ERA CoBioTech Strategic Agenda – a vision for biotechnology in Europe

November 2018

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Foreword

Next steps for European biotechnology: a strategic vision from ERA CoBioTech

The strategic agenda for ERA CoBioTech describes a highly valuable direction for the future of biotechnology research and innovation in Europe. ERA CoBioTech is based on experiences and best practices from three previous ERA-NETs: ERASynBio, which brought together leading researchers in synthetic biology; ERASysAPP, which focussed on applied systems biology; and ERA-IB, whose industry involvement pushed technology readiness levels and innovation potential. ERA CoBioTech draws on the synergies between these previous ERA-NETs and allows projects to develop and use key technologies to address the challenge of transforming our fossil fuel based economy into a bio-based economy.

As coordinators and partners of several ERA-NET projects we cannot emphasise enough their importance and the many advantages they bring for the research community in Europe. Only through such programmes it is possible to establish strong international consortia who are driven by shared ambitions, supported by complementarities in the sciences, and have therefore the capability to think ahead and recognise what is needed to further biotechnology skills, knowledge and competence.

The first ERA CoBioTech projects are now up and running and we are confident that their goals, ambitions and scope are pointing in the best possible direction. They are driven by innovation and its relevance for a circular bioeconomy. We strongly believe that the results and expertise generated through these projects will provide an important contribution to the future European bioeconomy. Not only will they bring scientific advances, but also contribute to transnational capacity building, sharing of infrastructures and resources, and networking supported by researcher mobility for scientists at all stages of their career.

More emphasis has now also been placed on bringing social sciences into biotechnology and we warmly welcome Responsible Research and Innovation (RRI) and Communication & Dissemination as firmly integrated elements of ERA CoBioTech. Both are vital to better understand the societal, political and ethical impacts of new technologies and innovation generated through biotechnologies. Modern research has brought our society to the verge of a green revolution and we have to engage all societal actors as public awareness and acceptance of biotechnological processes, tools and technologies will be essential to achieve a sustainable bioeconomy.

With this vision for the future of biotechnology in Europe, ERA CoBioTech presents an example of how we can harness cutting edge biotechnology research, funding processes and awareness for science to create significant impact and ma e a difference for society and our future away from fossil fuels. The decisions taken today will be key to help us and the next generations to enable excellent science and tackle global societal challenges.

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Executive Summary

Biotechnology has been named a key enabling technology for the transformation from a fossil-based to a sustainable bio-based economy as envisaged by the European Union. Europe is a global leader in supporting and developing key enabling technologies across the European Research Area (ERA) but is lagging behind in the industrial translation of this knowledge. Hence the European Union has increased its efforts to close that gap and improve the innovation and knowledge translation towards more marketable products and services.

Previously, three strong and innovative disciplines within biotechnology, synthetic biology, systems biology and industrial biotechnology, have been supported individually through specific European Area Research networks (ERA-NET). Since late 2016, the ERA-NET Cofund on Biotechnologies (ERA CoBioTech) combines, builds on and learns from these three disciplines and programmes in order to influence and strengthen biotechnology research and technology development across Europe.

To achieve this, the ERA CoBioTech partners, together with the biotechnology community, developed this strategic agenda to highlight the needs and potential of biotechnology in Europe and beyond. Additionally, this document explores ways to create a more open and inclusive research community supported through tailored funding, which focusses on innovative and emerging topics supporting the European goal of achieving a sustainable bio-based economy.

Overall, this strategic agenda emphasises the importance of collaborative and interdisciplinary research which is open not only to the biotechnology community but for all groups of society. Only through this way of working it seems possible to tackle the global challenges our society is facing and to strengthen the position of biotechnology within a sustainable and bio-based economy.

SMWK, René Plaul

ERA CoBioTech – aligning biotechnology in Europe and beyond

The European Research Area Network (ERA-NET) Cofund on Biotechnologies (ERA CoBioTech) was set up in 2016 in response to the Horizon 2020 Leadership on Enabling and Industrial technologies (LEIT) theme "Nanotechnologies, Advanced Materials, Biotechnology and Advanced Manufacturing and Processing"[1]. These Key Enabling Technologies (KETs) have the potential to help address the societal challenges Europe and the world are facing today, and exploitation of KETs will lead to the creation of advanced and sustainable economies[2].

While Europe is a leader in developing KETs, it is currently lacking in translation of this knowledge into marketable products and services, a problem which is often branded as the "European Valley of Death". By supporting activities with a strong focus on research, innovation and knowledge translation, the European Commission (EC) aims to overcome this obstacle and to expand its leading role in the development of KETs towards translation[3].

Therefore, the key objectives of ERA CoBioTech are to:

- Maximise synergies between current mechanisms of biotechnology research funding in Europe
- Foster the exchange of knowledge across borders
- Demonstrate how a bio-based economy can be beneficial fo different groups in societ
- Maintain and strengthen Europe's position in biotechnology

ERA CoBioTech builds on and learns from the work of three previous ERA-NETs ERA-IB2[4], ERASynBio[5] and ERASys*APP*[6], and brings together industrial biotechnology (IB), synthetic biology (SynBio) and systems biology (SysBio). ERA CoBioTech has a strong focus on innovation and the synergy of these scientific areas at the forefront of technology development will ensure an accelerated translation of knowledge.

The ERA CoBioTech objectives will be pursued through eight work packages (WP) which encompass work on transnational funding activities, communication and dissemination, strategic planning, and other activities supporting the biotechnology community in Europe and beyond. This work will help to make ERA CoBioTech and biotechnology in general visible to a larger community and boost research efforts in the geographical and scientific area.

The first major activity of ERA CoBioTech was a cofunded transnational call "Biotechnology for a sustainable bioeconomy", which was launched in December 2016, and brought together 22 funders from 18 countries with a total funding volume of over €31 million. A total of 22 research consortia with researchers from 17 countries, all embracing the incorporation of IB, SynBio and SysBio approaches, were successful in securing funding through this call[7].

[1] [Reference/webpage no longer available – February 2019]
[2] [Reference/webpage no longer available – March 2019]
[3] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52012DC0341&from=EN; http://ec.europa.eu/growth/industry/policy/key-enabling-technologies_en;
https://ec.europa.eu/growth/industry/policy/key-enabling-technologies/challenges_en
[4] ERA-NET "Towards an ERA in Industrial Biotechnology" https://www.cobiotech.eu/about-cobiotech/era-ib
[5] ERA-NET on Synthetic Biology https://www.erasynbio.eu/
[6] ERA-NET for Systems Biology applications https://www.erasysapp.eu/
[7] https://www.cobiotech.eu/index.php?index=9&news=Outcome_of_ERA_CoBioTech_rsquo_s_co_funded_call

ERA CoBioTech strategic agenda – towards a vision for European biotechnology

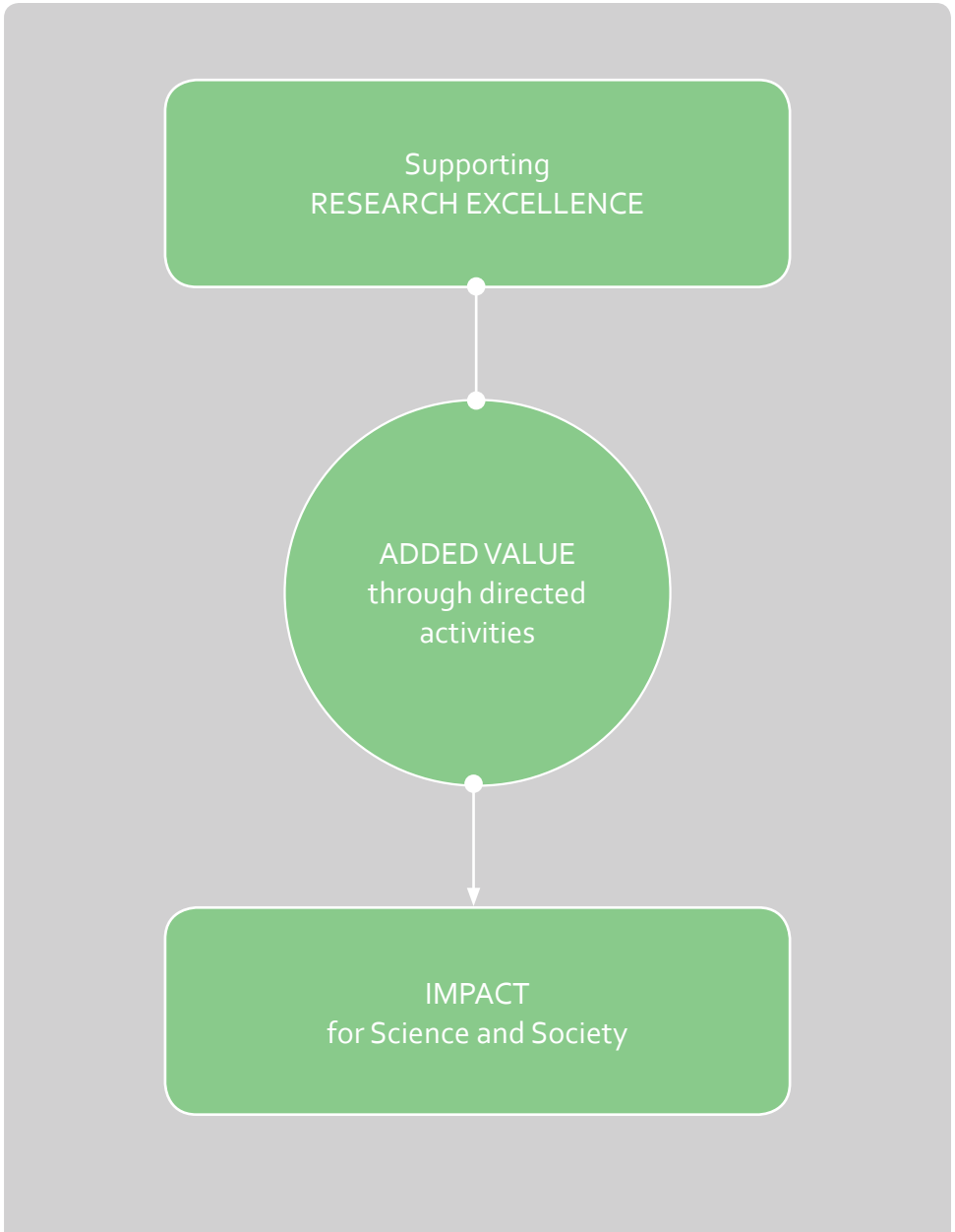
The ERA CoBioTech partners aim to advance research and innovation in industrial biotechnology, to address innovation needs in conjunction with arising societal needs, and to establish systems and synthetic biology as technology drivers. This is only possible through comprehensive strategic planning. For ERA CoBioTech this includes the analysis of the current biotechnology sector in Europe, and the development of a strategic agenda and RRI framework. While this requires quite some effort from the individual partners, there is a definite benefit in this work. It will support researc funders in maximising their funding input and achieve the best value for money, and it will encourage the scientists to deliver the best research possible.

The development of this strategic agenda allowed all stakeholders to co-design a future vision for biotechnology in Europe by setting out goals which will be supported by ERA CoBioTech through various activities. This will eventually lead to the enhancement of the potential for industrial exploitation and thereby support the pan-European attempts to overcome the "European Valley of Death".

Data from a national and European mapping exercise (described in the chapter Biotechnology in Europe) formed the basis for a strategic workshop which was held as part of the 1st European Biotechnology Hub Meeting in Dresden in January 2018[8].

The Biotechnology Hub Meting was initiated by ERA CoBioTech in order to increase the exchange of knowledge and experience within the biotechnology community in Europe. The workshop identified goals, priorities and ideal scenarios for biotechnology in Europe. The participants hailed from academia, industry, policy making bodies, funding and governmental organisations as well as European programmes and initiatives with expertise beyond synthetic biology, systems biology, and IB. This enabled ERA

FIGURE 1 THE VALUE OF STRATEGIC PLANNING



[8] https://www.cobiotech.eu/index.php?index=9&news=1st_European_Biotechnology_Hub_Meeting_ndash_Part_1

CoBioTech to gather a holistic view on the biotechnology sector in Europe and to act with all players in mind. In contrast to previous strategic activities, Responsible Research and Innovation (RRI) was fully integrated into the sessions of the workshop and not treated as an independent entity. This approach successfully led to a better acceptance of RRI topics by the workshop participants and the awareness that, at least in biotechnology, RRI is an integral part of modern research. This strategic agenda therefore includes aspects of RRI, but a detailed RRI framework, aligned to this agenda will be published alongside this strategic agenda.

Throughout the workshop, addressing global societal challenges to achieve the UN's sustainability development goals[9] through modern research emerged as the common theme from all discussions. The impact of human behaviour and consumption on the global environment is now recognised and becoming a growing concern on all levels, from academia to industry as well as politics. Providing sufficient energy and foo for the increasing global population without negatively affecting the environment are currently two of the largest topics for discussion politically, and in the research community. Local, national and international initiatives must be utilised to address these issues and it has been recognised that an effective solution to targeting environmental concerns will require the integrative work of a variety of countries.

The vision of ERA CoBioTech is to have a direct influence on the transformation of the economy into a sustainable bioeconomy by focussing its research activities in certain biotechnology areas related to the global challenges, and by changing the Research, Development and Innovation (R,D&I) landscape towards a more streamlined and supportive environment.

To work towards this, ERA CoBioTech will give recommendations on the following topics:

- Maximise synergies between current mechanisms of biotechnology research funding in Europe
- Foster the exchange of knowledge across borders
- Demonstrate how a bio-based economy can be beneficial for different groups in societ
- Maintain and strengthen Europe's position in biotechnology

This work will also continue the strategic work that was started by the ERA CoBioTech predecessors, particularly ERASysAPP and ERASynBio which have both a published strategic research agenda[10] and strategic vision[11], respectively. While the implementation of some recommendations in this document is anticipated from autumn 2018 onwards through additional funding activities, others are more ambitious and will require a longer timeframe, as well as the involvement of additional stakeholders. Overall, this ERA CoBioTech strategic agenda for the European biotechnology sectors can be used as a guide to impact on the development and improvement of research and innovation on a national and European level.

[9] https://www.un.org/sustainabledevelopment/sustainable-development-goals/
[10] https://www.erasysapp.eu/lw_resource/datapool/_items/item_138/sra_sbineurope_august2016_double_pages_fastviewing.pdf
[11] https://www.erasynbio.eu/lw_resource/datapool/_items/item_58/erasynbiostrategicvision.pdf

Biotechnology in Europe

The initial work for developing a strategic agenda for ERA CoBioTech explored the current position of biotechnology, defined as synthetic biolog , systems biology and industrial biotechnology, within the European scientific landscape. This comprehensive mapping activity was undertaken between summer 2017 and spring 2018, and involved a desk-review and surveys to theERA CoBioTech partners. This provided an initial insight into the following questions:

- What funding opportunities, programmes, and initiatives are available on a national and transnational level?
- What are the strategic priorities within Europe?
- Who do we currently engage with?

This analysed data was combined in a strategic inventory which was submitted to the EC in May 2018. The content will be available on the ERA CoBioTech website under the Biotech Hub Platform[12]. The platform will give the scientific community – academics, funders, policy makers, industrialists – easy access to available funding opportunities, country-specific information, and other information rel vant to the biotechnology sector in Europe.

TABLE 1 JOINT PROGRAMMING INITIATIVES (JPIS) ADDRESSING RELEVANT SOCIETAL CHALLENGES

Name	Keywords	Link
FACCE JPI -Tackling the challenge of agriculture, food security and climate change	agri-tech, climate change, food	https://www.faccejpi.com/
Water JPI -Working towards sustainable water systems	socio-economics, tools & technologies	http://www.waterjpi.eu/
JPI Climate - Joint Programming Initiative Connecting Climate Knowledge for Europe	climate change, socio-economics, innovation	http://www.jpi-climate.eu/home
JPI HDHL - Promoting a healthy diet for a healthy life	health, food, socio-economics, industry	http://www.healthydietforhealthylife.eu/index.php
JPI Oceans - Working towards healthy and productive seas and oceans	marine, tools & technologies, socio-economics, climate change, industry, food, IB	http://www.jpi-oceans.eu/
JPND - Working on the challenge of neurodegenerative diseases	health, socio-economics, tools & technologies	http://www.neurodegenerationresearch.eu/
jpiamr - Working on the challenge of antimicrobial resistance	health, socio-economics, innovation, tools & technologies, industry, agri-tech	https://www.jpiamr.eu/

[12] https://www.cobiotech.eu/biotech-hub

Biotechnology funding opportunities, programmes, and initiatives in Europe

The preliminary work for this strategic agenda, revealed at least 17 ERA-NETs operating in a similar or close scientific area to ERA CoBioTech within the last five years (see Annex 1). These programmes have their focus either on a scientific area, e.g. synthetic biology (ERASynBio), a sector, e.g. sustainable food production (SUSFOOD), or collaboration with specific countries, e.g. orea (KORANET). The now finished ERA-NET programme on marine biotechnolog , ERA-MBT, was probably closest to ERA CoBioTech and therefore still provides a useful example for the work of ERA CoBioTech. Similar to ERA CoBioTech, it attempted to integrate biotechnology with tools from bioinformatics, systems and synthetic biology, however specifically in the context of blue biotechnolog . ERA-MBT organised three transnational calls, established stakeholder meetings to encourage dialogue between scientists, industry and policy makers, and published a strategic Research Agenda. In addition, ERA-MBT also set up a database containing all relevant information about the marine biotechnology sector in Europe and beyond, similar to the Biotech Hub platform set up by ERA CoBioTech.

TABLE 2 EUROPEAN INFRASTRUCTURE WITH RELEVANCE TO ERA COBIOTECH

Large European Infrastructures	Link
EMBRC - The European Marine Biological Resource Centre	http://www.embrc.eu/
EU-OPENSCREEN - The European Infrastructure of Open Screening Platform for Chemical Biology	http://www.eu-openscreen.eu/
ISBE - Infrastructure for Systems Biology Europe	http://project.isbe.eu/
MIRRI - The Microbial Resource Research Infrastructure	http://www.mirri.org/home.html
INSTRUCT - The Integrated Structural Biology Infrastructure	https://www.structuralbiology.eu/
IBISBA - Industrial Biotechnology Innovation and Synthetic Biology Accelerator	http://www.ibisba.com/

Europe, like the rest of the world, is facing major societal challenges, which include dealing with climate change, the supply of sustainably produced energy and food, and the preservation of human and environmental health. In 2010, to tackle these challenges, the EC initiated 10 Joint Programming Initiatives (JPIs)[13] of which seven are addressing challenges in areas where biotechnology can provide solutions. These are agriculture, food security, climate and climate change, water and oceans, nutrition, neurodegeneration and antimicrobial resistance (see table 1). Through interdisciplinary working and collaboration with those JPIs, ERA CoBioTech will be able to support the work to overcome the challenges and thereby continue the work that was started by ERASynBio, which identified "Lifelong health and wellbeing", "Energy security, living with and avoiding environmental change", and "Global food security" as the areas were synthetic biology could have the biggest societal impacts[14].

Further to this, biotechnology in Europe is supported by seven established and one recently established large European research infrastructures. They are already or will be included in the ESFRI Roadmap, and cover marine biology resources, microbial resources, chemical screening platforms, structural biology, systems biology, synthetic biology, and bioinformatics (see table 2). During the preparatory phase of this agenda, the scientific community has emphasised that research infrastructures are vital to high quality research. As will be discussed under theme 3, the current issues lie with access to the infrastructures by the scientists.

On the national level, funding opportunities vary between countries and funders. While some do not offer biotechnology specific funding, others drive R,D&I i biotechnology by specific investments. Examples of those specific activities an investments are:

[13] http://ec.europa.eu/research/era/joint-programming-initiatives_en.html
[14] https://www.erasynbio.eu/lw_resource/datapool/_items/item_58/erasynbiostrategicvision.pdf

- Norway implements the "National Strategy for Biotechnology" through activities supported by "Biotechnology for Innovation (BIOTEK2021)[15]. Approximately €17 million per year are available for biotechnology research under this programme (see Box 1).
- The UK's Synthetic Biology for Growth programme saw the investment of more than €110 million in SynBio research centres, DNA foundries, doctoral training centres and start-up money in 2013[16].
- Germany's focus is the bioeconomy as a whole which is addressed in the "National Research Strategy BioEconomy 2030 (NFSB2023)"[17]. Based on this strategy, the federal government provided €2.4 billion of funding for research projects within the bioeconomy between 2010 and 2016.
- Switzerland's SystemsX.ch programme, the country's largest public research initiative, supported systems biology through a network of 23 universities and five research institutes. It funded approximately 250 projects during its lifetime[18].

[15] https://www.forskningsradet.no/en/Home_page/1177315753906
[16] https://bbsrc.ukri.org/research/programmes-networks/synthetic-biology-growth-programme/
[17] https://www.bmbf.de/pub/Nationale_Forschungsstrategie_Biooekonomie_2030.pdf (in German)
[18] http://www.systemsx.ch/

Box 1. Case Study: Digital Life Norway - working together to shape the scientific landscap

The Centre for Digital Life Norway is a striking example of how a national funder, in cooperation with national universities, can shape, direct and advance scientific research and innovation.

The Centre for Digital Life Norway is a national centre for biotechnology education, research and innovation and comprises of a governance and networking project, a graduate school and research projects. The centre is organised with the University of Bergen, the University of Oslo and the Norwegian University for Science and Technology as the hub, and the research project's host institutions as the nodes. The complete structure is supported by the Norwegian Research Council.

The vision of the centre is to "Significantly improve the innovation potential of Norwegian biotechnology to create economic growth and societal and environmental value the four thematic focus areas, marine, agricultural, industrial and medical, in which biotechnology can play a role in addressing societal challenges".

To achieve this, the Centre for Digital Life Norway facilitates multidisciplinary cooperation on all levels, from projects to areas of research.

Research projects that would like to join the centre should share the vision and have two routes of joining; either by applying directly to the centre to become a partner project or by applying to calls under the BIOTEK2021 programme of the Research Council of Norway. Projects must be transdisciplinary and include areas like biology, IT, physics, mathematics, medicine or engineering, have the aim to contribute to innovation and creation of value for society, and have Responsible Research and Innovation (RRI) as an integral part of the project. It is notable that RRI is an important factor in every research project hosted by the centre. In line with the "Digital Life – Convergence for Innovation" paper, published in 2014 by the Norwegian Research Council, projects are working on developing anticipatory competence to be able to answer the following question: "What kind of future do we collectively want science, technology and innovation to bring to the world?" To achieve this, the centre's RRI team provides guidance, training and facilitation of public engagement efforts.

Further Information

https://digitallifenorway.org/gb/

https://www.forskningsradet.no/prognett-biotek2021/Documents/1253970728136

https://www.forskningsradet.no/prognett-biotek2021/Documents/1253970728136

Strategic Priorities within Europe

Europe has a very strong focus on the bioeconomy. The European bioeconomy strategy "Innovating for sustainable growth: A bioeconomy for Europe"[19], launched in February 2012, describes the production of renewable biological resources and their conversion into vital products and bioenergy while dealing with the challenges the world is facing today. The strategy is based on three pillars:

- Investments in research, innovation and skills
- Reinforced policy interaction and stakeholder engagement
- Enhancement of markets and competitiveness

In 2017, a review by an expert group found that the European bioeconomy strategy has led to increased amounts of dedicated R&I funding, and a number of national and regional bioeconomy strategies across Europe. However, it also found that better coherence and monitoring as well as further mobilisation of investments are needed to achieve the actions set out in the strategy and to implement the new technologies. In addition, since publication of the strategy in 2012, developments in global policies, such as the Paris Agreement[20], Energy Union[21], and Circular Economy[22], have shown the need for a sustainable, circular bioeconomy. Therefore, objectives and actions outlined in the bioeconomy strategy should be reassessed in view of these recent developments[23].

As a KET, biotechnology plays a key role within the bioeconomy and is firmly incorporated into Horizon 2020[24]. With a budget of approximately €80 billion between 2014 and 2020, H2020 will be vital in supporting research, development and technology in the European Research Area in order to bring new ideas from the lab to the market. ERA CoBioTech will therefore play an important role in implementing the European bioeconomy strategy by developing technologies and products to move away from fossil fuels towards more sustainable feedstocks.

On a national level, the strategic priority areas are mostly decided by the respective government upon consultation with their research communities, advisory boards or other stakeholders. In general, the national priorities align with the H2020 priorities, often to trigger an increased participation of researchers in the programme. However, the number of supported strategic priority areas varies by country.

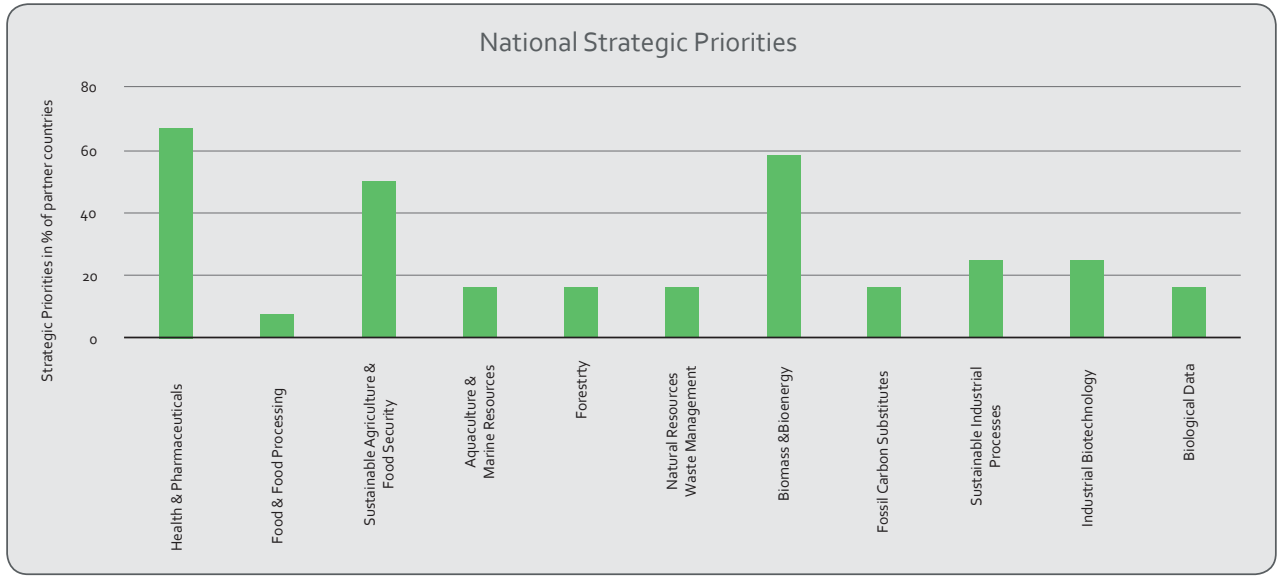
Across Europe, the ERA CoBioTech partner surveys[25] identified 11 overarching areas of strategic priorities, which can all be seen as part of the bioeconomy. These are:

- Health & Pharmaceutical
- Food & Food Processing
- Sustainable Agriculture & Food Security
- Aquaculture and Marine Resources
- Forestry
- Natural Resources & Waste Management
- Biomass & Bioenergy
- Fossil Carbon Substitutes
- Sustainable Industrial Processes
- Industrial Biotechnology
- Biological Data

Health & Pharmaceutical, Biomass & Bioenergy, and Sustainable Agriculture & Food Security are the most prevalent strategic priority areas across Europe (Fig. 2).

[19] https://publications.europa.eu/en/publication-detail/-/publication/1f0d8515-8dc0-4435-ba53-9570e47dbd51
[20] https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement
[21] https://ec.europa.eu/commission/priorities/energy-union-and-climate_en
[22] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52015DC0614
[23] https://publications.europa.eu/en/publication-detail/-/publication/e5685a20-c9c9-11e7-8e69-01aa75ed71a1/language-en; http://ec.europa.eu/research/bioeconomy/pdf/review_of_2012_eu_bes.pdf#view=fit&pagemode=none
[24] http://ec.europa.eu/programmes/horizon2020/en/area/biotechnology
[25] These countries replied to the surveys: Estonia, France, Germany, Israel, Moldova, Norway, Poland, Portugal, Romania, Russia, Saxony, Spain, Switzerland, Turkey, United Kingdom

FIGURE 2 ANALYSIS OF NATIONAL STRATEGIC PRIORITIES
National strategic priorities as stated in an internal ERA CoBioTech survey. A total of 13 out of 19 countries/regions responded to the survey.



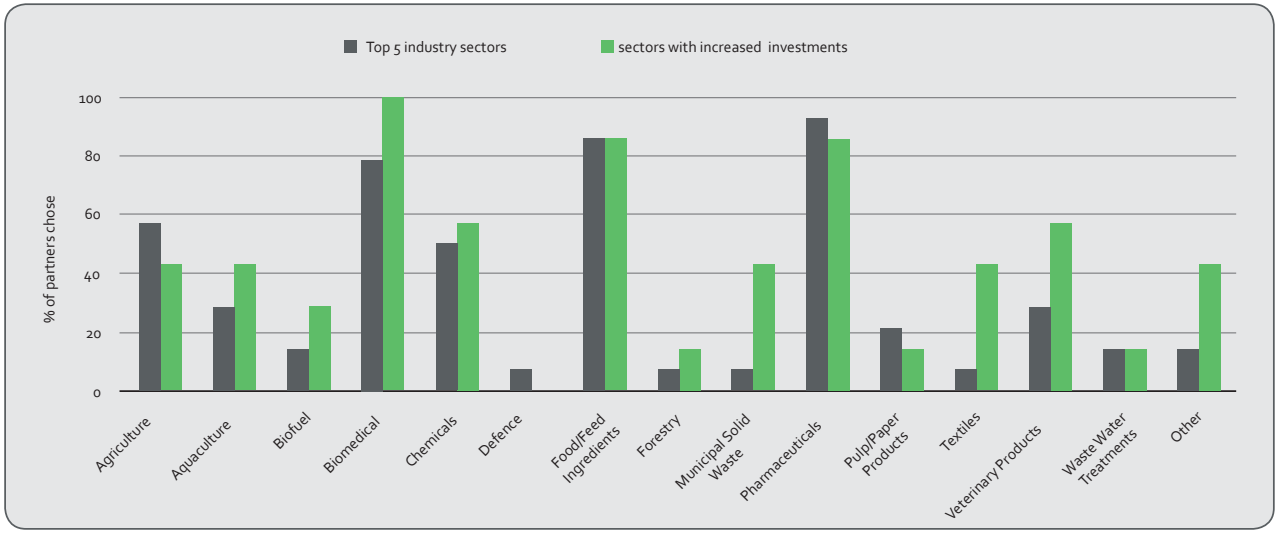
The strategic priorities largely overlap with those commercial sectors which have seen the biggest increase in investments over the past five years and also which are considered to be the top sector by the respective country (Fig. 3). The Biomedical, Food/Feed Ingredients and Pharmaceutical sectors are leading the list and generally overlap with the priority areas Health & Pharmaceutical and Sustainable Agriculture & Food Security.

It is therefore interesting to see that the majority of funded projects of the 1st ERA CoBioTech call are within the Sustainable Industrial Processed and Fossil Fuel Substitutes sectors, hence outside of the top commercial sectors. This result might reflect the current translation gap for biotechnology in Europe. How ver, ERA CoBioTech is a positive step towards increasing translation and enhancing the importance of some industrial sectors. Through its strategic work, ERA CoBioTech aims to further support activities targeting the strategic needs of biotechnology in Europe, from targeted technology development to translation of marketable products and services for the bioeconomy.

Enabling cooperation within the biotechnology community

One of the pillars of the European Research Area (ERA) and its resulting funding opportunities is the establishment of transnational cooperation on all levels, from the academic and commercial research base to funders and policy makers. This way of working allows the alignment of strategic funding and priorities, sharing of resources, broader knowledge exchange, better translation of results and a more comprehensive training of early-career scientists.
A survey amongst the ERA CoBioTech partners and observers revealed that this approach seems to have been adopted on a national level as well. The ability to add commercial partners to research projects is common practice across Europe, which contributes to the translation of research outcomes and drives innovation. While ERA CoBioTech includes several partners who are able to fund commercial consortium

FIGURE 3 ANALYSIS OF TOP 5 INDUSTRIAL SECTORS AND SECTORS WITH LARGEST INVESTMENT INCREASE
ERA CoBioTech partners (14 responses) indicated their Top 5 industrial sectors according to pre-defined categories. In addition, partners also identified the sector with the largest increase in investments over the last 5 years. The "Other" sector includes bioremediation, bioanalytics and companies at the interface of biomedical and medtech.



members and academic research, some individual funders are bound to strict funding rules, meaning that they can only fund academic or commercial research, but not both.

Across Europe, a majority of funders also allow the addition of international partners to research projects and grant applications, thereby acknowledging the importance of collaborative transnational working. But as these international partners are usually ineligible to receive national funding, ERA-NETs still provide a unique opportunity for fully funded transnational working.

ERA CoBioTech - advancing biotechnology together

ERA CoBioTech provides a unique opportunity for the entire biotechnology community in Europe to come together in pursuit of a shared goal. It is built on and learns from previous European programmes and brings together three strong scientific areas: synthetic biolog , systems biology and industrial biotechnology. Classic biotechnology techniques such as fermentation have been used as early as 5,000 years ago in the production of beer in China[26]. Since then, tools and technologies have become more refined but the basic principles of selection and use of microorganisms have persisted. While during the 20th century, advances in molecular biology enabled biotechnology researchers to have a more targeted selection of organisms or even simple modifications of microbial genomes, only the 21st century brought ground-breaking changes to biotechnology with the rise of synthetic biology and systems biology. Both disciplines provide tools and technologies such as metabolic modelling or seamless genome modifications that drive developments in industrial biotechnology and enable the biotechnology community to address challenges and areas of research that would have been unthinkable before.

This potential was soon realised by the policy makers in Europe, and pan-European investments in synthetic biology and systems biology through programmes such as ERASynBio and ERASys*APP* enabled the development of new tools and technologies and the set-up of transnational networks and organisations such as FAIRDOM (data management for SysBio, set up by ERASysAPP)[27] which act as key enablers in the field. Early on, joint activities with other networks such as ERA-IB2 showcased the synergy between these disciplines and the benefits for applied biotechnolog .

ERA CoBioTech is the culmination of these previous efforts and will be important in shaping the future of biotechnology in Europe. Through the work with all stakeholders, three key areas were identified in which ERA CoBioTech can make a difference:

- Theme 1: Research and Technology to address sustainability in Europe and beyond
- Theme 2: Streamlined and purpose orientated funding across Europe
- Theme 3: Engaging the scientific community and b yond

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[26] http://www.pnas.org/content/early/2016/05/18/1601465113
[27] https://fair-dom.org/

Theme 1: Research and technology to address sustainability in Europe and beyond

In the English language, sustainability has two meanings, firstl , the ability to be maintained at a certain rate or level, and secondly, the avoidance of the depletion of natural resources in order to maintain an ecological balance[28]. In the scientific community, the latter definition is more commonly used, whereas the former is usually associated with the economic sector. However, the sustainable bioeconomy is based on both by trying to establish a stable economy while not depleting natural resources. Biotechnology is vital for the bioeconomy and encompasses a wide range of areas which have the potential to contribute significantly to economic growth and addressing global challenges by creating jobs, revitalising existing industries, and fuelling innovative new sectors.

Promote interdisciplinary work to support innovation

Biotechnology has evolved into a highly specialised area which requires highly skilled professionals. This specialisation, and the fact that biotechnology spans across a wide number of research areas, often requires expertise from other disciplines to be brought in. This is something that has already been recognised by the ERA CoBioTech predecessor programmes and has been discussed in the ERASynBio strategic vision, which since publication in 2014 has not lost its topicality[29].

Evidence shows that conducting research within linked multidisciplinary environments provides added value to both parties, and that encouraging academic institutions to form multidisciplinary research networks will facilitate collaboration, creativity and idea generation[30].

ERA CoBioTech builds on three previous ERA-NETs which covered IB, synthetic biology and systems biology, and is therefore a multidisciplinary approach to biotechnology itself. Hence, interdisciplinary work is at the heart of ERA CoBioTech and the defining theme across all future activities.
Over the last two decades, the field of synthetic biology has seen biologists, physicists, engineers and many more scientists work together to develop new tools and technologies.

This includes the engineering of metabolic pathways and synthetic gene circuits to alter the functionality, performance and behaviour of individual enzymes and whole cells. These developments will affect a number of sectors, e.g. combating antimicrobial resistance with new classes of antibiotics, producing advanced biofuels, restoring ecosystems through bioremediation, and manufacturing of value-added products. While some achievements of biotechnology will sound more profound than others, they will all contribute to building a more sustainable society. Examples of these developments can already be seen today. Engineered bacteria help to clean radioactively polluted water in Fukushima, Japan (see Box 2), oils from microalgae replace palm oil in soaps[31], and barbeque enthusiasts in the United States can enjoy a low smoke lighting fuel produced by a metabolically engineered Clostridium bacterial strain[32].

Those developments would not have been possible without the advances in systems biology and the ability to generate and store vast amounts of experimental data and use bioinformatics for reliable data analysis and process modelling. Systems biology underpins a variety of data intensive disciplines, including synthetic biology, and therefore involves several levels of collaborations between biologists, bioinformaticians, computer scientists, physicists, mathematicians and engineers.

The computational power now available, makes it possible for biotechnology to develop new ways of producing value-added products and establishing new processes the scientific community would not even have considered a decade ago.

Classic biotechnology, from brewing beer to generating advanced biofuels, is based on growing monocultures of microorganisms in bioreactors and fermenters. While this is effective, and provides contamination free production environments, it is far removed the complexity and overall efficiency o microbial communities in natural systems. The constant improvement in metagenomics metaproteomics, scientists are just starting to discover understand the microbiomes of soil, oceans, the human gut, and many more. In these natural microbial communities, variety of different microorganisms share a common living space

copyright: Jovanmandic/iStock/Thinkstock

[31] [Reference/webpage no longer available – February 2019]
[32] http://greenflame.com/

to enjoy mutually beneficial relationships, from commensal, predatory to symbiotic, which have developed over millions of years of natural selection.

If future biotechnology is able to mimic these naturally occurring communities, it will be possible to establish "one-pot" production processes, such as providing cellulosic biomass for subsequent transformation by a microbial community into a pure, high value product, or to extract metals from sewage sludge. These processes will still face the scale up challenges of an applied biotechnology approaches, but eventually, this integration of processes will be more cost effective. Production plants will be better tailored and include all production steps on one site, which will lead to shorter transportation routes of feedstock or intermediate goods. In addition, optimised rates of high value product recovery, and generally improved processes will support this sector and make it economically worthwhile. Scientificall , this will bring together researchers from different disciplines including microbiolog , ecology, engineering, and mathematics for the design of new fermentation devices, colony modelling etc. This is a rapidly emerging topic, which attracts more and more attention from the biotechnology sector. In the UK, the Microbiology Society identified synthetic ecology and the design of functional microbial communities as an emerging area, whereas, the EU is planning a call on the use of microbial communities for plastic degradation . So far, only few stable synthetic microbial communities exist but initial projects are promising. While researchers in the United States used the fungus *T. reesei* and the bacterium *E. coli* for the production of isobutanol from cellulosic biomass , scientists at Stellenbosch University in South Africa are trying to decipher the microbial communities in vineyards and wine . This shows that this field offers opportunities in all areas of biotechnolo , and that there is currently unused potential which could be released by the promotion of interdisciplinary working by ERA CoBioTech.

The promotion of interdisciplinary working is at the heart of ERA CoBioTech and will ensure the best possible outcomes for the biotechnology and other relevant communities. As described above, ERA CoBioTech's work can contribute to a variety of sectors, many of which are at least partially covered by more specialised programmes such as personalised medicine through ERAPerMed or seafood processing by COFASP (see Annex 1). This provides opportunities to establish new partnerships to utilise and combine existing knowledge and experience for example by working with SUSFOOD or M-era.Net. However, it would go beyond the scope of this strategic agenda and the abilities of this programme to try to address every sector and potential partnership.

Hence, theme 1 of this strategic agenda will look in more detail at two example sectors, which have been developed in accordance with the ERA CoBioTech partners and the European biotechnology community:

- Sustainable alternatives for animal-based products
- Sustainable bio-based feedstocks

Recommendation 1-1: ERA CoBioTech will continue to promote interdisciplinary working by scoping future calls and activities towards holistic approaches. Specificall , ERA CoBioTech will explore the development of whole new production processes, for example the establishment of synthetic microbial communities rather than single step process optimisation. This will increase the innovation value of biotechnology research in Europe and increase collaborations between biotechnology and other relevant areas.

Box 2. Case Study: A UK-Japan collaboration is helping with the decontamination in Fukushima

The UK Research Councils BBSRC, EPSRC and NERC, in collaboration with the Japan Atomic Energy Agency, have been funding research to help clean up water contaminated with radioactive material at the Fukushima Daiichi Nuclear Power Station in Japan.

The nuclear power plant in Fukushima was damaged by the tsunami in March 2011, which led to radioactive contamination of groundwater and seawater. The Japanese electricity company TEPCO is now facing the challenge of decontaminating the water already in the environment as well as any water still on the site.

The team from the University of Birmingham were initially interested in using bacteria to produce hydroxyapatite for use in scaffolds for osteoblasts. They then discovered that hydroxyapatite can, similar to other metal phosphates, bind radioactive metals and therefore be used to capture radioactive elements from waste water. Further funding enabled to build the partnership with researchers from Japanese Atomic Energy Agency, Kyushu University and Shibaura Institute of Technology. Due to their combined efforts this unique approach is now one of the clean-up technologies being tested at the Fukushima site to treat contaminated seawater, surface and groundwater. Early results from the work are promising; testing at Fukushima has shown that biological hydroxyapatite is substantially more effective than alternatives, including chemical hydroxyapatite and the mineral clinoptilolite, at removing radioactive Strontium from saline water.

Further Information

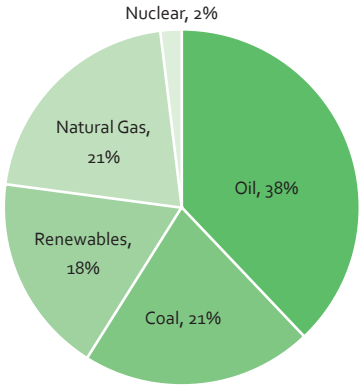
http://bbsrc.ukri.org/documents/1601-fukushima/

Changing (attitudes towards) feedstocks

The growing global population is increasing our demand for fossil-based resources. However, the current petrochemical industry is unsustainable due to shrinking available reserves, geopolitical instability and the impact on the climate.

In its Bioeconomy Strategy, the European Commission set out the clear target to replace fossil fuels with sustainable bio-based feedstocks to achieve the post-petroleum society. This includes a reduction of GHG emissions by 20% and the replacement of 10% of transport fuels with renewables compared to figures from 1990 by 2020. Upon a review in 2016, which found the current reduction at 22.4%, the target was increased to a reduction of 32% by 2030[36,37]. To achieve this new goal, Europe needs to boost its efforts and

- Transform fossil-based processes into resource and energy efficien biotechnology based ones
- Establishing reliable, sustainable and appropriate supply chains of biomass, by-products and waste streams connected to a respective network of bio-refineries throughout Europ
- Support market development for bio-based products and processes, and take into account associated risks and benefit



[36] http://ec.europa.eu/eurostat/documents/3217494/9087772/KS-02-18-728-EN-N.pdf/3f01e3c4-1c01-4036-bd6a-814dec66c58c
[37] https://ec.europa.eu/energy/en/topics/renewable-energy

This shows that the EU clearly recognises the importance of developing sustainable bio-based feedstocks, and Horizon 2020 is supporting these developments with tailored funding opportunities for the bio-based economy. ERA CoBioTech itself was created as a response to the Leadership in Enabling and Industrial Technologies theme[38].

During the ERA CoBioTech Strategic Workshop, support for biomass research towards a low-carbon economy was also identified as a ey topic for future work in the biotechnology sector. Fossil-based feedstocks can be found in nearly all everyday items from fuel, food, cosmetics, pharmaceuticals to cleaning products. Biomass from any renewable biological material can offer a direct replacement for fossil fuel feedstocks and may be used as fuel, by direct combustion, biofuel through transformation into liquid or gaseous substances, or other usually fossil-based products and platform chemicals through biotechnological conversion.

However, the remaining problem with biomass for any kind of process is to achieve a sustainable production of fuels and feedstocks from non-food resources while at the same time reducing GHG emissions. Having to produce biomass, e.g. on existing agricultural land, can lead to a shift in food production on previously unused land (forests, wet lands etc.). This then increases the net GHG emissions due to the loss of CO_2 absorption by trees, and other plants and soil. To counteract this, the EU has introduced regulations on indirect land use change, which state that biomass cannot be produced on land with a high biodiversity or previously high carbon stock[39].

The use of biomass as biofuel is the most commonly known use and Europe has a good track record of supporting research in this area through programmes like BESTF- Bioenergy Sustaining the Future and ERA-NET Bioenergy (both see Annex 1). Biofuels can be divided into two categories:

- Conventional biofuels: firs -generation biofuels, produced from food crops (palm, rapeseed, soy, beets and cereals)
- Advanced biofuels: second and third-generation biofuels, produced from wastes and agricultural residues, non-food crops and algae, not directly competing with food and feed crops

[38] https://ec.europa.eu/programmes/horizon2020/en/area/bio-based-industries
[39] https://ec.europa.eu/energy/en/topics/renewable-energy/biofuels/sustainability-criteria

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Currently, only 2.5% of the world's biofuel production covered by advanced biofuels[40], and following worldwide concerns about the impacts of using food for feedstocks, the European Union has introduced measures to encourage the use and production of advanced biofuels. These include restricting state aid for conventional biofuels, a proposed cap on biofuels from food crops, and preferential treatment of biofuels produced from certain wastes and residues.

Similar to biofuels, biomass for non-biofuel use can also be produced from food crops or substances not directly competing with the food sector, i.e. waste, agricultural by-products, non-food crops or algae. For this, biorefiner , analogous to petroleum refiner , has been named the most sustainable concept. Bio-based feedstocks such as proteins, sugars, lignin, fibres and oils, are used to produce platform chemicals and other usually fossil-based feedstocks for food, feed and materials (see Box 3). These include amongst others fast moving consumer goods, building materials, and chemicals for a variety of uses. Biomass for this process often requires biological, physical, chemical or thermochemical pre-treatment to release the required feedstocks, which are the converted into the intermediate platforms of sugars or bio-based synthesis gas (SynGas), before being further transformed, for example by microbial fermentation, into chemicals similar to the ones produced by the petrochemical industry[41].

Microbial SynGas fermentation in particular, using bio-based, SynGas (green SynGas) produced from biomass, was highlighted as a key tool for working towards a sustainable economy away from fossil fuels. The use of bacteria in the fermentation process enables the conversion of waste and greenhouse gases into commodity chemicals and biofuels (H_2, methanol, mixed alcohols, liquid hydrocarbons etc.) therefore having an impact on the mitigation of climate change. SynGas fermentation for ethanol production can now be executed on an industrial scale and a collaboration between ArcelorMittal, LanzaTech and Primetals Technologies is currently building an industrial-scale ethanol production facility in Ghent, Belgium, which is expected to be in operation by mid-2020[42] (see Box 4).

[40] http://task39.ieabioenergy.com/2013/12/report-on-the-status-of-advanced-biofuels-demonstration-facilities-in-2012/, http://www.etipbioenergy.eu/advanced-biofuels-overview
[41] https://www.nrel.gov/docs/fy04osti/35523.pdf
[42] http://corporate.arcelormittal.com/news-and-media/news/2018/june/11-06-2018

Box 3. Case Study: Replacing fossil based feedstocks in everyday life – BioSurf (ERA-IB 2nd call)

An interview with Steffen upp, Fraunhofer Institute for Interfacial Engineering and Biotechnology, Stuttgart, Germany

Can you briefly summarise the aims of BioSurf?
We aim at an increased replacement of petro-based surfactants by biosurfactants generated from renewable resources. Central topics are the identification of novel enzymes and microorganisms for new and more efficient biosurfactant production, understanding o cellular regulatory processes involved, and consequent metabolic engineering for the improvement of the respective microorganisms. This is also with respect to stress resistance during production, enzyme design combining rational and or evolutionary methods for enzymatic synthesis of surfactants and scale-up of bioprocesses, including innovative down-stream processing (DSP) using membrane technologies and biocatalyst recycling.

Who is part of your consortium and did you collaborate with your consortium partners before the ERA-IB application?
From Germany: Steffen upp, Fraunhofer-Gesellschaft zur Förderung der Angewandten Forschung e.V. (coordinator); Christoph Syldatk, Karslruhe Institute of Technology; Thomas Greiner-Stöffele, c-LEcta GmbH
From Belgium: Ludo Diels, Flemish Institute for Technological Research; Eddy Laeremans, Tomans Engineering Noord BVBA; Dirk Develter, Ecover Belgium NV
From France: Michael O'Donohue, LISBP
I had previously collaborated with three of them.

Were you able to achieve your goals?
Partially. New Surfactants were produced at testable amounts and validated by the consortium. Furthermore, new enzymes for modifying the surfactants or generating novel types of surfactants were developed. In addition, new downstream processing was developed which reduced the cost both for new and already in the market microbial surfactant significantl . Within the timeframe of the project no new products could be placed on the market.

What motivated you to apply to the ERA-IB programme?
The possibility to integrate competencies from research institutions and companies not existing in Germany into the project.

With Ecover, your consortium involved a quite prominent industrial partner. How did this affect the project? Did it provide you with opportunities for industrial translation?
The main purpose of the project was to extend and translate existing know how into industrial application. In this regard, Ecover was key for designing the overall project and for putting some of the results into application, e.g. the novel DSP-process developed within the project. They also were very helpful in guiding the development of new surfactants with regard to the preferred properties in cleaning agents.

Can we actually buy products containing your bio-based surfactants?
You can buy products where the production process was made more efficient cleaning agents with sophorolipids from Ecover). The new surfactants are not on the market yet.

What was good about the ERA-IB programme, what could have been better?
Good about the program is the ability to select form a much larger amount of research partners / companies than only from national partners. Diverging funding possibilities within the partner states sometimes make it difficult to conduct the projects recommende for funding.

Further Information

http://www.era-ib.net/biosurf

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Biorefining has been named as the most promising concept to achieve a sustainable way of producing bio-based feedstocks from biomass and green SynGas. Traditionally, industrial biorefinery processes like fermentations have been performed using pure cultures of microorganisms. However, with our growing knowledge of the microbiome of different environments, microbial consortia have attracted the attention of scientists for use in industrial fermentation applications in the food, environment, energy and chemical sectors. Due to the fact that e.g. high concentrations of alcohol can be toxic to the pure culture cells, there approaches have been developed using co-cultures and microbial consortia. Examples of these approaches include an upflow anaerobic sludge bed (UASB) to produce bioga [43] and a bacterial consortium to produce ethanol from cellulose[44].

Ultimately, any developments in this area depend on a reliable and affordable biomass supply of consistent quality. Setting up an efficient supply chain, fro production to collection or harvest, will require optimisation of processes but will also provide new economic opportunities. Currently, the refining of petroleum is less expensive than biorefining, as it is highly optimised and therefore a mainly waste free process. In the biofuel sector, technology advances over the last two decades led to a reduction of costs of conventional biofuels of up to three times[45].

Recommendation 1-2: ERA CoBioTech will continue to support R,D&I towards sustainable biorefinery products and processes. The focus should lie on emerging innovative and new products and processes which are beneficial to a range of industrial sectors so that industrial translation is more probable and economically viable.

[43] http://aem.asm.org/content/72/7/4942
[44] https://biotechnologyforbiofuels.biomedcentral.com/articles/10.1186/s13068-014-0186-7
[45] Stephen J D, Mabee W E, Saddler J N (2012). Will second-generation bioethanol be able to compete with first generation ethanol? Opportunities for cost reduction. Biofuels, Bioprod. Bioref 6:159-176.

Box 4. From waste gas to bioethanol

Key Players:

- LanzaTech: global leader in gas fermentation of fossil- and bio-based SynGas
- ArcelorMittal: leading steel and mining company
- Primetals Technologies: service and technology provider to the iron and steel industry

Aim:

- Promoting the circular economy
- Achieve zero waste steel production

Impact:

- Production of 80 million litres of bioethanol per year
- Carbon offset equivalent to 100,000 electric car
- 500 construction jobs
- 20-30 new permanent direct jobs

Technology:

- Capture carbon monoxide-containing waste gas from steelmaking process
- Gas conversion into bioethanol through microbial fermentation
- Refinement of bioethanol into biofuel, jet fuel or platform and commodity chemicals

Background:

- Supported by H2020 with about €10 million
- Process development and upscaling since 2008
    - Pilot facility in New Zealand: 56,000 litres per year
    - Pre-commercial facilities in China: 380,000 litres per year
    - 4 commercial plants in Europe, Asia, North America and Africa from 2018: 37-113 million litres per year

Further Information

http://www.lanzatech.com/arcelormittal-lanzatech-primetals-technologies-announce-partnership-construct-breakthrough-e87m-biofuel-production-facility/

http://www.lanzatech.com/wp-content/uploads/2018/03/LanzaTech-Overview-March-2018.pdf

http://corporate.arcelormittal.com/news-and-media/news/2018/june/11-06-2018

Sustainable alternatives for animals and animal-based products in everyday life

In recent years, the use of animals in various sectors has been challenged and attitudes towards using animals and animal products in research, food, and other everyday items is changing.

The reasons behind this change in attitude towards animal-based products, are not only ethical but also based on the increasing awareness that our current diet and food production is neither healthy nor sustainable. Taking into account a growing population, from seven billion in 2012 to 9.6 billion in 2050[46], and shifting diets, the world will need to produce 69% more food calories in 2050 than in 2006, a figure that is not achievable using the current mechanisms for food production[47].

In 2008, a study commissioned by the EU found that the consumption of meat and dairy products causes on average nearly a quarter of the diet based environmental impacts in the EU, while only accounting for 6% of the total economic value[48].

However, it is not only the food sector in which animal-based products are used. Animal-based ingredients are also found in the feed industry, for example in fish and poultry feed, or veryday items like plastic banknotes or cosmetics. Palm oil has been investigated as a replacement for tallow e.g. in banknotes[49], however, this comes with a number of environmental concerns. concerns. Only recently, UK researchers have launched a trial to counteract the decreasing levels of omega-3 fatty acid in farmed salmon with feed containing omega-3 fatty acid from genetically modified plants instead of marine fish oi [50].

While the use of animal-based products in everyday items has only been widely

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[47] http://scet.berkeley.edu/wp-content/uploads/CopyofFINALSavingThePlanetSustainableMeatAlternatives.pdf
[48] http://ftp.jrc.es/EURdoc/JRC46650.pdf
[49] http://www.bbc.co.uk/news/business-39441971
[50] https://www.stir.ac.uk/news/2018/08/new-study-could-revolutionise-salmon-farming/

challenged over recent years, the use of live animals for research, education or testing has been in the limelight for decades and is, in the EU, covered by the Directive 2010/63/EU on the protection of animals used for scientific purpose [51].

The document also points out that, if possible, non-animal methods should be employed for research, education and testing. Therefore, the "3Rs" (Replacement, Reduction and Refinement) polic [52] is promoted across Europe. Increasing available computer power and the ability to model and disentangle complicated metabolic networks through advances in systems biology have resulted in impressive progress and some already commercially available alternatives. In Germany, the Fraunhofer Institute for Material and Beam Technology in collaboration with the Institute for Biotechnology of the TU Berlin, developed a mini-organism inside a chip which replicates metabolic processes with high accuracy[53].

These examples of successful collaboration of scientists across a wide spectrum of areas, from engineering to biochemistry, show that multidisciplinary working is pivotal for high impact research outcomes.

An important aspect of this topic is also that the issue of using animal and animal-derived products in food, research and everyday items is often a topic of public debate, which can generate strong feelings, and which is not always robust and fact-based. However, biotechnology, which could provide solutions to the use of animals and animal-based products for example through using synthetic biology for the modification of plants, is also often publicly discussed and can suffer from th same emotive and non-factual contributions. In many cases, these discussions are not in favour of the scientists and their work, and public opinion may tend towards a negative image of the scientific communit . Therefore, an open dialogue is needed to avoid this mistrust in science. Responsible Research and Innovation (RRI), or Science for and with Society, supports this approach and social scientists now have an established role in synthetic biology projects from the beginning to encourage an open and interactive dialogue with society outside of the scientific communit .

Recommendation 1-3:
ERA CoBioTech should, where appropriate, include the support for sustainable replacements of animals and animal-derived products in its activities. For this, collaborations between ERA-NETs, JPIs, and other initiatives and social scientists addressing relevant sectors, from food production to health, should be encouraged to tackle this challenge. Building relationships with the following key programmes could be beneficial:

- Joint Programming Initiative on Agriculture, Food Security and Climate Change (FACCE JPI)
- ERA-NET Cooperation in Fisheries, Aquaculture and Seafood Processing (COFASP)
- ERA-NET Cofund on Sustainable Food Production and Consumption (SUSFOOD)
- The ERA-NET Cofund on Sustainable and Resilient agriculture for food and non-food systems (FACCE SURPLUS)

[51] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:276:0033:0079:en:PDF
[52] https://eurl-ecvam.jrc.ec.europa.eu/glossary/glossary/3-rs-principle-replace-reduce-refine
[53] https://www.fraunhofer.de/en/press/research-news/2015/february/mini-synthetic-organism-instead-of-test-animals.html

Theme 2: Streamlined and purpose orientated funding across Europe

During the development of this document, it was stressed by members of the biotechnology community that adequate funding is vital for establishing an environment for high quality research to deliver the objectives of their projects. Therefore, ERA CoBioTech plays an important role in identifying and contributing to an optimised funding landscape in Europe. Due to its nature as an ERA-NET and part of H2020, the focus for recommendations is primarily concerned with funding provided by the EC.

Availability of Funding

In the Europe 2020 strategy , the EU maintained the target of spending 3% of gross domestic product (GDP) on Research & Development (R&D). In 2015, the figure had reached approximately 2% or EUR 299 billion, an increase of 47.8 % compared to 2005[55].

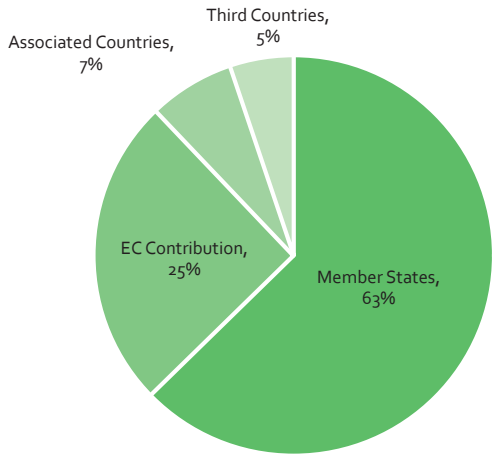
Within the EU-28, R&D spend varies considerably with Sweden, Austria and Denmark above 3% and Bulgaria, Greece, Croatia, Malta, Latvia, Romania and Cyprus below 1% in 2015.

Horizon 2020 (H2020), the EU's Research and Innovation programme from 2014 to 2020 has a budget of EUR 77 billion, of which approximately EUR 25 billion has been spent so far[56]. This equals nearly 14,000 signed agreements between 2014 and 2016. With 115,235 proposals submitted to the 329 different H 020 calls, it makes this programme very complex and competitive[57]. While such competition ensures that only projects of the highest quality are funded, it can create the perception of insufficient vels of funding being made available amongst the scientific communit . Additionally, the complexity of operating in 22 areas, from agriculture to transport, with over 300 calls so far makes Horizon 2020 daunting for any applicant. While clearer and more transparent than previous Framework Programmes, applicants still find it difficult to gather information about and apply to r vant calls.

An analysis of the first ERA-NET Cofunds under H2020 in 2014/15 showed total investments of €797.6 million of which 25% have been provided by the EC[58] (see figure 7). The preparatory work for this strategic agenda revealed a number of ERA-NETs which were or still are operating in a similar scientific space or with a similar aim in outcomes to ERA CoBioTech. While all of those programmes operate within their own specific area and harbour specialist knowledge, care has to be ta en not to duplicate efforts. How ver, this provides the opportunity for collaboration, complementary knowledge and sharing of experience.

During the first European Biotechnology Hub meeting in early 018, ERA CoBioTech established contact with about 20 European initiatives and programmes which are relevant to ERA CoBioTech either through their technological approaches or topic areas. The presentations and discussions on the day clearly highlighted the commonalities and areas where collaboration and joint working would be possible.

FIGURE 5 ERA-NET COFUND BUDGET BY FUNDING SOURCE



While collaboration and joint working is being encouraged and happening increasingly, there is still room for improvement. By establishing the Biotechnology Hub meeting series, ERA CoBioTech initiated a platform for all biotechnology initiatives to exchange ideas and experiences, to plan joint activities, and to communicate with the scientific communit .

[55] http://ec.europa.eu/eurostat/statistics-explained/index.php/R_%26_D_expenditure
[56] https://ec.europa.eu/programmes/horizon2020/en/what-horizon-2020
[57] [Reference/webpage no longer available – February 2019]
[58] [Reference/webpage no longer available – February 2019]

Recommendation 2-1: With the help of ERA CoBioTech and other relevant programmes and initiatives, the Biotechnology Hub meetings should become an established event for the biotechnology sector in Europe. While in this early stage these meetings are restricted to the representatives of the relevant programmes, possibilities to open future meetings to a broader audience should be explored in order to better reach the broader scientific communit .

One target of Horizon 2020 is to allocate at least 20% of funding to Small and Medium Enterprises (SMEs). A report from 2017 shows that H2020, on average, has already surpassed this target[59]. Obviously, H2020 consists of various different programmes and funding streams, so the figure may vary within H 020. Depending on the type of national/regional funder, the organisations eligible for funding, such as universities, companies, research institutes etc., for a country or region might be limited. It is therefore not given that every country participating in an ERA-NET will be able to fund all types of research. In the case of the first ERA CoBioTech call, there were several participants who were able to fund either academic or industrial partners in research consortia but not both, a fact that was seen as a barrier by some researchers wanting to participate in the first ERA CoBioTech call. To counteract this, some partners promoted the ERA CoBioTech programme on their national level and successfully engaged additional funders for the first call

Especially in the biotechnology sector, where industrial translation plays a vital role, a seamless funding stream, from low to high TRLs, would be advantageous for all countries participating in an ERA-NET. On a European level, this would ensure a generally higher translation rate without unnecessary delays due to lack of funding, whereas on a national level, technology developed by one country could also be commercialised in country or at least within the broader European Research Area.

Recommendation 2-2: For future funding activities, ERA CoBioTech will continue to encourage an equal participation of funders for academic and industrial research for all partner countries involved. Future ERA-NET programmes should include funders for all types of R,D&I for all participating countries from the planning stage onwards.

With the introduction of EC contributions of 33% for ERA-NET+ and ERA-NET Cofund calls[60], the European funding system came one step closer to a real "common pot" of funding. Previously, once a national funder had reached its maximum of available funding, potentially excellent research consortia could not be funded as funders usually cannot cover costs of other participating nations due to strict national regulations. The EC contribution eased this problem by providing transnational funding distributed equally amongst the participating funders but also by providing the opportunity to fill funding gaps of individual funders.

Nevertheless, funding gaps of individual funders continue to create multilevel issues. Individual funders might not be able to fund any of their researchers despite the scientific excellence of the proposals if one or more other involved funders have reached their funding limit. Researchers involved in scientifically excellent proposals affected by this gap will not be funded, transnational collaborations will not be established, training opportunities for early career researchers will be missed, and industrial translation will be at least delayed.

Recommendation 2-3: In cooperation, the EC, funders, and H2020 programmes and initiatives should investigate options to minimise funding gaps. This might include work to exchange best practice of research funding on a national level or modifications to the ERA-NET funding process such as EC cofunding for ERA-NET additional activities.

Variety of ERA-NET funding

Since the introduction of ERA-NETs under FP6, they have been constantly evolving and are at the heart of H2020. ERA-NET Cofunds allow more flexibility in the scope of activities than the classic ERA-NET or ERA-NET+ programmes[61]. In addition to the compulsory cofunded call, ERA-NET Cofunds can also receive funding for other joint networking activities. Table 3 highlights the key changes that have been implemented over the years.

[59] [Reference/webpage no longer available – February 2019]
[60] https://www.era-learn.eu/manuals-tools/p2p-in-h2020/practical-documentation/ERANET_FP7_H2020_comparison_.pdf
[61] http://ec.europa.eu/research/era/era-net_en.html

However, the main focus of the ERA-NET Cofunds lies on the compulsory cofunded call, which is often hampered by its ambiguous rules, and due to its two step evaluation process takes approximately 12 month from launch to project start. In a fast-moving area like biotechnology, this is often detrimental to research projects, especially when industrial partners are involved. High TRL projects with industry participation require a quicker decision phase to suit the needs of the competitive industrial biotechnology sector. Also, for projects in the laboratory and industrial environment, up-scaling and exploratory phase projects are needed to reach the necessary high TRLs. These types of technology development projects require short-term funding with quick turnaround times. Those are usually not covered by ERA-NET calls as these tend to focus on longer and more hypothesis driven projects.

In addition, non-call activities are becoming increasingly important for the scientific community. These include training for early career researchers (e.g. state of the art technology, business knowledge etc.), networking activities and researcher mobility which are all an integral part not only of a defined project but for the basis of excellent high quality research.

TABLE 3 COMPARISON OF ERA-NET, ERA-NET+ AND ERA-NET COFUND

	FP7		H2020
	ERA-NET	**ERA-NET +**	**ERA-Cofund**
Minimum network size Duration	3 MS or AC	5 MS or AC (Call budget > €5m)	3 from 3 different MS or AC
	No specified	max. 5 years	5 years with possibility of extension
EC funded joint activities	Networking activities incl. joint calls (not cofunded)	1 cofunded call (until 2011: including its design and implementation)	• 1 compulsory cofunded call • Optional additional activities
EC contribution	Networking costs (100% actual direct costs plus 7% indirect costs)	• 33% budget for transnational projects funded in call • until 2011: partial dedication part of the EU contribution to call design and implementation possible - deducted from the EU contribution replaced by national budget	• 33% budget for transnational projects funded in the call • "unit costs" for additional other joint activities (€11.962,5 per beneficiary per year/maximum 0% of total EC funding) • partial dedication part of the EU contribution to call design and implementation possible - deducted from the EU contribution replaced by national budget
EC conditions for cofunded call:	Evaluation: n/a Ranking list: not mandatory to follow	Evaluation: • 2 step procedure • international peer review • FP7 evaluation criteria Ranking list: • joint ranking list • mandatory to follow	Evaluation: • 2 step procedure • peer review by 3 independent experts • observer • Horizon 2020 evaluation criteria Ranking list: • joint ranking list mandatory to follow in cofunded calls

The ERA-NET Cofunds under Horizon 2020 provide the opportunity to address some of those activities via the EC funded other joint networking activities. Unfortunately, these activities are often only partially defined and lack a clear direction from the start of the ERA-NET.

Recommendation 2-5: Additional joint activities in ERA-NET Cofunds should be better defined at the planning stage to tailor them to the needs of the specific programme. Current ERA-NET Cofund partners should ensure a continuation of the EC funded additional joint activities in the future Framework Programme Horizon Europe.

Under H2020, ERA-NET Cofunds last for five years with the possibility of an extension. This means that generally only the research projects funded in the first cofunded call will finish within the lifetime of the ERA-NE . For ERA CoBioTech the first projects will finish by May 021, while the programme will continue until December 2021. As ERA CoBioTech is focussed on innovation and the development of new tools, technologies and products, it is anticipated that the projects will result in a variety of licences and patents. Many of these will be expected well after the end of the current projects as they reach higher TRLs and move towards industrial translation.

However, registering patents and licence agreements are time and cost intensive, and in general not covered by the initial or any follow-up research grant, especially if it involves different consortium partners. Some European funders even require reporting on research projects for several years after the end date, e.g. the UK with five years b yond the end date, in order to record these post-grant outcomes. Despite this, funding of these post-grant outcomes and activities is not possible under the current rules and has to be obtained from elsewhere.

Recommendation 2-6: Arrangements should be made to ensure that research projects with commercially exploitable outcomes will have opportunities to pursue this exploitation. This could include follow-on funding, agreements with industrial partners or knowledge exchange for researchers.

Theme 3: Engaging the scientific community and beyond

Biotechnology is clearly multidisciplinary with the potential of affecting all areas, from health to agriculture. The continued advancement of research and technology in this field requires interaction of academic and non-academic researchers with expertise in engineering, biology, chemistry, physics, computer and, social science, economics, and policy development, to name a few. Those collaborations are crucial and there is the need to build new and stronger links between all groups involved.

Therefore, multidisciplinary work should be encouraged throughout the biotechnological field on all l vels (researcher – funder – policy maker), as it allows the development of new perspectives and will in turn result in greater impact.

While the establishment of the ERA has already removed some barriers, there are still several to be addressed in order to increase interdisciplinary networking, research and innovation across Europe.

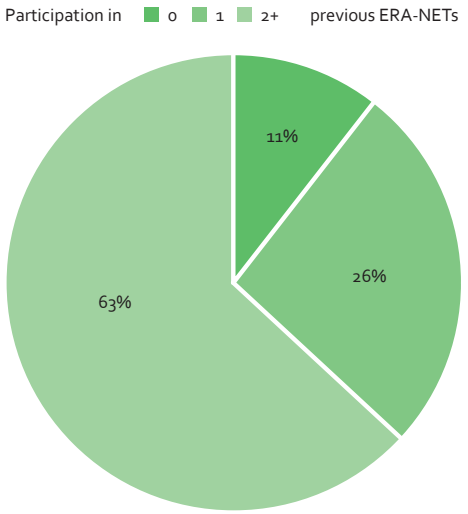
Coordinating and enabling collaboration

Successful implementation of ideas requires the participation of all relevant stakeholders. This allows different perspectives to be brought together and can help academic and non-academic researchers and funders to consider new approaches to solve biotechnology challenges. Encouraging participation and engagement early during a research programme helps ensure that the research outcomes meet societal needs and expectations.

Unfortunately, research outcomes are often hard to measure and cannot always be put into numbers and figures. Therefore, more obvious, measureable benefits, e.g. financial incentives, can ma e participation more justifiable and worthwhile at firs glance. For the current ERA-NET Cofunds, the EU can now contribute up to 33% of the total eligible costs of the ERA-NET action, including not only cofunding of projects in the transnational call but also for the preparation and management of additional joint activities. Hence, participation in these Cofund programmes has very obvious benefits for the partner countries

Despite these financial incentives, ERA-NET+ and ERA-NET Cofunds have often suffered from a varied participation of funding partners in additional activities after the EC-funded call. Across all ERA-NETs, the average number of countries per cofunded call is 16 with a total call budget of approximately €21.6 million[62]. According to the figures available for the rel vant ERA-NETs listed in annex 1, the average call budget for biotechnology ERA-NETs is approximately €12 million per call, provided by 11 countries, showing that biotechnology budgets are comparably small. However, they benefit from good l verage and ratio of European cofunding. The three ERA CoBioTech predecessors (ERA-IB2, ERASynBio, ERASys*APP*) were successful in attracting a total of 27 countries to participate, and of those, 19 countries became involved in ERA CoBioTech[63]. Of the initial 19 participating countries in ERA CoBioTech, 63% took part in at least two, and 26% participated in one of the previous ERA-NETs (see Figure 8), thereby continuing the work that was started by those programmes. Unfortunately this also means that the biotechnology community in some countries might miss out on European funding and transnational collaborations, and might not be able to continue work that has been started under ERASynBio, ERA-IB2 or ERASys*APP*.

FIGURE 6 ERA COBIOTECH PARTNER COUNTIES AND THEIR INVOLVEMENT IN PREVIOUS ERA-NETS (ERA-IB2, ERASYNBIO AND ERASYS*APP)*



[62] [Reference/webpage no longer available – February 2019]
[63] Belgium, Croatia, Cyprus, Denmark, Estonia, Finland, France, Germany, Iceland, Israel, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Russia, Slovenia, Spain, Sweden, Switzerland, Turkey, UK, USA

It has been suggested that ERA-NETs would have greater impact on the R,D&I landscape if all funding partners were consistently involved in all activities of the programme. Through continued support, strengths and weaknesses from initial calls and activities can be identified, and ta en into account for the future. From a funder's perspective, this will lead to a continuous representation on the international funding platform as well as an increased familiarity with the European funding system and how to achieve the best outcomes from it. From a scientist's perspective, consistent access to funding programmes and initiatives will allow the development of research projects over a greater TRL range and strengthen the collaborations with international partners.

Recommendation 3-1: ERA CoBioTech will encourage consistent participation of partners and partner countries in all future activities and calls. These activities shall be designed with the input from all partners to maximise participation. Through the European Biotechnology Hub meeting series, ERA CoBioTech will discuss further incentives to encourage continued participation in EU funding programmes and initiatives.

With changing national strategic priorities and an ever stronger connected ERA, it is highly desirable for ERA-NETs to attract new funding partners. Being open for new partners throughout the lifetime of the programme allows the building of new global and strategically important relationships for future activities and access to additional facilities or resources that would not be available otherwise. Joining an established programme has similar benefits for the joining part . For scientific communities in smaller countries, this opens up an excellent way of creating international impact and establishing international collaboration.

Including partners from countries outside of Europe and of strategic importance, e.g. USA and Japan, makes ERA-NETs even more attractive to the scientific community. Having Argentina as an ERA CoBioTech partner, opens up a gateway to South American countries and future collaborations. South America has a growing bioeconomy, and biotechnology plays an important role in various sectors, e.g. mining, food and health[64].

Recommendation 3-2: ERA CoBioTech will continue to approach new European and non-European partners to join the programme under a selective strategic approach. The current focus on South America will be reviewed regularly and updated if necessary.

Inclusion of commercial partners

When H2020 came into being in 2014 it had set the goal of spending 20% of funding for SMEs. The official report for 020 2014-2016 revealed that the actual figure lies at about 24% of funding being allocated to SMEs, thereby exceeding expectations[65].

However, industry participation in many EU programmes, e.g. ERA-NETs, is still seen as difficult, and rules for industry partners are not perceived as transparent. Lack o support for industrial partners on a European level, was highlighted several times by the participants of the ERA CoBioTech strategic workshop. Hence, there needs to be clearer regulations and guidance for industry involvement, as commercial partners are key in bringing academic research outcomes towards applications and marketable products.

In the first call, ERA CoBioTech recommended the participation of commercial partners in research consortia and the majority of participating funders were able to fund academic and commercial partners according to national regulations[66]. Further analysis also showed that all ERA CoBioTech funders encourage and allow the addition of industry partners to research projects, even if they are not able to directly fund them. However, there seems to be a lack of communication between funders and the commercial sector on a national level.

Recommendation 3-3: National funders should, within their own countries, support open and clear dialogue with the commercial sector. This could involve discussion of new ideas and exchange of useful information between sectors to allow better understanding of, and guidance for future participation in European programmes and initiatives.

[64] https://www.sciencedirect.com/science/article/pii/S1871678417300080, http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0191267
[65] [Reference/webpage no longer available – February 2019]
[66] https://www.submission-cobiotech.eu/call1

Access to Infrastructure

Currently, the major European research infrastructures are supported by the European Strategy Forum on Research Infrastructures (ESFRI)[67]. Their aim is to maintain a coherent and strategy-led approach to policy-making on research infrastructures in Europe. ESFRI produces the strategic infrastructure roadmap, which lists the existing and identifies new important European research infrastructures for the coming years. There are seven research infrastructures relevant for ERA CoBioTech and biotechnology in general (see table 2). Except IBISBA, the research infrastructure for synthetic biology, the other ERA CoBioTech relevant infrastructures are all part of CORBEL (Coordinated Research Infrastructures Building Enduring Life-science Services), which provides a platform to facilitate biomedical research from bench to bedside across Europe[68].

Several European countries have adopted the concept of a research infrastructure roadmap at a national level and launched similar approaches. The federal government in Germany provided €1.1 billion in 2015 for funding of large scale equipment. In the same year, they launched a national roadmap process during which education and research institutes could present their ideas for new research infrastructures. The roadmap is expected to be published in 2018[69]. The UK has launched a UK research and innovation infrastructure mapping process in January 2018, which will contribute to the UK government's plan to spend 2.4% of UK GDP on R&D by 2027[70]. These roadmapping exercises are beneficial for the scientific community and will help to strategically establish and fund important research infrastructure on a national level. Across Europe this might also be a step towards aligning the national infrastructures and to overcome the currently existing fragmentation. In addition, these roadmapping exercises increase the visibility of infrastructures within the scientific communit .

Research infrastructures are seen as beneficial for ERA-NE s and will boost the outcomes of these programmes. ESFRI associated infrastructures are usually open to academic and non-academic researchers from countries supporting the respective infrastructure. Access from outside these countries can in most cases be arranged under special conditions. The requirements for access vary, but sometimes can be arranged by simply contacting the contact person (e.g. EMBRC), or by submitting a proposal (e.g. INSTRUCT). EU-OPENSCREEN actively encourages potential applicants for specific ERA-NET calls to contact them to discuss projects.

Nevertheless, access to research infrastructures is perceived as difficult amongs the biotechnology community, hinting to a communication problem between the infrastructures, funders and researchers.

Recommendation 3-4: ERA CoBioTech will attempt to identify relevant infrastructures for future activities and make this information available to the community. ERA CoBioTech will improve communication about available national and European research infrastructures in Europe through the Biotech Hub Platform.

Support for the scientific community

Not surprisingly, the amount of available funding has the biggest influence and plays a major role in supporting the scientific communit . However, with funding calls becoming increasingly highly competitive and the need for all science to be more open and accessible to the general public, the support for the scientific community has to go beyond funding alone.

One of the pillars of modern and open research is communication. Traditionally, science communication was restricted to a closed community and was done through publications in scientific journals and presentations at scientific conferences whic have a limited audience. With the rise of biotechnology and the potential impact on the everyday life of everyone, science had to evolve and become more accessible. However, discussions e.g. about the pros and cons of genetically modified food or cloning of animals in the late 20th century showed that researchers were not always ready to open a dialogue with the general public. Initially, this was not changed by the advent of social media in the early 2000s, which opened the scientific community even more to the public.

[67] http://www.esfri.eu/
[68] http://www.corbel-project.eu/home.html
[69] https://www.research-in-germany.org/en/research-landscape/research-organisations/research-infrastructures.html
[70] https://www.ukri.org/news/infrastructure-roadmap/

Nevertheless, these changes were quickly seen as opportunities and funders, researchers and universities increased their outreach activities, and started to work on their communication skills. Today, it is not unusual for the scientific community to maintain social media accounts and blogs[71], or PhD students and other early-career researchers taking part in outreach activities (see Box 5).

The European Commission also supported the change in the way the scientific community communicates by funding various programmes, e.g. CommBeBiz[72] or synenergene[73]. ERA CoBioTech worked together with CommBeBiz to provide communications training for everyone involved in the programme. ERA CoBioTech partners and applicants received communications training prior to the submission deadline and at the start of their projects[74].

Recommendation 3-5: ERA CoBioTech will work towards providing continuous communications training. The focus of the training should be on early-career researchers to set them up with the essential skills for their future career in modern and open scientific research.

While science communication is increasingly important for everyone involved in biotechnology research, there are other topics which might be of importance for at least a subset of scientists. One of those is the collaboration with industry, which is hampered by a lack of knowledge on how to work with or approach each other. Industrial R,D&I requires different skills and expertise compared to academic research, which often leads to misunderstandings and a delay or failure in translation or research outcomes. Many European funding programmes, including ERA CoBioTech, can fund industrial partners and at least recommend the inclusion of industrial partners in research consortia. However, there is still an insecurity about approaching potential partners on both sides. Academics tend to find it difficult establish contact with industry, whereas different working practices in industry often impede collaborations with academics. Therefore, targeted training and networking will help to establish a better relationship between academics and non-academics.

Recommendation 3-6: ERA CoBioTech will work towards providing tailored workshops, training and networking events to address current needs of the biotechnology community.


Joel Knight

The "Science with and for Society" programme under Horizon 2020 is aiming to better the image of science, research and innovation, and allow all societal actors to align research activities with the values, needs and expectations of European society[75]. This so called Responsible Research and Innovation (RRI) approach has been successfully implemented in various research programmes, e.g. ERASynBio, and supports synthetic biology research across Europe through programmes such as RRI tools or synenergene[76,77]. ERA CoBioTech will publish an RRI framework aligned to this strategic agenda, which will explore how RRI can be included in biotechnology research. Currently, RRI work is mostly conducted separately by social scientists and a large percentage of researchers in biotechnology view RRI as a necessary evil on the way to obtain funding. This lack of understanding is not least caused by a lack of training in RRI on all levels: researchers, funders and proposal evaluators. In general, funders do not allocate sufficient funding to address societa issues, and proposal evaluators are insufficiently qualified to judge and supp appropriate feedback on the applicant's approach to address RRI issues. This in turn, leads to applicants being discouraged to put effort into their RRI work

As ERA CoBioTech is also built on ERASynBio, which strongly supported the RRI approach, it will further promote the implementation of Responsible Research and Innovation approaches in biotechnology research across Europe.

Recommendation 3-7: For any additional calls, ERA CoBioTech will publish detailed guidelines for applicants and proposal evaluators on how to address, evaluate and provide feedback on RRI aspects in research projects. ERA CoBioTech aims to provide training for early career researchers in social sciences through funded workshops or similar activities.

[71] http://blogs.nature.com/naturejobs/2018/03/06/coming-to-the-us-for-a-postdoc-if-i-had-known-part-ii/, https://twitter.com/westboundsigned, https://twitter.com/era_cobiotech
[72] https://commbebiz.eu/
[73] https://www.synenergene.eu/
[74] https://www.cobiotech.eu/events?event=ERA_CoBioTech_webinars_Supporting_you_in_making_your_research_a_success
[75] https://ec.europa.eu/programmes/horizon2020/en/h2020-section/science-and-society
[76] https://www.rri-tools.eu/
[77] https://www.synenergene.eu/index.html

During the application stage, funders and evaluators will concentrate on the positive scientific or economic impacts of a research project. Therefore, project impact statements are typically tailored to emphasise the positive aspects and tend to ignore any negative impacts due to a fear of the negative implications for the proposal evaluation. However, the impact of new technology on society can have negative connotations which have to be addressed under ethical, legal and social aspects. This Responsible Research and Innovation approach should be an objective assessment of the effects of a particular research topic on society and should only be judged on its integrity. Most current national and transnational funding systems do not have structured assessment practices for RRI aspects which are then often inappropriately associated with and judged alongside the project impact.

Recommendation 3-8: ERA CoBioTech will explore opportunities to provide appropriate occasions for independent discussion and evaluation of the research project's RRI aspects. This could include dedicated sessions during status seminars or similar events.

Measuring/follow-up of research outcomes

Across Europe ERA-NET research consortia and funders are subjected to reporting requirements. For funders, this usually comprises yearly financial reports, internal call evaluations and a narrative for work package leaders in addition to any milestones and deliverables. For researchers, this includes yearly financial reports, but usually also mid-term and final reports or presentations within their ERA-NE s, e.g. the BioTech Research & Innovation Hack 2017[78]. This should lead to a close follow up of research outputs and consistent measurement against objectives across Europe. In addition, ERA-NET projects are also subjected to national follow-up requirements.

Interestingly, a survey amongst the ERA CoBioTech partners revealed that about half of the partners do not have any mechanisms in place to measure research outcomes. The funders that do require a follow-up generally rely on publications or mid-term and final reports. Notable exceptions are the German Federal Ministry of Education and Research (BMFB), which requires an evaluation by independent organisations after the projects funded through the national bioeconomy strategy have ended[79],[80], UKRI-BBSRC (UK), which requires detailed annual reporting via researchfish®, and Innosuisse (Switzerland), which have introduced periodic reports, audits and Go/no-go–meetings.

In general, mechanisms for measuring outcomes usually end with the research project and no follow-up is required. Amongst the survey participants, only UKRI-BBSRC (UK) requires a continuous reporting of key findings, associated funding, movement of personnel and other outcomes for five years after the end date of a grant.

Biotechnology thrives on innovation and depends on the development of new technologies. Like all scientific areas, biotechnology also depends on trial and error, and technology that has been state of the art a few years back, might now be outdated. This information is vital to the scientific communit , researchers and funders, and not only needs to be recorded but also made available and used to inform future activities. This will ensure a targeted distribution of funding in strategically important and relevant areas. ERA CoBioTech is advantaged as it is built on previous experience and monitors the success not only of the current but also of previously funded research. Many other programmes and initiatives do not have this opportunity, thereby losing valuable knowledge about research outcomes. The scientific community has acknowledged this issue and has recognised that monitoring and follow-up is beneficial for veryone involved. Interestingly, there is some support for a follow-up of up to 10 years post funding amongst researchers. While this would result in a very comprehensive dataset, current mechanisms of monitoring are not designed to capture this amount or type of data

Recommendation 3-9: ERA CoBioTech will work towards developing and adopting better tools for follow up for research projects after the funding has ended. This will help to ensure better monitoring of research outcomes and enable better tracking of translation efforts. As a long term goal, this might require a change in ERA-NET reporting practices. However, if ERA CoBioTech can be extended beyond its original five years for example by achi ving self-sustainability, this might address the issue in a more informal manner.

[78]https://www.cobiotech.eu/index.php?index=9&news=ERA_CoBioTech_BioTech_Research_amp_Innovation_Hack_2017 [79]https://www.uni-kassel.de/einrichtungen/cesr/forschung/projekte/aktuell/symobio.html
[80][Reference/webpage no longer available – February 2019]

Box 5. Case Study: How to communicate science

An interview with Elena Blanco Suarez, Salk Institute for Biological Studies, La Jolla, USA

Can you briefly say something about you and your scientific career?
I am originally from Spain, but did my PhD in Biochemistry at the University of Bristol and afterwards moved to San Diego to work at the Salk Institute where I focus on the study of specialized brain cells, called astrocytes. Besides this, I'm involved in several education outreach and science communication projects, including organising workshops for grad students and postdocs who wish to get better at communicating their research.

How did you get involved in science communication?
My first experience was through a collaboration between the University of Bristol, and the local science museum. They were looking for neuroscientists to carry out some activities for children at the museum. I had such a great time talking to the children that after that I took every opportunity to keep doing science outreach. It wasn't until I moved to the US that I started writing for different blogs and platforms, and giving public lectures for non-scientific audiences.

What motivated you?
I always found it frustrating that my family and friends couldn't see how amazing the things we do in the lab are. I always enjoyed taking the time to explain to them in an approachable way, showing them why it is important what we do, using metaphors and drawings, often on napkins after a family meal, or at the local pub with friends. So I thought "why not doing this for everyone else out there?"

Where can we find your work and who is your audience?
My blog posts have been published in Psychology Today, Nature Jobs blog, NeuWrite San Diego, PLOS Neuro community, and Marie Curie Alumni Association blog. In addition, I recently wrote a script for the science YouTube channel SciShow Psych that talks about neuroscience in a friendly and relatable way, keeping the scientific rigo .

I have given lectures in high schools, at local pubs and eateries for adults, and I have a talk coming up in the Fleet Science Center for seniors in the community. I have also delivered talks in Spanish for the Latino community in San Diego.

Recently, a very exciting opportunity has come up, and I've been invited to be part of a panel at the 2018 Comic Con "Shattering Stereotypes: Badass Female Scientists", where I will share the table with other scientists from San Diego and writers from shows such as The Big Bang Theory to talk about the need of inclusivity in science, and how pop culture can change the public perception of what a scientist is.

Did you receive any training or support?
The Salk Institute and the Fleet Science Center have provided me with multiple opportunities to improve my communication skills, and they are extremely supportive. Working with editors has helped me a lot to learn the best way of structuring a written piece, how to engage your reader, and make it interesting. As formal training, I attended a couple of workshops that provided me with some basic tips to start writing, but I reckon that it was practice what made me become better and confident

Due to the general lack of training for scientists in communication, I started organizing with other scientists local workshops aimed at grad students and early postdocs interested in getting some formal training to improve their own science communication skills.

What impact does the communication work have on your "normal" work?
Mostly, the communications work happens in my spare time. However, I think science communication has helped me a lot in several aspects as a researcher. First of all, I had the chance to meet many fellow scientists interested in science communication and outreach, giving me an excellent opportunity for networking. My writing skills have improved dramatically, which has helped at writing grants, and presenting at conferences. I feel like every minute I spent doing science communication and outreach has paid off in my normal work routine

Do you have any recommendations for other scientists interested in this field?
Keep an eye out, look for support from your peers as they may be involved already with some initiatives, find local science museums that may have volunteer programs, or start your own blog explaining your field. Anything will help you to get your work out there, and definitely getting more confident on communicating science to the public. In the end of the day, we work for the public, so we should be able to explain to them what we're doing in the lab.

Scott A Szikla

Increased reporting responsibilities will always bring increased administrative tasks. But with an already high administrative workload, European funding is often seen as overly bureaucratic and restrictive on actual research time. Therefore, any additional reporting/monitoring activity must be implemented without increasing the workload.

For a long time, publications and other measurable standards, e.g. patents and products, have been used as the sole measurement of success. However, research and programme outcomes cannot always be categorised or measured in traditional ways. While some projects result in a marketable product, others might just provide the basis for future research. Whole initiatives might not lead to significantly increased translation of results, but to better collaboration between individual disciplines or researchers. Compared with publications, outreach projects might not be classified with impact factors, but might inspire others to pursue science or help to inform the public opinion about a certain area of research.

Therefore, the process of defining monitoring standards requires and alternative metrics careful consideration.

Recommendation 3-10: ERA CoBioTech should work towards a monitoring system using standards which take into account the additional and alternative outcomes (e.g. outreach projects, collaboration increase, etc.). The reporting system should be easy to use while avoiding an increase in administrative workload for all parties involved.

Summary

By combining three strong and innovative scientific areas, synthetic biolog , systems biology and industrial biotechnology, ERA CoBioTech has the unique opportunity to influence biotechnology research and technology d velopment.

To achieve this, the ERA CoBioTech strategic agenda was developed together with and for the scientific community to support and advance biotechnology in Europe and beyond. Through the three themes on research, funding and engagement, this document explores ways to create a more open and inclusive community supported through tailored funding, which focusses on important, innovative, and emerging topics.

In theme 1, interdisciplinary working has been highlighted as essential to modern biotechnology research. The inclusion of additional expertise and the exchange of knowledge will enable scientists from industry and academia to combine the innovative potential of their disciplines, and encourage a better utilisation of research outcomes.

However, interdisciplinarity does not stop at research topics; it is also a common theme through the funding and engagement themes. The funding process cannot be changed without the input of all stakeholders as the needs and requirements, from researchers and funders alike, have to be known before improvements can be introduced. In theme 3, interdisciplinary working shifts towards working with different groups of society outside the research community as this section also discusses ways to make biotechnology more approachable and open to the potential users of research outcomes.

The sheer breadth of research areas and topics covered or touched by synthetic biology, systems biology and industrial biotechnology precludes the discussion of and recommendations for all of them. Hence in theme 1, this document emphasises the important headline topic of interdisciplinary working, and only focuses on a few specific areas which had been highlighted directly by the communit . The resulting recommendations should help the biotechnology community to strengthen their place as a key player in the bioeconomy and thereby tackling the global challenges our society is facing.

SMWK, René Plaul

Recommendations

Theme 1: Research and technology to address sustainability in Europe and beyond	
Recommendation 1-1:	Continued promotion of interdisciplinary working by scoping future calls and activities accordingly
Recommendation 1-2:	Continued support for R,D&I towards sustainable biorefinery products and processes with focus on emerging innovative and new products and processes, are beneficial to a range of industrial sectors
Recommendation 1-3:	Inclusion, where appropriate, of activities to support sustainable replacements of animals and animal-derived products
Theme 2: Streamlined and purpose orientated funding across Europe	
Recommendation 2-1:	Establish the Biotechnology Hub meetings as a regular event for the biotechnology sector in Europe
Recommendation 2-2:	Encourage equal participation of funders for academic and industrial research for all partner countries involved
Recommendation 2-3:	Investigate options to minimise funding gaps in cooperation, the EC, funders, and H2020 programmes
Recommendation 2-4:	The EU Member States to ensure further development of the ERA-NET programme funding scheme according to better commercialisation and translation needs of the scientific communit
Recommendation 2-5:	ERA-NET Cofunds to better define and tailor additional joint activities at the planning stage to tailor them to the needs of the specific programme; ERA-NET Cofund partners to ensure a continuation of EC funded additional joint activities in the Horizon Europe
Recommendation 2-6:	Ensure research projects with commercially exploitable outcomes have opportunities to pursue this exploitation

Theme 3: Engaging the scientific community and beyond	
Recommendation 3-1:	Encourage consistent participation of partners and partner countries in all future activities and calls
Recommendation 3-2:	Continue to approach new European and non-European partners to join the programme under a selective strategic approach
Recommendation 3-3:	National funders to support an open and clear dialogue with the commercial sector
Recommendation 3-4:	Attempt to identify relevant infrastructures for future activities and make this information available to the community
Recommendation 3-5:	Work towards providing continuous communications training
Recommendation 3-6:	Work towards providing tailored workshops, training and networking events to address current needs of the biotechnology community
Recommendation 3-7:	Publish detailed guidelines for applicants and proposal evaluators on how to address, evaluate and provide feedback on RRI aspects in research projects
Recommendation 3-8:	Explore opportunities to provide appropriate occasions for independent discussion and evaluation of the research project's RRI aspects
Recommendation 3-9:	Work towards developing and adopting better tools for follow up for research projects post funding
Recommendation 3-10:	Work towards a monitoring system using standards which take into account the additional and alternative outcomes

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- Agence Nationale de la Recherche (ANR), France
- Biotechnology and Biological Sciences Research Council within UK Research and Innovation (UKRI-BBSRC), United Kingdom
- Bundesministerium für Bildung und Forschung (BMBF), Germany
- Centro Para El Desarrollo Tecnologico Industrial (CDTI), Spain
- Estonian Research Council (ETAg), Estonia
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- FASIE, Russia
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- Innosuisse, Switzerland
- Innovate UK within UK Research and Innovation (Innovate UK), United Kingdom
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- Ministerio de Economia y Competitividad (MINECO), Spain
- Ministero dell'Istruzione, dell'Università e della Ricerca (MIUR), Italy
- Ministrstvo za izobrazevanje, znanost in sport (MIZS), Slovenia
- Ministry of Health (CSO-MOH), Israel
- Narodowe centrum badan i rozwoju (NCBR), Poland
- Nederlandse Organisatie voor Wetenschappelijk Onderzoek (NWO), The Netherlands
- Norges Forskningsrad (RCN), Norway
- Sächsisches Staatsministerium für Wissenschaft und Kunst (SMWK), Saxony - Germany
- Service Public de Wallonie (SPW-DGO6), Wallonia - Belgium
- Turkiye Bilimsel ve Teknolojik Arastirma Kurumu (TUBITAK), Turkey
- Unitatea Executiva pentru Finantarea Invatamantului Superior, a Cercetarii, Dezvoltarii si Inovarii (UEFISCDI), Romania
- Valsts Izglitibas Attistibas Agentura (VIAA), Latvia

Annex 1: ERA-NET programmes relevant to ERA CoBioTech

Name	Keywords	Link
ERACoSysMed - Promote the implementation of systems biology approaches in clinical research and medical practice	SysBio, data intensive science, health, bioinformatics	https://www.eracosysmed.eu/
ERASys*APP* – ERA-NET for applied Systems Biology research	SysBio, bioinformatics, tools & technologies	https://www.erasysapp.eu/
ERA-IB – Strengthen IB-related R&D in Europe	IB, innovation, industry	http://www.era-ib.net/
ERASynBio – promote the development of Synthetic Biology in Europe	SynBio, biotech, innovation, industry, tools & technologies	https://www.erasynbio.eu/
COFASP – Cooperation in fisheries, aquaculture and seafood processing	innovation, tools & technologies, industry, marine	http://www.cofasp.eu/
KORANET – Korean scientific cooperation network with the European Research Area	innovation, tools & technologies	[Reference/webpage no longer available – February 2019]
ERA-MBT – Marine Biotechnology ERA-NET	marine, socio-economics, ecosystems, biodiversity, food, energy, innovation, biotech, biorefiner , industry, metagenomics, IB	http://www.marinebiotech.eu/marine-biotechnology-era-net
BESTF - Innovative steps to boost bioenergy in Europe	bioenergy, innovation, industry, climate change, biofuels	[Reference/webpage no longer available – February 2019]
ERA-NET Bioenergy – Renewable energy sources for the future	self-sustainable, bioenergy, innovation, tools & technology, agri-tech, industry, biomass	http://www.eranetbioenergy.net/
ETB - Foster competitiveness of the European biotechnology industry	industry, IB, innovation, health, marine, food, agri-tech	https://www.eurotransbio.eu/index.php?index=42
SUSFOOD - Towards sustainable food production and consumption	food, socio-economics, agri-tech, industry, IB, tools & technologies	http://susfood-db-era.net/drupal/
M-era.Net - Strengthen research and innovation in materials science and engineering	materials, innovation, engineering	https://m-era.net/

ERANet-LAC - Improve collaboration in science, technology and innovation between Latin America and Europe	tools & technology, innovation	https://www.eucelac-platform.eu/
ERA.Net RUS Plus - Improve collaboration in science, technology and innovation between Russia and Europe	health, materials, climate change, socio-economics, innovation, tools and technologies	http://www.eranet-rus.eu/index.php
EIG CONCERT-Japan - Improve collaboration in science, technology and innovation between Japan and Europe	tools & technology, innovation	http://concert-japan.eu/
FACCE SURPLUS - Develop a diverse but integrated food and non-food biomass production and transformation system	agri-tech, socio-economics, food, innovation, biomass, biorefiner , climate change	http://faccesurplus.org/
ERAPerMed - Improve research and innovation in personalised medicine	health, data intensive science, bioinformatics, industry	http://www.erapermed.eu/

Annex 2: Acronyms

AC	Associated Country
BMBF	German Federal Ministry of Education and Research
DSP	down stream processing
EC	European Commission
EIT	European Institute of Innovation and Technology
EU	European Union
ERC	European Research Council
ERA CoBioTech	ERA-NET Cofund on Biotechnologies
ERA-IB	ERA-NET "Towards an ERA in Industrial Biotechnology"
ERA-NET	European Research Area Network
ERASys*APP*	ERA-NET for Systems Biology Applications
ERASynBio	ERA-NET on Synthetic Biology
GHG	Greenhouse Gas
H2020	Horizon 2020
IB	industrial biotechnology
JPI	Joint Programming Initiative
JRC	Joint Research Centre
KET	Key Enabling Technology
LEIT	Leadership in Enabling and Industrial Technologies
MS	Member State
R&D	Research and Development
R&I	Research and Innovation
R,D&I	Research, Development and Innovation
RRI	Responsible Research and Innovation
SME	Small and Medium Enterprise
SynBio	synthetic biology
SynGas	synthesis gas
SysBio	systems biology
TRL	Technology Readiness Level
UKRI-BBSRC	Biotechnology and Biological Sciences Research Council within UK Research and Innovation
WP	Work package

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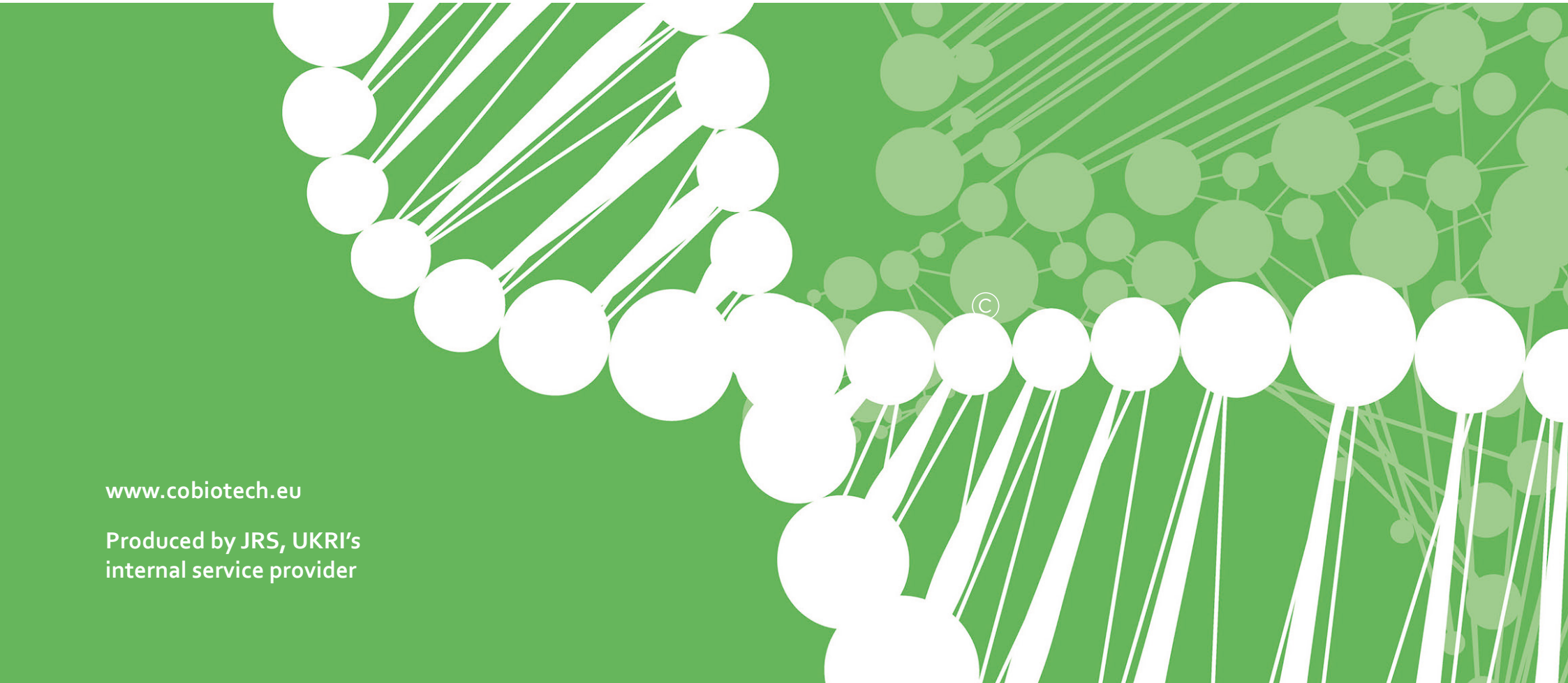

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