Progress

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Deliverable D 5.2: Role of EU member states and EU wide collaboration in Industrial Biotechnology[1]

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[1] In the Description of work the title of Deliverable 4.2 has been „ Guidebook for fostering collaboration across EU member states"

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About PROGRESS

PROGRESS is a coordination and support action for the European Commission and aims to support and accelerate the deployment of Industrial Biotechnology (IB) in the EU industry by identifying high-value opportunities for IB and proposing actions to address them successfully. For that purpose, we will first provide a comprehensive and dependable information base (including modelling and simulation approaches) which allows for plausible estimations on the future of IB in the EU in the short and medium-term. Second, in collaboration with stakeholders we will elaborate a future scenario and a common vision for IB in Europe containing the most promising value chains, related R&D&I needs and necessitated policies for IB in Europe. Based on these steps, we will provide strategic advice for research, industry and policy making regarding potential issues and topics for collaboration, future policy programmes, the required technological infrastructure, capabilities, and economic structures. A main focus will be to identify opportunities for collaboration between EU member states and proposed actions to increase awareness and incentives for those collaborations. For more information see www.progress-bio.eu

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Content

1 Scope and structure of the deliverable

This deliverable documents the results of Task 5.2 of the PROGRESS project, which aims to clarify the roles of EU member states in the field of IB, and the opportunities for cross-border collaboration in industrial biotechnology (IB).

The main basis for the results is an expert workshop, which took place on September 6th, 2017 in Brussels. The workshop brought together 13 IB experts from industry, academia, related governmental institutions and business associations with acknowledged expertise in IB research and innovation policy. The experts came from different EU countries, representing major EU regions. In this workshop, the role and potential of EU member states in the field of IB and opportunities for cross-border collaboration in IB were discussed. Against the background of specific needs and potential of different EU countries in the field of IB, a range of policy recommendations and actions, which would respond best to the previously identified countries' specific characteristics, was elaborated during the in-depth discussion with the experts.

In the following, the procedure of the workshop is described in section 2 as well as the input by the workshop participants are documented. This input includes a significant number of concrete propositions for actions. Section 3 discusses the role and potentials of EU member states in IB. Section 4 presents the rationale and recommended actions for intensified collaboration between EU countries in IB. These two sections are based on the results of the workshop as well as on further elaboration of these results by the project team.

2 Workshop procedure and results

2.1 Procedure of the workshop

The overall objective of this workshop was to discuss the role of different EU member states in the field of IB and to use expert knowledge for the elaboration of concrete policy recommendations for member state groups: actions were identified with the aim to foster innovative capacities and to better use synergies and complementarities within the EU.

The specific objectives of the workshop were to:

- validate the general recommendations previously elaborated within the PROGRESS project,
- differentiate the focus of the recommendations according to the differing strategic goals and framework conditions in the EU member states and regions,
- identify opportunities for cross-border collaboration in IB and propose adequate actions to foster it.

The workshop was based on the results of previous work packages: The project team had derived policy recommendations to support the future development and uptake of IB. These recommendations were presented to the workshop participants and subsequently discussed with the experts for the purpose of their validation and modification (see Annex I). There was a general approval of the identified areas of priorities for policy actions and the specification of the recommended actions by the workshop participants.

Since there is a great variety in terms of the thematic focus as well as potentials and needs of EU countries in IB, it is necessary to differentiate between country profiles to define policy recommendations with an optimal fit to the respective country. Therefore, the project team had carried out a comprehensive analysis of the EU member states to characterize their priorities, potentials and activities in the field of IB and to define the specificities of each individual country with regard to its positioning in IB. As a result, the EU member states could be assigned to one of four groups of countries with similar IB profiles. The results of the analysis including the description of the identified country groups and their characteristics were presented and discussed with the workshop participants. The assignment of individual countries according the specified criteria along with their reasoning were widely accepted by the experts and they assessed the classification as very useful. They also fully shared the project team's stance that specific characteristics of individual countries should be taken into consideration when elaborating IB policy recommendations in order to address the needs and potentials of these countries

adequately. The classification of country groups and the related methodology are presented in sections 3.1 and 3.2 of this deliverable.

After the presentations and the subsequent discussions of their contents, the experts were asked to make specific proposals on recommendations discussed in the earlier session as well as concrete policy actions according to the needs and potentials of the EU country groups with regard to the development of IB. To facilitate a more focused and productive discussion, the participants were divided into two groups, each of them working on one set of recommendations. First, the experts were asked to formulate their ideas in written form. Afterwards they were invited to participate in the discussion on the identified recommendations and actions. The discussion raised a number of critical points and helped to provide important insights. Within the discussion, a particular attention was also given to opportunities for collaboration between countries. The results of the workshop discussions are documented in section 2.2.

Based on this group work by the workshop participants, the project team brought policy recommendations in line with specific framework conditions of different country groups. The results are documented in section 3.3. Section 4 presents the recommendations to foster collaboration across EU member states. The results of sections 3 and 4 were presented at the PROGRESS Final Conference on September 27th, 2017 in Brussels and were confirmed by the participants of the Final Conference.

As noted above, the workshop experts were asked to make specific proposals on recommendations discussed in the earlier session as well as concrete policy actions according to the needs and potential of the EU country groups with regard to the development of IB. To facilitate a more focused and productive discussion, the participants were divided into two groups, each of them working on one set of recommendations. The propositions for key actions by the workshop participants are documented in the tables below. Based on the discussions the moderators of the two groups summarized the key aspects and propositions for each recommendation. This summary is presented after the tables.

2.2 Workshop results

Detailed propositions of actions:

The following tables summarizes the propositions of actions by the participants in the group discussions. The participants wrote these propositions on prepared structured cards, which asked about the topic and action and discussed by the group.

Advanced Technologies

Country group	Topic	Action
1	IB as a strategic policy priority	Regular update of strategy and policies to maintain leading position
1	Maintain and improve competitiveness	On EU level, increase low TRL R&D to improve European competitiveness On national or regional level, develop strong clusters and link with other innovators
1, 2	Integration of life science technologies with other technologies (e.g. chemistry -> green chemistry with very positive public perception, digital technologies)	Research on value chains (food, chemicals, agrobusiness) Research on global market opportunities (food, chemicals, agrobusiness) Effective communication between stakeholders
1	High level of technological expertise should be maintained	Cross-country collaboration to access state-of-the-art technologies Organise science and innovation missions to leading countries outside the EU EU should support leading EU countries to cooperate with global leaders
1b, 2	High level of technological expertise (in certain fields), but scope could be broadened	Increase cross-country collaboration in areas of national strengths with the aim to • broaden one's own expertise (e.g. diversification into novel sectors), • to acquire or integrate complementary competencies • to jointly cooperate with partners with complementary strengths
1, 2	Scaling up of production processes	Support cooperation between academia and industry Incentives for activities within a value chain in order to reach maximum product or technology added value within the country or EU, respectively Support for joint (academia and industry) facilities for scaling up Support for companies to provide practical training for students in scaling up (= incentives for training and re-training)

1, 2	Raise investors' awareness of opportunities	Engage with business angels and investors at national level through funding agencies Educate investors
2	Development of an IB policy and strategy on national level	Engage with all relevant ministerial/governmental departments Carry out mapping exercises at national level with the aim of clustering Customize national innovation programmes to IB
3+4	Raise awareness of all relevant departments in order to give IB a priority in innovation policy	Joint efforts of all relevant departments to promote IB Carry out educational missions with the EU IB policy leaders to learn how they support innovation processes in IB
3+4	Build up competencies in IB and advanced technologies in general, achieve critical mass	Provide national funding for IB in fields of specific national strengths Support collaboration between academia and industry to foster innovation Support the increased participation of group 3 countries in IB programmes at EU level
		EU should support specific regional activities; use structural funds for IB Carry out educational missions with the EU IB leaders to learn from their competencies in IB
3+4	Improve IB education at university	Set up and improve national university curricula in IB Provide incentives to attract excellent IB researchers to universities in group 3 and 4 countries
3+4	Exploit abundantly available feedstocks	Make an inventory of locally/nationally available feedstocks For the specific feedstock: focus the R&D efforts and funding initiatives on pre-treatment and early conversion steps, establish close links to agriculture or the industry where the feedstock originates

Transfer of R&D results into commercialization

Country group	Topic	Action
1, 2	Support transfer of R&D results to commercialisation	Maintain a high level of expertise and engagement at universities/research institutes Maintain a high level of readily accessible IB R&D infrastructure for all R&D phases from basic research (e.g. databases) to demonstration and pilot facilities Ensure access to R&D infrastructure, also outside the EU

		Continue the collaboration between research institutions and industry, also across EU borders, and successively intensify for R&D as value chains mature Intensify the collaboration with brand owners and companies in direct contact with end users/consumers
1, 2	Relevant expertise is in principle available, but must be shared	Support communication between research and production (resp. academia/industry) in order to meet market needs in a better way
1, 2	R&D infrastructure	Maintain a high level of IB infrastructure Expand funding mechanisms to support the use of (existing) infrastructure with sufficient budget Address existing gaps in demonstration and pilot infrastructures
1	Overcome lack of market intelligence	Provide incentives for using consulting services Provide funding in addition to scientific work for integration of business expertise in finance, legal, marketing affairs in IB R&D&I
1, 2	Focus on the non-technological barriers to transfer	Foster demand pull, market demand (both private consumption and business demand) Regulatory compliance Build trust through standards and labels Educate investors Mobilize capital by public-private-partnerships, risk-sharing models or other financing models
1, 2	Highly capital intensive innovation steps required for commercialization, access to capital may be challenging	Educate investors/banks of opportunities Raise awareness of national departments and EU of the importance of capital availability Continue level of investment in R&D Increase EU funding for pre-commercialization activities in the TRL range of 6-8
1, 2	Create a favourable climate for innovation and commercialisation	Educate the public/the consumer Raise awareness of funding agencies at national level
1, 2	Increase skills in IB workforce	Customize post-graduate programmes at university accordingly and provide world-class retraining programmes (Good Practice example National Institute for Bioprocessing Research and Training (NIBRT) in Ireland; http://www.nibrt.ie)
3, 4	Integrate actors from groups 3 and 4 into transfer activities of groups 1 and 2	Intensify collaboration in EU-funded R&D projects, e.g. by mandatory inclusion of partners from group 3 and 4 countries Combine established EU instruments (grants and loans)

3, 4	Overcome barriers, such as lack of capabilities, lack of infrastructure, lack of industry pull, value chains not in place	EU funding for regional initiatives to work with leading countries
3, 4	Position the country as host country for demonstration and pilot plants	Establish links with actors who are likely to develop demonstration facilities Establish an innovation-friendly environment for hosting demonstration facilities Ensure the local availability of qualified staff and English language skills
3, 4	Policy and strategy activities in funding agencies and industry	Learn from good practice in own country, which may be available in adjacent sectors Learn from good practice in other countries Specifically address national strengths and/or gaps Support the use of external expertise, of external advisors (e.g workforce with expertise in IP issues), e.g. on a part-time basis
3	Support start-ups	Crosslink the start-up sector with academia
3, 4	Skilled IB workforce with business skills	Incentives for universities to run postgraduate programmes in IB which also comprise business skills Use next Framework Programmes for training Support and organize missions to visit other member states with advanced IB sector
3	Lack of investment opportunities	National funding agencies should work with investors
3, 4	National IB strategy	Develop a national IB strategy[2], which also addresses the transfer of R&D results to commercialization and thus make the issue visible

Multidisciplinarity of skills

Country group	Topic	Action

[2] While it wasn't discussed at the workshop, whether there is a need of an EU wide IB strategy as starting point for national strategies, at other occasions in the projects expert mentioned that EU wide actions are very helpful to enforce national activities. For the concrete strategy on the national activities / strategies country-specific resources and capabilities have to be taken strongly into account.

1, 2	Maintaining and increasing the level of expertise in the IB workforce to keep at the cutting edge	Continue IB education programmes at universities (national funding) Continue internationally oriented education programmes (national and EU funding, e.g. Marie Curie programme, Erasmus programme, H2020 research funding), support the cross-border exchange of expertise Tailor the programmes in a way that they are multidisciplinary, internationally oriented, provide business skills at PhD level and beyond, include some compulsory courses on non-technical skills and issues Continue or set up joint programmes academia-industry Set up an "industry-Erasmus programme" for PhDs and Post-docs
1, 2	IB-specific skills	Set up or run national training centers for specific technologies
1, 2	Specific skills in IB production and scale-up	Set up post-graduate training and retraining programmes for these skills; a good practice example is the NIBRT in Ireland
1, 2	Improve access of academia and companies to skilled workforce	Public Private Partnerships as good practice examples Give incentives to companies (e.g. in the form of tax exemptions, or reduction of social and healthcare payments) for upskilling and retraining their workers, or for setting up new study programmes for this purpose
2, 3	Learning from others	Set up or intensify expert exchanges between similar or with more advanced countries. The exchanges can be of disciplinary or cross-thematic nature.
all	Skill pool as a competitive factor in choice of location for industry	Ensure high quality education and training for all levels (from academic down to blue collar workers) Continuous improvement of curricula
3, 4	Develop skilled workforce	Encourage more intensive use of/engagement in EU funded programmes Support missions to more advanced countries Intensify collaboration with industry by implementing joint industry-university programmes Offer IB specific university courses Offer IB specific training in other EU countries for PhD students As not all required skills are available nationally, acquire part-time support in the missing skills from experts from other EU countries
3,4	Skills required for conversion of abundantly available feedstock in the respective country	Focus the development of IB skills specifically on cultivation, pre-treatment and early conversion steps of nationally available feedstocks in order to position the country for this part of international value chains; link with demonstration plants

Co-evolution of regulatory environment and S&T development

Country group	Topic	Action
1-2	Need for a supportive, innovation-friendly regulatory framework which allows competitiveness with other world regions	Regular update of regulations Anticipate new, emerging developments (e.g. synthetic biology, genome editing) Close interaction of S&T actors with regulators and standardizing organisation Strive for a global regulatory framework for IB
1-2	Address public perception, create a positive climate for IB (and the bioeconomy)	Set up indicators for measurement of "sustainability" Engage CEN or national standardization agencies in R&I projects, e.g. by running workshops in year 3 of the project with these actors
1-2		Communication strategy to raise people's awareness of EU and member state's goals in IB and bioeconomy Run workshops on EU or national level to increase visibility of IB in the public/by consumers
3-4	Create a level playing field for bio-based products	Engage industry with policy makers Carry out missions to further advanced countries

Sustainable Feedstock Supply

Country group	Topic	Action
2	Understand Value of Different uses from feedstock supply	Assessment of values for different products / uses and elaboration of “best-use” hierarchy (=products with high value per feedstock input) for various products, pathways and feedstocks[3]
2	Improvement of food waste collection	Introduction of mandatory food waste collection in the EU Promotion of R&D and commercialization for using food waste for variety of products
1-4	Ensuring sustainable feedstock supply	Monitoring system for feedstock supply (developed on EU level, but adapted and implemented nationally) Regulations to ensure “food first principle”, high sustainability and efficient waste use: regulation on EU level, but with enough flexibility for member states to implement it regarding own context

[3] Currently, such hierarchies are only available very generally in the biomass value pyramid form (see e.g. http://www.betaprocess.eu/the-value-pyramid.php), but not for concrete products

		Increase technological potential: individual support measures in the member states, exchange of knowledge between them
1-4	Consumer/public acceptance of feedstock uses and regulations	Enhance consumer understanding of political and legal measures, via higher media presence, understandable language and argumentation supported by data/statistics/experiences in other countries
1-4	Mapping of competencies	Introduce mapping of competencies of feedstock suppliers and IB companies

Collaboration along value chains

Country group	Topic	Action
1-4	Create links between both ends of value chain (primary producers + end users / public)	Support to build up meeting platforms for suppliers of biomass and users of biomass Cross border collaboration of countries/regions with similar economic environment (e.g. NL, Flanders, North-Rhine Westphalia) as they have similar value chains)
1-4	Access to value chains for small countries	Foster European cooperation and tools to enable creation of strategic projects
1-4	Bottom-up elaboration of value chains by regions / member states	Adoption of good examples of policies in other member states Communication of good examples of collaboration Encourage cooperation in next FP, ESIF, EUREKA, EUROSTARS, etc,

Address public perception and acceptance + Demand pull for IB

Country group	Topic	Action
1-4	Public perception & demand pull	Better connect downstream and upstream industries (e.g. bio-based industries with brand owners) Develop communication strategy for IB (facilitation by the EC) in different EU languages Share benefits and advantages (price, quality, environment etc.) in a simple language
2	Address public perception and acceptance	Active media communication Identify and communicate stakeholder benefits and direct consumer benefits

		Identify opinion leaders and create dialogue with them
1-4*	Public Procurement	Introduce public procurement scheme in member states for bio-based products

* It has been noted that it is more urgent in countries in the groups 1-2, as industry would benefit more, but it might be easier to implement for country groups 3-4 due to less history in (conventional) public procurement and changes easier to implement

Summary of discussions:

Make use of advanced technologies (Differentiation of all four country groups)

A key issue for countries in the groups 1&2 is to keep at the cutting edge of the scientific-technical development. Therefore, their strategic priority should be upskilling. That means that their policy needs to be revised and updated regularly and that they aim to cooperate with the best scientists all over the world. This applies also to country group 2: Especially small countries in group 2 should maintain their specialisation focus (e.g. on certain feedstocks, technologies) and develop advanced technologies further in these focus areas. However, these countries should additionally link with other industries that have complementary competencies, e.g. by cross border collaboration.

Countries in groups 3 and 4 suffer from low innovation capacity and only partial or hardly any support by policy. Measures therefore would be to develop a favourable policy framework and to bring those few actors - often in different industrial sectors - together who could promote industrial biotechnology. Another strategic option for these countries could be a focus on locally produced feedstock and its pre-treatment. For example, funds for regional development could be used to set up demonstration facilities which could form another focal point for further development of IB in these countries. These additional measures have also been suggested: mandatory inclusion of actors from group 3 and 4 countries in certain EU funded R&D projects or giving financial incentives to projects which include actors from these countries; attraction of skilled personnel to these countries; support learning from other countries (e.g. by COST actions or InterReg projects); adaptation of good practice from other countries in group 3 & 4 countries.

Transfer of R&D results to commercialization (differentiation between group 1&2 (significant IB activities) and group 3&4 (lower or hardly any IB activities)

For countries in the groups 1 and 2, which have the policies, actors and competencies in place, the following priorities were identified:

- there is a clear need for demonstration facilities and a facilitated access to them. These demonstration facilities could be located in the group 3&4 countries, as their specific unique selling point.
- there is a need to support pre-commercialisation activities at TRLs 6-8, e.g. the active promotion of proof of concept .
- focus on the non-technical hurdles to commercialization (e.g. implement measures to increase the demand pull both by industry and consumers; support regulatory compliance; implement novel standards and labels to build trust among customers; educate the financing community; mobilization of capital, e.g. in public-private-partnerships or risk-sharing financing models).

Multidisciplinarity of skills (no differentiation between country groups)

This issue needs to be addressed in all countries and in all country groups: while in group 1&2 upskilling is the priority, group 3&4 should concentrate on building a critical mass of qualified staff. In many ex-communist group 3&4 countries, there is a lack of entrepreneurial and business skills which should be addressed specifically. The local branches of multinational companies could play an important role as focal points for qualification activities, e.g. through academia-industry collaborations.

Co-evolution of the regulatory environment and science and technology development (no differentiation between country groups)

Participants pleaded for a technology-supportive, responsible and innovation-friendly regulation. The starting position was assessed as good, due to the fact that regulators and stakeholders are in dialogue, and that regulations are shaped interactively. Additionally, measures on the strategic level were suggested regarding the way a knowledge- and evidence-based, innovation-friendly regulation could be achieved, such as by strategic intelligence studies, scenarios[4] and impact assessments (see table above).

[4] See e.g. the scenarios for six value chains in the PROGRESS project (downloadable under https://www.progress-bio.eu/progress-bio-wAssets/docs/Deliverables/Progress_Deliverable_D4_1_final.pdf). In those scenarios it is shown that it is crucial for a positive development of IB in the EU that future regulation acknowledges concerns of the public or consumer and provides high clarity for industry as well as technology progress in related fields are crucial.

Sustainable feedstock supply (few differentiation between country groups)

Policy issues regarding sustainable feedstock supply have to be mostly clarified at the European level, followed by implementation in the member states. The following actions should be taken:

The elaboration of a platform, which brings different actors together. This platform should include the identification of supply and demand. Additional issues on a European level are the biomass capacities of different regions and the mapping of different routes (high or low value) of biomass use. The monitoring, communication, etc. could be conducted on a member state level.

A general important point from a European point of view are the individual interests of different countries in an open market, and possible conflicts like the primary production for national or regional use instead of trading. The only difference between the country groups were the limited resources of group 2, for whom a sustainable feedstock supply is more urgent, (in comparison to countries that have a lot of resources, like Germany).

Collaboration along value chains (differentiation between group 1&2 (significant IB activities) and group 3&4 (lower or hardly any IB activities))

We already see the exploitation of synergies between countries with similar resources and capacities: for example Germany, the Netherlands, Belgium, and France which take profit of each other. To ensure high efficiency and sustainability of value chains, regionally focused value chains are desirable, because trading and transport of bio-products over long distances is avoided. As the respective regions are often cross-national, it has to be ensured that policies foster cross-border development of IB.

In the long run, it would be fruitful to have collaborations between country groups 1 & 3/4. However, high barriers will have to be overcome. Among them are difficulties for group 3 and 4 countries to become integrated into already established networks and a lack of incentives for countries from group 1 to establish collaborations with actors from group 3 and 4 countries along value chains. This issue is also a matter of cohesion policies.

Address public perception and acceptance + Demand pull for IB (differentiation between group 1&2 (significant IB activities) and group 3&4 (lower or hardly any IB activities))

Public perception of IB is mostly a European-wide issue. For example, Eurobarometer surveys on attitudes towards technologies show that the issues and concerns are similar, even if the percentages of disagreement and agreement regarding related questions to IB and the bioeconomy are a bit different. As required measures may differ on a national level, these actions (e.g. communication, language, partial regulation) should be implemented on member state level. Especially the political acceptance of hard measures, like taxes and bans, may differ between countries.

Moreover, the priority and urgency of actions may differ between country groups. Public procurement is most likely not a priority for country groups 3&4, as they do not have an industry which could benefit much. On the other hand, it might be easier for countries without a long tradition in public procurement, to make important changes.

3 Role and potential of EU member states in IB

3.1 Methodological concept

Within the EU, there is a huge diversity across countries with respect to framework conditions determining the extent and scope of their activities in the field of industrial biotechnology. In fact, countries differ from each other considerably in terms of their research and innovation capabilities in industrial biotechnology. Closely related to different innovative capabilities is the variety of deployment of industrial biotechnology and the development levels of the industrial biotechnology sector in different EU countries. Moreover, the availability and effectiveness of policy support mechanisms aiming at promoting the deployment of industrial biotechnology differ from country to country to a considerable extent.

Taking into account the diversity and different potential of European member states in industrial biotechnology, there cannot be one-size-fits-all strategy approach to foster IB in different countries. Consequently, when elaborating policy recommendations for the uptake and development of industrial biotechnology, specific situations of countries must be considered, and their potentials and needs identified and thoroughly analysed. This would enable to develop a package of measures, which would be tailored to the specific framework conditions of different countries to respond best to their needs and potentials. This way an additional value can be created from the diversity by combining complementary expertise and gaining synergies across countries, which would also make a positive contribution to the regional cohesion of the EU.

For this purpose, an extensive desk research and data analysis from official statistics were performed to identify potentials and capabilities of individual countries within the EU with respect to the research and innovation, industrial sector capacities, policy framework conditions and the availability of the biomass resources. To reflect the innovation performance of countries in industrial biotechnology, the patent analysis for IB were conducted by using the World Patent Index Database. The expenditures on R&D is another key indicator of countries innovative efforts. However, as no direct data on R&D expenditures dedicated to the industrial biotechnology is available, the Eurostat data on the total business enterprise R&D expenditures of the chemical industry as well as the OECD data on the biotechnology R&D intensity in the business enterprise sector were used as a proxy for each country research efforts in the industrial biotechnology related areas. As industrial biotechnology is highly dependent on research, a network of academia and research institutions engaged in basic and applied research are crucial to advance the

technological development. Hence, key research and academia players involved in industrial biotechnology related research and their activities at country level were scrutinized to estimate the overall research and innovation potential of each individual country.

The activities of industrial sector are the major driver for the industrial biotechnology and therefore need to be looked more closely at, when assessing the industrial capabilities of different countries in this field of technology. Therefore, particular attention was given to the key industrial players and especially small and medium enterprises at country level specializing in industrial biotechnology related activities.

Since industrial biotechnology is far from being mature and thus lacking competitiveness compared to conventional technologies, it relies heavily on an effective policy support. Therefore, an analysis of policy framework conditions provided by national governments to foster industrial biotechnology was performed.

An essential precondition for the uptake and successful development of industrial biotechnology is the availability of affordable biomass feedstocks. In some value chains IB enables the valorization of large amounts of biomass. Also, commercial production sites are dependent on the availability of biomass, which differs highly between European countries. Against this background, it was considered important to include the estimations of the biomass potential of different EU countries in the analysis. The estimation is based on the biomass potential assessments made within the Biomass Policy projects[5] and on the Eurostat data on forest areas and land use, because among all main sources for the biomass supply (agriculture, forestry and waste), forestry and the agricultural sector hold the largest biomass potential, contributing 53% and 30% each to the overall potential of the total biomass. The waste biomass, which can be used for the bio-industry applications, accounts for the rest. The amount of wastes available at the country level is directly related to the size of the economy and population of each country. However, a group of European countries has in relation to their size a relatively small amount of waste because of a high waste recovery level. This country group comprises Austria, Germany, Belgium, the Netherlands, Denmark, Ireland, United Kingdom, Slovenia and Estonia. Moreover, many countries have lesser amounts of wastes available for the purposes of IB, because large parts of bio-wastes are used for the energy generation.[6] Because of its current and future importance of the biomass originating from the agricultural and forestry sector for the needs of IB, the endowment with the two major sources of the biomass supply was considered crucial to focus on. For the estimation of wastes

[5] Elbersen et al., Outlook of spatial biomass value chains in EU28, Deliverable 2.3 of the Biomass Policies project, March 2016. http://www.biomasspolicies.eu/

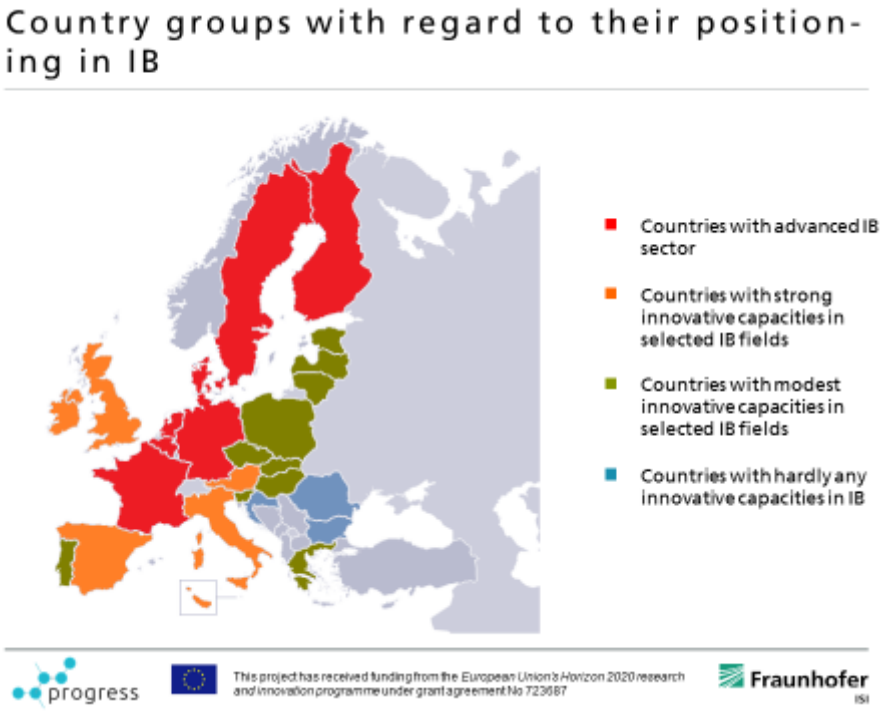
[6] See Elbersen et al., above

potentials at country levels, which would be available for the application of IB, a comprehensive and differentiated assessment is required, which, however, would exceed the scope of the present analysis. As our focal point are the innovation capabilities of the IB, the characteristics of the IB related research, innovation and industrial sector as well as policy framework conditions influencing their development were considered as critical determining factors underlying the country group classification. Therefore, the identified biomass supply potentials have no significant effect on the country group assignment.

The evaluation of EU countries according to the above mentioned aspects led to the identification of four groups of countries[7] sharing common characteristics:

1. Countries with advanced industrial biotechnology sector
2. Countries with strong innovative capacities in selected IB fields
3. Countries with modest innovative capacities in IB
4. Countries with hardly any innovative capacities in IB

The following slide highlights a schematic representation of different EU country groups according to their positioning in IB.



[7] EU-countries with less than 1 Million inhabitants, such as Luxembourg, Malta and Cyprus, were excluded from the analysis.

3.2 Description of country groups

3.2.1 Countries with advanced industrial biotechnology sector

This country group includes Germany, Belgium, the Netherlands, France, Finland, Sweden and Denmark. As for the scope of their industrial biotechnology related activities, two subgroups can be identified: countries covering a broad spectrum of activities (Germany, Belgium, Netherlands, France), and countries, which have a special focus in industrial biotechnology. These countries are Finland and Sweden, which have a strong focus on woody biomass biotechnology, and Denmark specializing mainly in microorganisms and enzymes.

The governments of all these countries have a strong commitment to foster the bio-based industry and recognize industrial biotechnology as a strategically important field of technology for realizing bio-economy. Accordingly, they provide a relatively broad range of measures and instruments to support the bio-economy and IB, so that much of the achieved progress in industrial biotechnology within this country group has been heavily driven by dedicated policies and strategies of their governments.

These countries are characterized by the availability of a well established and highly competitive industrial biotechnology sector, which originally has been developed from the efforts of their chemical industry to remain competitive. These countries are the largest R&D performers within the EU with the most R&D intensive chemical industry. Moreover, in recent years the governments of these countries have allocated a significant amount of resources to promote world class research in industrial biotechnology and to invest in a state-of-the-art research infrastructure (e. g. piloting and testing facilities). Each of these countries hosts a number of research institutions involved in different IB related research topics. Also the bulk of patenting activities in IB is mainly concentrated within this country group Strong academic base linked to a long established research tradition in biotechnology related fields underpins the high potential of IB of these countries. Of critical importance for the success of these countries are activities of private sector comprising a large number of highly innovative and dynamic small, medium and large companies, which specialize in various niches of industrial biotechnology. The high levels of business expenditures in R&D reflect the strategic importance of the chemical industry for the private sector.

Beyond that, France and Germany exhibit in an EU-wide comparison a relatively high agricultural biomass potential (measured as the sum of starch and sugar crops, oil crops, forage crops, woody/lignocellulosic crops, manure, straw, cuttings). Sweden, Finland, and to a lesser extent Germany, are particularly rich in forest biomass.

3.2.2 Countries with strong innovative capacities in selected IB fields

This country group comprises Ireland, Austria, United Kingdom, Spain and Italy. These countries have no overall national industrial biotechnology policy: Some of them have either recently published a bioeconomy strategy that emphasizes the importance of Industrial Biotechnology (Italy, Spain) or are currently working on a bioeconomy strategy with strong links to IB (Ireland, Austria). However, the governments increasingly recognize the potential of IB, which in recent years led to some important initiatives and investments in IB as well as to launching of promotion schemes or some changes in legislation[8].

This country group hosts several important players in IB - companies, which are mostly active in selected speciality sectors, among them a large number of innovative SMEs, playing a crucial role in boosting industrial biotechnology in these countries.

Research is mainly focusing on some selected priorities in IB. However, large countries like United Kingdom, Spain and Italy specialize and have a strong position in different IB related areas. Especially United Kingdom draws on a long history of research expertise in several industrial biotechnology related areas. It has been actively engaged in high quality research and gained a strong innovative potential in some of the biotechnology related fields such as synthetic biology, biochemistry and bioenergy. Spain has a strong innovative position in engineering of microorganisms, food biotechnology and production of second generation biofuels, whereas Italy focuses particularly on bioplastics and next generation biofuels.

In recent years, many research infrastructure investments have been made within this country group reflecting a growing research profile in some biotechnology relevant technology fields. This group of countries contributes considerably to the technological progress and commercialization of industrial biotechnology, which high levels of patenting activities in some selected biotechnology topics confirm. According to the individual specialization of each country, there is a high concentration of business R&D investments in selected fields of industrial biotechnology.

With the exception of Austria, which holds a relatively high potential of forest biomass, these countries have limited biomass resources.

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8 Worth mentioning are recent major changes in Italy's legislation, which had a strong impact on the national biotechnology sector of the country. These include the ban of bags made of fossil based materials, a national law providing for high quotas of second generation biofuels and the national "bio-refinery decree" supporting the construction of new next generation biorefineries.

3.2.3 Countries with modest innovative capacities in IB

Countries with modest innovative capacities in IB represent the largest country group within the EU. To this group belong: Portugal, Slovenia, Czech Republic, Slovakia, Poland, Estonia, Greece, Hungary, Latvia and Lithuania. Overall, these countries have little targeted policy aimed to foster IB. Governments of Latvia and Estonia set knowledge-intensive bio-economy as one of the specialization priorities of their country, to which industrial biotechnology could make a major contribution. Some of the countries, such as Czech Republic, Slovenia and Greece, have no policy in place, which is directly related to industrial biotechnology. However, research institutions and innovative businesses benefit significantly from different EU support schemes. Although the relevance of industrial biotechnology has been increasingly recognized at the governmental level in recent years, which led to considerably higher level of investments in this field of technology, European Union remains the main funding source for most of the IB related projects in these countries.

Each of these countries is involved in only some IB related activities. Accordingly, a few business sector players specializing in selected fields (e.g. biotechnological production of natural aroma ingredients in Slovakia; processing of biological raw materials in Lithuania) are located there. Also there are some domestic research intensive companies specializing in niche products (e. g. bioprocess development, optimization of microorganisms in Portugal; development of technology to produce PHA from used cooking oil and protein engineering in Czech Republic). However, for this country group foreign direct investments are one of the main source of technology transfer in industrial biotechnology, as foreign owned firms dominate the domestic industrial biotechnology market in many of these countries. Overall, the R&D business investment intensity of the chemical industry is much lower, compared to the first and second country groups. Exceptions thereof are Slovenia and Hungary, which exhibit a high share of R&D business funding of the chemical sector driven mainly by the high research intensity of the pharmaceutical industry.

Some academia and research centers of these countries are active in selected topics of IB, e.g.: development of enzymes in Poland, production of prebiotics and optimization of bioprocesses in Slovakia, biomass utilization and food biotechnology in Hungary etc. Estonia focuses mainly on research in biotechnology for health applications, allocating a lot of financial resources to it; also Hungary, Czech Republic, Slovakia, Latvia and Slovenia have a strong tendency towards healthcare biotechnology due to established pharmaceutical industry and longstanding expertise in healthcare biotechnology.

Overall, this country group shows a rather moderate patenting performance in IB. Several weaknesses of their research and innovation system, such as low public and business R&D expenditures, lack of interaction between academia and industry in general, and lack of linkages among key players in IB in particular, as well as skill shortages, are the main barriers to the improvement of innovation capacities in IB. Furthermore, some of these countries are too small to be able to host large scale competitive industries.

Many countries of this country group hold a high potential in biomass resources. Agricultural biomass is abundantly available in Poland, Hungary, Czech Republic and Lithuania. Furthermore, Poland, Portugal, Czech Republic, Lithuania, Latvia and Estonia are rich in woody biomass.

3.2.4 Countries with hardly any innovative capacities in IB

To this country group belong Bulgaria, Croatia and Romania. These countries have no strategies or policy measures dedicated to the promotion of IB. However, in the national strategy of Croatia industrial biotechnology is referred to as a strategically important area. Current national strategies of Romania and Bulgaria emphasize biotechnology as one of the priority areas for research and announce their ambition to promote it. However, there is no evidence of any concrete significant measures taken so far. This is closely connected with poor awareness of the government officials and the public of the potential of industrial biotechnology and the relevance of bio-economy in general.

These countries exhibit hardly any industrial biotechnology related research and innovation activities. They generally lack a necessary critical mass to conduct scientific research in the field of industrial biotechnology. However, Croatian research organizations are largely involved in some EU-funded research projects related to IB. According to statistical data, the patenting performance of these countries ranges from extremely weak to non-existent in the field of industrial biotechnology. Resources allocated to R&D by private companies in Bulgaria and Romania in the industrial biotechnology related fields are by far the lowest in the EU. Compared to that, the significantly higher level of private investments in Croatia is mainly driven by the pharmaceutical industry.

However, in the past, these countries attracted a lot of foreign direct investments in the IB related production where modern technologies are applied to produce traditional IB products (e.g. food and feed, fertilizers, chemicals, cosmetics etc.).

Bulgaria, Romania and Croatia have a high potential in endowment with agricultural biomass resources. In Romania the woody biomass is also abundantly available.

3.3 Strategic priorities for country groups

The discussion on policy actions under the consideration of specific framework conditions of different country groups led to the elaboration of the following major strategic priorities for stimulating IB within the EU:

Policy Framework

It was agreed that in terms of policy framework it would be essential for the countries with the advanced IB sector to continue their efforts in fostering IB and to continuously update the IB policy framework to make sure that policy and strategies remain effective to be able to respond to new developments and challenges. As the second group of countries generally lacks a comprehensive IB policy, the development of such could be helpful to clearly define the thematic priorities in IB as well as to ensure the government commitment to foster IB by taking concrete policy measures and actions. For country groups with little innovative capacities (country group 3 and 4) it would be important to increase the awareness of the relevance of IB at government level and to enhance commitment among policy makers to promote IB. Careful consideration should be given to the definition and specification of strategic foci in IB and to the identification of thematic priorities according to the potential and framework conditions of each individual country.

R&D&I Capability

To improve and enhance the R&D&I capabilities in IB within the EU is of crucial importance for innovation and commercialization of IB based products, processes and services in Europe. The main challenge for the group with advanced IB is to be able to maintain their leading position in IB in the future by investing in cutting edge technologies, exploiting emerging topics and ensuring closer cooperation between biomass production and biomass conversion. The latter is in issue in all country groups, but especially a key bottleneck at the forefront in those IB value chains with high feedstock use. Encouraging continuous investments in cutting edge technology should be also one of the priorities for countries with strong innovative capacities in selected fields. In view of increasing international competitiveness in IB, it would be advisable for countries focusing on selected topics in IB to explore which existing strengths and capabilities in these selected fields can be used to broaden the strategic focus in some novel fields. For country group with modest and very little innovative capacities in IB it was considered essential to strengthen the efforts in fostering research and development and to expand capabilities in the identified priority fields. To establish the necessary R&D infrastructure, the EU regional development funds should be used in a more targeted and efficient way. This

refers to the necessity to improve public funding targeted at the needs of IB, since with regard to bio-industries, the most EU funding to date aims to support bio-energy and the agricultural sector, while lesser public funding is available to foster IB. Moreover, the support should be better aligned to the individual IB profiles and development levels of each country.

Transfer of R&D results into commercialization

One of the most central challenges for the country group 1 and 2 is the exploitation of knowledge and transfer of R&D results into commercialization generating economic value from them. Targeted policy measures are needed to incentivize the commercialization of research and to support the diffusion of industrial biotechnology into different industrial sectors. Apart from this, countries with strong innovative capacities in selected IB fields could gain more complementary expertise through stronger cooperation with partners from other EU countries or regions. It would enable them, among other things, to accumulate necessary expertise in the novel fields of IB. For the country groups 3 and 4 it would be crucial to support the expansion of relevant activities around the national champions (e. g. by means of the cluster policy) and to foster the cross-country integration into existing networks and value chains.

Biomass Resources

In this regard, the role of each country depends largely on the country specific availability of biomass resources. As many of the EU countries from the country group 3 and 4 hold a high potential of biomass resources, they should be better integrated in the European value chains as feedstock suppliers. However, it is important to ensure that these countries do not position themselves only as raw material suppliers along the European value chain in IB, but are able to build up their own industrial and innovative capability in IB in order to be able to adopt technologies for higher value added activities (e.g. for building up commercial plants for technologies developed in leading technological countries).

4 Collaboration between EU countries

In view of the growing global competition, cooperation across the EU and interregional projects are of critical importance for the fostering of IB in the EU. It is particularly crucial for the transfer of practical knowledge and in mastering of main challenges. There are compelling reasons for intensified collaborations between actors from different EU member states. The most obvious among them are:

- with joined forces countries and regions can gain the necessary critical mass in different crucial fields (e. g. research, human resources, venture capital funds);

- bringing together the complementary resources needed for innovation and industrial application. E. g.: one side of the border may have a strong research and the other a strong industrial base that can use the knowledge;

- achieve a higher quality of R&D&I through knowledge transfer, synergies and avoidance of duplication of research;

- contribution to more balanced regional development within the EU.

Recommended actions resulting from the working group discussions for establishing and intensifying collaboration in IB between EU member states are the following:

- Support the establishment of cross-country value chains, e.g. between feedstock providers and IB firms, IB providers and firm users of IB products (e.g. for bio-based plastics). Therefore, an introduction of a monitoring system that allows a consistent uniform assessment of the available biomass and type of feedstock across the EU would be useful. Moreover, funding mechanism for projects across EU (post H2020 programme, EUREKA, etc.) should ensure that there are incentives to support projects that include participants from different value chain stages and countries.

- Support the integration of actors from countries with moderate IB innovation activities into existing networks. For this, a Europe wide mapping of relevant IB competencies as information base for complementary competencies and for higher visibility of actors would be very useful. Apart from that, support measures for various actors would be necessary to gain higher visibility and foster integration of actors from more countries in networks. Therefore, information exchange and coordination platforms should be developed further and countries with lower

developed IB sectors should be supported in developing necessary capacities to join these networks.
    - Support cross-border clusters, as cross border collaboration in clusters has proven to be very effective in stimulating innovation and growth.
- in order to incentivize the participation of actors from countries with modest or low activities in IB the following modification of existing measures and procedures may be considered, e.g.
    - "restriction" of the national freedom to assign EU structural funds by linking part of those funds to IB relevant topics
    - further simplification of application processes for EU R&D&I programs, as those actors from lagging-behind countries often lack of skilled workforce to write proposals
    - increase the EU budget for programs like EUREKA, EUROSTAR. Currently these measure require high national co-funding, which isn't available in some countries

5 Annex : Workshop discussion on general recommendations for policy actions

The workshop started with a presentation of recommendations for policy actions derived from the results of the cross-analysis of the value chains. They were formulated at a broad level so far, without differentiating between specific framework conditions of different EU countries. The recommendations focused on the following areas:

- Advanced technologies
- Sustainable feedstock supply
- Transfer of R&D results into commercialization
- Collaboration along value chains
- Multidisciplinarity of skills
- Co-evolution of regulatory environment and S&T development
- Address public perception and acceptance
- Demand pull for IB

The description of policy actions and their rationales were outlined by the Fraunhofer ISI team in more detail to give the workshop participants a better understanding of their contents and backgrounds. These recommendations for policy actions provided the basis for discussions during the workshop. For an overview, copies of the presentation slides are included below.

At the end of the presentation, an open discussion was initiated aimed at receiving from the experts a feedback and constructive criticism on the raised issues. In particular, the workshop organizers invited the participants to answer the following questions:

- Are the main ideas of the recommendations reasonable?
- Are the identified key thematic areas adequate?
- Do you have any suggestions for modification?

There was a general approval of the identified areas of priorities for policy actions and the specification of the recommended actions from the workshop participants.

Advanced Technologies

Rationale:

- Indispensable for advancing IB further and maintaining international competitiveness
- Game changing role in few value chains;
  in most value chains necessary, but alone not sufficient

Action:

- Enable absorption and exploitation by addressing not only R&D, but also skills, public perception, regulatory environment...
- Integration of life science technologies with other technologies (e.g. "green chemistry", digital technologies/bioinformatics)
- Pretreatment of biomass: R&D into low-cost, robust processes for many different feedstocks of variable quality
- Production organisms: develop high-throughput systems metabolic engineering (design – build – test); optimize productivity and robustness
- Production processes: Scale-up, optimization; development of integrated biorefineries; combination with green chemistry, exploiting digitilisation

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Sustainable feedstock supply

Rationale:

- Expansion of markets in some IB value chains lead to an increasing demand of feedstock
- Concerns of potential negative (environmental / societal) impacts if industrial use of biomass increases

Action:

- Effective instruments for "food-first" use and measures for sustainable cultivation of biomass have to be implemented
- Increase of technological potential: Addressing technological and logistical challenges to use all fractions of biomass and non-food biomass
- Further exploring of economic potential: monitoring system for a consistent uniform assessment across the EU countries regarding the amount of available biomass potential and type of feedstock
- Develop standard definitions of sustainable production of feedstocks, and the related tools for measuring sustainability
- Revision of waste regulation such as the EU Waste Framework Directive

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Transfer of R&D results into commercialization

Rationale:

- Long-known hurdle in IB, but becomes even more valid as an increasing number of (R&D) projects are entering a more mature stage
- Shortcomings: Missing knowledge for commercialization (e.g. scaling-up, market intelligence), access to capital-intensive infrastructure

Action:

- highly skilled workforce, with competencies in commercialization-relevant expertise (e.g. scaling up, market intelligence)
- access to capital-intensive infrastructure
  - set-up of pilot and demonstration plants
  - more efficient network of existing infrastructures
  - provision of commercialisation consulting services even for actors in early stages of R&D
- continuous support of collaboration between academia and industry and fostering the start-up scene, including financing

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Collaboration along value chains

Rationale:

- Collaboration of actors from different stages of the value-chain important to realize synergies of different perspectives and to address all bottlenecks
- Fostering of networks a key issue in emerging value chains (e.g. microbiomes) or in existing ones, where novel approaches enable an innovation push (e.g. flavors & fragrances)

Action:

- Intensive use of existing instruments in those value chains, such as national and cross-border cluster policies; promotion of R&D projects that include actors along the value chains
- Address specific lack of cooperation between biomass production and supply, and its conversion: R&D policy should address research questions that require closer cooperation between these sectors

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Multidisciplinarity of skills

Rationale:

- IB requires a highly skilled and specialised workforce, but is only a niche
- Greater breadth of skills is needed, e.g. specific skills for scale-up of processes from lab to production, business issues, basic competences in other technology fields

Action:

- University curricula and vocational and continuous training have to be adapted: Qualified staff has to be rooted in a scientific discipline, but should be able to swiftly interact with specialists from other disciplines in a multidisciplinary environment
- Cross-country exchanges of expertise
- Public-private partnerships as opportunity for scientists from academia to gain industry-relevant experiences

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Co-evolution of regulatory environment and S&T development

Rationale:

- The regulatory environment has significant impact on growth opportunities and innovation incentives in many IB segments
- Regulatory landscape for IB: not generally positive or negative impacts on innovation incentives and growth opportunities, but impact differs between value chains

Action:

- Co-evolution of S&T developments with regulation: align R&D policy with regulatory activities, both with respect to timeline and areas incentivized
- Balancing incentives for industry and R&D with the interests of the public and consumers, thus contributing to establishing trust and credibility and shaping IB according to the UN Sustainable Development Goals
- Key instruments: development and international agreement of tools and indicators for measurement of sustainability, environmental performance standards, etc.

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Address public perception and acceptance

Rationale:

- Public perception of IB rather positive, but attitudes and acceptance differ depending on stakeholder group, application, and technologies

Action:

- IB R&D strategies tailored in a way that they are guided by the UN Sustainable Development Goals
- Constructive stakeholder dialogues and public participation in order to develop a commonly shared future vision for IB; results should have consequences for regulation or thematic R&D funding

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Demand pull for IB

Rationale:

- Demand pull needed as cost-competitiveness currently unlikely for many products
- Broad range of IB products makes it very challenging to reach consumers, to increase their awareness, to communicate the benefits of IB products and thus influence their purchasing decisions

Action:

- Business-to-Consumer sector: More specific approaches, tailored to the needs and expectations of different target groups, dialogues as well as establishing different communication channels
- Business-to-Business sector: policy support may address the development and implementation of respective sustainability assessment tools, European and international standardisation of sustainability labels and certificates, communication of IB success stories

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