Chapter 1.

The bioeconomy concept: Then and now

The bioeconomy concept is expanding rapidly. Around 50 countries, including the G7, have either a national strategy or policies consistent with a future bioeconomy. While many published strategies have laudable goals for solving large societal problems, they lack policy detail. Moreover, the bioeconomy concept means different things in different nations. As a result, gathering comparable metrics is becoming a real challenge. For these reasons, a policy framework for a bioeconomy would be useful for countries to identify their relative strengths and weaknesses, fill policy gaps and understand the bigger picture for the international bioeconomy. This chapter provides an overview for such a framework.

Overview

There is no universally agreed definition of "bioeconomy". Consistent with OECD (2009), this report understands bioeconomy as the set of economic activities in which biotechnology contributes centrally to primary production and industry. This is especially the case where advanced life sciences are applied to the conversion of biomass into materials, chemicals and fuels. Nevertheless, policy must reflect that the bioeconomy has moved beyond biotechnology. It is in fact embedded in the far-reaching transitions that are taking place in energy, transport and industrial production (OECD, 2017).

Momentum has been building for the bioeconomy for over a decade. The OECD set the wheels in motion within the membership with its landmark 2009 publication, *The Bioeconomy to 2030: Designing a policy agenda.* Events of 2015 propelled the bioeconomy concept to the forefront of politics: the Conference of the Parties (COP21), the UN Sustainable Development Agenda and its 17 goals, and the Global Bioeconomy Summit. These events responded to the so-called grand challenges of climate change, energy security, food and water security, and resource depletion. However, the bioeconomy is aligned naturally with more mainstream policy, such as knowledge-driven reindustrialisation, circular economy, smart specialisation, green growth and rural regeneration.

The world has realised that economic growth can be allied to environmental policy goals via a bioeconomy. At least 50 nations (Figure 1.1), including the G7, have put in place national bioeconomy strategies or have policies that are steering towards a bioeconomy (El-Chichakli et al., 2016). Since then, France, Italy, Norway, Spain and the United Kingdom (at least) have produced or are working on dedicated bioeconomy strategies.

Figure 1.1. **How the world is gravitating towards bioeconomy policy**

Note: be = bioeconomy.

Source: Adapted from Bioökonomierat (2018), "Internationale Bioökonomiestrategien", http://biooekonomierat.de/biooekonomie/international.

The transition to an energy and materials production regime based on renewable resources is expected to be fraught with many setbacks and obstacles, technically and politically. Earlier transitions from wood to coal and then from coal to oil were not complicated by the grand challenges faced today. Bennett and Pearson (2009) argued the transition from coal-based to petrochemical feedstocks in the United Kingdom occurred between 1921 and 1967. However, they pointed out the transformation was not inevitable. It was hastened by mass production of cars in the United States in the 1920s. More or less by the end of the 1940s, the United States had a large supply of olefins for transformation to petrochemicals. Diffusion east took time, but by the late 1960s the UK organic chemical production industry was totally transformed to petrochemistry.

Bioeconomy policy makers can take at least one lesson from this: the transformation to a bioeconomy will take time. The energy transition is at least two decades old already and is proving expensive: the cost of *Energiewende*, recently described as "Germany's energy gamble" (Schiermeier, 2013), is expected to top EUR 1 trillion. The world human population is continuing to rise, while stagnating or falling in most of the OECD. Most importantly, the global middle class could increase to 4.9 billion by 2030, with 85% of the growth coming from Asia (OECD, 2010). With middle-class status comes consumption, but also emissions.

Managing the transition towards a bioeconomy largely hinges on the development of advanced biorefineries (e.g. Iles and Martin, 2013; Kleinschmit et al., 2014). The International Energy Agency (IEA Bioenergy Task 42 Biorefinery, 2012) described a biorefinery as "the sustainable processing of biomass into a spectrum of marketable products (food, feed, materials, chemicals) and energy (fuels, power, heat)". This definition suggests that biorefineries should produce both non-energetic and energetic outputs, and applies to product-driven biorefinery processes. Both primary products and energy-driven processes are considered as true biorefinery approaches provided that sustainable processing of biomass is the final goal (de Jong and Jungmeier, 2015). One of the visions for the bioeconomy is of distributed manufacturing in small- and medium-scale integrated biorefineries. However, this flies in the face of massive fossil fuel and petrochemical economies of scale married to gargantuan subsidies for fossil fuel consumption. Further, this is occurring in a world where an explicit price on carbon and carbon taxation is politically difficult.

For bioeconomy policy makers, the future is complex and multi-faceted. As the first generation of bioeconomy policies comes to a close, the vision of a bioeconomy pitched against grand challenges clearly needs better national and international policies to succeed. This part of the book will address policy issues systematically across global, national and regional scales, and where these intersect and interact. It will use a familiar innovation framework to present these ideas, but will adapt the framework to the specific exigencies of the bioeconomy, illustrated by international examples of policy actions.

The global nature of the societal challenges

In common with bioeconomy goals, the climate agreement reached in Paris in 2015 aims at reducing carbon pollution, while creating more jobs and economic growth driven by low-carbon investments (UNFCCC, 2015). On 5 October 2016, with 97 of the 197 Parties to the Convention having ratified the Paris Agreement, the threshold for entry into force was reached. The agreement subsequently entered into force on 4 November 2016.[1]

At least 97% of actively publishing climate scientists agree that climate-warming trends over the past century are extremely likely due to human activities (Cook et al., 2016).

At the heart of the challenge is the need to decouple economic growth from environmental degradation, and particularly to drastically cut emissions (OECD, 2009). The G7 has called for as-close-as-possible to a 70% reduction on 2010 emissions by 2050 (G7 Germany, 2015). However, when a country doubles its wealth, its emissions rise by about 80% (UNEP, 2010).

At the start of mass production of vehicles, all the major oil reserves remained to be found. At the start of the bioeconomy period, fewer new reserves were being added year-on-year. Conventional oil reserves have been in decline since 1980 (Owen et al., 2010). Discoveries of new oil reserves have dropped to their lowest level in more than 60 years, pointing to potential supply shortages in the next decade (Katakey, 2016). For governments and the private sector alike, resource depletion affects many of the grand challenges. But resource depletion also offers opportunities estimated at USD 80 trillion by 2050 (Cayuela, 2013). By 2100, more than 95% of chemicals and polymers may need to be derived from renewable resources (Devaney et al., 2016).

The relationship between challenges and opportunity is at the heart of replacing the oil barrel and building the bioeconomy. Grand challenges need not be insurmountable obstacles leading to economic despair, but rather the chance to rebuild industry and society in a sustainable manner. Such a process could bring jobs and value added through exploitation of biomass rather than fossil resources. This has been explained as a vision of the future in the United States because "the core petroleum-based feedstock is a limited resource and diversification of feedstocks will provide even greater opportunity for the chemical manufacturing industry" (National Academy of Sciences, 2015).

Past energy and production transitions arguably flourished through "more from more", but the bioeconomy may well have to flourish through "more from less". All bioeconomy aspirations depend on supplies of sustainable biomass (Piotrowski et al., 2015). In the post-fossil fuel world, an increasing proportion of chemicals, plastics, textiles, fuels and electricity will have to come from biomass, which creates greater competition for land (Haberl, 2015). By 2050, the world will need to produce 50-70% more food (FAO, 2009), increasingly under drought conditions (Cook et al., 2015) and on degraded soils (Karlen and Rice, 2015; Nkonya et al., 2016). Herein lies one major conundrum for the bioeconomy – reconciling the conflicting needs of agriculture and industry (Bosch et al., 2015). Inevitably food must come first (e.g. SCAR, 2015; El-Chichakli et al., 2016). The extent to which industrial production can rely on biomass is undetermined (Kim et al., 2011; PBL, 2012).

In another conundrum, bio-based products, including biofuels and bioenergy, are not necessarily sustainable. All biofuels are not equal in this regard, and the same applies to other bio-based products. Evidence is amassing (e.g. Hermann et al., 2007; Weiss et al., 2012; Carus, 2017) that bio-based products can offer environmental advantages, such as significant savings on greenhouse gas (GHG) emissions. However, such benefits cannot be assumed, and products need to be treated case-by-case. Further, estimates of environmental impacts of these products vary greatly, becoming a serious impediment to bio-based production. Critics have raised serious misgivings concerning the use of life cycle analysis (LCA) as the sole tool in environment impact assessment (ANEC, 2012). International standards are required to build the credibility of the industry.

Towards a policy framework for the bioeconomy

Momentum is building across the world towards a policy framework for the bioeconomy. Around 50 countries have adopted the bioeconomy in their economic and innovation

strategies. Some have dedicated bioeconomy strategies e.g. Finland, France, Germany, Japan, Malaysia, Norway, South Africa, the United States and the West Nordic countries. Others, such as Austria, Iceland and Tunisia, have plans to develop them. Still others have policies consistent with development of a bioeconomy. These include Australia, Brazil, India, Ireland, Korea, the Netherlands, the People's Republic of China (hereafter "China"), Russian Federation (hereafter "Russia") and Sweden. Bioökonomierat (2015) gives a comprehensive roundup of different national intentions. Countries differ in their priorities, with some focusing more on health and others on bioenergy. Many express the intention to develop a bio-based industry with higher added value products than biofuels or bioenergy.

While national bioeconomy strategies demonstrate intent and commitment, they tend to be short on detail. For this reason, a single document that examines the major policy implications of a bioeconomy, whether a framework is feasible or not, could be useful. Creating such a framework is difficult, however, as the bioeconomy transcends a large range of policy families, including tax, innovation, industry, agriculture, waste and trade. Carus (2014) identified several critical policy areas, many of them under innovation policy. Others can be found in Table 1.1 grouped under three essential categories. These can roughly be translated to supply-side, demand-side and a mixture of both (i.e. cross-cutting measures). This is consistent with the view that both supply- and demand-side policies are needed for effective innovation.

Table 1.1. **Policy inputs for a bioeconomy 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	Knowledge-based capital
Improved investment conditions	Incentives related to GHG emissions (e.g. ETS)	
Technology clusters	Taxes on fossil carbon	
Governance and regulation	Removing fossil fuel subsidies	

Note: R&D = research and development; GHG = greenhouse gas; ETS = emissions trading system.

Source: Adapted from Carus (2014), "Strategy for a rethink of the policy framework for the bio-based economy".

Demand is a major potential source of innovation, yet government policy may not recognise it as such (Edler and Georghiou, 2007). Historically, OECD countries 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 countries and emerging economies such as Brazil and China have used more targeted demand-side innovation policies. These include 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 (OECD, 2011).

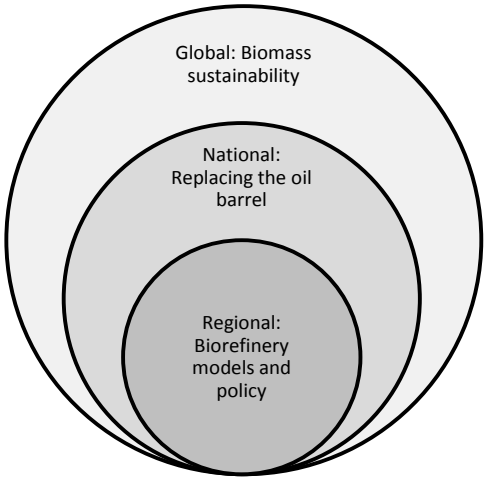
Experience in OECD countries has shown that use of such demand-side policies remains limited to areas in which the market alone cannot meet societal needs (e.g. environment) or in which private and public markets intersect (e.g. energy supply). Both the environment

and energy drive bioeconomy policy goals. This focus on the demand side also reflects a general perception that traditional supply-side policies – despite design refinements over recent decades – have not brought innovation performance and productivity to desired levels.

Policy at multiple scales

The complexity of bioeconomy policy is partly due to the multiple scales of action required (Figure 1.2). These scales range from regional development (e.g. biorefinery deployment) through to national research and development (R&D) into synthetic biology, information technology (IT) convergence and automation to global issues of biomass and its sustainability. The distributed bioeconomy manufacturing model calls for a "glocal" approach i.e. both global and local. It stresses the importance of locating the growing industry close to both raw materials and the goods and energy that are 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. This could prove to be a major challenge (IHS Markit, 2015).

Figure 1.2. **Bioeconomy policy moves from regional to global**



Source: Philp (2018), "The bioeconomy, the challenge of the century for policy makers", http://dx.doi.org/10.1016/j.nbt.2017.04.004.

The bioeconomy arguably has regions at its heart; building future production facilities in regions throws up both threats and opportunities. However, a large amount of R&D is still required across a wide range of topics. This speaks more to national-level funding, especially as biotechnology depends highly on basic science. Further, prevention of over-exploitation of natural resources is a matter for global effort. Treating policy in these separate, but related scales, hopefully removes confusion and points it more directly to where specific measures are needed.

The book may seem to paint a rosy picture of international co-operation with plenty of infrastructure investment and therefore a booming bioeconomy sector. In fact, it demonstrates the beginning of the transition to a new model of production based on decentralisation and sustainability (Il Bioeconomista, 2016). Several countries are strong in bioeconomy research and relatively poor in deployment. In terms of biorefining capacity, perhaps Finland is in the lead. Great hopes are pinned on the cellulosic biorefineries, but

they are worryingly susceptible to technical failure. To date, cellulosic ethanol volumes are still but a trickle and depend on government largesse (Peplow, 2014). Clearly, research progress is way ahead of full-scale deployment, which is not surprising in such a young industry. This book points to the major policy needed to redress the balance between R&D and commercial success – a long and tortuous journey.

Schieb et al. (2015) suggest the need to increase biorefineries to 300-400, both in the United States and Europe, for the industrial bioeconomy to succeed. That represents a very large investment, most of which will need to come from the private sector. The bio-based private sector, however, needs stable and long-term policies to invest in risky projects. Thus governments need to share the same view of the future of the bioeconomy. A view from Australia could be easily generalised to any country: future prospects for industrial biotechnology are "predicated on governments taking a long view of the nation's future strategic position in an industrial world that will be green of necessity" (Glenn, 2017).

Despite its growing pains, the bioeconomy is marching forward. Il Bioeconomista (2015) suggests providing the bioeconomy with a 15-25 year competitive advantage over the fossil industry. At first glance, this seems an expensive option. However, after a century of operation, fossil industries enjoy astronomically high subsidies. Further, even the fossil industry has accepted the reality of climate change, and recognises the need to adapt. Progress is being made when the Rockefeller Family Fund trustees say: "While the global community works to eliminate the use of fossil fuels, it makes little sense – financially or ethically – to continue holding investments in these companies" (Cunningham, 2016). Even Saudi Arabia plans to diversify its economy and end its reliance on oil in the near future (Kingdom of Saudi Arabia, 2017).

Note

1. http://unfccc.int/paris_agreement/items/9444.php.

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Part I.

Biomass sustainability