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Common Agricultural and wider bioeconomy reSearch Agenda

Bioeconomy Research & Innovation Policy Landscape in Europe: A Review

CASA Deliverable 3.3
November 2017

EUROPEAN UNION
Project co-funded by **H2020 Programme** under Grant Agreement n° 727486

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The overall objective of CASA, a Coordination and Support Action (CSA), is a **consolidated common agricultural and wider bioeconomy research agenda** within the European Research Area.

CASA will achieve this by bringing the Standing Committee on Agricultural Research (SCAR), which has already contributed significantly to this objective in the past, to the next level of performance as a research policy think tank. CASA will efficiently strengthen the strengths and compensate for the insufficiencies of SCAR and thus help it evolve further into “SCAR plus”.

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List of Abbreviations

BBI JU = Biobased Industries Consortium Joint Undertaking

CAP = Common Agricultural Policy

CASA = Common Agricultural and wider bioeconomy reSearch Agenda

CFP = Common Fisheries Policy

CSA = Coordination and Support Action

DG = Directorate-General

DG Agri = Directorate-General Agriculture and Rural Development

DG Grow = Directorate-General for the Internal Market, Industry, Entrepreneurship and SMEs

DG Mare = Directorate-General for Maritime Affairs and Fisheries

DG R&I = Directorate-General Research and Innovation

EC = European Commission

EGE = European Group on Ethics in Science and New Technologies

EIB = European Investment Bank

EIC = European Innovation Council

EIP = European Innovation Partnerships

EIT = European Institute of Innovation and Technology

EU = European Union

ERA-Net = European Research Area Networks

FP = Framework Programme

IP = Intellectual Property

JPI = Joint Programming Initiative

JRC = Joint Research Centre

KETs = Key Enabling Technologies

KICs = Knowledge and Innovation Communities

NGOs = Non-governmental Organisations

PPP = Public Private Partnership

R&D = Research and technological Development

R&I = Research and Innovation

SCAR = Standing Committee on Agricultural Research

SIRA = Strategic Innovation and Research Agenda

SMEs = Small and Medium Sized Enterprises

SWOT = Strength, Weaknesses, Opportunities, Threats

TRL = Technology Readiness Level

Introduction

The bioeconomy accounts for 18.6 million jobs and €2.2 trillion turnover in the European Union (EU) (Ronzon et al, 2017). It has been hailed as a win-win for economy and environment, boosting jobs and competitiveness in both rural and urban areas while at the same time shifting society away from a reliance on fossil fuels towards more renewable, biobased resources. According to EC (2012, p9), the bioeconomy:

> "*Encompasses the production of renewable biological resources and the conversion of these resources and waste streams into value added products, such as food, feed, bio-based products and bioenergy"*

The bioeconomy thus encompasses a wide array of sub-sectors from traditional resource sectors (e.g. agriculture, forestry, marine) to industrial categories and applications (e.g. chemicals, materials and energy). The concept of innovation is equally as complicated, and indeed complex. As stated by Wiebe Bijker (quoted in Mandelin and Ringrose, 2016, p2)):

> *"While a new idea is a thought about something new or unique, and making that idea real is an invention, innovation is an invention that has a socioeconomic effect. Innovation changes the way people live"*

Innovations related to the bioeconomy thus have the potential to have a truly transformative effect, ultimately changing how society produces and consumes resources and meets food, feed, fuel and fibre needs. A successful bioeconomy will involve changes in land use, business models, regulatory supports, market standards and consumer expectations. It will involve radical innovation demanding not just new technologies but changes in practices, values, beliefs, configurations of actor groups, networks and policies (Darnhofer, 2015).

Operating at the interface *"between technical opportunity and user needs"* (Lundvall, 2007, p21), processes of innovation are regularly endorsed by the EC as central to securing the present socio-economic context and essential to developing the future (EC, 2016). More recently, the concept of innovation has been connected to processes of research, particularly within the Horizon 2020 funding framework. Indeed, research and innovation (R&I) are inextricably interlinked in this work programme, with the aim of fostering sustainable jobs, industry competitiveness and economic growth in way that also helps to overcome identified societal challenges (for example, related to climate change, food and energy security, green transport, population health, demographic change, economic recession, unemployment and citizen protection). A number of R&I policy supports and mechanisms thus exist across the EU to support the growth and development of the European economy with funding increasingly channelled to the development of the biobased alternative of this, the bioeconomy. Responding to at least eight of the United Nations Sustainable Development Goals (Von Braun, 2017), conclusions of the 21st Conference of the Parties (COP21), and directly contributing to at least four of the Juncker Political Priorities established for the Commission (2015-19), political commitment and support to the bioeconomy is thus growing and receiving increasing attention in the past decade.

This report aims to review some of the principal R&I policy frameworks existing and adopted at the EU level to support the bioeconomy, and in particular across the Directorate-General (DG) network including DG Research and Innovation (DG R&I), DG Agriculture and Rural Development (DG Agri) and DG for the Internal Market, Industry, Entrepreneurship and SMEs (DG Grow). These three DGs were chosen given their high relevance and close connection to bioeconomy development from perspectives of securing biomass inputs, improving processing technologies, creating industries and appropriate business models and forming and informing market demand. While the policies and supports of many other DGs inevitably also contribute to the European bioeconomy (e.g. DG Environment, DG Climate Action, DG Competition and DG Energy), the aim of this focused assessment is to review principal R&I policy interactions and identify any gaps in the system.

To achieve this assessment, the report adopts a critical lens based on innovation systems thinking (and in particular sustainable innovation systems literature) and the process of bioeconomy product maturity development based on Figure 1 and Figure 2 below. Figure 1 (taken from Hagemann et al., 2016) maps the broader elements of an innovation system as applicable to many technological innovation systems, including the bioeconomy. Within this figure, R&I policy can be seen as one, yet

crucial, element within the broader innovation system. As with Bijker above and Lundvall (2007), the aim of any innovation system is ultimately to support ideas through the invention process and ultimately out the other side to become an innovation that has a socioeconomic effect. The innovation system achieves this through carrying out a number of key functions including:

Creating and diffusing new knowledge

- Guiding search processes among technology suppliers and users to influence the direction in which stakeholders deploy their resources (e.g. providing expectations of growth)
- Supplying financial, human capital and other resources
- Creating positive external economies and conditions through the exchange of information and a positive vision
- Facilitating market formation and demand

(Johnson and Jacobsson, 2001; Foxon et al., 2004)

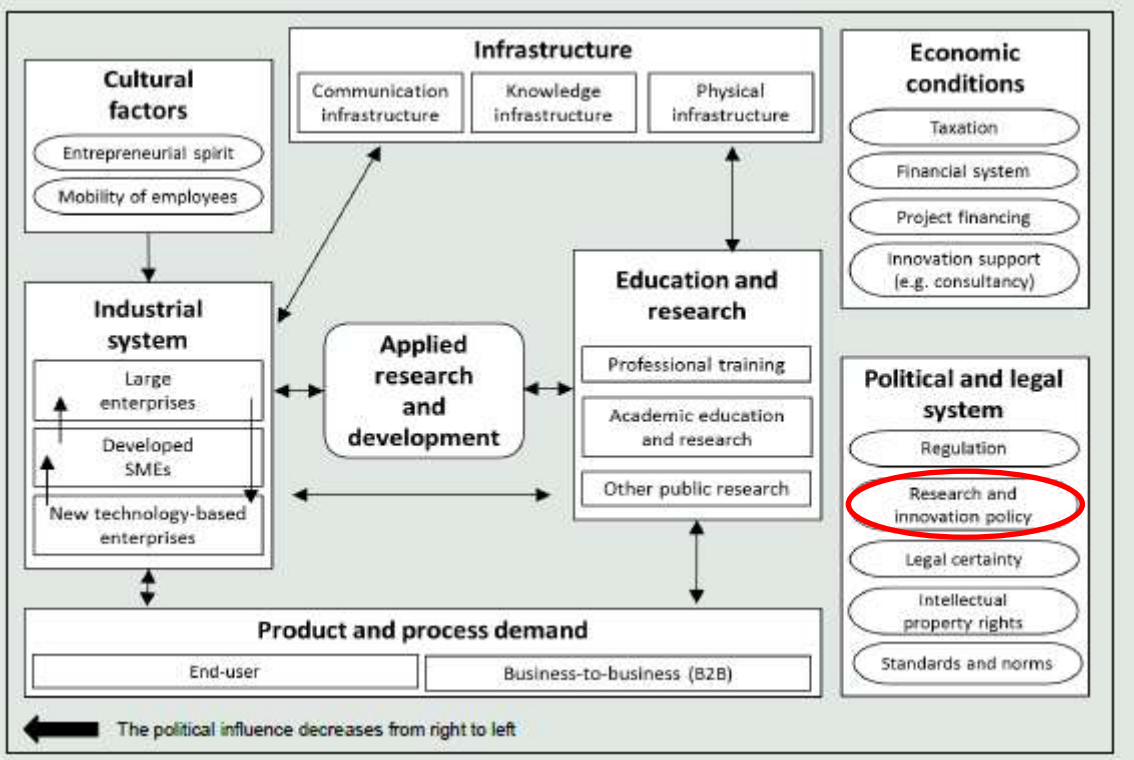

Figure 1 Elements of an innovation system (taken from Hagemann et al., 2016; based on Kuhlmann and Arnold, 2001; own emphasis)

Processes of innovation in the bioeconomy are particularly important to ensure the development of renewable resource-based technologies that are environmentally sustainable, socially acceptable and economically competitive i.e. innovations that ensure competitiveness with fossil-based alternatives and reduce ecosystem pressures associated with increased biomass demands of the bioeconomy (Purkus et al., 2017). Policy contributions are reported to play a particularly important role in transition-orientated innovation systems, and particularly in light of the complexities and uncertainties that typify the bioeconomy transition (Purkas et al., 2017). Progressing bioeconomy innovations through a well-developed innovation system is thus vital to translate ideas into actions, progress along the learning curve and ultimately work towards a more bio-based, sustainable society.

An additional layer of analysis that focuses on maturity levels of bioeconomy product development is thus useful to understand how different supports, schemes, policies and work programmes support the development of biobased products and services to market (Figure 2). This is in keeping with the TRL (technology readiness level) framework commonly adopted in Horizon 2020 thinking and beyond, that aims to invest in research and innovation from unproven concepts (TRL 1) through to full commercial application (TRL 9) (Mankins, 1995; EC, 2014).

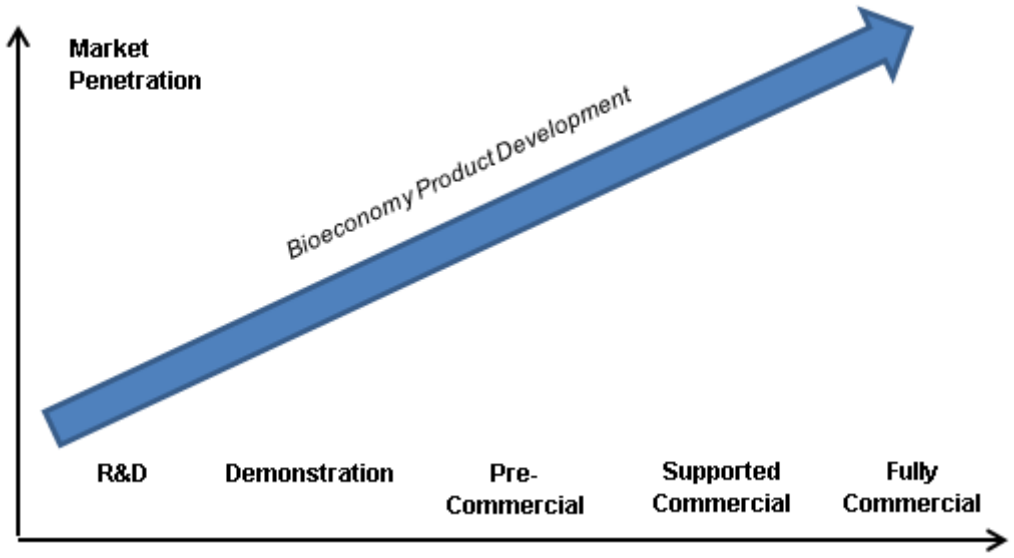

Figure 2 Maturity stage of bioeconomy product development (based on Foxon et al., 2005)

The report is structured as follows. First, an overview of the diverse range of R&I policies prevalent across DG R&I, DG Agri and DG Grow is provided with respect to bioeconomy supports. This overview does not intend to be exhaustive but merely reflective of the diversity and complexity of bioeconomy R&I policies and supports at the European scale. This is followed by a summary table of the identified supports/frameworks, mapping their key characteristics and bioeconomy product maturity level addressed. The report concludes by highlighting some preliminary gaps and overlaps of the bioeconomy innovation system as identified by this review of the European R&I policy landscape.

Research and Innovation in Europe

Dating back to the Treaty of Amsterdam (1997), research and technological development (R&D) has always been high on the agenda of the European Commission (EC) and positioned as an essential element to ensure the prosperous functioning of Member States (EC, 2015). The language of innovation has since infiltrated political thinking and related support frameworks, with an emphasis on transformative change and breakthrough innovations to address growing societal and environmental challenges (for example, related to healthy ageing, unemployment, population wellbeing, climate change, environmental degradation, economic recession, etc.). Developing and implementing European R&I policies and programmes thus moves far beyond a legal and political obligation associated with a founding treaty to encompass the ultimate aim of making Europe a better place to live and work. It represents something pivotal and promising for a smarter, more inclusive, healthy, prosperous and sustainable society. A number of Directorate Generals (DGs) contribute to realising this vision, as scientific and technological advances continue to become increasingly complex, costly and interdisciplinary (EC, 2015). Support from the EC and its variety of DGs is thus essential and enabled through dedicated R&I policies and programmes that allow research teams, laboratories,

companies, universities, NGOs, civil society actors and Member State policymakers to play active and leading roles in scientific and technological advance. The extent and diversity of these supports as relevant to the bioeconomy are explored in this report, with a focus on three departments in particular: DG R&I, DG Agri and DG Grow.

DG Research and Innovation

Central to this review of the European R&I policy landscape, the Directorate-General for Research and Innovation (DG R&I) is responsible for defining and implementing all R&I policy in the EU. This remit is set within the context of achieving the goals of both the Europe 2020 strategy (the EU's ten-year jobs and growth strategy for smart, sustainable and inclusive development) and one of its seven flagship initiatives, the Innovation Union (a Europe 2020 initiative that strives to create an innovation-friendly environment that enables ideas to transform into products and services that foster growth and employment). Ultimately, DG R&I develops and implements R&I policy that improves competitiveness, creates jobs, boosts economic growth, and tackles current and future societal challenges (DG R&I, 2017). It does this also within the wider context of global agreements and legislation, including implementing the United Nations' Sustainable Development Goals that seek to achieve economic prosperity, environmental protection and social well-being concurrently and the COP 21 Paris Agreement related to greenhouse gas emission targets and climate change.

To achieve its remit, central functions of DG R&I include analysing national R&I policies (formulating country specific recommendations where appropriate) and monitoring the realisation of the Innovation Union and the European Research Area (a central policy that aims to overcome fragmentation to create a unified research area across Europe that is open to the world and in which scientific knowledge, technology and researchers freely circulate). One of the principal functions of DG R&I in the context of the bioeconomy however include its numerous and varied policies that fund world class R&I through its strategic Framework Programmes. A number of these are outlined below following a brief overview of the DG R&I structure, showcasing the breadth of support that DG R&I offers to the development of the bioeconomy.

DG R&I: structure and mission

Operating under a Commissioner for Research, Science and Innovation, DG R&I is led by a Director-General and a number of principal advisors, under which a number of Deputy Director-Generals operate across three thematic areas. This includes a Deputy dedicated to Open Innovation, Open Science, Open to the World (including a scientific advice mechanism unit), another to Research Programmes and a third to Human Resources, Budget and Common Support (DG R&I, 2017)**.** The unit dedicated to Research Programmes is divided into six priority research areas, with one specifically dedicated to the bioeconomy (Directorate F in this unit). Other priority research areas also hold relevance to dimensions of the bioeconomy including energy, health, transport, industrial technologies, climate action and resource efficiency (Stahel et al., 2015**).**

As expected, research and innovation form the heart of all DG R&I activities, with an increasing recognition of the need for more open, collaborative and global science in the digital age. As such, in 2015, three specific goals were set by Commissioner Carlos Moedas for EU R&I policy. Commonly referred to as the 3 O's strategy, these include: Open Innovation, Open Science and Open to the World (DG R&I, 2017). While not representing a new policy initiative per se, these goals reinforce the mission of DG R&I and its existing policies including the European Research Area and Horizon 2020. The 3 O's focus on involving more actors in the innovation process, ensuring the free circulation of knowledge, fostering a culture of entrepreneurship and increasingly recognising the importance of international cooperation in R&I practices. Given the potential of systematic and supported R&I to address global societal challenges, this renewed focus furthers the potential for transformative change (economically, environmentally and socially) through the work of scientists, researchers, entrepreneurs, industry leaders and civil society actors across Europe. Indeed, symptomatic of

increasing support to this cause, the European Innovation Council (EIC) was subsequently set up under DG R&I, as part of the 3 O's strategy. Responding to a perceived gap in innovation supports in the EU innovation ecosystem, the EIC works to support start-ups and companies that are innovating in new markets with the aim of driving disruptive, market-creating innovations (as opposed to incremental innovation often witnessed in research realms and supported already by Horizon 2020) (EIC, 2017). With a focus on market-creating innovations that hold potential for scale up, the EIC thus supports investment in high risk technologies, markets, regulatory and business models. In this way, the EIC aims to further strengthen the integration of R&I at a European scale, supporting breakthrough and game-changing innovations that hold potential to create new markets, jobs and prosperity (EIC, 2017).

Additional structures nested within European R&I policy include the European Group on Ethics in Science and New Technologies (EGE) and the European Institute of Innovation and Technology (EIT). The EGE provides independent advice for EC policy on all ethical, societal and fundamental rights in the development of science and technology, while the EIT connects universities, researchers and companies through diverse pan-European partnerships to boost innovation and entrepreneurship. This latter institution represents another integral element of the Horizon 2020 Programme. It works to establish partnerships between research and industry through Knowledge and Innovation Communities (KICs) operating in diverse thematic areas to develop products and services, start new companies and train new entrepreneurs (EIT, 2017). Working across the innovation system, there are six KICs at present related to diverse societal challenges including climate change, healthy living, energy, digital technologies, food and raw materials (aspects also integral to a successful bioeconomy).

Finally, under the auspices of the Innovation Union and addressing the socio-economic weaknesses revealed by the 2007 financial crisis, European Innovation Partnerships (EIP) were developed to enable innovative solutions to critical societal challenges in the context of wider European growth, social welfare and efficiency (Aho et al., 2014). EIPs operate to connect diverse stakeholders, performing an essential integrative function that particularly enhances the dialogue between innovators and policy-makers. They also serve an observatory function, monitoring innovation practices across Europe (Aho et al., 2014). EIPs are challenge-driven R&I initiatives with a focus on the rapid modernisation of sectors and markets and achieving societal benefits through the inclusion of diverse actors across scales. Working across the innovation system (Johnson and Jacobsson, 2001; Foxon et al., 2005; Hagemann et al., 2016) and aiming to implement each step in parallel, EIPs simultaneously develop R&D efforts, coordinate investments in demonstration and pilot facilities, predict and fast-track necessary regulatory changes and aim to mobilise market demand (including through coordinated public procurement measures) (Aho et al., 2014; EC, 2017). EIPs aim to better coordinate and build upon existing innovation instruments, working to integrate them into a single coherent policy framework where appropriate and complementing with new actions where necessary. No 'one size fits all' framework thus exists in the establishment and operation of EIPs, with five thematic areas already launched and elaborated upon in diverse arenas (Figure 3). All of these topic areas can nonetheless be linked with the bioeconomy including from input supply, resource use, technological, geographical and market perspectives.

Figure 3 EIPs operational across Europe (EC, 2017)

Many of the listed bioeconomy policy R&I structures are linked to, financially supported or at the very least influenced by DG R&I's key funding policy, Horizon 2020. This is explored in more detail below alongside two other policy instruments particularly relevant to the bioeconomy: the Joint Research Centre and its related Observatories and the Biobased Industries Consortium Joint Undertaking.

FP7 and Horizon 2020

As stated by Mandelin and Ringrose (2016, p16): *"Fundamental and excellent research is one indispensable driver of innovation"*. One of the key funding programmes in this context is Horizon 2020, an R&I policy instrument established in 2014 following the end of the successful Framework Programme 7 (FP7).

Framework Programme funding mechanisms for research have been in existence since 1984 (EC, 2013). The predecessor to Horizon 2020, FP7, ran from 2007-2013 with a total budget of €55 billion and a focus on four thematic areas (people, ideas, cooperation and capacities). An evaluation of FP7 revealed the success and impact of the programme, involving participants from over 170 different countries and producing over 1700 patent applications and 170,000 peer-reviewed papers (EC, 2016a). It further supported SMEs with over €6.5 billion in funding, created durable R&I networks and contributed to sustainable development. Moreover, it is estimated that for every €1 invested through FP7, €11 was generated in economic benefits through the development of innovations (EC, 2016a). This reflects the importance of investing in R&I for European global competitiveness, long term economic prosperity and to tackle the wicked problems and grand societal challenge of our time (Coenen et al., 2015). Calls for greater framework programme efficiency, coherence and ability to respond to emerging challenges nevertheless also featured in this review, alongside a need to reduce administrative complexity (particularly for SME involvement). The need to address the *"European paradox"* is also frequently cited, whereby European countries are perceived to frequently lead globally in terms of creating high quality academic and scientific output but fail at translating scientific advances into wealth-generating, marketable innovations (Dosi et al., 2006, p1450). Such features highlighted aspects to be addressed in the new framework programme, Horizon 2020. Designed to operate from 2014 until 2020, Horizon 2020 indeed responded to some of these programme weaknesses. For example, reflecting an ability to respond to emerging and real-life challenges, funds were quickly redirected during the Ebola outbreak to search for a suitable vaccine with Horizon 2020

funding (EC, 2016b). Symptomatic of increasing commitment to R&I at the European scale, Horizon 2020 is the largest EU R&I programme to date, with c. €80 billion of funding available over the 7 year period (Figure 4).

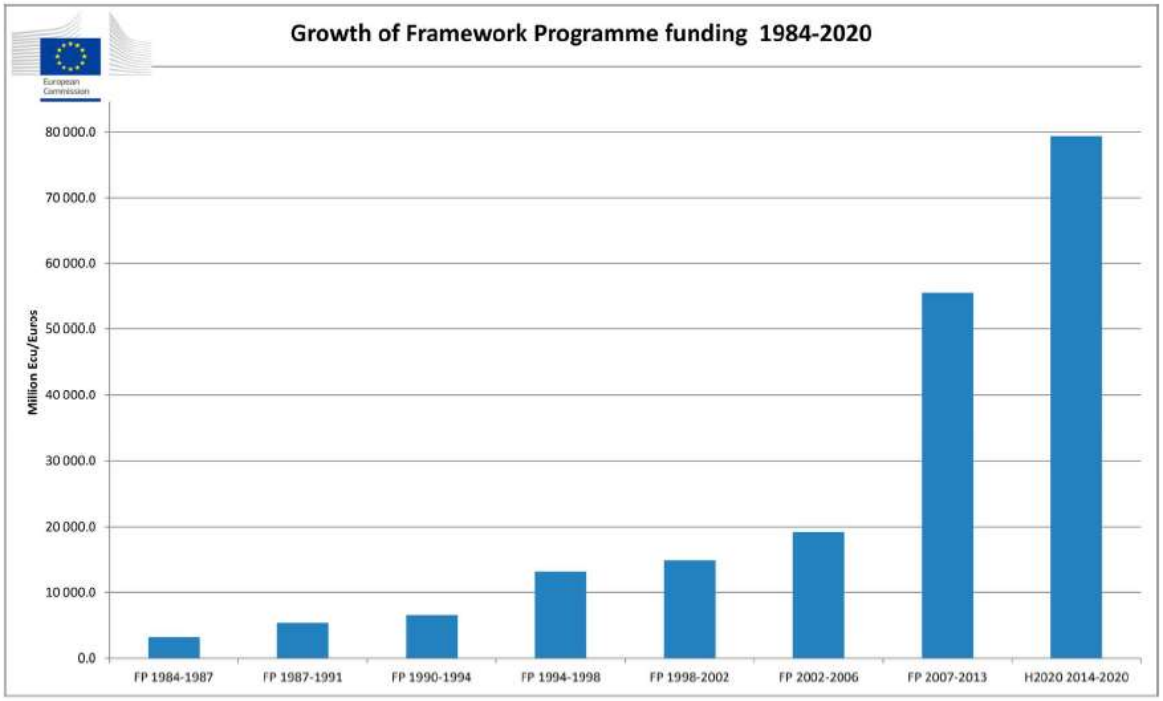

Figure 4 Growth of Framework Programme Funding 1984-2020 (EC, 2013)

With an increased emphasis on innovation, the European paradox and the commercialisation of research, Horizon 2020 aims to bring good ideas to market in a quick and efficient manner (EC, 2016b). Climate action and positive societal impact are particularly prioritised in this programme, reflecting a strong sustainability focus in the R&I to be supported. Focusing on the EU's long term priorities and addressing its most pressing challenges, the three main pillars of Horizon 2020 are structured around:

- Pillar 1 *Excellent Science* – advancing scientific leadership in Europe
- Pillar 2 *Industrial Leadership* – helping EU industries become more competitive
- Pillar 3 *Societal Challenges* – addressing escalating societal and environmental problems

Numerous and varied grant schemes exist within these pillars, as detailed in Figure 5. In terms of supporting bioeconomy R&I specifically, attention must be drawn to Pillar 3 of the programme and Societal Challenge 2 in particular outlined to address issues of *"Food Security, Sustainable Agriculture and Forestry, Marine, Maritime and Inland Water Research and the Bioeconomy".* Approximately €4 billion is solely dedicated to Societal Challenge 2, representing c.5% of the Horizon 2020 budget total (EC, 2013), while approximately €25 billion resides with other societal challenges in Pillar 3 that also hold relevance to the bioeconomy (for example, health, clean energy, green transport, climate action and environment resource efficiency) (EC, 2013). The total sum of money dedicated to supporting bioeconomy R&I may however be even higher on consideration of the vast remit of the bioeconomy where biomass, technological and/or product advances may emerge from across Horizon 2020 funding streams from supporting diverse fundamental science in Pillar 1 to fostering leadership in enabling and industrial technologies and SME innovation in Pillar 2.

Figure 5 Structure of Horizon 2020 (Mc Carthy, 2017)

Pillar 1, '*Excellent Science*', can be typified by a bottom-up approach to research whereby scientists and researchers largely propose topics for consideration, compared to Pillars 2 and 3 which tend to be driven by the EC agenda in a top-down manner (e.g. the EC identify gaps in research and problems that require addressing and structure the call for proposals accordingly). Nevertheless, across Horizon 2020 there is a tendency to structure calls according to a challenge-based approach. In other words, they are structured in a way that does not prescribe particular technology options, providing more flexibility for researchers and businesses and potential for further breakthrough innovations (Schild, 2014). This is reflective of the broader shift from mission- and technology-orientated innovation policy to wider challenge-based policies in recent times that require a mix of technological and social innovation, new actor constellations and more open-ended ambitions that are open to contestation (Coenen et al., 2015).

Several other smaller programmes operate alongside the three pillars of Horizon 2020 including the European Institute of Innovation and Technology (funding regional innovation), the Spreading Excellence Initiative (assisting regions that are less involved in EU research to become more involved), Science with and for Society (dealing with ethics and gender in science) and Euratom (funding nuclear research). These aspects however represent just 8% of the Horizon 2020 budget compared to Pillars 1, 2 and 3 that constitute the primary focus and account for over 92% of the total budget available.

In keeping with the discussion on product maturity levels (Foxon et al., 2005) and technology readiness (Mankins, 1995; EC, 2014), Horizon 2020 also uses the TRL scale as a decision-making tool for R&I investments. Indeed, many of the grants and calls for proposals are structured according to the different TRL levels (see Figure 6 in conjunction with Table 1) representing a new dimension to this funding policy compared to previous initiatives. For example, FP7 previously only developed research up to TRL 4 (small scale laboratory prototypes) compared to Horizon 2020 that now expands research and innovation up to TRL 7 (successful in operational environment at pre-commercial scale i.e. at demonstration level). Due to international competition law, Horizon 2020 cannot fund further along the TRL scale without co-investment or funding by an industry partner. This prevents supporting one national company in a way that could make it more competitive than another in the single market EU. Industry R&D funds are thus generally required to bring a concept up to TRL 9 (or full commercialisation). Utilising the TRL scale nevertheless aims to provide a common understanding of technology status across disciplinary and sectoral arenas within Horizon 2020. Originating as a concept in the aerospace industry, many of the call topics in Horizon 2020 have a

starting TRL highlighting where the proposal should intend to start, as well as a target TRL that the project should reach upon completion. The use of TRLs is not as prevalent in Pillar 3 (societal challenges) as Pillar 2 though it is still used to express the focus of the funding scheme. Proposal evaluation criteria can also vary according to the TRL level assigned, with a higher weighting on scientific excellence when evaluating proposals aimed at the beginning of the scale (TRL1-3) compared to a focus on impact subsequently (TRL4-6) (McCarthy, 2017). The TRL level defined thus impacts the R&I investment protocol in a number of ways – from setting the parameters of the original proposal call to defining impact from, and end users of, the end project results (e.g. earlier TRL projects results tend to stay within the scientific community compared to later TRLs that may aim to target SMEs, businesses, regulators and investment companies).

ERA-NETs represent an additional R&I support structure associated with Horizon 2020 funding. Initiated by ERA-Net calls in Horizon 2020, consortia of research funding agencies submit proposals for appraisal with the aim of forming an ERA-Net that runs joint transnational calls and networking activities. The ERA-NET instrument thus aims to support the establishment and running of public-public partnerships and the design, implementation, longevity and coordination of joint activities. ERA-NETs are also increasingly used to top-up individual joint calls for transnational R&I in priority areas (including a significant number relevant to the bioeconomy). This approach aims to increase the share of funding that Member States dedicate jointly (in cash or in kind) to challenge-driven R&I agendas. In 2014-15, over 20 ERA-NET cofund actions were planned along with a number of CSAs or Coordination and Support Action initiatives that support studies and networks. CSAs are typically not research orientated but involve multi-national networking projects in topical areas (including the bioeconomy). For instance, CommBeBiz, BioLINX, Columbus, ProBio represent CSAs funded under Horizon 2020 in 2015 with the ambition of accelerating innovation in the bioeconomy, helping researchers to commercialise their bioeconomy-related research and bridging the gaps between research, industry and other end-users (Cordis, 2017). InnProBio and BioSTEP meanwhile were funded in the same period with more specific emphasis on the public procurement of bio-based products and public understanding and acceptance of the bioeconomy respectively. Similarly, in 2016, CASA represents an example of a CSA operating to support the development of SCAR as a research policy think-tank with the aim of developing a more strategic consolidated agricultural and bioeconomy research agenda within the European Research Area (Cordis, 2017).

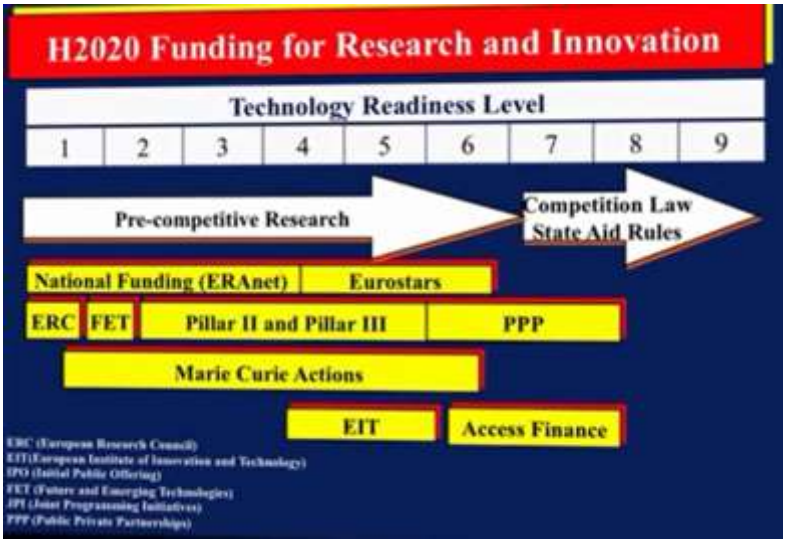

Figure 6 Use of the TRL scale in Horizon 2020 funding (McCarthy, 2017)

JRC: Bioeconomy and RIO Observatories and the Bioeconomy Knowledge Centre

A number of additional initiatives stemming from Horizon 2020 exist to support the growth, development, understanding and political influence of the bioeconomy. For example, of the two thematic observatories established by the Joint Research Centre (JRC) (the EC's in-house science service), one of these is specifically dedicated to the bioeconomy. Representing a science and knowledge service of the EC and supporting EU policy makers with independent scientific evidence, the JRC provides scientific advice on issues related to the internal market (e.g. work on standardisation), industrial policies (e.g. through foresight exercises), raw materials and smart specialisation. Particularly relevant to this review is its activities on smart specialisation that enables the JRC to strategically addresses economic development at regional levels and target support to R&I across the EU. The Bioeconomy Observatory, established by the JRC in close co-operation with DG R&I provides and tracks the most recent data and information related to the European bioeconomy, including statistics on investments in research, bioeconomy country profiles, policy mapping and analytical reports. An additional Research and Innovation Observatory also operates, again developed by the JRC in close cooperation with DG R&I and serving as another tool to monitor EU R&I policies and activities. Acting as a policy support facility to Horizon 2020, the Research and Innovation Observatory delivers insights, data and best practices on designing, implementing and evaluating R&I policy at EU and national levels with the aim of supporting better policy making in Europe (Research and Innovation Observatory, 2017).

Striving to develop more evidenced-based policies, the Bioeconomy Knowledge Centre has since been specifically launched in July 2017, created by the EC's JRC, in cooperation with DG R&I. Rather than generating new knowledge, the new Bioeconomy Knowledge Centre aims to collect, structure and communicate information from across disciplines and sources on the bioeconomy in a bid to provide a knowledge base for policymakers across scales developing and attempting to connect bioeconomy-related policies (EC, 2017a). This purpose draws on JRC strengths in knowledge management, with the Centre thus acting as an accessible and timely knowledge platform for interested policy stakeholders. It is the fourth Knowledge Centre to be established by the EC in recent years, with previous centres dedicated to migration and demography, disaster risk management and territorial policies. With high political hopes of addressing the societal challenges facing the EU, this signals the importance of the bioeconomy to European development and commitment of the EC to progress this arena (EC, 2017a).

BBI JU

Finally, public funds are also provided by Horizon 2020 to the Biobased Industries Consortium to form the Biobased Industries Consortium Joint Undertaking (BBI JU); a public private partnership (PPP) that aims to develop and increase investment in the European biobased sector and capitalise on, and support, EU R&I strengths (BBI, 2017). Playing a role in addressing the "European paradox" with regard to research commercialisation (Dosi et al., 2006), the BBI JU I encourages researchers to works more closely with industry and promotes an R&I agenda that is driven even more by industry. In doing so, the PPP endeavours to deliver environmental and socio-economic benefits for Europe, increase European competitiveness, reduce reliance on fossil fuels, valorise waste and establish Europe as a key player in the research, demonstration and deployment of advanced biobased products. Ultimately, it aims to contribute to achieving a prosperous and sustainable bioeconomy in Europe. The PPP approach reduces risk for the private sector who may wish to invest in bioeconomy-related R&I but are discouraged to invest in pre-competitive, demonstration activities that are nonetheless required to ensure a reliable biomass supply, advanced processing technology and large scale demonstration capacities (BBI, 2017). Approximately €1 billion is provided by Horizon 2020 to the BBI JU which is subsequently topped up by private funds of approximately €2.7 billion (BBI, 2017). Activities of the BBI JU are driven by a Strategic Innovation and Research Agenda (SIRA) that has been developed by the industry; an updated version of which was launched in June 2017 to guide direction and activities. The new SIRA roadmap promotes significant multi-value chain thinking for the bioeconomy and integrates new feedstocks previously missing from older versions. Reflective of the

latest developments and political interest in the development of a more holistic and circular bioeconomy, this includes the further use of aquatic based resources, biowaste and CO_2 (BIC 2017).

Further links between DG R&I and other DGs through Horizon 2020 are elaborated in further detail below, including with DG Agri and DG Grow.

DG Agriculture and Rural Development

When considering inputs to the European bioeconomy, it is important to note that separate and distinct DGs operate to manage, control and implement policies across primary production arenas. While DG Agriculture and Rural Development (DG Agri) functions to develop and implement policies primarily related to agriculture, forestry and the wider rural renaissance, DG Mare (or the Directorate-General for Maritime Affairs and Fisheries) works to develop the potential of the European maritime and blue economy. Marine resources boast significant and largely untapped potential, for further food, feed, fuel, chemical, pharmaceutical and material outputs in the bioeconomy including the further use of underutilised marine species, catch by-product and cultivated seaweed and aquaculture (Devaney and Henchion, 2017). This is enabled through continuously advancing technologies, extraction methods and marine-related product development (Hayes and Fagan, 2014; Hamed et al., 2015). The Common Fisheries Policy (CFP) holds particular relevance in this primary production arena, with new landing obligations phasing out the discard of marine catch at sea and furthering the need to find new and innovative ways to add value to unwanted material (Blanco et al., 2015). DG Mare works to implement policies of the CFP, developing the potential of the blue economy and aiming to secure sustainable fisheries, seas and coastal communities.

Overall, there is strong academic interest and political support for the bioeconomy to revitalise rural communities, create rural employment, support rural economies and facilitate rural development (EC, 2012; Johnson and Altman, 2014; Schmid et al., 2012). How to achieve this in practice however and ensure that the benefits of the bioeconomy filter to the primary producer, is often more complicated and unclear. Some ideas proposed to ensure the sharing of bioeconomy benefits include the development of new business models that involve rural partnerships, producer co-operative schemes and public-private partnership investments (Bonsall, 2017). Input from DG Agri is thus essential to frame the contribution of the bioeconomy to rural Europe and ensure the trickle-down effect of capital accumulation (Aghion and Bolton, 1997). Key bioeconomy R&I policy supports connected with DG Agri thus include a suite of policies, programmes, practices and events, often nested within the wider understanding and implementation of the Common Agricultural Policy (CAP) and the European Rural Development Policy. These elements are explored in turn below following a brief overview of the structure and functioning of DG Agri.

DG Agri: structure and mission

Working under a Commissioner for Agriculture and Rural Development, DG Agri is led by a Director-General, under which three Deputy Director-Generals manage ten distinct but interconnected directorate divisions. Topics of focus here include sustainability and income support; markets and observatories; strategy, simplification and policy analysis; rural development I and II (including units dedicated to rural development in different Member States); international affairs; and quality, research, innovation and outreach. Signalling support and commitment to the bioeconomy and reflecting the increasing EC narrative related to the development of the circular bioeconomy, there additionally exists a principal advisor dedicated to ‘Innovation and the Circular Economy’ operating under one of the three Deputy Director-Generals and working with DG Agri units dedicated to R&I (Unit B.2) and ‘Environment, climate change forestry and the bioeconomy’ (Unit D.4). Intentions for innovation in the bioeconomy, and possible contributions to rural development, can thus be seen to have infiltrated the structure, mission and objectives of this DG.

The principal responsibility of DG Agri lies in the development and implementation of EC policies on agriculture and rural development. As a principal source of biomass for the European bioeconomy, over 77% of the EU's territory can be classified as rural (broken down into 30% Forest and 47% farmland) with approximately half of the European population residing here. Support for the endeavours and functioning of rural Europe is therefore crucial from economic, environmental, political and social standpoints. Facilitated by policies of the EC (including, for example, CAP and Rural Development 2014-2020), the primary objective of DG Agri remains on supporting primary producers in the production of safe, sustainable and high quality food. This includes through the provision of economic systems that help to stabilise farmer income and by facilitating infrastructural and R&D investment to create a sustainable, modern farming sector (DG Agri, 2017). Other stated objectives of DG Agri relate to the maintenance of viable and diverse rural communities and the creation of jobs throughout the food chain. Highlighting the need for *"new knowledge, new technologies, new products and new ways to organise, learn or cooperate"* (DG Agri, 2017a), effective R&I is increasingly recognised by DG Agri as essential to meeting EU objectives of viable food production, balanced territorial development, climate action and the sustainable management of natural resources. Holding potential to boost competitiveness, ensure sustainability, contribute to food security, empower local communities and diversify rural economies, the potential offered by bioeconomy-related R&I is particularly noteworthy to create change for farmers, foresters and rural biobased industries through accessing and implementing new knowledge and practices.

DG Agri achieves its objectives through a number of policy supports and programmes, particularly in the context of CAP, the Cork 2.0 Declaration and Rural Development 2014-2020. It additionally contributes to the European Network for Rural Development, the publication of sectoral dashboards that map agricultural markets and the implementation of agricultural product quality assurance schemes (DG Agri, 2017). Furthermore, a principal support related to bioeconomy R&I within DG Agri relates to its functions and duties in EIP-AGRI; the European Innovation Partnership for Agricultural Productivity and Sustainability. These supportive elements of DG Agri are discussed in turn below.

Common Agricultural Policy

The Common Agricultural Policy (CAP) is one of Europe's oldest policies, surviving and evolving through much iteration to become a policy that supports modern, market-orientated agricultural production (DG Agri, 2017b). The focus of CAP remains on the provision of high quality, safe and affordable food, produced according to strict environmental and animal welfare standards. The CAP also aims to support investment in the broader rural economy. CAP Direct Payments form an integral supportive element of the policy ensuring the economic prosperity of European farmers and providing much needed income support in diverse production systems. A number of market measures are also provided through CAP to further ensure viable value chains for the c.22 million agricultural workers across the EU. Such economic support in the context of market price volatility and biomass production uncertainties (e.g. weather conditions) ensures c.€130 billion worth of food and drink are exported every year from the EU (DG Agri, 2017b).

A number of additional policy areas pertinent to the bioeconomy also operate within the context of CAP that relate to, for example, the impact of agriculture on the environment; trade and promotion; animal welfare; plant health and product quality ((DG Agri, 2017b). Several other policies in existence through CAP and DG Agri also relate to the development of a diverse bioeconomy, including policy supports related to bioenergy, biotechnology and R&I. For example, while CAP does not provide financial support to bioenergy production, its associated rural development policies allow Member States to introduce measures that support it. Mindful of sustainable agri-environmental practices, the use of agricultural residues for bioenergy production is particularly emphasised, for example, while the potential offered by forestry-based biomass (in the context of sustainable forest management) is also taken into account (DG Agri, 2017b). Innovative projects funded through such rural development programmes include the building of biogas plants; the planting of trees for short-rotation coppicing; the installation of wood- and straw-based heating systems; and the establishment of perennial energy grasses. Similarly, R&I supports and policies related to biotechnology in the context of CAP relate primarily to minimising real and perceived safety risks associated with genetically modified organisms

(GMOs) in a way that does not hinder the development of modern biotechnology. Such policies hold relevance to the funding, support and commercialisation of bioeconomy research in such arenas and the implementation of any innovative ideas or solutions uncovered.

Cork 2.0 Declaration

Examining and supporting bioeconomy development through the lens of rural development is beneficial from a holistic bioeconomy perspective, holding the potential to connect resource sectors across agriculture, forestry and marine communities. Providing a basis and recommendations for more integrated rural policy in Europe, the Cork Declaration was established in 1996 at the European Conference on Rural Development under the Irish Presidency of the European Union. Setting aims to develop a living countryside and better lives in rural areas, the declaration was superseded by the Cork 2.0 Declaration in 2016. With a strong emphasis on the creation of a more sustainable future and aware of the diversity of rural communities across Europe, the updated Cork 2.0 Declaration specifically refers to rural contributions to the bioeconomy, *"convinced of the value of rural resources capable of delivering sustainable solutions to current and future societal challenges"* (EC, 2016c, p4). Such sustainable solutions include in terms of future food security, resource efficiency and a reduced reliance on fossil fuels, highlighting a key role for rural areas in also implementing the United Nations Sustainable Development Goals and conclusions of COP21.

Setting out ten policy priorities for innovative, integrated and inclusive rural and agricultural policy, point 7 of the Cork 2.0 declaration specifically refers to the need to boost knowledge and innovation in rural communities, ensuring that they participate in the knowledge economy and maximise opportunities arising from advances in research (EC, 2016c). This includes across technology, digitisation, education, social innovation and management spheres.

Rural Development 2014-2020: Operational Groups and Innovation Support Services

Funding for R&I in the agriculture and forestry (key sub-sectors of the European bioeconomy) typically derives from one of two policies: the Rural Development Programmes (RDPs) of the Rural Development Policy and Horizon 2020. As reiterated by EIP-AGRI (2017), these two policies work to complement one another, with RDPs typically applied within a specific programme region while research policy operates to co-fund R&I across borders and at the EU level. The scale of funding is thus very important in the context of R&I policy supports in DG Agri with schemes varying at local, regional, national and supranational scales.

R&I funding through Rural Development 2014-2020 focuses more on innovation compared to research (relative to Horizon 2020). Indeed, *"fostering knowledge transfer and innovation in agriculture, forestry and rural areas*" is established as the first of six priorities of the Rural Development Policy given its role in boosting competitiveness and sustainability in rural areas. This signals increasing political commitment to support innovation in rural (bio)economies. In practice, Rural Development 2014-2020 is implemented through RDPs throughout Europe that are created and managed at national and regional scales. Guidelines for managing authorities implementing the innovation priority have been published by the EC, including advice and measures related to funding, operating and accessing innovation supports and including diverse actors in this process.

Two principal R&I policy supports funded through the Rural Development Policy of DG Agri include a variety of *Operational Groups* and *Innovation Support Services* across EU Member States and regions. Supporting agricultural innovation and R&I in rural topics, operational groups connect diverse actors at the local level (e.g. farmers, advisors, researchers, private companies and NGOs) allowing them to work collectively to develop innovative solutions to a shared problem. They may also involve testing an innovative idea in practice (EIP-AGRI, 2015). Creating a more productive and sustainable European agricultural sector remains the guiding ambition of operational groups and can include developing new products or pilot plants, cooperating among small operators and/or promoting certain practices (EIP-AGRI, 2017). Innovation Support Services, by comparison, recognise the need to move beyond stand-alone funding for groups cooperating on innovation projects to provide the

broader innovation brokering services to bring the right people together in the first instance (EIP-AGRI, 2015). Adapted to local conditions, Innovation Support Services thus emphasise the brokering, bridging and knowledge transfer services required to bring the correct range of actors together and the networks, advisory services, funding and investment supports they will need to progress innovative projects (EC, 2015a). Member States and regions decide on priority areas, actions and groups of actors relevant to their geographical context.

Horizon 2020 and DG Agri

The second key source of R&I support under the remit of DG Agri relates to Horizon 2020 and the funding available for biomass-, forestry- and agriculture-related projects, co-fund mechanisms, thematic networks, and multinational innovation studies. Contributing to more innovative agriculture and forestry sectors, approximately €4 billion is solely allocated to Horizon 2020's Societal Challenge 2 *'Food security, sustainable agriculture and forestry, marine and maritime and inland water research, and the bioeconomy*'. The contributions possible through this Horizon 2020 support are especially noted by DG Agri as helping to address the challenges faced by rural areas. Moreover, supporting the development of biobased markets and products is specifically mentioned as one of six priority areas in which Horizon 2020, as a supportive R&I policy framework, contributes to the work and mission of DG Agri (DG Agri, 2017). This includes an emphasis on the demand side of biobased innovation, including the development of life cycle assessment methodologies, assessing product functionalities and developing standardisation and certification measures.

Further concentrating R&I supports to the remit and ambition of DG Agri, a number of co-funding programmes can also be found within the Horizon 2020 framework. This provides options for national governments and companies to invest and become part of the research programme and supportive innovation system (Johnson and Jacobsson, 2001; Foxon et al., 2005; Hagemann et al., 2016). Such co-funding opportunities typically complement EU policies allowing companies to benefit from the outcomes of co-operation whilst providing co-funding and experiential knowledge to the process.

European Innovation Partnership for Agricultural Productivity and Sustainability

Finally, within the context of DG Agri, the European Innovation Partnership for Agricultural Productivity and Sustainability (EIP-AGRI) was established in 2012 with the aim of creating more demand-driven research policy and evidence-based agricultural policy. Linking CAP and R&I policies and the desire for more competitive and sustainable farming and forestry, EIP-AGRI aims to ensure that research responds to ground-level needs (demand-driven) and that innovative solutions and research results are implemented by primary producers (effective knowledge and technology transfer). It provides regular updates on agricultural innovation throughout the EU, connects diverse stakeholders and serves as a hub for knowledge exchange, best practice and the formulation of innovative solutions to agriculturally-based problems. Narrowing the gap between science and practice, EIP-AGRI is nested within 'Europe 2020' ambitions of smart, sustainable and inclusive growth, reflecting strategy desires for a more interactive approach to innovation in Europe (EIP-AGRI, 2017). Ultimately, this R&I initiative aims to assist agriculture and forestry sectors become more sustainable, productive and capable of tackling challenges associated with volatile market prices, international competition, stricter environmental regulations and climate change (EIP-AGRI, 2015). Ultimately, EIP-AGRI aims to enhance the resilience of European primary production and producers.

Deemed the *"one-stop shop for agricultural innovation in Europe"* (EIP-AGRI, 2017), the EIP-AGRI web portal enables visitors to voice their research needs, share project ideas and find funding, partners and collaborations through the EIP-AGRI Meeting Point. They are also encouraged to join temporary EIP-AGRI focus groups to share practical innovation knowledge and experience on a pre-assigned subject (e.g. animal husbandry, forest biomass, organic farming or soil-borne disease) and keep abreast of the latest agricultural innovation publications, events and updates.

In keeping with more holistic bioeconomy thinking including in terms of multi-functional production systems (Jordan et al., 2007), while food production remains a key priority for EIP-AGRI, its remit also

broadens to include feed and biomaterial considerations. It strives to pool funding from both Horizon 2020 and European Rural Development policy to achieve interactive innovation, forming partnerships between actors across the innovation system (e.g. farmers, private companies, researchers, NGOs, advisors and others). This R&I initiative operates at the EU level compared to the EIP Operational Groups funded under the RDPs that are project-based and operational at national and regional levels. Connecting these actors in an EU-wide network is deemed beneficial to speed-up the innovation processes and turn innovative ideas into realisable actions. Results of multinational, multi-actor Horizon 2020 projects, thematic networks and Operational Groups can be shared via EIP-AGRI, with a view to allowing all primary producers across Europe to benefit from the latest research results and innovations (EIP-AGRI, 2015). The network is further supported by a number of sub-structures, including the permanent "Subgroup on Innovation for Agricultural Productivity and Sustainability" operating under the Rural Network Assembly (the EIP-AGRI coordinator) (EIP-AGRI, 2017). The EIP-AGRI Service Point represents a further supportive organisational feature that allows DG Agri to run the network. The Service Point features a helpdesk to answer queries, organises focus group sessions and events, supplies news items for the Meeting Point and manages EIP-AGRI's newsletter, Agrinnovation magazine and social media accounts. Ultimately the EIP-AGRI Service Point works to stimulate interaction between all those involved in the EIP-AGRI Network (EIP-AGRI, 2015).

Shifting from an input supply perspective, the final section related to the DGs of Europe considers bioeconomy R&I policy supports evident through the aegis of DG Grow, the EC directorate for the internal market, industry, entrepreneurship and SMEs.

DG Grow

Responsibility for matters related to economic growth in the EU falls under the remit of the Directorate-General for the Internal Market, Industry, Entrepreneurship and SMEs (DG Grow). All of these aspects are critical to the success of the bioeconomy including in terms of ensuring the coherent function of the internal market with respect to biobased goods, fostering biobased developments in large businesses with large R&D budgets and encouraging and supporting SMEs and new entrepreneurs into the bioeconomy with novel products, processes and ideas.

The website of DG Grow provides a range of information and services for both citizens and business alike. This includes citizen information on travelling, vehicle ownership, healthcare and consumer rights in Europe, while information on taxation, intellectual property rights, public contracts, tendering processes, access to finance and product certification is available for businesses looking to locate in Europe.

DG Grow: structure and mission

In terms of its structure, DG Grow operates out of Brussels with approximately 1,400 staff (DG Grow, 2017). Highlighting the politics as well as the policies that operate in the R&I landscape, like other DGs DG Grow is managed by a Director-General and also works under the political leadership of a Commissioner with a remit in SME promotion and support. The work of DG Grow is primarily supported by a Chief Economist Team that develops, coordinates and produces economic analyses to ensure that its initiatives are based on sound economic evidence. This includes monitoring the functioning of the EU Single Market as well as analysing the competiveness of EU industries. This is directly in line with two of the Juncker priorities for the EC: 'Jobs, Growth, Investment and Competitiveness' and the 'Digital Single Market'. Overall, the principal aim of DG Grow is to promote growth in Europe. It does this by:

- supporting the completion of an Internal Market for goods, services and professionals;

- implementing industrial policies of Europe 2020 to achieve a smart, sustainable, and inclusive economy and strengthen the European industrial base;
- fostering entrepreneurship and SME growth by facilitating access to funding and global markets and reducing administrative burden (in keeping with the Small Business Act);
- delivering the EU's space policy including supporting the development of a satellite-based navigation infrastructure and wider EU earth observation services;
- fostering research that focuses on technological and industrial innovation and thus economic growth;
- improving access to public contracts throughout the EU by implementing a modern public procurement system;
- generating policy related to the protection of intellectual property (IP) rights including coordinating the EU position in the international IP system and assisting innovators in using their rights.

(DG Grow, 2017)

Many of the aims and policies implemented by DG Grow directly support the development of the European bioeconomy and related R&I, from the support given to SMEs through the Small Business Act (a crucial actor in delivering bioeconomy innovations) to allowing for the commercialisation of R&I by facilitating a free-flowing Internal Market, internationalising businesses and developing effective public procurement mechanisms (creating markets and demand for bio-based products). The protection of IP rights is also crucial in terms of supporting bioeconomy innovations while a specified focus on research that fosters innovation and economic growth is similarly conducive to bioeconomy breakthroughs and innovative game-changers. In addition, DG Grow contributes to many policies that impact the field of biotechnology including relating to Lead Market Initiatives for the biobased products sector, key enabling technologies (KETs), competitive pharmaceutical and healthcare industries, specialised enterprise clusters, finance for SMEs and the patenting of biotechnological inventions. A number of these policies specific to the organisation and delivery of bioeconomy R&I are outlined below, couched within the EU Industrial Policy and the Single Market Strategy of DG Grow. The former policy underpins the importance of EU competitiveness and innovation in European industries, while the latter maximises the benefits of the free movement of capital, goods, services and people in the EU.

Industrial Policy

Industrial Policy is central to the remit and objectives of DG Grow (and the development of the bioeconomy in general), priorities for which were established in the 2014 Communication *'For a European Industrial Renaissance'*. The 2014 Communication highlights the importance of European industry in creating jobs and growth, while the subsequent Industrial Policy aims to support industrial modernisation and calls for European leadership in global markets, particularly in the context of digital transformation and the industrial revolution (DG Grow, 2017a). Industry is considered to represent the *"backbone of the European Economy"* (DG Grow, 2017a), providing high skilled jobs, exports and space for innovation. This signals the importance of supporting industry through comprehensive R&I supports and policies that enable research commercialisation, market access and business success. Europe is considered to have a competitive advantage globally in terms of high value-added products, and innovation is reported to be at the heart of these endeavours (DG Grow, 2017a).

Fostering the modernisation and digital transformation of European industries, the 2014 Industrial Policy Communication holds particular relevance to bioeconomy R&I supports as it seeks to:

- maximise the potential of the EU Single Market, particularly through establishing standards (technical specifications defining requirements for products, services and production methods) and engaging in market surveillance;

- mainstream industrial competitiveness in other policies;
- support innovation, skills and entrepreneurship development at a regional scales (e.g. through the European Regional Development Fund);
- facilitate labour mobility and meet industry skills needs;
- foster access to inputs (including raw materials and energy) to encourage industrial investment;
- promote EU companies in global value chains.

(DG Grow, 2017b)

Driving the development of new industries, an additional area of relevance to bioeconomy R&I includes support for Key Enabling Technologies (KETs) within European Industrial Policy. In particular, the designation of bioeconomy-relevant nanotechnologies, industrial biotechnologies, advanced materials and advanced manufacturing technologies as four of six priority areas within this categorisation is critical, deemed to showcase high growth potential and an ability to address grand societal challenges (DG Grow, 2017a). Working across industrial sectors, KETs provide a basis for innovation for a range of products, with an overarching focus on the green economy symptomatic of additional industrial supports and commitment to exploring bioeconomy-related arenas. Indeed, KETs are deemed to underpin the shift to a more sustainable and circular economy, as the EC attempts to balance industrial development with environmental, climate and energy considerations (DG Grow, 2017). This reflects the broader EC agenda to transition to a low-carbon economy and also highlights the pivotal role of industry and technology development (through effective R&I) in achieving this sustainable future.

Single Market Strategy

Ambitions of the Single Market Strategy are also particularly pertinent to bioeconomy R&I support. Aiming to create more opportunities for businesses and consumers, the Strategy facilitates goods, services, people and capital to move more freely throughout Europe, representing one of the principal defining points and achievements of the EU. While the Single Market Strategy increasingly focuses on standardising rules and new business models associated with the collaborative economy, the strategy also works to support SMEs, encourage modernisation and innovation, modernise standards and intellectual property rights and create more efficient and transparent public procurement mechanisms. All of these aspects are pivotal to establishing, supporting and progressing R&I relevant to the bioeconomy, allowing for the practical delivery of bioeconomy innovations through businesses and people, and demand for accurately labelled and protected bio-based goods and services.

Indeed, the EC's Lead Market Initiative between 2008 and 2011 specifically focused on the development of the bio-based products sector with emphasis on aspects of standardisation, labelling and public procurement. Developing demand-side innovation policy tools in this way further highlights increasing recognition for supporting bioeconomy R&I across Europe, culminating in an interim report on *"Taking Biobased from Promise to Market"*, lists of recommendations for enabling market uptake, and policy papers on financing and communicating about bio-based products. A number of standardisation mandates were also issued, including related to biopolymers and biolubricants, biosolvents and biosurfactants and horizontal standards for biobased goods.

An additional Commission Expert Group for Biobased Products was established in 2013, charged with evaluating the progress of the Lead Market Initiative and provide recommendations for the further development of the biobased sector. In their 2015 evaluation report (DG Grow, 2017c), the working group assessed for the level of implementation, uptake and tangible impact of fifteen priority areas noting significant progress in biobased actions related to R&I (including for example, the establishment of the BBI JU), public procurement and communication. However, they also noted few visible results concerning access to feedstock and access to markets for biobased products (two of the five priority recommendations established in the Lead Market Initiative in 2008). The working group concluded that these failed actions have hindered the transformation of the EU's fossil-based economy and transition to a biobased alternative. Areas that require significant attention and further

action include the implementation of biobased standards and tax incentives at Member State level, political consensus regarding binding biobased targets and balancing bioenergy and biobased product legislation to ensure sustainable access to biological feedstock (currently biomass for bioenergy use is incentivised in comparison to biobased products) (DG Grow, 2017c).

Other aspects of legislation pertinent to DG Grow, bioeconomy R&I support and the operation of the Single Market include CE marking (the fair competition marking and harmonisation legislation that ensures all traded products meet the same high safety, health, and environmental criteria) and REACH legislation (the framework for chemical regulation and risk management in the EU). Both of these aspects are also pertinent to developing bioeconomy R&I and commercialising research, particularly the transition to biochemicals in the future.

Access to Finance

Given that over 99% of businesses in the EU are classified as SMEs (DG, Grow 2017d), supports that specifically target and support their innovation processes are essential to wider industry growth, competitiveness and economic prosperity. Accessing finance represents a crucial step at almost every stage of the innovation cycle and product maturity phases (Figure 2; Foxon et al., 2005), from supporting preliminary R&D to demonstration and scale-up activities to achieving final commercialisation. Accessing and securing finance however is simultaneously one of the biggest challenges facing SMEs in Europe according to DG Grow (2017d), signalling an urgent need for government intervention and support in this pertinent area.

DG Grow is one of the key departments working towards improving business access to finance at the EU level, representing one of its preliminary purposes with a variety of programmes operating to provide a more supportive financing environment for small businesses. This includes DG Grow working with financial institutions directly to stimulate the provision of loans and venture capital and the provision of advice, support, coherent policy and dedicated financing programmes for SMEs. Financial aid is generally not provided directly through the EC but channelled through local financial institutions including regional, national and local authorities and intermediaries such as banks or venture capital organisations (DG Grow, 2017d). DG Grow provides an ‘Access to Finance Portal’ to help SMEs identify relevant intermediaries by country, highlighting types and amount of finance available alongside varied investment foci (many of which relate to bioeconomy R&I including clean technology, start-ups, R&D, innovation and business expansion).

EU financial instruments under DG Grow include risk-sharing schemes that allow the EU and local financial institutions to work together to provide lending, lease finance or co-investments with venture capital funds (e.g. through guarantees backed by EU funds). With a focus on market-driven instruments, EU financial instruments work with reputable financial intermediaries believed to be closer to the ultimate beneficiaries (the entrepreneurs) and thus better placed to understand their needs. The instruments (and funds available) thus vary from country to country depending on the local financial institutions interest in participating in the scheme and the needs of local SMEs in their market.

To achieve the aforementioned industrial policy goals, and further promote research, innovation and entrepreneurship across the EU, DG Grow manages a number of targeted financial support actions as part of the wider remit of EU programmes. This includes, but is not limited to:

- **COSME**: with a budget of €2.3billion, COSME, or the programme for the Competitiveness of Enterprises and Small and Medium-sized Enterprises, helps enterprises access markets and finance, promotes entrepreneurship and develops supportive conditions for business creation and expansion. Aiming to improve SME access to capital, COSME aims to leverage up to €4 billion in equity finance by 2020. It guarantees loans up to €150,000 and is usually targeted at business growth and expansion phases.
- **CIP**: the Competitiveness and Innovation framework Programme (CIP) financial instruments are the predecessor of COSME, helping SMEs to raise equity and debt financing. Although

the programme officially finished in 2013, some finance is still available through intermediaries that were selected and approved. It is estimated that over 340,000 small businesses benefited from the guarantees provided by CIPs since 1998.

- **InnovFin**: COSME financial instruments operate in conjunction with InnovFin under the Horizon 2020 Framework focusing on supplying EU finance to innovators. The InnovFin initiative particularly focuses on providing equity at early and start-up phases, financing R&D projects and providing loans and guarantees to innovative companies.
- **SME Instrument**: again operating under H2020, SME instruments allow SMEs to invest in R&I internally in way that helps them to expand their activities internationally. The SME Instrument offers funding and coaching support across all phases of the innovation cycle from concept and feasibility phases to pilot demonstration to final commercialisation.
- **ESIF:** European Structural and Investment Funds (ESIF) provide loans, guarantees, business grants and equity finance on a regional basis. ESIF accounts for over half of EU funding, channelled through five strategic funds that are jointly managed by the EC and the Member States to support economic development, job creation and a sustainable, healthy Europe. The five focus areas all hold relevance to the bioeconomy, namely R&I; digital technologies; the low-carbon economy; sustainable management of natural resources; and small businesses. Two of the five specific funds on offer also relate directly to bioeconomy development (e.g. the European Agricultural Fund for Rural Development and the European Maritime and Fisheries Fund) while the other three funds hold promise in terms of supporting balanced regional development, building cohesion across Member States and supporting social, employment-related projects.
- **Venture Capital**: DG Grow also advises on, and sets policy related to, venture capital – the equity investment businesses require to grow and reach new markets. While this capital is essential to the growth of innovative firms, investors can nonetheless be reluctant to invest in start-ups and firms that are deemed too high risk, creating a challenge in achieving transformative breakthroughs as required in the bioeconomy. The EC continues to work to improve the efficiency of equity investment markets connecting viable projects with suitable investors, with the goal of creating a pan-European venture capital market that operates under a single set of rules.
- **Crowdfunding**: recognised as a new and increasingly popular form of finance, crowdfunding involves open calls to the public, generally online, with the aim of sourcing finance for projects through donations in exchange for a reward (e.g. product pre-ordering or investment). Any type of organisation can launch such a financing campaign. They are particularly associated with innovative SMEs and creative start-ups making them pertinent to the support and progression of transformative bioeconomy R&I. The EC launched a Communication in 2014 entitled *"Unleashing the potential of Crowdfunding in the European Union"* to develop a common understanding and explore the potential opportunities and risks involved. A European-level policy has yet to be developed in this area but is under consideration.
- **EaSI:** Under the programme for Employment and Social Innovation, the EaSI schemes providing both microfinancing (up to €25,000) for micro-enterprises and vulnerable groups who wish to set up a micro-company and funding for social enterprises (up to €500,000) or companies that aim to achieve social impact over the maximisation of profits.
- **EFSI:** working to overcome perceived investment gaps in the EU, the European Fund for Strategic Investment (EFSI) mobilises private investment in conjunction with the European Investment Bank for projects of strategic importance to the EU.

Wider policies, networks and supports relevant to bioeconomy R&I promoted through and supported by DG Grow include:

- **Business Angel Networks**: networks of individual investors that invest in new and growing businesses providing entrepreneurs with capital, management experience, contacts and skills. While the EC does not provide direct funding in this space, it advises on good policy in this area and promotes the sharing of knowledge and best practice between EU countries.
- **EU Access to Finance Days:** seminars organised for SMEs across Europe to raise awareness about funding opportunities and how to access capital
- **Start-up and Scale-up Initiative**: adopted in 2016, the Start-up and Scale-up Initiative supports European entrepreneurs in becoming world leading innovative companies
- **Smart Specialisations Platforms**: partnerships designed to facilitate industrial modernisation and coordinate innovative industrial efforts in EU countries and regions. These industry platforms are funded under the European Structural and Investment Funds with the aim of boosting competitiveness and innovation at local scales in priority areas (including bioeconomy-relevant circular economy and advanced manufacturing themes).
- **Enterprise Europe Network:** helping companies to innovate and grow internationally, the Enterprise Europe network helps innovators find international partners, provides expert advice on international expansion and promotes a range of solution-driven services that help businesses to commercialise innovative ideas. The network is active in more than 60 countries, connecting over 3,000 experts renowned for excellence in business support (e.g. from regional development authorities, universities, chambers of commerce and innovation support organisations). It thus represents the world's largest network support for SMEs with international ambitions.

Tools Tracking Progress…

Given the potential for diversity in the translation of DG Grow policies at member state level, a number of tools exist to track progress and developments across R&I arenas. These include:

- **SAFE**: the **Survey on the Access to Finance of Enterprises (SAFE) is** issued by the EC and the European Central Bank to monitor developments in SMEs' access to finance. It has been operational since 2008 and has been issued on an annual basis since 2013.
- **European Innovation Scoreboard**: in collaboration with DG R&I, the European Innovation Scoreboard assesses and ranks innovation leaders and laggards across the EU, comparing innovation performance in Member States and in a global context. Using defined metrics (e.g. related to human resources, research systems, sales impacts, intellectual assets, collaborative approaches, number of innovative SMEs etc.), the scoreboard assesses relative strengths and weaknesses of national innovation systems, helping countries to see areas for improvement. This analysis is also conducted at a regional level in larger EU Member States, culminating in a Regional Innovation Scoreboard providing more detail on local innovation nuances. Results of the 2017 high level, national European Innovation analysis are presented in Figure 7.

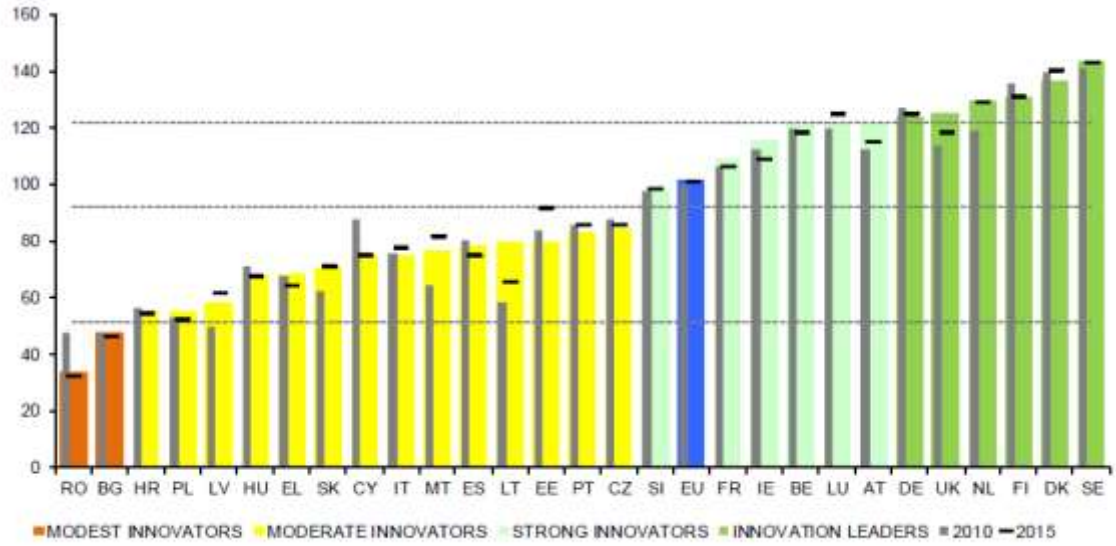

Figure 7 Performance of innovation systems across EU Member States (taken from Hollanders and Es-Sadki, 2017, p6)

- Single Market Scoreboard: the EC also tracks and monitors progress of the European Single Market, another essential support to the elaboration of successful bioeconomy R&I to allow biobased goods, services and skills to flow freely between Member States. Green, yellow and red score cards are assigned according to how Member States perform against a variety of policy and governance indicators highlighting above average, average and below average performance respectively (e.g. with regard to the implementation of specific single market policies including tracking public procurement measures and number of infringements).

Additional DGs, institutions and supports relevant to Bioeconomy R&I in Europe

While DG Agri, DG R&I and DG Grow were identified as holding particular relevance to the support, funding and implementation of bioeconomy R&I, a number of other DGs host and contribute additional policies and programmes that foster the development of a successful, sustainable and innovative bioeconomy in Europe. This includes, but is not limited to, DG Environment, DG Climate Action, DG Competition, DG Energy, DG Sante, DG Education and DG Mare (Maritime Affairs and Fisheries). At the other end of the spectrum, conflicting policies, programmes and objectives may also exist across and within these DGs that may hinder bioeconomy development and/or its sustainable implementation (for example, policies related to food safety or waste recovery). This mimics the inevitable trade-offs and compromises that will be necessary between agricultural, forestry, marine and bioeconomy for holistic sustainable development (Lewandoski, 2015; Devaney and Henchion, under review). The bioeconomy in and of itself will not necessarily be environmentally friendly or sustainable unless these objectives align and rebound effects are rigorously monitored and controlled for through effective policy development and implementation (including R&I policy). The above analysis thus does not claim to represent the complete bioeconomy R&I policy landscape but rather an initial insight into the range of supports and assistance existing in this transformative space. The bioeconomy will demand transformative change and innovation not just in technological terms but in social and regulatory ways also. It will demand radical innovation across technologies, practices,

values, beliefs, configurations of actor groups, networks and policies (Darnhofer, 2015). The bioeconomy contributes to a number of EU objectives from environmental, social and economic standpoints. It holds potential to contribute to economic prosperity and rural development, create employment and increase European competitiveness all the while meeting sustainability objectives related to climate change, environmental degradation and the transition to a post-carbon society. Political commitment to the development of the bioeconomy is thus obvious, and increasing, with the EU Bioeconomy strategy itself under review to reflect the latest thinking and developments achieved in recent years.

Additional institutions operate outside of the DGs of the European Commission that also hold relevance to the development, deployment and implementation of the bioeconomy. The European Investment Bank (EIB), for example, funds projects, both within and outside of the EU that help to achieve EU policy objectives. With 90% of the funding allocated to internal projects, this includes in relation to mitigating climate change and boosting jobs and economic growth (aspects relevant to the bioeconomy). Through lending money to clients of all categories and sizes, EIB support often helps to attract further investment and investors to noteworthy projects. It works as an independent body making all its lending, borrowing and investment decisions and is jointly owned by all EU countries. At a more strategic policy development and think-tank level, the Standing Committee on Agricultural Research (SCAR) meanwhile works to advise on, and develop, a more consolidated agricultural and bioeconomy research agenda in Europe. Established in 1971 but re-launched in 2005 with a more bioeconomy-driven remit, SCAR acts as a catalyst for the coordination of national research programmes with overall objectives of creating a more integrated European Research Area, removing barriers to innovation and coupling research and innovation practices. It promotes and facilitates collaborations in public-public and public-private networks to achieve this with the aim of delivering the innovation required to address inevitable bioeconomy challenges.

National and regional policies may also offer alternative funding schemes and opportunities that can bring benefit to bioeconomy-related R&I. The diversity of translation of European policies to national level means that no one size fits all exists, with varying levels of support for different sub-sectors of the bioeconomy obvious according to national strengths and preferences (e.g. supports for agriculture and food-related R&I in Ireland compared to a forestry dominated focus in Finland). All such project groups are nevertheless encouraged to join pan-European thematic initiatives (such as the EIPs outlined in this report) to connect at a European level and boost collaborative thinking, partnerships and the sharing of international best practice.

The hosting of numerous R&I events further supports the sharing of knowledge, international best practice and technology adoption across Europe, helping to further shape, define and support the European bioeconomy. For example, with aims of gathering more than 500 farmers, rural businesses, start-ups, national rural networks, researchers, advisors and NGOs, the 2017 Agri-Innovation Summit is due to take place in Portugal in October 2017 with support from the EIP-AGRI network and the European Network for Rural Development. The summit aims to promote collaboration between multi-actor innovation initiatives (in keeping with Horizon 2020 and Rural Development Programme aims), and raise awareness about digitisation and innovation opportunities in rural economies more broadly (including how they might be supported through existing Rural Development Programmes). The summit also aims to provide input to EU innovation policies with respect to agriculture and rural areas post-2020. Similarly, the Global Bioeconomy Summit is due to be hosted in Europe in April 2018, following on from the successful inaugural event which took place in Berlin in November 2015. Bringing together more than 700 bioeconomy stakeholders from over 80 countries, the inaugural Global Bioeconomy Summit produced a bioeconomy communiqué outlining summit conclusions and next steps relating to the development of a sustainable global bioeconomy. Hosting such events in Berlin places Europe at the heart of international bioeconomy development, with the 2018 summit aiming to re-visit established bioeconomy strategies, focus on international cooperation and partnerships and identify promising global bioeconomy policy and innovation agendas.

Summary

In keeping with Hagemann et al. (2016), R&I Policy represents a crucial element of any given innovation system (Figure 1). It must however work in conjunction with a range of other policies, supports, services and conditions to ensure ultimate success i.e. to successfully progress an idea into a tangible and successful output, product or service for market and ultimately achieved the biobased transition. Supports targeted at different stages of the innovation chain are thus essential from supporting initial R&D through to full commercial success. This is in keeping with Foxon et al. (2005) and others who highlight the different stages of bioeconomy product maturity (Figure 2). Tables 1 and 2 list and summarise the policies and programmes of relevance to bioeconomy R&I policy as nested within DG Agri and DG Grow. Table 3 meanwhile summarises the progammes and supports related to bioeconomy R&I as showcased by DG R&I, including detail on the bioeconomy product maturity level they aim to address.

DG Agri
Common Agricultural Policy
Cork 2.0 Declaration
Rural Development 2014-2020
Operational Groups
Innovation Support Services
European Network for Rural Development
European Innovation Partnership for Agricultural Productivity and Sustainability

Table 1 Examples of relevant bioeconomy R&I policy nested within DG Agri

DG Grow
EU Industrial Policy
Single Market Strategy
Competitiveness of Enterprises and Small and Medium-sized Enterprises programme
Competitiveness & Innovation framework Programme
InnovFin
European Structural and Investment Funds
Employment and Social Innovation schemes
European fund for Strategic Investment
Business Angel Networks
Smart Specialisation Platforms
European Enterprise Network

Table 2 Examples of relevant bioeconomy R&I policy nested within DG Agri

R&I Funding/Support	Description	Typical Maturity Level target
Horizon 2020 Pillar 1	*Excellent Science*	
European Research Council	Operating under Pillar 1 of Horizon 2020, ERC grants fund frontier or basic research in any topic, primarily driven by a bottom-up, researcher-led agenda. Does not require a consortium to apply for this funding	R&D
Future and Emerging Technologies	Also operating under Pillar 1 of Horizon 2020, FET grants fund radical innovation (rather than incremental research) aiming to bring known concepts together in a different way	R&D to Demonstration phase
Marie Sklodowska Curie Actions	Marie Curie Actions fund research fellowships under Pillar 1 of Horizon 2020, including postdoctoral research, industrial PhDs and staff exchanges between academia and industry	R&D through to pre-commercial phases
Research Infrastructures	EC does not build research infrastructures per se but supports their establishment and collaboration through the design of future research infrastructures. This forms a final essential element of fostering excellent science under Pillar 1 of Horizon 2020 Pillar 1 re excellent science	R&D
Horizon 2020 Pillar 2	*Industrial Leadership*	
Leadership in enabling and industrial technologies	The LEIT initiative works to make European industry more competitive in a number of leading and emerging technologies including ICT, Space. biotechnology and nanotechnology and new materials	Demonstration to Pre-commercial phases
Innovation in SMEs	Support for small and medium sized companies to participate in studies of entrepreneurship and high growth	Pre-commercial to supported commercial
Access to Risk Finance	The Access to Risk Finance element of Pillar 2 aims to stimulate investment in research infrastructures and funding for high growth SMEs and companies. This includes co-funding with financial intermediaries such as venture captialists and banks	Pre-commercial to fully commercial phases
Horizon 2020 Pillar 3	*Societal Challenges*	
Societal Challenges	R&I supports to examine, address and solve escalating environmental, economic and social challenges including: Health, changing demographic and wellbeing Food Security, sustainable agriculture and the bioeconomy Secure, clean and efficient energy Smart, green and integrate transport Climate action, resource efficiency and raw materials Innovative, inclusive, reflective societies Secure Europe (e.g. cyber security)	R&D to Support Commercial Phases

Different Grant options in H2020:		
Research and Innovation Actions	100% publically funded multi-national projects for knowledge creation and innovation	R&D to early pre-commercial
Innovation Actions	70% publically funded focused on demonstrating, prototyping, living laboratory style projects	Pre-commercial to supported commercial
SME Instrument	70% publically funded (c.€3 billion 2014-2020) aimed at bringing technologies closer to the market. Mono-participant SME-led high potential innovation projects are funded in a way to help help the SME grow and expand their activities in Europe and beyond. Phased support through feasibility assessment, innovation project development through to commercialisation supports (e.g. access to finance, customers and investors).	Pre-commercial to supported commercial
Fast Track to Innovation	Developed in 2014 with a focus on pilot project phases	Demonstration to supported commercial
Public Procurement	When public bodies demand innovation or research to bring ideas closer to market	Supported to fully commercial
Coordination and Support Actions (CSAs)	Support studies and networks (not research) typically involving multi-national networking projects	R&D to fully commercial
ERAnets	National funding operating under Horizon 2020, the ERA-NET instrument aims to support the establishment and running of public-public partnerships and the design, implementation, longevity and coordination of joint activities. ERA-NETs also top up single joint calls for transnational research and innovation in high value topic areas	R&D through demonstration to pre-commercial phase
Eurostars	For research intensive companies aiming to bring an innovative product or service closer to market. Eurostars is a joint programme co-funded by Horizon 2020 and over 40 participating countries helping research-performing SMEs gain competitive advantage	Focusing at pre-commercial to supported commercial phases
European Innovation Partnerships	Working across the R&I chain and aiming to implement each step in parallel, EIPs work in thematic areas to develop R&D, invest in demonstration and pilot plants, fast-track necessary regulatory changes and mobilise demand (including through public procurement). The emphasis is on connecting actors across scales to ensure that innovative breakthroughs reach the market.	Work across the system from R&D to market
Public Private Partnerships	European, national and private funding combine allowing to surpass competition law with industry funding involvement. Allows projects to reach full commercialisation	Pre-commercial to fully commercial
Thematic Networks	Thematic networks aim to find solutions to challenges inherent in agriculture and forestry production. They are innovation projects funded under Horizon 2020 involving a range of actors from science and practice, collecting existing scientific knowledge and disseminating best practice in an accessible format.	R&D to full commercial
Knowledge and Innovation Communities (KICs)	Nested within the European Institute of Innovation and Technology and working across the innovation system, KICs operate in diverse thematic areas to establish partnerships between research and industry to develop products and services, start new companies and train new entrepreneurs.	R&D to Fully Commercial

Table 3 R&I policy supports in the European Bioeconomy

Conclusion

Following a traditional neoclassical economics perspective, policy intervention by governments, including R&I policy, is necessary to correct market failures (for example, related to sub-optimal resource allocation by firms, environmental pollution and inconsistent technology diffusion) (Jaffe et al., 2005). When critiquing the role of innovation policy in addressing societal challenges more specifically, Coenen et al. (2015) built on this neoclassical approach to include an innovation systems perspective that also considers the complex interactions between the different institutions involved in innovation. In particular, they focus on if and when these interactions do not function effectively. They thus reiterate Weber and Rohracher (2012) when they claim that *"the main focus of innovation policy and rationale for policy intervention"* involves correcting *"structural innovation systems failures"* (Coenen et al., 2015, p485). This includes:

a) *Infrastructural Failures*: incomplete physical infrastructure needed to facilitate innovations
b) *Capabilities Failures*: the lack of necessary competencies and resources at the firm and organisational level, limiting knowledge generation, access and exploitation.
c) *Network Failures*: characterised by either excessively tied networks of intensive cooperation that limits the generation of new ideas or too limited interaction that limits knowledge exchange, peer and interactive learning and the exploitation of complementary sources of knowledge
d) *Institutional Failures*: the shortcomings of formal institutions that either lack or have an excess of laws, regulations and standards that inhibit innovation, particularly regarding intellectual property rights (IPR) and investment procedures. A lack of social norms, cultural values, trust, entrepreneurial spirit and risk-taking tendencies may also impede innovation success.

Furthering the innovation systems thinking approach described in Figure 1, policy intervention can therefore help to address structural gaps and limitations in the system including in terms of infrastructure, education and research, applied R&D, the industrial system and elements of product and process demand (Hagemann et al., 2016). As evidenced by the number of policies, programmes and practices outlined in this R&I policy review, the EC can be seen to be attempting to address the majority of these structural innovation systems failures with respect to the bioeconomy innovation system. For example, R&I policies aimed at supporting biorefining demonstration facilities and pilot plants (e.g. through the BBI JU and Horizon 2020) attempt to address infrastructural failures in this innovation system. Similarly, regarding capabilities, policies aimed at solving the 'European paradox' in terms of research commercialisation (Dosi et al., 2006) help to boost SME human and financial capacity to undertake research (e.g. SME instruments, Eurostars and Pillar II of Horizon 2020 as well as the financial assistance provided through initiatives like CIP and COSME). The number of established CSAs and ERA-NETs meanwhile highlight efforts to correct network failures in the bioeconomy innovation system, promoting knowledge exchange and collaboration between diverse actors across scales and regions. Finally, the increased focus on bio-based labelling, standards and clear IPR (e.g. as evidenced in the EC's 2008-2011 Lead Market Initiative on *"Taking Biobased from Promise to Market"* and the wider remit of DG Grow with respect to the Single Market Strategy) respond to evident institutional failures in the bioeconomy innovation system. All of these initiatives combined represent principal strengths of the bioeconomy R&I policy landscape at present in Europe.

In keeping with Weber and Rochracher (2012), transitioning to the bioeconomy however requires innovation policy that moves beyond merely correcting structural innovation system failures and incremental business as usual approaches to facilitate wider transformative change. Moving beyond simplistic innovation-based growth and competitiveness, such policy intervention aims to address higher *"transformational systems failures"* defined by Weber and Rohracher (2012) and Coenen et al. (2015, p486) as including:

a) *Policy Coordination Failures*: failure to connect and bring coherence to diverse policies
b) *Directionality Failures*: the lack of capacity to guide innovations towards a particular pathway of transformative change
c) *Demand Articulation Failures*: the inability to understand and account for user needs, impeding innovation uptake
d) *Reflexivity Failures*: inadequate monitoring and adjustment of innovation to achieve transformative change

Addressing transformational systems deficits however is more complex and difficult to achieve, and indeed measure, in policy and practice. While the EC has implemented a number of supply- and demand-related policies that support the bioeconomy and attempt to address some of these transformational systems deficits (for example, with the 2017 review of the EU bioeconomy strategy attempting to set a clearer definition and pathway for transformative change (directionality failures)), a number of gaps in the bioeconomy innovation system, and related R&I policy supports, have been identified by this review. Highlighting strengths, weaknesses, opportunities and threats of the innovation system, the below analysis holds promise to improve and re-orientate R&I policy support towards a more transformative bioeconomy. Using the transformational systems failures as a frame (Weber and Rohracher, 2012; Coenen et al., 2015), weaknesses, threats and opportunities of the bioeconomy R&I policy landscape in achieving transformative change include:

Policy Coordination Failures

1) **Insufficient policy coordination and collaboration amongst DGs:** while President Juncker aimed to promote increased cooperation amongst the DGs by establishing cross-cutting objectives and thematic project areas (e.g. the digital single market, energy union and jobs and investment and competitiveness), a gap remains regarding the level of interaction between DGs, particularly from a policy coordination perspective, that may hinder bioeconomy R&I progress. While separate DGs can help to translate ambiguous and vague bioeconomy narratives into more tangible terms, the bioeconomy demands holistic thinking and a need to move out of sectoral silos to develop a comprehensive, sustainable and fair bioeconomy and necessary policies. It is only in this way that decisions regarding the most sustainable allocation of resources can be made that maximise economic gain, reduce waste and ensure the optimum use of biomass (cf. the cascading principle) (SCAR, 2015). Considering the supply side alone, the current structure of DGs and associated policy at the European level however separates agriculture and forestry from the marine sector (DG Agri and DG Mare respectively), creating challenges for the development of coherent supranational and national bioeconomy and R&I policies. It also demonstrates potential for underutilised biomass and underexploited opportunities which if not addressed further undermines the sustainability of the European bioeconomy.

Opportunity: There is a significant opportunity to extend principles of good governance (including principles of accountability, transparency and participation, among others (Devaney et al., 2017)) and establish bioeconomy governing principles across DGs to create a more coherent and connect policy landscape. Such an approach would help to find commonalities and consensus at a higher EC level that all policies, institutions and supports could work towards. The need for enhanced policy coordination is paramount and increasingly cited both at national and European scales in relation to the bioeconomy. The establishment of an interdepartmental group at the EU level could further contribute to achieving such policy coordination ambitions.

2) **Inconsistencies and overlap in the implementation of existing R&I supports:** a number of interim reviews continue to highlight persisting weaknesses and threats in established R&I supports, including joint programming initiatives (JPIs) (EC, 2017b), European Innovation Partnerships (EIPs) (Aho et al., 2014) and ERA-NETs (Favo, 2017). For example, in an interim review of Horizon 2020, JPIs were reported to have a limited impact on policy alignment as originally intended with less co-investment than expected and limited prospect for Member States to increase their contribution. The report concludes that joint programming may not be sustainable without further EC intervention. The broader confusion arising from the large number of R&I instruments operating at the European level is also criticised in this evaluation report, believed to cause overlaps and difficulties in understanding for potential applications (EC, 2017b). Similarly, following a 2013 review of the EIP structure, an independent expert group concluded that while EIPs are an essential tool in enabling European growth and promoting systemic innovation and innovation diffusion, they suffer from inconsistencies in execution (Aho et al., 2014). Favo (2017) similarly reports a plethora of overlapping JPIs and ERA-NETS operating in the Mediterranean bioeconomy, duplicating functions and research activities and highlighting inefficiencies in funding efforts.

Opportunity: There is a need for comprehensive coordinating mechanisms for existing R&I programmes and supports, including JPI, EIP and ERA-NET mechanisms. This would help to increase efficiencies, boost complementarities and maximise funding and TRL impact from associated projects. A more coherent structure in their interactions with the EC and clearer channels to include under-represented groups (e.g. SMEs) and Member States are also required for future R&I success, not just in the bioeconomy but all research arenas. A possible streamlining and enhanced coherence in the R&I supports on offer at an EC level may also be required to increase efficiencies and improve understanding for potential applicants. Any changes however would have to be made in a systematic and transparent manner with the aim of building a more coherent and efficient bioeconomy innovation system (Favo, 2017).

Directionality Failures

3) **Lack of a clear bioeconomy ambition within individual DGs**: even within individual DGs, gaps remain in terms of the level of coordination and established overarching objectives towards high value bioeconomy applications. DG Agri, for example, remains focused on food production to the detriment of other potential biomass opportunities in forestry and agriculture including high value biochemicals, biopharmaceuticals and biomaterials relevant to the bioeconomy. While ‘food first’ can remain a priority for the European bioeconomy (SCAR, 2015), the opportunity to add value to purpose-grown crops, animals and trees and the residues, by-products and waste streams from these processes should not be ignored.

Opportunity: Bioeconomic objectives need to be integrated more clearly into all relevant DGs, including in terms of their primary aims, policies and support programmes. For example, DG Agri could expand both its principal ‘user group’ and food producing objectives to include broader primary producers and the development of biochemicals, biopharmaceuticals and other biomaterials from rurally-produced biomass. This would generate a high level signal of support for exploiting bioeconomy opportunities, providing a top-down lead and cohesion to the number of innovative ideas and developments that are already happening from the bottom-up.

Demand Articulation Failures

4) **Gaps in education policy and societal understanding:** considering the 'knowledge' triangle of research, innovation and education (Maassen and Stensaker, 2011) a considerable gap remains in connecting bioeconomy R&I efforts to educational regimes, policies and practices. Education policy, for example, may offer opportunities in terms of the training and education required to create the next generation of bioeconomy researchers, biomass producers, innovators and entrepreneurs. While the 'Science with and for Society' element of Horizon2020 provides education and training opportunities to a certain extent (for example, through the Marie Sklodowska Curie Actions and Erasmus Mundus programmes for students and academics) and there is increasing recognition of the need for participatory R&I actions in Horizon 2020 and to engage society under the framework of Responsible R&I, gaps remain in the linkages between the three elements of the knowledge triangle, particularly concerning wider society. However, research and innovation have only recently been merged in EC thinking under the Horizon 2020 framework (2014), with consideration yet to be given to the educational arm in this regard.

Opportunity: Increased attention and focus to connections between research innovation and education represents an opportunity for the next Framework Programme following Horizon 2020, with potential to complete the knowledge triangle through better and more connected educational and training opportunities for publics of all backgrounds. This could also apply to creating better bioeconomy education, understanding and knowledge amongst the public (the ultimate end user in the bioeconomy) through tailored education and communication regimes at all educational levels and direct involvement and engagement of society in bioeconomy negotiations and activities.

5) **Balancing science push with market pull:** a common challenge in the development of any innovation in the bioeconomy includes managing and matching science and technology developments with *"agreed social consensus"* (Aguilar et al., 2017, p1). A clear and accepting market demand and end user is essential to the successful uptake of innovation. For example, with reference to genetically modified organisms, the Common Agricultural Policy discusses the need to manage potential risks and consumer acceptance issues associated with any technology development or biomass inputs. This thinking is predominantly lacking in the bioeconomy R&I policy supports identified in this review. Such thinking needs to infiltrate across the innovation system harnessing as much attention to demand-side policies and consumption thinking as input supply and transformation technology development.

Opportunity: As emphasised by Aguilar et al., 2017 (p1) "*The development of smart bioeconomies needs excellence in science-based concepts, long-term support of innovative and mission-oriented research and a subtle equilibrium between science push and market and social pull".* A clear understanding of demand side interests, concerns and perceptions is thus required alongside any technologically driven innovation developed with the support of bioeconomy R&I policy. The need for inter-disciplinary, collaborative research with input from the social sciences is thus increasingly called for and needs to be recognised in bioeconomy R&I policies and the related innovation system.

Reflexivity Failures

6) **Accurate monitoring mechanisms and targets:** the importance of clear, measurable targets is often reiterated as key to the success of environmental policies, providing specific benchmarks for all stakeholders to strive towards, even if overly ambitious (Crabbé and Leroy, 2008). The lack of measurable aims with respect to bioeconomy R&I policy is noteworthy. Measuring the success of the bioeconomy is problematic, further raising challenges in assessing the impact and success of R&I policies. For example, the limited nature of patents as a quantified measure of innovation is reported by De Bass (2013) when reflecting on lessons of FP7, calling for the inclusion of pending patents, peer reviewed papers and an evaluation of innovativeness by experts as additional assessment pathways. The potential for calls and projects to also document their *"Manufacturing Readiness Level"* in addition to the TRL is also mooted here i.e. that successful innovations are not just about technology readiness but their ability to be rapidly adopted commercially and successfully. These ideas have yet to manifestly infiltrate bioeconomy R&I.

Opportunity: Developing specific targets with respect to the bioeconomy could provide clear and measurable aims for R&I policy to strive towards. Setting targets, even if ambitious, may help to quantify and solidify the need for transformative change, re-orientating R&I policies and supports in a bid to meet them. The development of multi-dimensional monitoring and assessment criteria is essential to measure the impact of bioeconomy R&I policy and make adjustments accordingly. Such criteria should incorporate both quantitative and qualitative reasoning and a clear emphasis on further research deployment and commercial success.

Representing an ideal vision of what the bioeconomy innovation system should look like, and by no means exhaustive, addressing identified weaknesses and pursuing associated opportunities represent crucial first steps in allowing bioeconomy R&I policy to develop past addressing *"structural innovation systems failures"* to targeting the *"transformational systems failures"* required for a comprehensive, successful, sustainable and holistic bioeconomy (Coenen et al., 2015). This includes in terms of setting a clearer direction and vision across and within DGs and beyond (directionality failures), enhancing coherence and coordination amongst governing institutions and R&I policy supports (policy coordination failures), paying increased attention to educational regimes and market and social pull (demand articulation failures), and developing more effective innovation and bioeconomy targets and assessment criteria to monitor progress, measure R&I impact and allow for developmental adjustments (reflexivity failures). Pursuing these opportunities will require considerable financial and human capital but with significant benefits on offer in the development of a holistic bioeconomy that brings economic growth and prosperity, social and rural development and environmental protection and savings.

Overall, significant progress has been made in the bioeconomy R&I landscape in a relatively short period of time since the EU first considered the benefits of the bioeconomy in its 2012 strategy "*Innovating for Sustainable Growth"* (EC, 2012). This progress is clearly demonstrated by the plethora of supports discussed in this policy review. Monitoring the implementation and impact of the above innovation system represents the next crucial step to encourage reflexivity and allow for adjustments and the re-orientation of supports to achieve the desired and required transformative changes. As mooted by the transformational systems failures literature above, policy coordination will be key here, something that may begin to be addressed in the 2017 review of the EU bioeconomy strategy and through increasing attention to the governance system required for holistic and sustainable bioeconomy development (Devaney et al., 2017;

Von Braun, 2017). Attention to the demand side of the bioeconomy must also increase such that the uptake of innovations is facilitated and the bioeconomy does not become self-defeating in its sustainability aims i.e. that it does not result in the consumption of more resources, further unsustainable production and/or the creation of more waste. While further attention to accurate biobased labelling, standards and fossil-based substitution will be essential here (addressing traditional structural innovation system failures), to be truly transformative the concept of degrowth and reduced consumption may also need to feature with respect to the development of the bioeconomy. As highlighted by Narberhaus and von Mitschke-Collande (2017) with regard to the circular economy, society cannot ignore *"the fact that on a finite planet endless economic growth is not an option"*. Alternate options for sharing-, circular-, green- and bio-economies, among others, may thus need to be considered concurrently, with a view to reducing wasteful consumerism, eliminating undemocratic power structures, avoiding rebound effects and transitioning to a more sustainable future in a real way. Clear direction will be required in pursuing all of these objectives, highlighting the need for top-down governance approaches alongside bottom-up initiatives in the bioeconomy innovation system. A clear marker and remit must be set by the EC so that the future success and welfare of Europe lies in the creation of more sustainable economies, with governing principles established that promote commonalities and a level-playing field amongst the multiple sub-sectors that make up all of the economy (not just the bioeconomy). Such an approach would help to address some of the directionality failures that typify the bioeconomy innovation system to date, providing scope to truly address the grand economic, environmental and societal challenges of our time.

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