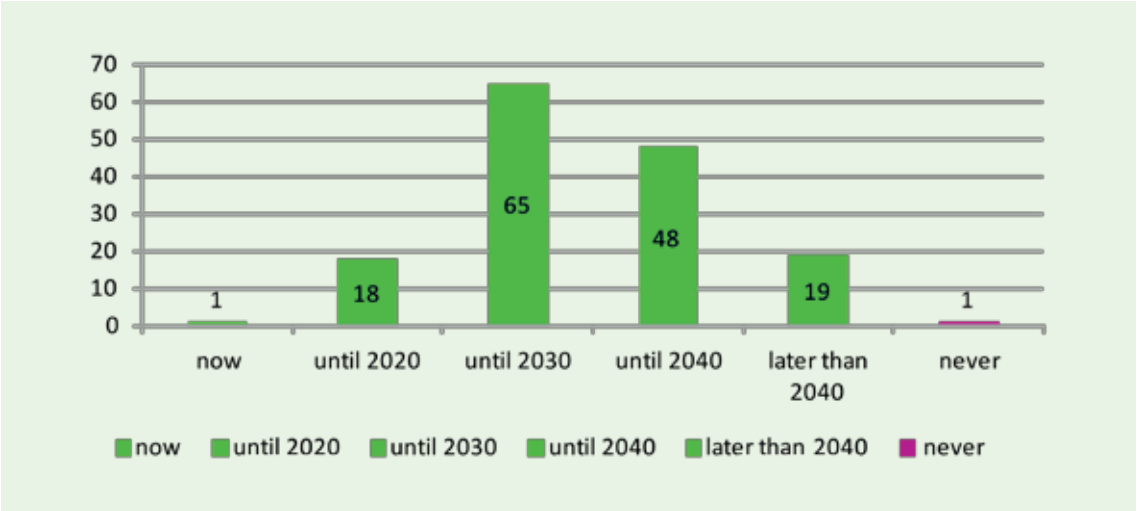

Figure 6-6: Time horizon (n=152)

Experts pointed to the fact that as a consequence Biorefineries 4.0 will require new logistics: *"As to minimise transport of raw materials, biorefineries should be designed to operate at local or regional level, close to where the feedstock is being produced. This flagship may require new logistics, both in physical and economical terms."*

6.3 Developing Consumer Markets

Bioeconomy under the principle of sustainability is a part of everyday life. The foundations of Bioeconomy are integrated into primary education. Higher education transfers knowledge on the complex interplay within the Bioeconomy. Entrepreneurs, engineers and farmers have access to hands-on training in biobased technologies and economy. These efforts contribute to a new understanding of sustainability. Preserving nature by using it, is part of it. People are used to think in categories of renewability and re-usability and are trained in adapting their behavior to new knowledge. Useful and easy-to-understand labels or apps inform of a product's life-cycle cost. Consumers and entrepreneurs prefer sustainable, biobased products and understand the costs and benefits involved. Consumption becomes more value and less quantity oriented.

Participatory approaches are common in policy making at local, regional and national level. Citizens are involved in different sustainability projects and learn by doing. There are no taboos for creativity in research & development – but risks are made transparent and are not neglected. Marketing and product development rely strongly on consumer collaboration and feed-back.

Developing Consumer Markets for the bioeconomy of the future was regarded as relevant (see Figure 6-7), although with an average score of 67% this flagship project was rated a bit weaker than the other "new" flagship projects.

A majority of participants found it beneficial to develop consumer markets as described in the flagship project. However, around 20% did not like the project (see Figure 6-8). This is a rather high percentage compared to the other flagship projects.

The estimated time horizon for the realization of this flagship project reflects a classic "undecided" situation (bell-shaped curve) with as many experts saying "now" as "never" and the assessments peaking in the middle of the timeline, i.e. realization by 2030 (see Figure 6-9). This may be due to the vagueness of the flagship formulation, some comments pointed out that the title seemed to be misleading: *"The title is clearly misleading. The description is about educated consumers and not development of a market (which only happens indirectly). It is clearly needed to work with the society and in education"*.

On the other hand, consumers were definitely regarded as the starting point for the bioeconomy of the future: "*This flagship is the starting point for all other initiatives if they want to be successful because without consumer participation all other flagship will fail.*" "*Be sure to include this project in the discussion. Bioeconomy is primarily the people who create the conditions that produce and apply knowledge in their lives.*" and "*This is needed to start immediately. Many consumers are not willing to pay a 'green premium', even for a supermarket plastic bag. Bio-based products cannot be sold on*

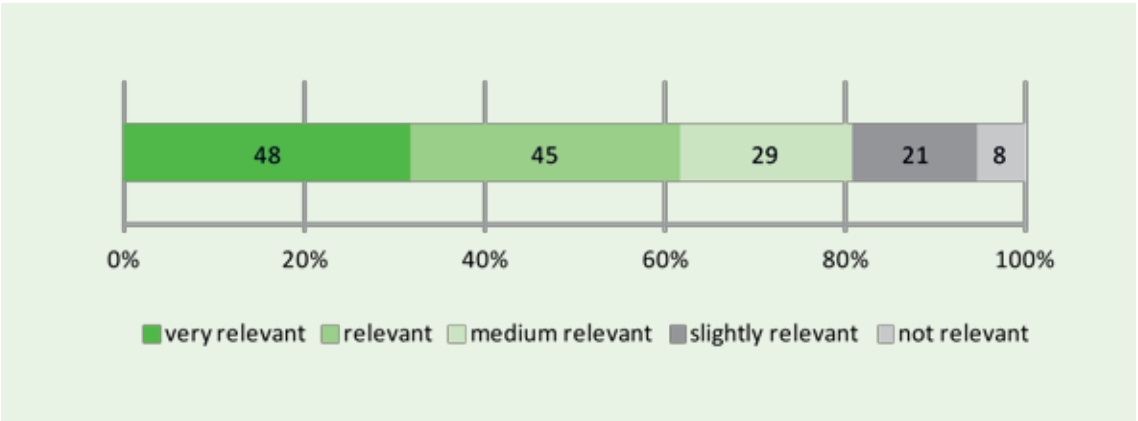

Figure 6-7: Relevance (n=151)

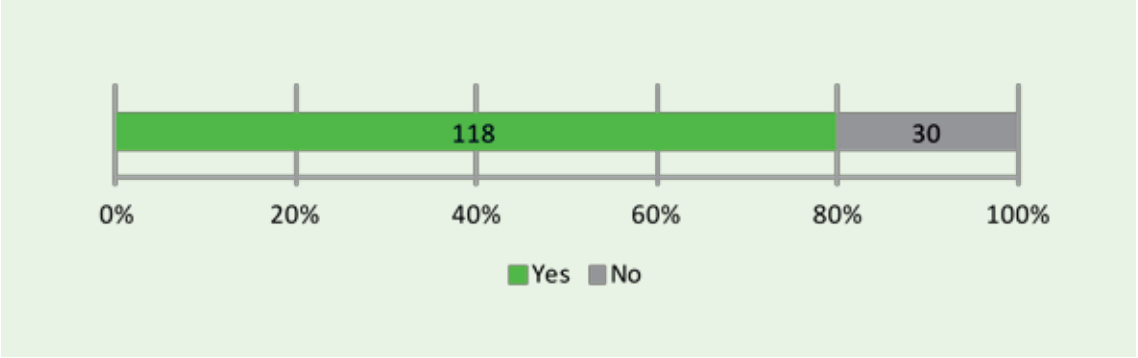

Figure 6-8: Desirability (n=148)

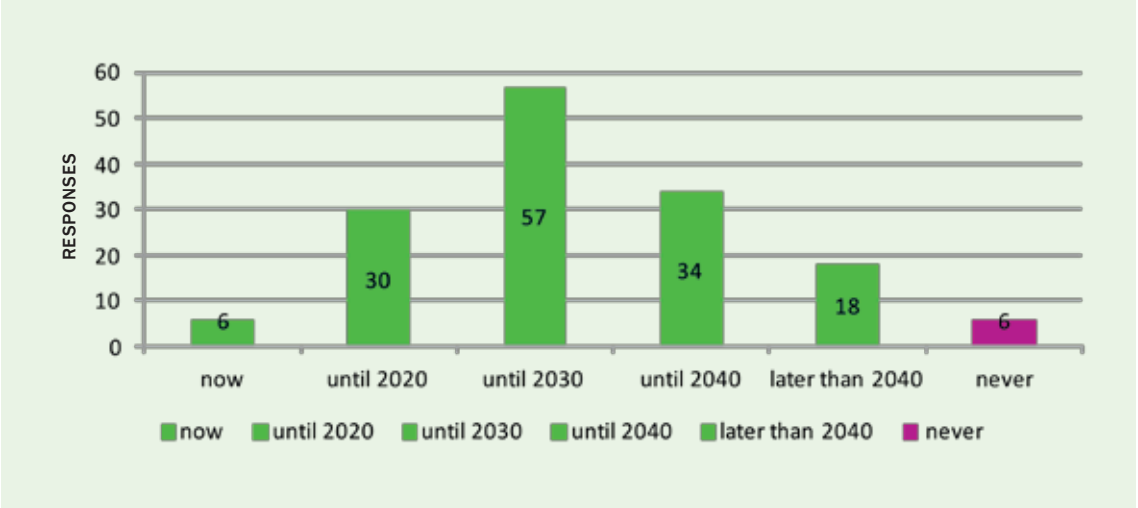

Figure 6-9: Time horizon (n=151)

their green credentials alone - they must be economically competitive (...). This absolutely depends on consumer buy-in."

Experts regarded sustainable behavior and education as key and mental changes as necessary for realizing a bioeconomy. But *"Sustainable behaviour is more often than not an economical question!"* and *"A mental change needs to be that people become aware of the fact that we need to change from consumers which (often) irreversibly use resources as much as we can financially afford it - that has to be changed to a mindset where everyone becomes aware of the fact that we can /should only use what we can in a renewable and sustainable fashion." "I am sceptical about the effect of learning alone. Learning something may help changing something, but it does not necessarily change my behaviour."*

Incremental learning and slight changes do not seem to be forceful enough for some of the experts: *"How much is enough? The above project does not represent a paradigm shift from excessive consumption."* was therefore one of the critiques.

Developing Consumer Markets is also about labeling products based on the full lifecycle costs – and politics and the economy have to participate: *"If consumers see directly the environmental impact of their purchases, it should lead to significant changes in consumption patterns. The problem is just to do this in a fair and standardized manner which is accepted by the majority of producers." "Politics and economy also have to participate! For example, people usually would not like to buy clothes from production plants, where employees are treated like slaves. People are already well informed about that. Ethics have to be established."*

7 Future Investments

The participants were further asked to distribute 100 units of future investment to the most beneficial projects. For the first round, they could spend it on four candidate flagship projects and for the second round on seven different flagship projects. As the following figure (7-1) indicates, in the first round New Foodsystems and Bioprincipled Cities received higher average shares than Artificial Photosynthesis and Global Governance. At the end of the second round, the distribution was nearly equal on average and the projects all got between 14 and 18 units except Developing Consumer Markets (9 units). Without further analyses, it is difficult to derive any priorities from the participants' investment behavior in the survey.

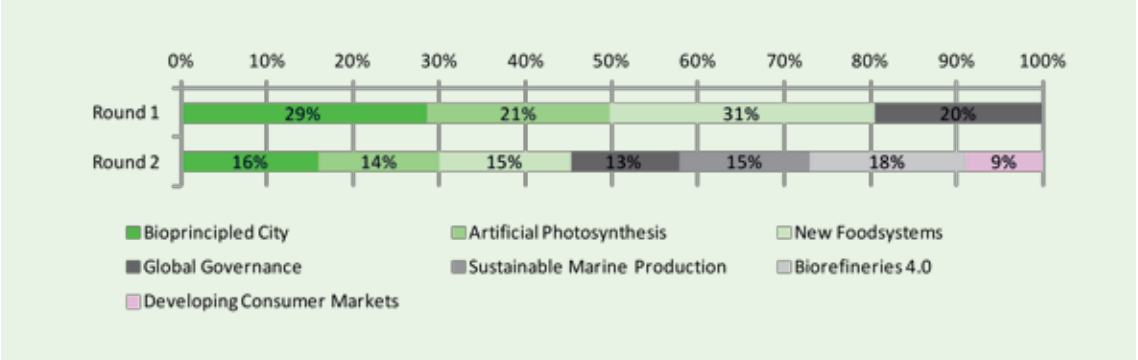

Figure 7-1: Distribution of 100 units of future investment

8 Outlook

Looking ahead, all proposed Bioeconomy flagship projects were regarded as important and desirable with differences in the details. The flagship projects were regarded as feasible – but experts pointed out that they still see a lot of challenges, some of them more general (e.g. culture changes), others more detailed (e.g. technical problems). The technical challenges for Artificial Photosynthesis, for example, seem to be the highest. Some flagship projects were regarded as too idealistic and single comments indicated doubts that they will be realized. But the majority of the participants stressed that the direction was right in each single case (high ratings in relevance and desirability). In the case of "Bioprincipled City" and "New Foodsystems", a paradigm shift or at least culture change and change in consumer behavior is necessary – participant comments indicated, that they see early signals for this.

Comparing the different flagship projects, there was a preference (more investment units given) for Bioeconomy City and New Foodsystems in the first round with arguments that Artificial Photosynthesis is very specialized and Global Governance very broad and difficult to manage. But the distribution of investment units in the second round was nearly equal on average; there was no longer any clear preference.

Relevance and desirability estimates were also very close, although they differed when it came to assessing the relevance of specific aspects of the flagship projects.

All flagship projects will definitely need time (more than 15 years minimum) for their realization, include a lot of work, need effort to convince policy-makers and citizens but were regarded as a worthwhile trial. A participant's comment summarized it like this: *"I think you have picked the most important ones in agriculture, forestry and aquaculture. Go on!"*

9 References

General Delphi literature:

Bolger, F. and Wright, G.: Improving the Delphi process: Lessons from social psychological research, in: Technological Forecasting and Social Change 78 (2011) no. 9, pp. 1500-1513.

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Rowe, G. and Wright, G.: The Delphi technique: Past, present, and future prospects — Introduction to the special issue, in: Technological Forecasting & Social Change 78 (2011) pp. 1487–1490.

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10 Annex

Questionaire Round 1

Survey of the German Bioeconomy Council

Dear Delphi-Participant,
We would like to find out your opinion about potential Flagship Projects of the global Bioeconomy. We are using a two-round Delphi approach: In this first round, we will introduce our ideas, and ask you to answer some questions or give your personal opinion. The second round of the Delphi survey will provide you with feedback on the aggregated but anonymous results of the first round. In between, we might also interview some of the participants in case their views are very different from the "mainstream answers". Your answers will be treated confidentially. Only the project managers have access to the results and might approach you.

As a Delphi participant you share and compare your views with those of other experts and you will receive a pre-publication of the results. You will also be granted preferential admission to the Global Bioeconomy Summit 2015, November 25–26, 2015 in Berlin/Germany, where the results will be presented.

It takes about **15 minutes** to complete the survey. Please follow the questions and topics by choosing or adjusting your assessment. Even if some questions are outside your core expertise, please answer them to the best of your knowledge. To go back or leave out assessments, you can navigate back and forth between questions. You can leave the survey at any time and return to it at your own convenience. Please make sure to save your answers by clicking forth or back.

The survey is open until **May 4th, 2015**.

On behalf of the German Bioeconomy Council, we thank you very much for your contribution. We are looking forward to your assessments.
If you have any questions concerning the survey, please feel free to contact us.
Dr. Kerstin Cuhls
Fraunhofer-Institut für System- und Innovationsforschung ISI
Breslauer Straße 48
76139 Karlsruhe
Email: kerstin.cuhls@isi.fraunhofer.de

Flagship Projects for the future global Bioeconomy

The German Bioeconomy Council would like to ask you about your own ideas and visions for so-called 'Flagship Projects'. Flagship Projects are new ideas, large breakthrough innovations or even 'visions' with a cross-sectoral and convincing aim. They should be realistic and evoke a big change during the next 25 years. On the next pages, the ideas for Flagship Projects from the Bioeconomy Council are presented. You have the opportunity to assess them. But at first, please describe your personal Flagship Project(s) for the future global Bioeconomy.

Bioeconomy is broadly defined as the production and utilisation of biological resources and innovations in order to provide sustainable goods and services in all economic sectors.

What Flagship Project can you imagine personally? .....

1. Project: Bioprincipled City

Please read carefully to be able to answer the questions on the next page.

Background:
In 2045 about 2/3 of the world's population are expected to live in mega cities with more than 10 million inhabitants. In the coming 30 years urban development and construction may require more resources than in the entire human history. Innovative solutions are needed in order to enable these mega cities to function in a sustainable way, to provide quality of life for their inhabitants and for a multitude of (endangered) living organisms.

Flagship Project:
The integration of biological principles into urban planning and city life has become a key element for the achievement of greener cities with high levels of self-sufficiency and quality of life. Locally coordinated production, provision, use and recycling systems ensure that mega cities function on the basis of closed material and energy cycles. Emissions, waste and losses are minimized. Renewable resources, cropping techniques and biotechnology play a major role in closing the loops. Value-chains are based on the cascading use of natural and renewable resources, e.g. water. Urban (vertical) farms are economically and ecologically efficient high-tech production centres. Spaces for recreation, production, services, work and living are integrated and decentralized in city districts. Mega cities innovate sustainable building designs and construction techniques by referring to biological principles and renewable resources. Green areas, and especially the green belts of big cities are recognized as important retreats and contribute to biodiversity, water regulation and filtration, air cleaning, halting soil erosion and desertification, mitigating temperature extremes (saving energy consumption) and human recreation.

Relevancy of the Flagship Project:
Relevancy in this case means that the Flagship Project bears some importance, that it is significant for the future global Bioeconomy or that you personally regard its quality as of being important. Please rate the relevancy of the reflected Flagship Project on a scale from 0 (not relevant) to 100% (very relevant).

Desirability:
In this case, desirability means that it would be worth having this Flagship Project realized, that you would seek for it, regard it as being useful, advantageous, or pleasing. Do you want this Flagship Project to be realized?
◯ yes
◯ no

Time Horizon:
When do you regard this Flagship Project as feasible?

Further ideas or comments:
Do you have any further ideas or comments concerning the reflected Flagship Project?

2. Project: Artificial Photosynthesis

Please read carefully to be able to answer the questions on the next page.

Background:
Photosynthesis, i.e. the production of carbohydrates from water, CO_2 and sunlight in plants, algae and bacteria, is the basis of life on earth. When people implement this process in plant-independent systems, carbohydrates, such as sugar or starch, are available in every part of the world, regardless of environmental conditions and in any amount desirable. This can revolutionize the production of foodstuffs and make an important contribution to fighting world famine.

Flagship Project:
Aided by the renewable production of carbohydrates, people are no longer dependent on the use of fossil fuels, thus protecting the environment and nature. This can contribute to the decarbonization of the atmosphere. Artificial photosynthesis is superior to the plant-based systems or the solar cells common in 2015 in terms of sustainability and efficiency. Understanding and applying the photosynthetic process in man-made systems facilitates further steps that produce biofuels or primary energy.

Relevancy of the Flagship Project:
Relevancy in this case means that the Flagship Project bears some importance, that it is significant for the future global Bioeconomy or that you personally regard its quality as of being important. Please rate the relevancy of the reflected Flagship Project on a scale from 0 (not relevant) to 100% (very relevant).

Desirability:
In this case, desirability means that it would be worth having this Flagship Project realized, that you would seek for it, regard it as being useful, advantageous, or pleasing. Do you want this Flagship Project to be realized?
◯ yes
◯ no

Time Horizon:
When do you regard this Flagship Project as feasible?

Further ideas or comments:
Do you have any further ideas or comments concerning the reflected Flagship Project?

3. Project: New Foodsystems

Please read carefully to be able to answer the questions on the next page.

Background:
One of the bioeconomy's key objectives is to feed everyone on earth adequately and healthily. Although the number of people suffering from hunger in developing and emerging countries has been greatly reduced, it still remains at around 800 million people (status: 2014). The demands of the world's growing middle class, which is investing its rising income mainly in consumption, especially meat consumption, are increasing at the same time. As in many industrialized countries, emerging societies are confronted by the

rise of lifestyle diseases which are caused by poor diet and lack of exercise. The increasing global meat consumption is leading to an increase in resource consumption and CO_2 emissions, while the complex processing and packaging of food contribute to this and the volume of generated waste increases.

Flagship Project:
Sustainable consumption is implemented in new food concepts. Low-emission agriculture which sustains biodiversity contributes to this. The food industry offers products that represent an attractive alternative to resource-intensive meat consumption based on new sources of protein in plants, algae, fungi or insects. Individually tailored foods ensure that people receive a varied and healthy diet within the scope of new supply concepts. Efficiency gains lead to losses being prevented or reintegrated into the material cycle along the entire value chain. Regional approaches are implemented where appropriate.

Relevancy of the Flagship Project:
Relevancy in this case means that the Flagship Project bears some importance, that it is significant for the future global Bioeconomy or that you personally regard its quality as of being important. Please rate the relevancy of the reflected Flagship Project on a scale from 0 (not relevant) to 100% (very relevant).

Desirability:
In this case, desirability means that it would be worth having this Flagship Project realized, that you would seek for it, regard it as being useful, advantageous, or pleasing. Do you want this Flagship Project to be realized?
◯ yes ◯ no

Time Horizon:
When do you regard this Flagship Project as feasible?

Further ideas or comments:
Do you have any further ideas or comments concerning the reflected Flagship Project?

4. Project: Global Governance

Please read carefully to be able to answer the questions on the next page.

Background:
The bioeconomy is also based on the international division of labour, foreign investments and international trade in feedstock, services, technologies and bio-based products. Experience shows that international exchanges in the bioeconomy do not automatically ensure sustainable development. Recent examples are land grabbing, rising food prices due to speculation and industrial uses or monoculture plantation of economically interesting crops.

Flagship Project:
To take full advantage of the positive potential of the bioeconomy, a global policy framework has been adopted by most countries active in the bioeconomy. The framework defines the guiding principles of fair exchange, specifically respecting the sustainable development goals (ending hunger, ensuring eco-system performance, maintaining biodiversity). Mechanisms for monitoring and ensuring food security, protecting biodiversity and the eco-system performance are in place. This includes principles for knowledge sharing and intellectual property rights.

Relevancy of the Flagship Project:
Relevancy in this case means that the Flagship Project bears some importance, that it is significant for the future global Bioeconomy or that you personally regard its quality as of being important. Please rate the relevancy of the reflected Flagship Project on a scale from 0 (not relevant) to 100% (very relevant).

Desirability:
In this case, desirability means that it would be worth having this Flagship Project realized, that you would seek for it, regard it as being useful, advantageous, or pleasing. Do you want this Flagship Project to be realized?
◯ yes ◯ no

Time Horizon:
When do you regard this Flagship Project as feasible?

Further ideas or comments:
Do you have any further ideas or comments concerning the reflected Flagship Project?

Are there other Flagship Projects or single visions that you personally regard as more relevant or that are easier to be realized in the next 25 years?

If you should invest 100 units of investment capital for the next 20 years, how would you distribute this amount among the 4 flagship projects?
Bioprincipled City .....
Artificial Photosynthesis .....
New Foodsystem .....
Global Governance .....

How proficient are you concerning the different project ideas?
Please rate your expertise from one (no expertise) to five stars (high expertise).

	no expertise	little expertise	average expertise	above average expertise	high expertise
Bioprincipled City	◯	◯	◯	◯	◯
Artificial Photosynthesis	◯	◯	◯	◯	◯
New Foodsystem	◯	◯	◯	◯	◯
Global Governance	◯	◯	◯	◯	◯

Your Country of Residence: .....

I work in (please tick):
◯ Science/ Research
◯ Politics/ Policy-making
◯ Industry
◯ A Business Association
◯ A Government Agency
◯ A Non-government organization/Civil Society Organisation
◯ Cluster/Network
◯ International Organisation
◯ Consultancy/as single expert
◯ Other: .....

Age:
◯ 20–29
◯ 30–39
◯ 40–49
◯ 50–59
◯ 60–69
◯ 70 and older
◯ I do not want to provide information

We would like to thank you for taking the time to answer our questions. If you want to receive the evaluation of the survey directly, please leave us your email address. We will contact you to send the evaluation, as soon as we finalized it.

If you want to save your answers now, then please press the „Continue-Button“.
Afterwards they cannot be changed anymore.

Thank you very much!
You have reached the end of the survey.
For further questions, you can contact:
Dr. Kerstin Cuhls
Many thanks for your support!

Questionaire Round 2

Survey of the German Bioeconomy Council

Dear Delphi-Participant,
After the first round oft he Delphi study, we have analyzed all your ideas and comments. The ideas that were mentioned most often have been formulated into three new bioeconomy visions. All comments and ideas relating to the four proposed flagship projects have been incorporated where suitable.

On the following pages, you will discover the aggregated results of the first Delphi round for each flagship project. Please, assess the projects and specific aspects under the impression of these results. We also ask you to rate the three new visions.

Your answers will be treated confidentially. Only the project managers have access to the results.

As a Delphi participant you share and compare your views with those of other experts and you will receive a pre-publication of the results. You will also be granted preferential admission to the Global Bioeconomy Summit 2015, November 25–26, 2015 in Berlin/Germany, where the results will be presented.

It takes about **15 minutes** to complete the survey. Please follow the questions and topics by choosing or adjusting your assessment. Even if some questions are outside your core expertise, please answer them to the best of your knowledge. To go back or leave out assessments, you can navigate back and forth between questions. You can leave the survey at any time and return to it at your own convenience. *Exception: There are some (marked) questions you have to answer to continue*, e.g. the relevancy, the time horizon and the country you work in. Here, you have to answer first and then you can leave. Please make sure to save your answers by clicking forth or back.
The survey is open until **July 20, 2015**.

On behalf of the German Bioeconomy Council, we thank you very much for your contribution. We are looking forward to your assessments.

If you have any questions concerning the survey, please feel free to contact us.
Dr. Kerstin Cuhls
Fraunhofer-Institut für System- und Innovationsforschung ISI
Breslauer Straße 48
76139 Karlsruhe
Email: kerstin.cuhls@isi.fraunhofer.de

Flagship Projects for the future global Bioeconomy

The German Bioeconomy Council would like to ask you about your ideas, visions and assessments concerning so-called ‘Flagship Projects’. Flagship Projects are new ideas, large breakthrough innovations or even ‘visions’ with a crosssectoral and convincing aim. They should be realistic and evoke a big change during the next 25 years. On the next pages, the ideas for four Flagship Projects from the Bioeconomy Council and three Flagships derived from the first round recommendations are presented. You have the opportunity to assess them.

Bioeconomy is broadly defined as the production and utilisation of biological resources and innovations in order to provide sustainable goods and services in all economic sectors.

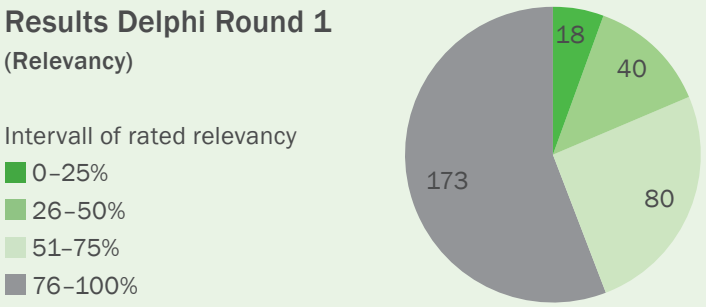
Project 1: Bioprincipled City

Please read carefully to be able to answer the questions and have a look at the first round results.

Background:
In 2045 about 2/3 of the world's population are expected to live in mega cities with more than 10 million inhabitants. In the coming 30 years urban development and construction may require more resources than in the entire human history. Innovative solutions are needed in order to enable these mega cities to function in a sustainable way, to provide quality of life for their inhabitants and for a multitude of (endangered) living organisms.

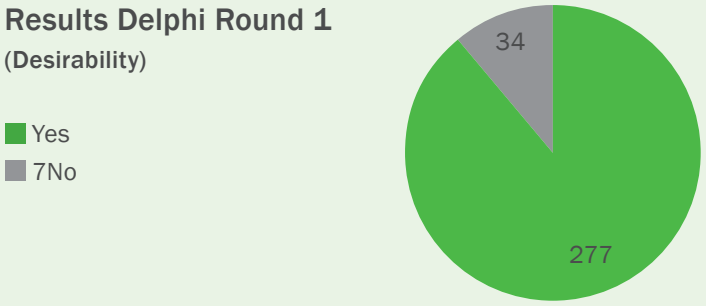
Flagship Project:
The integration of biological principles into urban planning and city life has become a key element for the achievement of greener cities with high levels of self-sufficiency and quality of life. Locally coordinated production, provision, use and recycling systems ensure that mega cities function on the basis of closed material and energy cycles. Emissions, waste and losses are minimized. Renewable resources, cropping techniques and biotechnology play a major role in closing the loops. Value-chains are based on the cascading use of natural and renewable resources, e.g. water. Urban (vertical) farms are economically and ecologically efficient high-tech production centres. Spaces for recreation, production, services, work and living are integrated and decentralized in city districts. Mega cities innovate sustainable building designs and construction techniques by referring to biological principles and renewable resources. Green areas, and especially the green belts of big cities are recognized as important retreats and contribute to biodiversity, water regulation and filtration, air cleaning, halting soil erosion and desertification, mitigating temperature extremes (saving energy consumption) and human recreation.

Results Delphi Round 1
(Relevancy)



Relevancy of the Flagship Project:
Relevancy in this case means that the Flagship Project bears some importance, that it is significant for the future global Bioeconomy or that you personally regard its quality as of being important. Please rate the relevancy of the reflected Flagship Project on a scale from 0 (not relevant) to 100% (very relevant). You cannot proceed to the next Flagship Project without assessing the relevancy.

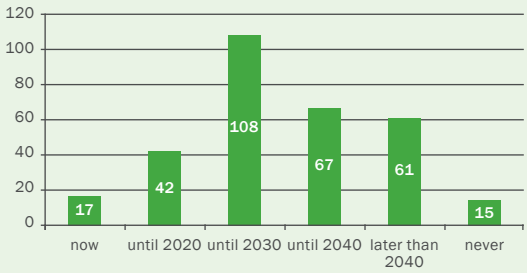
Results Delphi Round 1
(Desirability)



Desirability:
In this case, desirability means that it would be worth having this Flagship Project realized, that you would seek for it, regard it as being useful, advantageous, or pleasing. Do you want this Flagship Project to be realized?

◯ yes
◯ no

Results Delphi Round 1
(Time Horizon)



Time Horizon:
When do you regard this Flagship Project as feasible? Please estimate the time horizon to be able to proceed to the next Flagship Project.

Urban Planning
Please rate the relevancy of the following specific aspects of the Flagship Project on a scale from 0 (not relevant) to 100% (very relevant).

	not relevant				very relevant
Housing is organized in urban centers with green spaces ensuring social well-being. A majority of residents can use bicycles (dominant mode of private	◯	◯	◯	◯	◯
transport), public transport or walk as part of their daily routine, because work, shopping and leisure spaces are integrated into urban residential areas.	◯	◯	◯	◯	◯
Cities close material loops, e.g. by collecting rainwater, cleaning wastewater and establishing cascading use, purifying the air or substituting non-recyclable by recyclable and renewable materials so that “waste” is effectively abolished (“zero waste”).	◯	◯	◯	◯	◯

	not relevant				very relevant
Navigation, traffic regulation and logistic systems function on the basis of bio-inspired and natural principles (e.g. algorithms derived from social insects).	○	○	○	○	○
The cities are attractive and fully integrated into the region. Suburban areas will become part of sustainable urban supply systems for food, feedstocks and energy instead of being designed as purely dormitory towns.	○	○	○	○	○
Big cities establish and recover territories for wetlands, forests and green spaces by applying environmental biotechnology, optimized plants and biological cropping techniques.	○	○	○	○	○

Architecture and Buildings

Please rate the relevancy of the following specific aspects of the Flagship Project on a scale from 0 (not relevant) to 100% (very relevant).

	not relevant				very relevant
Bio-based and residual materials, such as wood or bio-based composites, successfully minimize the use of energy-intensive and non-renewable building materials. They are also used for cost-efficient retrofits of existing buildings.	○	○	○	○	○
Design solutions and functional materials make use of energy depots, natural lighting, waste water systems and strategic planting to achieve energy and water autonomy.	○	○	○	○	○

Urban Production

Please rate the relevancy of the following specific aspects of the Flagship Project on a scale from 0 (not relevant) to 100% (very relevant).

	not relevant				very relevant
Urban farms (e.g. on roof tops or facades) and urban forestry enable a decentralized and healthy provision of fresh food in shops, residential buildings and restaurants.	○	○	○	○	○
Industrial production is “green” (clean air, silent, green logistics, etc.) and co-exists with residential living.	○	○	○	○	○

Further ideas or comments:

Do you have any further ideas or comments concerning the reflected Flagship Project?

Project 2: Renewable Production of Hydrocarbons (“Artificial Photosynthesis“)

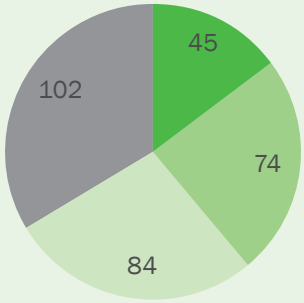
Please read carefully to be able to answer the questions.There were some changes according to your recommendations. Please have a look at the first round results.

Background:
Photosynthesis, i.e. the production of hydrocarbons from water, CO_2 and sunlight in plants, algae and bacteria, is the basis of life on earth. Since more than 40 years, scientists have been trying to harness this process to produce hydrogen (renewable energy source) and – as an even greater challenge - hydrocarbons (sugar, starches).

Flagship Project:
A breakthrough in artificial photosynthesis results in the efficient and environmentally friendly production of hydrogen, a significant renewable energy source. People are no longer dependent on the use of fossil fuels, thus protecting the environment and contributing to the decarbonization of the atmosphere. The use of the photosynthetic process in technical systems facilitates the development of biofuel cells which can deliver energy or hydrogen. Although more challenging, the direct production of hydrocarbons from water, CO_2 and sunlight is advanced and contributes to feeding people in geographically disadvantaged zones.

Results Delphi Round 1
(Relevancy)

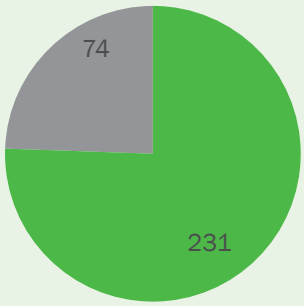
Intervall of rated relevancy
- 0–25%
- 26–50%
- 51–75%
- 76–100%



Relevancy of the Flagship Project:
Relevancy in this case means that the Flagship Project bears some importance, that it is significant for the future global Bioeconomy or that you personally regard its quality as of being important. Please rate the relevancy of the reflected Flagship Project on a scale from 0 (not relevant) to 100% (very relevant). You cannot proceed to the next Flagship Project without assessing the relevancy.

Results Delphi Round 1
(Desirability)

- Yes
- No

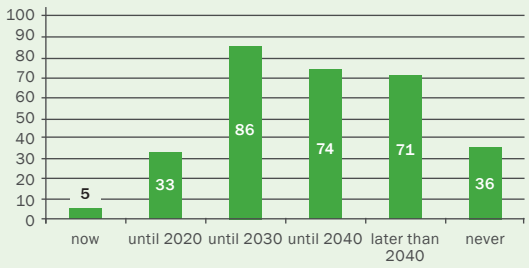


Desirability:
In this case, desirability means that it would be worth having this Flagship Project realized, that you would seek for it, regard it as being useful, advantageous, or pleasing. Do you want this Flagship Project to be realized?

◯ yes ◯ no

Results Delphi Round 1

(Time Horizon)



Time Horizon:

When do you regard this Flagship Project as feasible? Please estimate the time horizon to be able to proceed to the next Flagship Project.

Renewable Production of Hydrocarbons (“Artificial Photosynthesis“)

Please rate the relevancy of the following specific aspects of the Flagship Project on a scale from 0 (not relevant) to 100% (very relevant).

	not relevant				very relevant
Hydrogen, as a renewable and clean energy source, can be efficiently produced from water and sunlight with the help of bacteria and algae.	○	○	○	○	○
Hydrogen produced by artificial photosynthesis replaces fossil fuels, such as crude oil and coal. This contributes to the decarbonization of the atmosphere.	○	○	○	○	○
Biofuel cells and bio-batteries are alternative energy devices based on bio-electrocatalysis of natural substrates using enzymes or microorganisms. Biofuel cells have been developed to supply energy on an industrial scale.	○	○	○	○	○
Biofuel cells and bio-batteries have been developed to power small technical devices, such as consumer electronics.	○	○	○	○	○
Artificial photosynthesis produces hydrocarbons (sugars, starches) more efficiently than agricultural crops. This makes people more independent of local natural conditions and agricultural yields.	○	○	○	○	○
Hydrocarbons (sugars, starches) that are produced by artificial photosynthesis have become an important feedstock for the chemical industry.	○	○	○	○	○

Further ideas or comments:

Do you have any further ideas or comments concerning the reflected Flagship Project?

Project 3: New Foodsystems

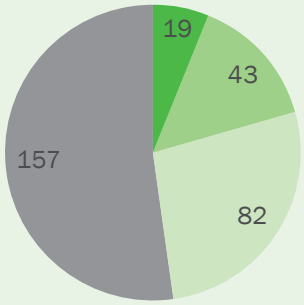
Please read carefully to be able to answer the questions. There were some changes according to your recommendations. Please have a look at the first round results.

Background:
One of the bioeconomy's key objectives is to allow everyone on earth to consume foods that provide adequate nutrition and promote health. Although the number of people suffering from hunger in developing and emerging countries was markedly reduced, it still remains at around 800 million people (status: 2014). The demands of the world's growing middle class, which is investing its rising income mainly in consumption, especially meat consumption, are increasing at the same time. As in many industrialized countries, emerging societies are confronted by the rise of lifestyle-dependent diseases which are caused by sedentary behaviours with lack of exercise and poor diet. The increasing global meat consumption is leading to an increase in resource utilisation and CO2 emissions; not only by production but also by its complex processing and packaging while the volume of waste generated also increases.

Flagship Project:
Sustainable consumption is implemented in new food concepts. The problem of unequal food distribution has been solved. Efficiency gains in food value chains (shelf life, logistics, packaging) lead to losses being prevented or reintegrated into the material cycle (zero waste). Regional approaches are implemented where appropriate. Low-emission agriculture, which sustains biodiversity (precision agriculture, individualized livestock farming, aquaculture, phosphate recycling) contributes to this. The food industry offers products that represent an attractive alternative to resource-intensive meat consumption. They are based on new sources of protein in plants, algae, fungi or insects. Individually tailored foods ensure that people receive a varied and healthy diet within the scope of new supply concepts (delivery services, 3D-food-printing, personalized nutrition bioprinting, nutrigenetics).

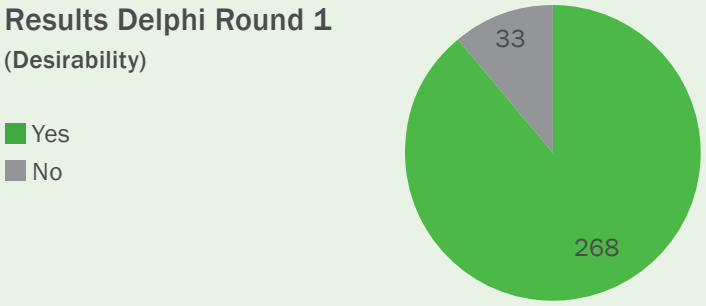
Results Delphi Round 1
(Relevancy)

Intervall of rated relevancy
- 0–25%
- 26–50%
- 51–75%
- 76–100%



Relevancy of the Flagship Project:
Relevancy in this case means that the Flagship Project bears some importance, that it is significant for the future global Bioeconomy or that you personally regard its quality as of being important. Please rate the relevancy of the reflected Flagship Project on a scale from 0 (not relevant) to 100% (very relevant). You cannot proceed to the next Flagship Project without assessing the relevancy.

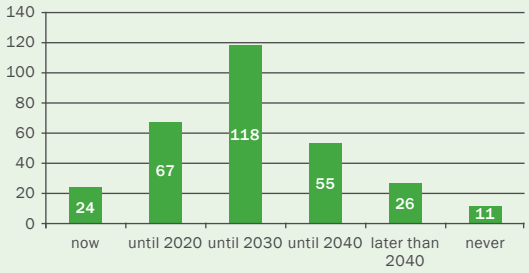
Results Delphi Round 1
(Desirability)



Desirability:
In this case, desirability means that it would be worth having this Flagship Project realized, that you would seek for it, regard it as being useful, advantageous, or pleasing. Do you want this Flagship Project to be realized?

◯ yes
◯ no

Results Delphi Round 1
(Time Horizon)



Time Horizon:
When do you regard this Flagship Project as feasible? Please estimate the time horizon to be able to proceed to the next Flagship Project.

New Food Systems

Please rate the relevancy of the following specific aspects of the Flagship Project on a scale from 0 (not relevant) to 100% (very relevant).

	not relevant				very relevant
Food value chains are designed in a way that virtually no more waste occurs.	◯	◯	◯	◯	◯
A large part of the food is produced and sourced within a 100km corridor of each city or regional hub. This is also due to biotechnological advance and innovations.	◯	◯	◯	◯	◯
Agriculture operates worldwide according to the principles of sustainability and lowers its emissions to air, water and soil by 80%. Agriculture no longer contributes to biodiversity losses.	◯	◯	◯	◯	◯

	not relevant				very relevant
There is a consensus on most successful policy targets for healthy food systems and sustainable food chains; also, through a “health-in-all-policies” approach, the policies along the food value chain are aligned (e.g. subsidies).	○	○	○	○	○
National food strategies with coherent goals and effective policy tool boxes have been developed and are regularly monitored and adapted.	○	○	○	○	○
Alternative protein sources are accepted and a variety of innovative products derived from them allow global meat consumption to drop. The per capita resource consumption needed to safely and healthily feed a growing population decreases.	○	○	○	○	○
The social role of food (beyond nutrition) is fully understood and accepted as part of national and international food strategies.	○	○	○	○	○
Personalized nutrition is a reality. Individualized nutrition products and services foster more healthy lifestyles and reduce the incidence for modern lifestyle diseases.	○	○	○	○	○
Microstructured foods enable the reduction of salt and sugar while maintaining a higher sensory quality.	○	○	○	○	○
All people on earth consume balanced diets and stay healthy.	○	○	○	○	○

Further ideas or comments:

Do you have any further ideas or comments concerning the reflected Flagship Project?

Project 4: Global Governance

Please read carefully to be able to answer the questions and have a look at the first round results.

Background:

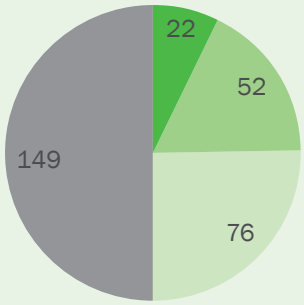
The bioeconomy is also based on the international division of labour, foreign investments and international trade in feedstock, services, technologies and bio-based products. Experience shows that international exchanges in the bioeconomy do not automatically ensure sustainable development. Recent examples are land grabbing, rising food prices due to speculation and industrial uses or monoculture plantation of economically interesting crops.

Flagship Project:

To take full advantage of the positive potential of the bioeconomy, a global policy framework has been adopted by most countries active in the bioeconomy. The framework defines the guiding principles of fair exchange, specifically respecting the sustainable development goals (ending hunger, ensuring eco-system performance, maintaining biodiversity). Mechanisms for monitoring and ensuring food security, protecting biodiversity and the eco-system performance are in place. This includes principles for knowledge sharing and intellectual property rights.

Results Delphi Round 1
(Relevancy)

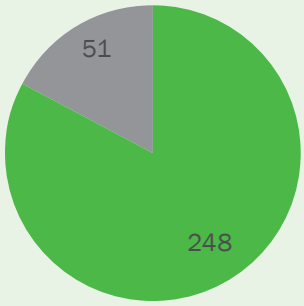
Intervall of rated relevancy
- 0–25%
- 26–50%
- 51–75%
- 76–100%



Relevancy of the Flagship Project:
Relevancy in this case means that the Flagship Project bears some importance, that it is significant for the future global Bioeconomy or that you personally regard its quality as of being important. Please rate the relevancy of the reflected Flagship Project on a scale from 0 (not relevant) to 100% (very relevant). You cannot proceed to the next Flagship Project without assessing the relevancy.

Results Delphi Round 1
(Desirability)

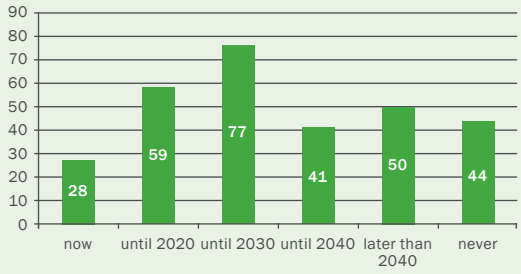
- Yes
- No



Desirability:
In this case, desirability means that it would be worth having this Flagship Project realized, that you would seek for it, regard it as being useful, advantageous, or pleasing. Do you want this Flagship Project to be realized?

◯ yes
◯ no

Results Delphi Round 1
(Time Horizon)



Time Horizon:
When do you regard this Flagship Project as feasible? Please estimate the time horizon to be able to proceed to the next Flagship Project.

A global policy framework fostering the sustainable bioeconomy has been accepted.

Please rate the relevancy of the following specific aspects of the Flagship Project on a scale from 0 (not relevant) to 100% (very relevant).

	not relevant				very relevant
A coordinated “green growth” strategy exists.	○	○	○	○	○
A mechanism for monitoring and ensuring food security is established.	○	○	○	○	○
A mechanism for monitoring and protecting eco-system performance (incl. biodiversity) is applied.	○	○	○	○	○
Principles for managing bio-safety and biotic risks exist.	○	○	○	○	○
A mechanism for responsible trade and sharing of the knowledge and technologies relevant for the bioeconomy (e.g. bioinformatics, smart breeding, sustainable agriculture) is established.	○	○	○	○	○
Principles for responsible investments in agriculture and bio-based industries are acknowledged.	○	○	○	○	○
Sustainability criteria are applied to the production and trade of biomass.	○	○	○	○	○
Sustainability criteria are applied to the industrial use of biomass.	○	○	○	○	○
International standards in biotechnology and synthetic biology are established.	○	○	○	○	○
Principles for responsible trade of bio-based products are acknowledged.	○	○	○	○	○
Principles for sustainable consumption of bio-based products are acknowledged.	○	○	○	○	○

Further ideas or comments:
Do you have any further ideas or comments concerning the reflected Flagship Project?

Discover and assess the new Flagship Projects based on participants‘ ideas!

Project 5: Sustainable Marine Production

Please read carefully to be able to answer the questions.

Flagship Project:
To meet the needs of a growing population and an expanding bioeconomy, the sustainable aquatic cultivation of marine organisms has become more important. New methods not only supplement the declining yields of non-sustainable fishing. They also have the potential to grow and harvest algae, mussels, krill, plankton and other marine organisms in sea-farms that are operated in an environmentally-friendly manner (e.g. avoiding antibiotics, preference for plant-based protein). Algae, for example, serve as a source for food and food supplements (e.g. omega 3 fatty acids), as the feedstock for fine chemicals (e.g. oils). Algae and marine plants can be used to produce hydrogen and biomass for energy generation (biofuels). Marine production is carried out sustainably by applying bio-principles and bioeconomic modeling and simulation tools. The cultivation processes are associated with additional positive effects on the envi-

ronment, e.g. treatment of marine littering (plastics and others), filtering harmful substances out of the water or protecting seashores.

Relevancy of the Flagship Project:
Relevancy in this case means that the Flagship Project bears some importance, that it is significant for the future global Bioeconomy or that you personally regard its quality as of being important. Please rate the relevancy of the reflected Flagship Project on a scale from 0 (not relevant) to 100% (very relevant).

Desirability:
In this case, desirability means that it would be worth having this Flagship Project realized, that you would seek for it, regard it as being useful, advantageous, or pleasing. Do you want this Flagship Project to be realized?
◯ yes
◯ no

Time Horizon:
When do you regard this Flagship Project as feasible?

Further ideas or comments:
Do you have any further ideas or comments concerning the reflected Flagship Project?

Project 6: Biorefineries 4.0

Please read carefully to be able to answer the questions.

Flagship Project:
Fourth generation biorefineries have become very important for the economy and now form an own industrial sector in their own right. They are based on multi-purpose concepts that convert feedstocks containing lignocellulose (wood, straw etc.), algae, food and even plastic waste efficiently and flexibly into energy, fuels, bulk and fine chemicals. Biomass is an established source for active pharmaceutical ingredients produced in energy-efficient biocatalytic downstream processes. In principle, any waste containing carbon can be transformed via gasification or enzymatic biotransformation. The production capacity of all biorefineries makes up 10 to 20 percent of the chemical and petrochemical industry. The dimension and number of agricultural monocultures has been reduced. The dilemma “food vs. fuel” has been solved. The new biorefineries fit elegantly into the landscape and do not produce any “waste”: a zero-waste circular economy is a reality.

Relevancy of the Flagship Project:
Relevancy in this case means that the Flagship Project bears some importance, that it is significant for the future global Bioeconomy or that you personally regard its quality as of being important. Please rate the relevancy of the reflected Flagship Project on a scale from 0 (not relevant) to 100% (very relevant).

Desirability:
In this case, desirability means that it would be worth having this Flagship Project realized, that you would seek for it, regard it as being useful, advantageous, or pleasing. Do you want this Flagship Project to be realized?
◯ yes ◯ no

Time Horizon:
When do you regard this Flagship Project as feasible?

Further ideas or comments:
Do you have any further ideas or comments concerning the reflected Flagship Project?

Project 7: Developing Consumer Markets

Please read carefully to be able to answer the questions.

Flagship Project:
The bioeconomy is a part of everyday life under the principle of sustainability. The foundations of the bioeconomy are integrated into primary education. Higher education transfers knowledge on the complex interplays within the bioeconomy. Entrepreneurs, engineers and farmers have access to hands-on training in bio-based technologies and the bioeconomy. These efforts contribute to a new understanding of sustainability which involves preserving nature by using it. People are used to thinking in categories of renewability and re-usability and are skilled at adapting their behavior to new knowledge. Useful and easy-to-understand labels or apps inform consumers of a product's life-cycle cost. Consumers and entrepreneurs prefer sustainable, bio-based products and understand the costs and benefits involved. Consumption becomes more value- and less quantity-oriented.

Participatory approaches are common in policy making at local, regional and national levels. Citizens are involved in different sustainability projects and learn by doing. There are no taboos for creativity in research & development – but risks are made transparent and are not neglected. Marketing and product development rely strongly on consumer collaboration and feedback.

Relevancy of the Flagship Project:
Relevancy in this case means that the Flagship Project bears some importance, that it is significant for the future global Bioeconomy or that you personally regard its quality as of being important. Please rate the relevancy of the reflected Flagship Project on a scale from 0 (not relevant) to 100% (very relevant).

Desirability:
In this case, desirability means that it would be worth having this Flagship Project realized, that you would seek for it, regard it as being useful, advantageous, or pleasing. Do you want this Flagship Project to be realized?
◯ yes
◯ no

Time Horizon:
When do you regard this Flagship Project as feasible?

Further ideas or comments:
Do you have any further ideas or comments concerning the reflected Flagship Project?

Are there other Flagship Projects or single visions that you personally regard as more relevant or that are easier to be realized in the next 25 years?

If you should invest 100 units of investment capital for the next 20 years, how would you distribute this amount among the 7 flagship projects?

Bioprincipled City .....
Artificial Photosynthesis .....
New Foodsystem .....
Global Governance .....
Sustainable Marine Production .....
Biorefineries 4.0 .....
Developing Consumer Markets .....

How proficient are you concerning the different project ideas?

Please rate your expertise from one (no expertise) to five stars (high expertise).

	no expertise	little expertise	average expertise	above average expertise	high expertise
Bioprincipled City	◯	◯	◯	◯	◯
Artificial Photosynthesis	◯	◯	◯	◯	◯
New Foodsystem	◯	◯	◯	◯	◯
Global Governance	◯	◯	◯	◯	◯
Sust. Marine Production	◯	◯	◯	◯	◯
Biorafineries 4.0	◯	◯	◯	◯	◯
Dev. Consumer Markets	◯	◯	◯	◯	◯

In which country do you work?

To finish the survey, please tell us the country, in which you work. This is necessary for the analysis.

We would like to thank you for taking the time to answer our questions. If you want to receive the end results of the survey directly, please leave us your email address. If you already provided us with your e-mail in the first round, you will receive the results automatically.

If you want to save your answers now, then please press the „Continue-Button“.
If you pressed this button, you cannot go back and your answers cannot be changed anymore.

Thank you very much!
You have reached the end of the survey.
For further questions, you can contact:
Dr. Kerstin Cuhls
Many thanks for your support!

About the German Bioeconomy Council

In 2009, the German Federal Ministry of Education and Research (BMBF) and the Federal Ministry of Food, Agriculture and Consumer Protection (BMELV) established the Bioeconomy Council as an independent advisory committee to the German Federal Government. In 2012, the Council has been newly nominated for a second four-year term. The 17 members represent industry, society and science and their expertise covers the full spectrum of the bioeconomy value chain. The Council is mainly tasked with providing advice on how to foster the development of a sustainable bioeconomy in Germany and in a global context. For this purpose it engages in political and scientific dialogue, published position statements and promotes the future vision of the bioeconomy to broader society. The activities of the council are oriented both towards long-term objectives as well as day-to-day policy requirements. Documents download and further information in English is availability under www.biooekonomierat.de/en/.

About the Authors

Fraunhofer Institute for Systems and Innovation Research: Kerstin Cuhls, Victoria Kayser, Stephan Grandt
German Bioeconomy Council: Ulrich Hamm, Lucia Reisch, Hannelore Daniel
Office of the German Bioeconomy Council: Beate El-Chichakli, Patrick Dieckhoff

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