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POLICY INITIATIVES FOR HEALTH AND THE BIOECONOMY

OECD SCIENCE, TECHNOLOGY AND INDUSTRY
POLICY PAPERS
October 2019 **No. 83**



OECD
BETTER POLICIES FOR BETTER LIVES

This paper was approved and declassified by written procedure by the Committee for Scientific and Technological Policy (CSTP) on 15 September 2019 and prepared for publication by the OECD Secretariat.

Note to Delegations:

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DSTI/STP(2019)22

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Policy initiatives for health and the bioeconomy

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This document presents twelve policy initiatives supporting health and the bioeconomy from different OECD countries. The initiatives reviewed include: i) funding for public health centres that translate biomedical research into clinical research and care; ii) cross-border public-private consortia around health research and innovation; iii) strategies developed by national health agencies promoting translational research; and iv) national high-level strategies for the bioeconomy. It also provides a comparison of these initiatives with a focus on policy objectives, targets groups, sectoral priorities, budget, time horizon, selection criteria, international collaboration, and evaluation of the initiatives.

This document was produced with support from the Investments for the Future Programme (Programme d'investissements d'avenir) of the French government.

Acknowledgements: This work is part of a policy benchmark analysis which has been financed and commissioned upon request of the French Surveillance committee of investments for the future (Comité de surveillance des investissements d'avenir), in the context of the evaluation of the first phase of the Programme d'investissements d'avenir (PIA). The benchmark study is presented as a series of six monographs. Each monograph provides examples of research, development, and innovation policies, organised by topic of relevance to the PIA. This document presents the fifth monograph, focused on the theme of health and the bioeconomy. It provides the main messages from the cross-country benchmark analysis of 12 case studies of public policy initiatives. The detailed case studies can be found at https://community.oecd.org/community/cstp.

The authors are grateful to Camille Viros (OECD) and Laura Kreiling (OECD) for research assistance.

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Executive summary

Governments across the OECD apply innovation policy in the fields of health and the bioeconomy to meet new challenges of health care and sustainable growth. In the health area, patients benefit from the improved translation of health research into new drugs and better care. New forms of innovation policies that support translational health research cover the entire innovation cycle, from preclinical to late-stage patient trials – the point at which industry takes up and commercialises the research. Different types of policy initiatives have emerged across OECD countries: Centres for health research aim to translate biomedical research into clinical research and care, mission-oriented policies support public-private consortia around health research and innovation, and national health agencies have developed strategies for translational health research.

The bioeconomy is widely seen as a sustainable economy initiative for the post-fossil world. Innovation policies for the bioeconomy include high-level strategies that target the development of a national bioeconomy. They aim to build new kinds of innovation ecosystems for bio-based products, i.e. industries broadly based on renewable feedstocks that seek to minimise fossil-based production and enhance a more circular economy.

A comparison of twelve policy initiatives supporting health and the bioeconomy from different OECD countries points to several similarities, success factors and challenges of these initiatives.

Common characteristics

The analysed policy initiatives have clear objectives and sectoral priorities. The objective of health initiatives under study is to accelerate the translation of research into better care for patients. Often organised as local partnerships between universities and hospitals, centres for health research advance simultaneously biomedical research, new therapies, and better care provision. As for sectoral priorities, all five initiatives focus on the precision medicine sector. Four out of five initiatives provide important funding for research around widespread diseases, including antimicrobial resistance, cancer, dementia, and diabetes. High-level strategies for the bioeconomy are multi-sectoral. Germany, for instance, targets energy, agriculture, food, water, chemistry, forestry, construction and services. The United States also includes biotechnology.

Regarding target groups, most health initiatives target existing research university laboratories and hospitals. An exemption is the European Innovative Medicines Initiative which supports the establishment of large cross-border consortia comprising pharmaceutical industries, small and medium-sized enterprises, patient organisations and medicines regulators. Bioeconomy strategies – being high-level policy strategies, target entire industrial value chains, including large enterprises and small firms.

Health initiatives employ diverse policy instruments, including block grants, competitive project grants, matching grants requiring private-sector participation, and instruments for SMEs, such as equity funding (in the case of the European Innovative Medicines Initiative). Block grants are the main funding source for centres of health research. Bioeconomy strategies often provide funding for regional biomass clusters, pilot and demonstration plants, and increasingly use public procurement, regulation, and standards. In the United States, for example, the BioPreferred Program was established in 2014 with the objective to increase the purchase and use of bio-based products in order to reduce reliance on petroleum, increase the use of renewable agricultural resources, and contribute to reducing adverse environmental and health impacts.

In terms of budget, information is mostly available for health initiatives and it shows the initiatives vary considerably. They account for 0.7% of government budget appropriations on R&D in Australia (2017), 0.5% in the European Union (2017), 0.3% in Germany (2018) and 1.5% in the United Kingdom (2018). The average annual budget for centres of health research is EUR 90 million, or EUR 10 million per centre. However, there also exists substantial variation in the amounts of funding per centre.

Evaluations in the health domain are widespread and consist mostly of interim evaluations. They are conducted either in-house by the managing national agency or by external panels of scientific experts. However, in all cases under review evaluation and monitoring structures are rather ad hoc. For bioeconomy strategies, evaluations are rare. A recent Finnish evaluations of Finland's bioeconomy strategy considered how the bioeconomy influences the implementation of the Sustainable Development Goals.

Success factors

Evaluation studies point to the following critical dimensions for the success of policy initiatives for health:

- **Institutional funding has helped build up strong translational research capacities** and improved hospitals' absorptive capacity (Hampson et al., 2017).
- **The governance model of centres for health research is key for the success of translational research initiatives.** Scientists and industrial partners agree on the research programme and work closely together, creating a mutual benefit; it is up to the commercial partners to transfer the research results into new products or processes.
- **In the case of cross-border initiatives, clearly defined policy missions provide guidance for the diverse stakeholders**. The Innovative Medicines Initiative, for instance, sets out a plan for future large R&D investment by the European Commission.

In the case of initiatives supporting the bioeconomy, the following success factors became evident:

- **Sound governance**: A governance body is needed to make the high-level strategies work by ensuring that milestones and deliverables are met. For instance, the Italian National Bioeconomy Task Force of the Presidency of Council of Ministers, comprises several ministries, clusters and university representatives that jointly identify barriers to the emergence of the bioeconomy, such as e.g. regulatory barriers.
- **Early engagement with regulators** can prevent later barriers and lock-ins, as in the United States.
- **Public-private partnerships** are powerful and should serve a broad range of stakeholders, as in Germany, Finland, the United States and Italy.

Challenges

Several challenges remain in the health domain:

- **Guarantee openness and inclusiveness of partnership models for start-ups.** Spin-offs are at a disadvantage compared to large incumbent R&D players. The European Commission, for instance, has identified this weakness and is using new instruments specifically targeted at SMEs.

- **External evaluations** of partnerships should be conducted on a regular basis using performance indicators related to translational processes and outcomes – including societal outcomes, e.g. improved care.
- **Improve the participation of civil-society actors** (e.g. patient advocacy groups), and their involvement in programme co-design (agenda-setting) and implementation (co-creation).

Challenges to the emergence of a bioeconomy are:

- **Adopting a systems approach**. Policy should consider barriers to the adoption of the bioeconomy throughout entire industrial value chains and not simply act on individual parts of an overall industrial system. Furthermore, government agencies need to be co-ordinated at both a micro and macro level.
- **Finding a unique policy mix**. A successful strategy to develop a bioeconomy framework will be highly dependent on the policy mix adopted, and the attention paid to both technology-push and market-pull measures.

1. Introduction

This monograph provides an overview of leading biotechnology and life science policies across bioeconomy and health/biomedicine, based on a comparison of 12 policy initiatives undertaken across nine advanced economies.[1]

"Bioeconomy" as a concept generally embraces all sectors of the economy drawing on natural and/or renewable resources – e.g. crops, forests, fish, animals and micro-organisms – to produce food, materials and energy (European Commission, 2019a). Unlike conventional non-renewable industrial processes, bio-based processes relying on renewable resources are more sustainable and reduce carbon dioxide (CO_2). Investment in the bioeconomy therefore contributes to sustainable growth because it enables breakthroughs in food quality, industrial products and energy (among other sectors). It follows that bioeconomic policy covers a wide terrain, from infrastructure policy to research policy. This monograph focuses on new research and development (R&D) and industrial policies around the world across aiming to build new kinds of innovation ecosystems for bio-based products, i.e. industries broadly based on renewable feedstocks that seek to minimise fossil-based production and enhance a more circular economy. The initiatives reviewed for this monograph include high-level strategies targeting the development of a national bioeconomy.

The bioeconomy is widely seen as a sustainable economy initiative for the post-fossil world. It is regarded as a "transition" phenomenon, in the same way that wood-to-coal and coal-to-oil were transitions. Thus, the bioeconomy can truly be regarded as an "investment for the future".

In the health arena, policies focus on national initiatives for translational health research. Performed by both the public and private sectors, translational health research covers the entire research cycle of research, from preclinical to late-stage patient trials – the point at which industry takes up and commercialises the research. The selected initiatives include funding schemes for: i) centres of excellence for health consisting of partnerships aiming to translate biomedical research into clinical research and care; ii) challenge-driven programmes supporting public-private consortia around health research and innovation; and iii) strategies developed by national health agencies.

The types of policy initiatives selected reflect new approaches aiming to support biosciences, health innovation and health-care provision simultaneously, which traditional R&D grant schemes cannot achieve. Centres of excellence for health encourage collaboration between academia, health-care institutions, industry and patient groups. The Australian Advanced Health Research and Translation Centres (AHRTCs), the German Centres for Health Research, and the National Institute for Health Research's Biomedical Research Centres (BRCs) and Academic Health Science Networks (AHSNs) in the United Kingdom are comparable to the French university hospital institutes (*instituts hospitalo-universitaires*) featured in the *Programme d'investissements d'avenir* (Investments for the Future Programme [PIA]). Like them, they support regional partnerships of universities, hospitals and other health-care providers – including private enterprises – around biomedical research, and their translation into health-care improvements.

Table 1. High-level national initiatives for health and the bioeconomy: Overview

Policy initiative	Country	Type	Period	Yearly budget	Main objective
Health					
AHRTCs	Australia	Centres of excellence	2014-present	EUR 25 million	• encourage excellent health research and translation by bringing together researchers, health-care providers, education and training to improve the health and well-being of patients and the populations they serve, including in regional/remote areas.
Innovative Medicine Initiative (part of Societal Challenge Health Horizon 2020)	European Union	Challenge-driven programme	2014-20	EUR 470 million	• develop new therapies for diseases for which there exists a high unmet social need (e.g. dementia) • focus on technologies with limited private research (e.g. antimicrobial resistance) • increase the success rate of vaccine candidates in light of reduced private-sector efforts in this field • reduce the failure rate of WHO-identified priority medicines in clinical trials • reduce the time to reach clinical proof of concept • increase efficiency and effectiveness of health care with view to strengthening the system of health-care provision.
German Centres of Health Research	Germany	Centres of excellence	2009-present	EUR 50-100 million	• support scientific breakthroughs around widespread diseases (cancer, diabetes, cardiovascular, lung and neurodegenerative diseases) • strengthen the translation of research into better prevention, diagnosis and personalised medicine • increase the potential for health innovation to make scientific results rapidly available to patients.
BRCs and AHSNs	United Kingdom	Centres of excellence	2013-present	EUR 180 million (BRCs) EUR 80 million (AHSNs)	• advance translational biomedical research and translate research into benefits for patients • drive innovation in the prevention, diagnosis and treatment of diseases • contribute to UK international competitiveness.
NIH-wide Strategic Plan 2016-2020	United States	High-level strategy	2016-20	Not applicable	• advance opportunities in biomedical research • drive innovation by setting NIH priorities • enhance scientific stewardship • excel as a federal science agency by managing for results.

Bioeconomy					
Flanders: The vision for a sustainable and competitive bioeconomy in 2030	Belgium (Flanders)	High-level strategy	2013-30	Not specified	Flanders has three ambitions for 2030: • by 2030 Flanders will be one of the most competitive bioeconomy regions in Europe • in 2030, Flanders will be one of the top regions in Europe for innovation and research relating to the bioeconomy • by 2030, Flanders will have created one of the most sustainable bioeconomies in Europe.
The Finnish Bioeconomy Strategy	Finland	High-level strategy	2014-25	EUR 323 million (2016-18)	• the Finnish Bioeconomy Strategy strives to develop Finland into a low-carbon, resource-efficient and smart society • its objective is to generate new economic growth and jobs thanks to an increase in the bioeconomy business ,and high value-added products and services, while securing the necessary operating conditions for natural ecosystems • the Bioeconomy Strategy has four strategic goals: • a competitive operating environment for the bioeconomy • new business from the bioeconomy • a strong bioeconomy competence base • accessibility and sustainability of biomass.
National Policy Strategy on Bioeconomy	Germany	High-level strategy	2013-present	EUR 2.4 billion over seven years	• the guiding principles, strategic approaches and measures aim to help create the bioeconomy in Germany, as well as underpin the structural transition to a bio-based economy • the goals are designed around a set of guiding principles. The bioeconomy must help ensure food security for a growing world population, mitigate climate change, and conserve soil fertility and species diversity.
BIT Bioeconomy in Italy. A new bioeconomy strategy for a sustainable Italy	Italy	High-level strategy	2019-30	Not specified	• create of an Italian bioeconomy, based on longer, more sustainable and locally routed value chains • achieve a 15% increase in the current turnover of the Italian bioeconomy (about EUR 330 billion/year) and the number of jobs (by about 2 million) by 2030, while increasing the level of circularity in the economy.

The Bio-based Economy in the Netherlands	Netherlands	High-level strategy	..	Not specified	• the long-term goal to 2030 is to use only biomass for the non-food and feed sectors (chemicals and materials, aviation and shipping, heavy long-distance road transport and high-temperature industrial heating) when other renewable alternatives are scare or not available • in the short term, the use of biomass is considered vital in order to meet the goals set in the country's Energy Agreement and Climate Policy Agreement • the Framework Memorandum on the Bio-based Economy in 2012 stressed how a bio-based economy provided opportunities to address major societal challenges • the strategy prioritises the efficient use of biomass. It emphasises "co-production" linked to biorefineries as a key technology for ensuring optimal use of biomass for food. The objective of the Energy Agenda is to reduce CO_2 emissions by 80-95% by 2050.
Growing the Bioeconomy. Improving lives and strengthening our economy: A national bioeconomy strategy to 2030	United Kingdom	High-level strategy	2018-30	Not specified	• unusually among national bioeconomy strategies, the United Kingdom places special emphasis on biotechnologies to develop the bioeconomy • the overall objective is similar: to harness renewable biological resources to replace fossil resources • the bioeconomy emerged as an government priority because of its potential for growth and job creation, in addition to other societal benefits.
The National Bioeconomy Blueprint	United States	High-level strategy	2012-present	Not specified	• the US bioeconomy is also one in which emerging biotechnologies and converging technologies play a central role • the United States also has a built-in strategy to harness and utilise biomass as a strategic resource of the future to replace (at least partially) fossil feedstocks.

Notes: EUR: euros; WHO: World Health Organization; NIH: National Institutes of Health.

An example of challenge-driven programmes is the European framework programme Horizon 2020, whose Innovative Medicines Initiative promotes large cross-border public-private consortia around innovative medicine. Lastly, high-level national health strategies aim to advance simultaneously biosciences, health innovation and the health-care system.

This monograph focuses on the high-level health strategies adopted by national agencies, e.g. the NIH in the United States. It compares initiatives supporting the development of a national bioeconomy and health, and provides insights into how governments can design their programmes to advance: i) the emergence of a national bioeconomy; and ii) the rapid translation of basic research into treatment and cure. The comparison will provide key findings for the

ongoing evaluation of the French PIA programme. The policy initiatives were selected based on an overview of initiatives gathered by the EC-OECD STIP Compass database. Information on their characteristics was drawn from the EC-OECD STIP Compass database, the programmes' official websites and other secondary sources, such as academic publications and evaluation reports.

The monograph synthesises the results of the compared case studies in the field of health and the bioeconomy; the detailed case studies are available online (OECD, 2019).

1. Health

Governments across advanced economies support regional public-private partnerships which, like the French university hospital institutes, aim to improve the translation of biomedical research into better care and innovation. All of these initiatives support research – both basic and clinical, often around widespread diseases – and aim to provide the conditions for translating research into new treatments, better health-care provision and new drugs. They apply a range of instruments spanning the entire cycle of research translation, including block grants dedicated to translational research purposes, competitive research grants and equity funding for spin-offs that commercialise research. This section describes five high-level initiatives from five advanced OECD economies. It reviews their characteristics, commonalities and differences with regard to objectives, target groups, priorities, instruments, budgets, selection, international co-operation, evaluation and success factors.

1.1. Objectives

The goal of the health policy initiatives under review is to support basic scientific research and accelerate the translation of research into better care for patients. As in France, three countries under study (Australia, Germany and the United Kingdom) rely on policy initiatives supporting research partnerships. These often involve local partnerships between universities and hospitals, organised around health and care provision. Like the French university hospital institutes supported by the PIA, these centres for health excellence aim to advance simultaneously biomedical research, health innovation (e.g. new therapies, better care provision and new drugs) and the health-care system (i.e. the organisation of health care, mostly provided by hospitals and local community health-care centres). These partnerships deliver two types of translational research: Type 1 translational research covers research "from the laboratory bench to clinical trials"; Type 2 targets the translation of clinical trials into clinical practice and policy (Snape et al., 2008).

All five health initiatives focus on developing a precision medicine or personalised medicine sector. Precision (or personalised) medicine embraces medical decisions, treatments, practices and drugs that are tailored to individual characteristics (e.g. risk of disease). Four out of five initiatives for health (in the European Union, Germany, the United Kingdom and the United States) promote scientific breakthroughs and innovation around widespread diseases. In Germany, for instance, the six centres work on cancer, dementia, diabetes, cardiovascular diseases, infectious diseases, lung diseases and neurodegenerative diseases. In the United Kingdom, the centres dover a broader range of diseases and health issues, including antimicrobial resistance, cancer, cardiovascular diseases, dementia, neurodegenerative disease and respiratory disease.

Besides translating research into better prevention, diagnosis and personalised medicine, the policy initiatives for health address additional and often complementary objectives. These include bolstering scientific excellence in biomedical research (in Australia, the European Union, Germany, Israel, the United Kingdom and the United States) and nurturing innovation, including new therapies, better health-care provision and new personalised medicine. Excellence is expected to translate into better treatment and increased potential for health innovation, such as new drugs.

In addition to nurturing scientific excellence in biomedical research and better translation of research results, UK health centres have a third objective, i.e. enhancing the contribution of health research to the country's international competitiveness.

The European Union's Innovative Medicines Initiative promotes research and innovation that targets the following challenges: 1) develop new therapies for diseases for which there is a high unmet social need (e.g. dementia); 2) promote technologies that are the subject of limited private research (e.g. antimicrobial resistance); 3) increase the success rate of vaccine candidates in light of reduced private-sector efforts in the field; 4) reduce the failure rate of WHO-identified priority medicines in clinical trials; 5) reduce the time needed to reach clinical proof of concept; and 6) increase the efficiency and effectiveness of health care, to strengthen the health-care system.

1.2. Target groups

The beneficiaries of the centres of excellence initiatives include research universities, university hospitals, public research institutions and health-care organisations. Like the French university hospital institutes, they are regional partnerships and consist of several institutions co-located in the same region. The only exception is the German Centres of Health Research, which support cross-regional partnerships. In all the cases under review, the centres of excellence provide funding to existing research structures.

The Innovative Medicines Initiative targets large cross-border consortia comprising universities, research centres, pharmaceutical and other industries, small and medium-sized enterprises (SMEs), patient organisations and medicines regulators.

1.3. Priority industries and technologies

The initiatives for health primarily cover biomedical research, clinical research and the translation of biomedical research into better care. The AHRTCs in Australia, for instance, support cross-sectoral partnerships around biomedical research and its translation into primary health care up to tertiary care. The French university hospital institutes, on the other hand, focus on specific priorities, e.g. cardiology.

Other initiatives reviewed clearly define specific diseases as funding priorities. In the case of the German Centres of Health Research (OECD, 2019), funding is provided for translational research around widespread diseases, including cancer, diabetes, cardiovascular, lung and neurodegenerative diseases. Similarly, the BRCs in the United Kingdom conduct translational research around specific diseases (e.g. cancer, cardiovascular diseases and mental health).

All of the initiatives clearly define non-technological objectives, primarily to improve patient care and well-being. Some initiatives, such as the Australian Centre for Health Innovation, aim to improve health-care provision in rural regions.

Policies tend to state mission-oriented objectives, e.g. health and specific diseases, reflecting a shift from traditional biomedical sector-specific initiatives towards cross-sectoral, challenge-driven programmes. Cross-sectoral initiatives cover a wide range of research disciplines, including biomedical research and clinical research, as well as clinical care and the provision of health-care solutions. In the European Union, the Horizon 2020 framework programme was the first programme to define societal challenges as priorities. Similarly, the German initiative was designed from the very beginning around specific diseases defined as health challenges. In the United Kingdom, the BRC initiative was reformed in 2017, cutting across research disciplines to address disease-oriented research.

All the initiatives analysed prioritise the development of a precision medicine or personalised medicine sector. Precision (or personalised) medicine covers medical decisions, treatments, practices and drugs tailored to an individual patient's characteristics, e.g. risk of disease. A patient's risk profile is created based on the analysis of genetic information linked to clinical information, which requires large-scale genomic databases. Linking genomic and clinical data provides competitive advantages for developing personalised medicine. Hence, the initiatives in Australia, the European Union, Germany, the United Kingdom and the United States provide funding for the construction of biomedical datasets to boost innovation in precision medicine. For instance, the Australian National Health and Medical Research Council (NHMRC) provides funding for data-driven health care through its Medical Research Future Fund. In Germany, the Centres of Health Research initiative funds platforms for precision medicine; at the German Consortium for Translational Cancer – one of six current centres[2] – funding was used to establish a genome sequencing platform.

Some initiatives, such as the AHSNs in the United Kingdom, support breakthrough innovations by selecting locally successful treatment methods or other health innovations that are subsequently adopted at other hospitals across the country. The National Health Service pays for the nationwide adoption and diffusion of innovations.

1.4. Instruments

The initiatives employ block grants; competitive project grants; matching grants requiring private-sector participation; and instruments for SMEs, such as equity funding (in the case of the European Innovative Medicines Initiative (OECD, 2019)). In Australia, Germany and the United Kingdom, as in France, the initiatives provide non-refundable block grants to institutional partnerships between universities, research centres and hospitals. Although the block grants are annual budgets dependent on the annual budget of the government, they provide more stable funding than competitive grants. The partnerships can generally use the funding to cover direct project costs for research and training activities; translational clinical research (e.g. pharmacy, pathology, radiology), often including the improvement or extension of physical infrastructure; the creation of digital infrastructures (platforms); researcher recruitment; and graduate training.

However, a large share of the block grant is used to cover personnel costs, limiting its directionality. In Germany, 46% of the block grant was used for personnel costs, 27% for equipment and 27% for investment in research infrastructure in 2015. Research infrastructure includes not only new laboratories, but also information technology (IT) infrastructure, e.g. platforms.

Some countries use R&D grants targeting translational research to avoid the pitfalls of block grants. For instance, the Australian NHMRC mainly uses R&D grants to support translational research, while the AHRTC initiative recognises specific partnerships' scientific excellence, increasing their likelihood of obtaining research grants. In this sense, the AHRTC is not primarily a funding initiative. It employs accreditation to recognise excellence in research, translation, collaboration and training of health-care professionals in evidence-based clinical research at internationally competitive levels.

The European Union's Innovative Medicines Initiative uses grants to fund research teams, cross-border public-private consortia and SMEs. The initiative requires 50% of the project costs to be funded by industry partners, ensuring the project has market prospects.[3] The grants consist of two schemes: Research and Innovation Actions, and Innovation Actions. Research and Innovation Actions provide financial support for basic and applied research, technology development and integration, and testing and validation on a small-scale prototype in a

laboratory or simulated environment. Innovation Actions support prototyping, testing, demonstrating, piloting, large-scale product validation and market replication, and are used to turn technologies into applications. Additional funding is provided through equity financing, especially for SMEs (e.g. the SME instrument); access to risk finance is jointly provided by the European Investment Bank and the European Investment Fund.

The US approach differs from France' university hospital institutes in that regional partnerships target research commercialisation, whereas conventional research grants fund basic and translational research. The NIH has programmes devoted to life science start-ups that contribute to its high-level strategy targeting the translation of biomedical research. The NIH Small Business Innovation Research (SBIR) programme provides seed-funding (equity) for start-ups conducting R&D with the potential for commercialisation. Two other initiatives related to the overall strategy of the NIH for health innovation are the NIH Centres for Accelerated Innovation (NCAI), and the Research Evaluation and Commercialisation Hubs (REACH). These are regional partnerships consisting of leading research institutions that receive NIH grants for their infrastructure and business support activities. The centres use the funding to provide grants of up to EUR 306 000 for research commercialisation, project management and entrepreneurial training for start-ups.

1.5. Budget and time horizon

The budgets of the initiatives account for 0.7% of government budget appropriations or outlays on R&D in Australia (2017), 0.5% in the European Union (2017), 0.3% in Germany (2018) and 1.5% in the United Kingdom (2018). The time horizon of the initiatives ranges from 11 years in Germany (2009 to date) and 7 years in the United Kingdom (2013 to date) to 6 years in Australia and the European Union (2014 to date).

The centres of excellence under review receive substantial funding over a relatively long period of time (five years on average) compared to grants. Based on data from Australia, Germany and the United Kingdom, the average annual budget for centres of excellence is EUR 90 million, or EUR 10 million per centre. However, the budget varies from EUR 180 million in the United Kingdom to EUR 25 million in Australia. There also exists substantial variation in the amounts of funding per centre. Of the three initiatives under review, the NIHR Oxford Biomedical Research Centre received the highest funding, at EUR 129 million per year (average annual budget for 2017-21).

The initiatives are often part of a broader policy mix administered by national health agencies. In Australia, the funding for AHRTCs is part of a broader portfolio for translational research, which stood at EUR 100 million for the period 2017-18. The AHRTCs had a budget of 25 million or 25%.

1.6. Selection criteria and procedures

In all the centres of excellence under review, the selection process consisted of one stage, conducted by expert evaluation committees, including international experts from biomedical research, clinical research and often bioethical councils. The selection criteria included: i) scientific excellence in biomedical and translational research; ii) existing research capacity and plans for increasing capacity, including through training; iii) plans for strategic partnerships; iv) relevance of the research portfolio to patient and public health; v) track record of translating advances in basic biomedical research into clinical research and benefits for patients; and vi) track record of attracting private funding (in the case of the European Union and Australia only). The selection criteria of the EU Innovative Medicines Initiative differ because of the

programme's challenge-driven nature. To be eligible for funding under the initiative, the applicants must indicate the expected impact in the proposals.

1.7. International co-operation

The EU Innovative Medicines Initiative supports cross-border partnerships and mobility. Its approach to breakthrough innovation consists in promoting industrial leadership by successfully involving the private sector and SMEs. Over 2014-17, 75% of all funding was allocated to instruments supporting collaborative and multi-disciplinary cross-border research and innovation consortia in the area of health care.

Public funding for centres of excellence targets international scientific collaboration and employment of foreign researchers. International collaboration among researchers is based on individual initiatives.

1.8. Evaluation strategies

Evaluations are widespread and consist mostly of interim evaluations, conducted either in-house by the managing national agency or by external panels of scientific experts. In most cases, however, evaluation and monitoring structures are not well implemented and rather ad hoc. Although they assess the impacts of the initiatives, the lack of performance indicators for translational processes and outcomes is a shortcoming. Moreover, the long-term nature of translational processes requires long-term evaluation studies. The Australian AHRTCs and the German Centres of Health Research, for instance, were subject to interim evaluations. In the United Kingdom, individual centres have been evaluated in the context of the BRC initiative.

Evaluations of excellence centres were based on interviews with beneficiaries (researchers, senior clinicians and hospital managers) and surveys of all companies interacting with health centres (in the case of the UK BRCs). European Commission evaluations are based on a variety of methods, including expert groups, surveys of beneficiaries and project co-ordinators, counterfactual analysis and macroeconomic modelling.

One example of impact evaluation is the Oxford BRC, which was evaluated by RAND[4] Europe (Hampson, 2017), based on interviews with clinicians and researchers, a survey of beneficiaries and case studies of industries (including spin-offs) involved in the BRC. The results showed the BRC increased active collaboration between clinical staff at hospitals and university researchers. The funding strengthened the absorptive capacity of the local hospitals involved through improved access to research infrastructure at universities – including better biobanking, such as a tissue database and consent management system – and improved pharmacovigilance and pharmacy support. The initiative was also associated with increased research activity, and improved capacity to conduct clinical trials based on interviews and case studies. However, the evaluators did not collect data on research outcomes, e.g. scientific publications or clinical trials. Regarding the initiative's impact on care, the participating hospitals gained better access to new treatments for patients, and their staff have become more interested in using and providing better information on novel treatments. Regarding the economic effects, a survey of beneficiary firms suggested that collaboration with the Oxford BRC helped firms obtain additional investment, hire additional staff and generate revenue.

In 2017, an international scientific panel evaluated the application and selection process of the Australian AHRTCs (NHMRC, 2017). The evaluation was mainly internal and consisted of seven experts, including one representative from the NHMRC. The panel provided the following recommendations: i) the centres should be designated for five years, with no automatic

extensions; ii) they should propose transparent performance indicators, to be considered in future assessment of achievements; iii) they should enhance the integration of research in health care; iv) they should strengthen governance for collaborative research, by introducing common ethics and governance requirements among partners, and creating in consultation with consumers a clear prioritisation framework for research and translation activities; and v) they should establish enabling structures, such as harmonised ethic approvals for better data linkages, and developing plans and platforms for data integration.

The German Council of Science and Humanities (Wissenschaftsrat, 2018) evaluated the model of the German Centres of Health Research in 2016. The individual centres also underwent independent evaluations between 2014 and 2016, underscoring the importance of evaluations for the programme. The overall evaluation found that stable, long-term institutional funding, and intense co-operation between leading research teams and establishments have produced strong translational research capacities. Further, the initiative has increased collaborations between leading scientists and research institutions in biomedical research in Germany. However, the evaluation suggested the following improvements:

- The centres should increase international collaboration with scientists and research institutions.
- The government should prioritise supporting new research structures that enable translational research in Germany.
- The decentralised structure of the centres makes them less internationally visible. Research excellence is attributed to single research teams and institutions, rather to the overall centres. However, the decentralised model has elicited interest in other countries, including Australia and the United Kingdom.
- External evaluations of the centre model should be conducted on a regular basis. They should measure not only the output of translational research, but also the processes of translational research.

The European Commission evaluates all of its programmes under Horizon 2020, including the Innovative Medicines Initiative. The programme's impacts are examined during the proposal evaluation, and through regular reporting and monitoring. The interim evaluation (European Commission, 2019b) found that the Innovative Medicines Initiative has led to increased cross-border collaborations between leading research institutions and industry. It determined that collaborative research has led to new medication and tools for diagnosis (e.g. 3D medical imaging, development of new antibiotics), and improved provision of personalised and mobile health services. The financial instruments for equity financing for SMEs have been particularly popular.

1.9. Critical dimensions

The success of initiatives supporting partnerships for health research and translational research lies in: i) de-risking investment in translational research by providing stable funding for excellent biomedical research and translating research results into daily care (e.g. access to better treatments); ii) governance structures that enable co-creation around health (e.g. large public-private consortia in the European Innovative Medicines Initiative); and iii) setting challenges around diseases and population health issues that provide guidance on future large-scale R&D investment. Evaluation studies found the following critical dimensions:

- **Institutional funding has helped build up strong translational research capacities and improve hospitals' absorptive capacity.** The evaluation of the UK BRC initiative

(Hampson et al., 2017) showed that a critical mass of institutional funding (EUR 180 million in total) strengthened the absorptive capacity of the local hospitals involved through better access to research infrastructure at universities, including better biobanking (e.g. a tissue database and consent management system) and improved pharmacovigilance and pharmacy support.

- **The initiatives channel funding to research and innovation activities around widespread diseases**, including antimicrobial resistance, cancer, cardiovascular diseases, dementia, diabetes, neurodegenerative diseases and respiratory diseases.

In the United Kingdom, the centres cover a broader range of diseases and health issues:

- **Governance of regional partnerships enables co-creation in health research.** Scientists and industrial partners agree on the research programme and work closely together, creating a mutual benefit; it is up to the commercial partners to transfer the research results into new products or processes.
- **Clearly defined challenges provide vision for industry partners.** The Innovative Medicines Initiative sets out a plan for future large R&D investment of European Commission. This means bringing together different technologies, sectors, scientific disciplines and innovation actors to find new solutions to health challenges.

Several issues remain to be solved in order to increase the effectiveness and inclusiveness of initiatives for health:

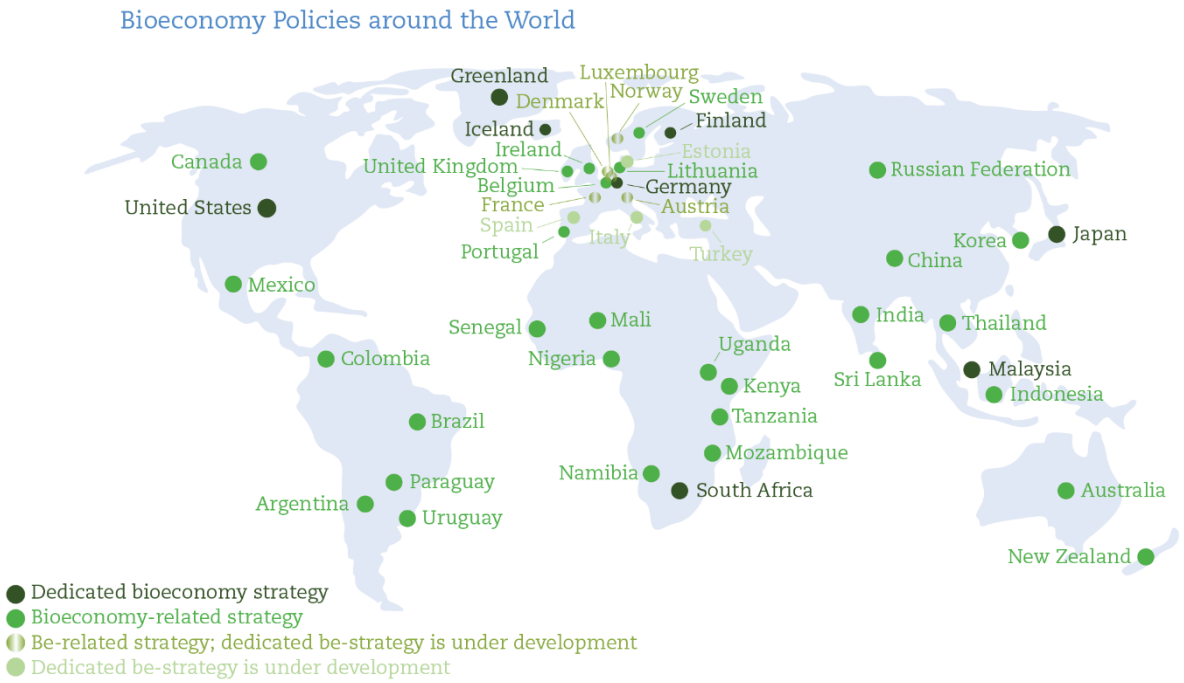
- **Guarantee openness and inclusiveness of partnership models for newcomers.** The evaluation of the German Centre of Health Research suggests that their designation should be effective for five years, with no automatic extensions (Wissenschaftsrat, 2018). A similar approach was suggested for the Australian AHRTCs (National Health and Medical Research Council, 2017). One unresolved issue is that spin-offs are at a disadvantage compared to large incumbent R&D players in terms of attracting public R&D funding. The European Commission is using new instruments specifically targeted at SMEs to address their structural disadvantage.
- **Strengthen linkages to innovation.** Priority should be given to stimulating breakthrough and market-creating innovation, notably by SMEs.
- **Prioritise external evaluations**. External evaluations of partnerships should be conducted on a regular basis. The centres should propose transparent performance indicators related to translational processes and outcomes – including societal outcomes, e.g. improved care – which should be factored into future assessments of achievements.
- **Strengthen governance of collaborative partnerships.** The partnerships should strengthen governance for collaborative research by introducing common governance requirements among the partners and a clear prioritisation framework for research and translation activities, developed in consultation with consumers.
- **There remains room to improve the participation of civil-society actors** (e.g. patient advocacy groups), and their involvement in programme co-design (agenda-setting) and implementation (co-creation).

2. Bioeconomy

The bioeconomy is a paradigm of the natural-resource economy that has been growing in acceptance over the last decade. The bioeconomy embraces all sectors of the economy drawing on natural and/or renewable resources – e.g. crops, forests, fish, animals and micro-organisms – to produce food, materials and energy (European Commission, 2019a). Bio-based processes that use renewable resources promise to be more sustainable and reduce CO_2 emissions compared to conventional non-renewable industrial processes. Today, some 50 countries possess either a bioeconomy strategy or a group of policies consistent with building a future bioeconomy (Figure 1). Public investment in the bioeconomy is seen as a contribution to sustainable growth because it can enable breakthroughs in food quality, industrial products and energy (among others).

Thus, bioeconomy strategies target a societal transformation from the current fossil economy to a more sustainable future for society where the feedstocks for industry are biomass-based. Different countries take different approaches to their bioeconomy strategies. Some countries (e.g. France) strongly emphasise sustainable agriculture, others (e.g. Finland) focus on forestry, still others (e.g. the United States) focus on medicine and human health, and biotechnology (e.g. the United States and the United Kingdom).

Figure 1. Bioeconomy policies around the world



Source: BÖR (2017).

Such societal transitions are few in history. It is common knowledge that each transition – e.g. from wood to coal, and then coal to oil – takes several decades. As time is constrained by grand societal challenges – especially climate change – the transition to a bioeconomy has to

proceed faster. To reflect the scope and importance of this transition, the following excerpt from the updated bioeconomy strategy of the European Union is noteworthy:

"*The bioeconomy covers all sectors and systems that rely on biological resources (animals, plants, micro-organisms and derived biomass, including organic waste), their functions and principles. It includes and links: land and marine ecosystems and the services they provide; all primary production sectors that use and produce biological resources (agriculture, forestry, fisheries and aquaculture); and all economic and industrial sectors that use biological resources and processes to produce food, feed, bio-based products, energy and services. To be successful, the European bioeconomy needs to have sustainability and circularity at its heart. This will drive the renewal of our industries, the modernisation of our primary production systems, the protection of the environment and will enhance biodiversity*". (European Commission, 2018)

2.1. Bioeconomy strategies chosen for the analysis

The bioeconomy strategies chosen for the purposes of this analysis demonstrate differences in sectors and approaches. All except one are based on a national strategy document. The Netherlands entry is based on policy documents that exemplify the aspiration towards a circular bioeconomy, without being an outright national strategy. The chosen strategies are as follows (in alphabetical order):

- Belgium (Flanders): emphasis on a mixed bioeconomy, comprising feedstocks and intended products, e.g. waste conversion and high value-added bio-based chemicals and materials
- Finland: focus on the forest bioeconomy
- Germany: highly diversified, covering energy, agriculture, food, water, chemistry, forestry, construction and bioeconomy services; supported by a research bioeconomy strategy and a separate bioeconomy policy strategy, which merged in mid-2019
- Italy: mixed bioeconomy, focusing on agriculture, forestry and the marine environment, and emphasising the recovery of old industrial sites for bioprocessing
- Netherlands: focus on agriculture and food, and chemistry and materials
- United Kingdom: focus on modern biotechnologies and engineering biology
- United States: focus on modern biotechnologies and engineering biology.

2.2. Specific sectoral priorities

The bioeconomy is multisectoral. In 2009, the OECD envisaged the bioeconomy as one in which biotechnologies could contribute to economic growth (OECD, 2009). Beginning in 2012, individual nations and the European Union started drafting bioeconomy strategies. It emerged that biotechnology was only one component of what countries considered as the "bioeconomy". Germany, a large economy with a diversified bioeconomy (multiple feedstocks), sees the main sectors as energy, agriculture, food, water, chemistry, forestry, construction and bioeconomy services. The German approach focuses on establishing bio-based industrial production. The United States also includes health biotechnology in the category, greatly expanding the bioeconomy, as most private investment in biotechnology is directed at health. This suggests that the bioeconomy is indeed a societal transition involving many sectors, including those to which biotechnologies can add economic value.

2.3. Mix of instruments

This can be best summarised in Table 2, which can also be rearranged into a sequence of Feedstock → Technology → Industrialisation → Market.

Table 2. Policy inputs for a bioeconomy innovation framework

Feedstock/technology push	Market pull	Cross-cutting
Local access to feedstocks	Targets and quotas	Standards and norms
International access to feedstocks	Mandates and bans	Certification
R&D subsidy	Public procurement	Skills and education
Pilot and demonstrator support	Labels and raising awareness	Regional clusters
Flagship financial support	Direct financial support for bio-based products	Public acceptance
Tax incentives for industrial R&D	Tax incentives for bio-based products	
Improved investment conditions	Incentives related to GHG emissions (e.g. EU Emissions Trading System)	
Technology clusters	Taxes on fossil carbon	
Governance and regulation	Eliminating fossil-fuel subsidies	

Notes: GHG: greenhouse gas.
Source: OECD (2018).

Different types of bioeconomy-related innovation instruments can be readily identified, grouped under three main categories: feedstock/technology push (supply side), market pull (demand side) and cross-cutting measures (a mixture of both supply-side and demand-side policies). This is consistent with the view that both supply-side and demand-side policies are needed to effectively drive innovation.

On the supply side, publicly funded technology, regional and biomass clusters are still popular instruments in national bioeconomy policies. Building circular bioeconomy ecosystems entails the very difficult task of making disparate industry sectors work together to identify business opportunities. The clusters fulfil this role by reducing the transaction and opportunity costs of bringing people together. Flanders illustrates the case for building international clusters, and this monograph discusses the potential benefits of internationalisation. As a general rule, however, policy makers find it difficult to assess the efficacy of clusters.

A second key observation on the supply side is that funding for pilot and demonstration phases has always been – and will continue to be – a top policy issue. Although the demonstration phase is considered essential, it also carries very high risk. The private sector looks to the public sector to de-risk the large investments needed. Finland, for example, has spent considerable time and energy on demonstrators. Funding the demonstration phase can help fill the gaps, by attracting foreign technology providers and/or encouraging the growth of these companies domestically.

Although technology-push instruments and mixed instruments are predominant, demand-side measures are underutilised relative to their potential. Historically, OECD governments have tended to rely on macroeconomic policies (e.g. monetary and fiscal) and framework conditions (e.g. competition, tax or entrepreneurship policy) to support market demand and avoid distortion. In recent years, however, OECD member countries and emerging economies such as Brazil and China have used more targeted demand-side innovation policies. These policies feature measures such as public procurement, regulation, standards, consumer policies and user-led innovation initiatives. They also include lead market initiatives to address market and system failures in areas with pressing social needs.

The gold-standard demand-driven measure in the bioeconomy might well be the US BioPreferred Program. On 7 February 2014, President Barack Obama signed into law a five-year reauthorisation of the Agricultural Act of 2014, which included the BioPreferred Program.[5]

Managed by the United States Department of Agriculture (USDA), the programme aims to increase the purchase and use of bio-based products in order to reduce reliance on petroleum, increase the use of renewable agricultural resources, and contribute to reducing adverse environmental and health impacts. It has two major components: a) a mandatory purchasing requirement for federal agencies and their contractors; and b) a voluntary labelling initiative for bio-based products.

Experience in OECD member countries has shown that the use of such demand-side policies remains limited to areas in which the market alone cannot meet societal needs (e.g. the environment) or in which private and public markets intersect (e.g. energy supply). Both the environment and energy drive bioeconomy policy goals. This focus on the demand side also reflects a general perception that despite design refinements in recent decades, traditional supply-side policies have not brought innovation performance and productivity to the desired levels.

2.4. Budgets

Although bioeconomy strategies themselves are not grant-awarding instruments, the monetary value of the programmes they recommend (e.g. the Finnish and German examples) can sometimes be estimated. The size of the existing EU bioeconomy (Figure 1) is indicative of the sums that will be required over the coming decades to drive a true transition away from fossil-based production.

2.5. Critical dimensions

- **Sound governance**. Some countries, e.g. Italy, the United Kingdom and the United States, demonstrate that a governance body is needed to make the strategy work by ensuring that milestones and deliverables are met. This is crucial in the context of a soft-law strategy, which may otherwise remain aspirational. The Italian governance body, the National Bioeconomy Task Force of the Presidency of Council of Ministers, comprises several ministries, clusters and university representatives. This diversity increases the chances of identifying opportunity barriers (e.g. regulatory barriers) beyond science and technology.
- **The virtues of a systems approach**. Not all governments have adopted systems innovation as a tangible concept. Any value chain is only as strong as its weakest link. If policy simply acts on individual parts of an overall industrial system, then the approach is fraught with potential for failure, as it fails to capture how the overall system works. Furthermore, government agencies need to be co-ordinated at both a micro and macro level. A particular danger is that agencies and departments involved in technology push (e.g. innovation agencies) will be at crossed purposes with those involved in market pull. Box 1 illustrates some of these points by describing an approach to the marine bioeconomy explicitly taken by Finland and other Scandinavian countries.

Box 2. The systemic challenge of mesopelagic fishing and fisheries

By definition, mesopelagic fish belong to the meso layer of the oceans, i.e. below 200 metres. This resource may be much larger than originally thought (Irigoien et al., 2014). Recent assessments suggest a global standing stock of more than 10 billion metric tonnes – 100 times more than the total current fisheries stock. If these estimates are correct, mesopelagic fish could be hugely important for human nutrition.

While the societal goal – contributing to food security – is clear, exploiting this resource from marine research to market development requires concerted action by many stakeholders. The ecosystem dynamics, the areas of high abundance and seasonal variation are yet to be elucidated. The conduct of biological research, and the development of more efficient fishing methods and avoidance of bycatch, will depend on innovation in improving detection systems and fishing gear suited for organisms living at greater depths. Researching the chemical and nutritional composition of the organisms will determine the optimal processing technologies and product opportunities. Regulatory aspects and policies will also influence both resource management and product approvals.

Here, the systemic challenge is clearly at play. The fishing companies will not undertake expensive trial fisheries without confidence in future commercial licences, suppliers of enabling equipment will not invest in innovation without customers, and tailor-made processing technologies will not be developed in the absence of an established market pull. Multiple failures thus exist in the value chain, which can only be overcome through public policy intervention.

- **Finding a unique policy mix**. A successful strategy to develop a bioeconomy framework will be highly dependent on the policy mix adopted, and the attention paid to both technology-push and market-pull measures. While this is true of most technology introductions, it is especially critical with the bioeconomy, as many of its products will compete directly with fossil products. As observed in the Flanders case, generic policy instruments are no longer applicable. A government will only be seen as taking the bioeconomy seriously when it dedicates specific budgets to specific instruments (Table 2.)
- **Other notable findings are as follows**:
  - Early engagement with regulators can prevent later barriers and lock-ins, as in the United States.
  - Public-private partnerships are powerful and should serve a broad range of stakeholders, as in Germany, Finland, the United States and Italy.

2.6. Evaluation strategies

Again, it is very premature to evaluate bioeconomy strategies, although Germany is an exception (as indicated below). Some country strategies have dedicated space covering evaluation, others less so or not at all. The Finland bioeconomy strategy grants considerable importance to success factors and evaluation, and is widely considered as excellent. The Finnish measures of success exemplify the ambitions of the bioeconomy: success in 2025 will be achieved if the national bioeconomy reaches EUR 100 billion and creates another 100 000 jobs. Other targets include:

- increasing exports

- replacing fossil fuels with renewable domestic natural resources to improve Finland's current account balance
- reinforcing supply and increasing energy self-sufficiency
- supporting the goals of sustainable development, biodiversity conservation and balanced regional development.

The strategic monitoring and evaluation strategies of Finland (and responsible agencies) have the following goals:

- The growth of the bioeconomy within the overall Finnish economy will be monitored using output/value added and job share in the national economy (Statistics Finland).
- The added value from natural-resource use will be monitored (Finnish Environment Institute, Thule Institute, Statistics Finland).
- The environmental benefits will be monitored by calculating raw material inputs/GHG emissions avoided (Finnish Environment Institute, Thule Institute, Statistics Finland).
- Bioeconomic sustainability will be monitored using total use of natural resources/growth and harvest volumes of standing timber, cereal crops, fish harvests, endangered species and urban waste (Statistics Finland, Luonnontila.fi). In addition, indicators will be developed for ecosystem services, environmental and resource efficiency, and wealth and environmental assets.

This snapshot from Finland demonstrates the magnitude of the task of measuring the bioeconomy and its success. A major impediment to evaluating bioeconomies is the lack of clear metrics for success. Turnover and job numbers can be measured relatively easily, and therefore currently comprise the primary metrics of the bioeconomy. Some countries have measured gross valued added (GVA).

Recently, evaluations have begun to consider how the bioeconomy influences the implementation of the Sustainable Development Goals, as with the Finland strategy. A set of environmental, social and economic indicators and the harmonisation of indicators at the international level will be problematic, as consensus building has met with barriers between nations. The Global Bioenergy Partnership has proposed a set of sustainability indicators for bioenergy (**Error! Reference source not found.**). These indicators have been agreed by 14 countries, only 4 of which are OECD countries. Note that bioenergy is independent of bio-based chemicals and materials, such as textiles and plastics.

Table 3. Sustainability indicators for bioenergy suggested by the Global Bioenergy Partnership

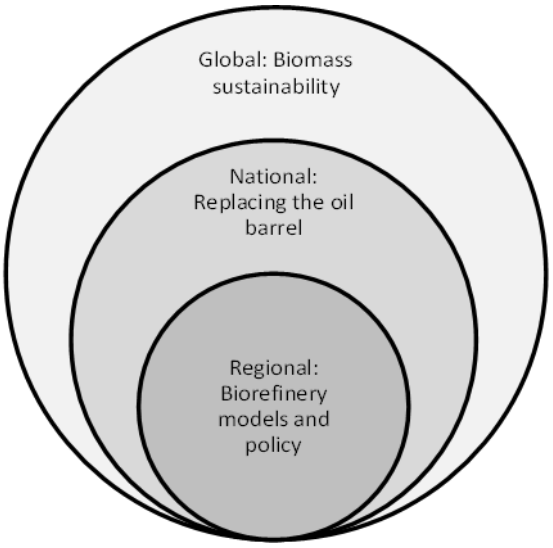
Environmental	Social	Economic
Life-cycle GHG emissions	Allocation and tenure of land for new bioenergy production	Productivity
Soil quality	Price and supply of a national food basket	Net energy balance
Harvest levels of wood resources	Change in income	GVA
Emissions of non-GHG air pollutants, including air toxics	Jobs in the bioenergy sector	Change in consumption of fossil fuels and traditional use of biomass
Water use and efficiency	Change in unpaid time spent by women and children collecting biomass	Training and re-qualification of the workforce
Water quality	Bioenergy used to expand access to modern energy services	Energy diversity
Biological diversity in the landscape	Change in mortality and burden of disease attributable to indoor smoke	Infrastructure and logistics for distribution of energy
Land use and land-use change related to feedstock production	Incidence of occupational injury, illness, fatalities	Capacity and flexibility of use of bioenergy

Source: OECD (2018).

2.7. International co-operation aspects

The complexity of bioeconomy policy is partly due to the multiple scales of action required (Figure 2), ranging from regional development (e.g. biorefinery deployment), through national R&D, synthetic biology, IT convergence and automation, to global issues of biomass and its sustainability. The distributed bioeconomy manufacturing model calls for a "glocal" – i.e. both global and local – approach. It stresses the importance of locating the growing industry close to both raw materials, and the goods and energy produced and consumed (McCormick and Kautto, 2013). Unlike the petrochemicals model, the success of the bioeconomy manufacturing model does not rely on economies of scale, which could prove to be a major challenge.

Figure 2. Bioeconomy policy moves from regional to global



Source: Philp (2018).

Arguably, the bioeconomy focuses on regions. Building future production facilities in regions presents both threats and opportunities, but considerable R&D is still required across a wide range of topics. This speaks more to national-level funding, particularly as biotechnology is strongly dependent on basic science. Further, preventing the over-exploitation of natural resources should be a global effort. Treating policy in these separate but related scales should dispel confusion and direct policy to where specific measures are needed.

Nevertheless, the bioeconomy has many international aspects. Relatively early in the process, various types of publicly funded clusters (regional, biomass, technology) in different countries started to sign formal agreements with clusters from other countries. This is especially evident in the chemical corridor of Northern Europe (Belgium, Germany and the Netherlands).

The Bio-based Industries Joint Undertaking (BBI JU), a EUR 3.7 billion partnership between the European Union and the Bio-based Industries Consortium, is the exemplar of European co-operation not only in research, but also in industrialisation. As of 10 May 2019, the BBI JU had funded 100 projects, with 224 beneficiaries from 27 different countries benefiting from 18 newly awarded project grants totalling just under EUR 85.95 million.

An increasingly important issue in the bioeconomy will be international trade in biomass and bio-based products. The international market for biomass – which is already a world-wide network, mostly for bioenergy applications of biomass – is the most controversial, as evidenced by both trivial and serious international biomass disputes (Bosch et al., 2015) over issues such as illegal logging and deforestation. As the bioeconomy expands, biomass disputes will only worsen, unless measures are found to control the illegal flow of biomass.

Endnotes

[1] Including Australia, Belgium (Flanders), the European Union, Finland, Germany, the Netherlands, the United Kingdom and the United States.

[2] Two additonal Centres of Health Research were under construction in Germany in 2019.

[3] The Australian initiative also includes private co-funding as a selection criterion for centres of excellence.

[4] RAND Corporation is an independent think tank originally established to provide research and advice to the United States Armed Forces. It is financed by US government private endowments and by industry.

[5] https://www.gpo.gov/fdsys/pkg/PLAW-113publ79/html/PLAW-113publ79.htm.

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