Innovation and Bioeconomy

Stefanie Heiden and Henning Lucas

Contents

D. Thrän, U. Moesenfechtel (eds.), *The bioeconomy system*,
https://doi.org/10.1007/978-3-662-64415-7_18

18.1 Introduction

The ability to innovate and the innovative activity of national economies are regarded as key success criteria for economic growth. Since innovations are usually associated with extensive investments, they have multiplier and (capital) accumulation effects. Consequently, innovations are considered to be the engine of economic development (Vahs & Brem, 2015). Therefore the word innovation cannot be missing in publications and discourses on the topic of future industries, key technologies and growth (European Commission, 1994). In this context, it suffers a fate similar to that of the term sustainability, which since Brundlandt (1987) has developed into an arbitrary term that occurs everywhere, but whose actual meaning is increasingly fading into the background. It therefore makes sense to begin with a few definitions.

For example, the Enquete-Kommission (1998) states that

> Innovations are processes of renewal or process results, whereby these – depending on the level of explanation – can consist in new products, processes and services, but also in the result of social or organisational change. (Enquete-Kommission, 1998, p. 194)

The National Science Foundation (NSF) emphasises the process, making it clear that innovation is not the same as Invention:

> The innovation process encompasses the entire process from the creation of an idea to its widespread application in society; the process begins with identifying the problem or finding an idea, extends through problem solving and creating production capacity, and ends with the dissemination of the new product to the market. (following NSF, 2010, n.d.)

The OECD Oslo Manual (2005) states that innovation is the introduction of a new or significantly improved product (good or service) or process, a new marketing method or a new organisational method in business/economic practices, workplace organisation or external relations. Innovation activities are all scientific, technological, organisational, financial and commercial activities that actually or intentionally lead to the implementation of innovations. Some innovation activities being innovative in themselves, others being not new activities but necessary for the implementation of innovations. Innovation activities also include research and development that are not directly related to the development of a specific innovation (OECD, 2005). In publications on the topic of innovation management, authors such as Vahs and Brem (2015) are often cited, who define innovation as the targeted implementation of new technical, economic, organisational and social problem solutions that are aimed at achieving corporate goals in a novel way. They thus refer to the result-oriented view of entrepreneurial activity. They distinguish innovation from technology. Technology is understood as collected expert knowledge that builds on a theoretical basis and attempts to develop it further. The focus is on the question of the functional principle, its explanation and description. Only engineering translates the knowledge gained from technology into concrete products and processes. Finally, the activities of research and development bring about changes in technology and engineering. Thomas and Ford (1995) already emphasise that innovation requires more than just knowledge: "not simply the possession of knowledge, but rather the ability to apply that knowledge to a particular problem" (p. 275).

18.1.1 Invention and Innovation

The sustainable increase in corporate success is the starting point, core and goal of any investment in innovation (Hauschildt et al., 2016); for national economies, analogous considerations mean increasing competitiveness through innovation. However, it is significant that the respective understanding of innovation must always go beyond invention and that innovation management sees the shaping of the existing innovation system as its focus.

Invention (Latin *invenire* = to discover, to invent) refers to the results of research and development and is a necessary precursor to innovation; it describes the process from the generation of ideas to the first implementation of a new idea.

In contrast, innovation (Latin *innovare* = to renew) basically refers to the first economic implementation of an idea *(exploitation),* i.e. it refers to the economic use of knowledge and thus to economic success. It encompasses the market launch (in the narrower sense) through to market diffusion or market proof in the broader sense.

18.2 Capital Market, Sustainability and Bioeconomy

The Austrian national economist Joseph Alois Schumpeter defined innovation as the implementation of new combinations with which companies leave the well-trodden paths of the static economy in the pursuit of profit (Röpke & Stiller, 2006). According to Schumpeter, the implementation of new combinations can be understood as the introduction of new production methods, the opening up of new sales markets or new sources of supply (for raw materials or semi-finished products), the implementation of a reorganisation or the manufacturing of a new product.

Schumpeter is regarded as the originator of today's understanding of the causes and effects of innovation through his explanatory approaches to the medium- to long-term development of national economies – by linking technological, economical, psychological and sociological considerations. Schumpeter's idea of the implementation of new combinations, which do not occur continuously but discontinuously, directs the point of view from a superficially technical or technological orientation to an economic one and at the same time organisational problem: innovation is thus not only a topic of natural science and engineering, but equally of economics and management theory; markets and organisation are thus on an equal footing with engineering and production:

Consequently, the three dimensions of "Integrated Innovation Management" include

1. technical innovations (products, processes, knowledge),
2. organisational innovations (structures, cultures, systems, management) and
3. business-related innovations (renewal of the business model, the industry structure, the market structure, its boundaries and the rules of the game) (Zahn & Weidler, 1995).
4. A fourth dimension would have to be added, namely that of the social innovation (political innovation, new lifestyles) (Zapf, 1994).

The current innovation discussions reflect these considerations, as they make it clear that innovation is by no means a privilege of (industrial) companies, but is also of considerable importance for non-profit organisations and thus ultimately for society as a whole. These innovations are also referred to as "post-industrial innovations".

Schumpeter identifies two central groups of actors for the basic phenomenon of economic development in his work "Theory of Economic Development" (1912), namely the (a) dynamic entrepreneurs and the (b) dynamic financiers: the former achieve a competitive advantage through the new combination of production factors and obtain a pioneering position, which helps an economy to achieve higher productivity and a higher level of welfare. The latter make the growth process possible through adequate financing, which makes the combination of the various factors feasible in the first place.

This insight, which is now more than 100 years old, is more relevant than ever, given the continuing difficulties in accessing growth financing and venture capital, especially in Germany: Since 2014, a group of renowned entrepreneurs (CEOs and founders of high-tech companies) has been advocating catchy models with which to mobilise private capital ("1% for the future – making innovations succeed") (E&Y Report, 2014 as well as Mietzsch, 2018) in order to bring about financing for the high-tech/high-risk businesses of biotech companies, as the editors explicitly put it. Thus, financiers of high-tech companies are rewarded for committing to a company for the long term by means of equity participation and also for taking loss risks by exempting income from taxation after a holding period of several years and by bearing losses themselves. This model is intended in particular to replace the federal government's "expensive subsidy programs, which are unsuitable as an instrument". At the same time, incentives should be created to establish new equity funds, with which companies should escape the "financing trap" and innovations could be brought to market.

18.3 Innovation Approaches in the Bioeconomy

In the bioeconomy, various definitions and (self-)understandings of "innovation" are represented, overlap or go hand in hand. For a simplified description here, innovation is understood as processes of renewal, or process results consisting of new products, processes and services, or as results of social and organisational change (transformation). These take place systemically, i.e. through interplay between different actors or groups of actors who are structurally and procedurally interwoven and form an innovation system through iterative interactions.

18.3.1 System Innovation

The bioeconomy as such is often also understood as a "system innovation", as it is linked to the idea of a profound change in a wide range of economic sectors and thus also in society. In various strategies, for example, it is often emphasised that bioeconomic innovations should be set up "in the system". The Institute for Innovation and Technology (IIT) at VDI/VDE Innovation + Technik GmbH, for example, states accordingly that system innovations are technologically based innovations,

> that can be transformed into economically viable and socially accepted products or services if the necessary components and competencies can be integrated into functioning system architectures. They overcome organisational and technical boundaries, are characterised by a functioning interaction of different stakeholders along value creation processes and enable business models that can only be led to success through the acceptance of the relevant actors. (IIT n.d.; o. S.)

System innovations are seen as a necessary response to the pressure of global environmental change, such as climate change. In this context, there is also talk of "transitions to sustainable development" (Grin et al., 2010). On the one hand, these system innovations are characterised by significantly different knowledge bases and technical capabilities (Blind & Quitzow, 2016; Geels, 2002, 2004, 2005, 2006). On the other hand, consumer behavior and markets are also changing. Finally, infrastructures, policies and cultures need to change to enable system innovations. System innovations usually also require new research and development programs or innovation initiatives, but also legal and regulatory changes and improved governance mechanisms. The German "Energiewende" (energy transition) is often cited as an example of system innovation, which ultimately leads to comprehensive political, economic and social changes (SRU, 2013; WBGU, 2011). Finally, it is important to convince and involve all stakeholders relevant for implementation (from entrepreneurs, service providers and trainers, but also users, consumers, NGOs, such as trade unions, environmental associations, etc.) through effective, new methods.

Life sciences and biotechnology are often described as the basis of "systems innovation", which in turn can trigger a wave of invention (The Economist, 2015; Zinke et al., 2016).

18.3.2 Environmental/Ecological and Sustainability Innovations

The European Union (EU) defines eco-innovation in its Action Plan for Eco-Innovation as "any form of innovation that brings about or seeks to bring about substantial and demonstrable progress towards the goal of sustainable development by reducing environmental pressures, enhancing resilience to environmental pressures, or leading to more efficient and responsible use of natural resources" (Europäische Kommission, 2019, n.d.).

In their paper, Blind and Quitzow cite Rennings (2000), who defines environmental innovations as "actions taken by various actors, such as businesses and households, to develop, apply, or introduce new ideas, behaviors, products, and processes to reduce environmental impacts or contribute to other environmental sustainability goals" (Rennings, 2000 in Blind & Quitzow, 2016).

At the same time, policy papers like to express that the bioeconomy always goes hand in hand with ecological advantage, which is why it is often regarded as a "sustainability innovation" (Zinke et al., 2016). According to this understanding, the aim of bioeconomic approaches should be to produce new, sustainably produced products and services using knowledge and biological resources, thus combining economic growth with ecological compatibility (German Presidency of the Council of the European Union, 2007; OECD 1998, 2009; European Commission, 2012). The future belongs to solutions with low CO_2 *impact*: "The business success of tomorrow is born to the low carbon opportunities of today" (Christiana Figueres, Executive Secretary UNFCCC at the CEO Sustainability Forum 2011, p. 3).

18.3.3 Digital Innovations

In recent years, particular attention has been drawn to the advantageous linking of bioeconomy and digitalisation as a new system innovation. The synergies expected from this have led leading German protagonists in the field of as sustainable understood biotechnology to call for a linking of the approaches "biologisation" and "digitisation" at the political level as early as 2015. However, a linkage of these approaches on a political level is currently hardly the case, although recently (2019) some FhG institutes presented "biointelligent concepts" (Competence Center Biointelligence, 2019) in cooperation with with universities from Baden-Württemberg. More detailed information on the topic of the digital bioeconomy can be found in ► Chap. 9.

18.3.4 Innovation Approaches in Bioeconomy Strategies

Bioeconomy strategies reflect different understandings of the bioeconomy. They thus also define the fields in which innovations take place or should take place. Different groups of strategy and thus innovation approaches can be identified:

Technology-Oriented Approaches

- focus on the development and application of modern biotechnology and knowledge from the life sciences and highlight their innovation potential (USA/OECD),
- the uses of biotechnology in the health sector (such as individualised solutions in medicine and pharmaceuticals, so-called red biotechnology) are part of the bioeconomy,
- do not attach any outstanding importance to biomass as a raw material base and
- understand the bioeconomy as the transfer of life sciences knowledge into new, sustainable/ eco-efficient and competitive products (Europäische Kommission, 2005; German Presidency of the Council of the European Union, 2007).

Transformation-Oriented Approaches

- focus on the replacement of petrochemical-based processes and products by biobased ones, and
- include all sectors of the economy involved in the production, processing and use of biological resources.

Resource-Oriented Approaches

- have been gaining acceptance in Europe since around 2010 and
- describe a bio-based economy; they focus on the production of biological resources (plants, animals, microorganisms) and their conversion into bio-based products and bio-energy.

18

Business-Oriented Approaches

- are closely linked to resource-oriented approaches/definitions and
- in general, the bioeconomy includes agriculture and forestry as well as all manufacturing sectors and related services that develop, produce, process or in any way use biological resources (Bioeconomy Council, 2009a, b; Bioökonomie, 2012; BMBF, 2010; BMEL, 2014).

Goal-Oriented Approaches

These approaches still contain a normative component, as can be seen in the definition of the bioeconomy by the German Bioeconomy Council (▶ Chap. 1). All strategies share, to a greater or lesser extent, the expectation that new findings, particularly in the life sciences, and the resulting innovations will lead to economic growth, improved international competitiveness and new jobs. The expectations of the last decades for biotechnology and the life sciences are therefore being continued in this context.

In the vast majority of strategies, biotechnology is seen as a key technology. The aim is to integrate biotechnology across different sectors of the economy. In contrast to the past, the bioeconomy is also opening up to other fields of technology and innovation approaches.

In recent years, the integration of research and innovation has gained increasing political importance (Aguilar et al., 2013). This is also reflected in bioeconomy strategies. With the increasing importance of the goal of promoting innovation, various fields of action to improve the framework conditions for innovation are integrated into the strategies beyond research policy approaches. The integration of different policy fields is most pronounced in the Federal Government's interministerial policy strategy for the bioeconomy (BMEL, 2014). It is embedded in other strategies ranging from the High-Tech

Strategy 2020 (HTS) to the National Sustainability Strategy in order to ensure that bioeconomy policy is both a consistent part of a comprehensive technology and innovation policy as well as a part of the sustainability policy. Thus, from the perspective of innovation research, a necessary embedding in a present dynamic and innovative knowledge society takes place.

18.4 Germany as a Location for Innovation

In 2016 no other European country spent as much money on innovation as Germany, as the EFI Report and the studies of the eponymous Expert Commission on Research and Innovation of the German Federal Government impressively confirm (EFI, 2018 ff.). Innovation intensity measures the share of innovation expenditure by the German economy in relation to turnover. This was 3% in Germany in 2016, as much as in the previous year. According to the Centre for European Economic Research (ZEW), innovation expenditure by German companies amounted to €158.8 billion in 2016, of which over 75% was attributable to industry: Compared to the previous year, innovation expenditure increased by 2% (BMBF, 2018). The increase in innovation expenditure in 2016 was not only driven by large companies, but also by small and medium-sized enterprises (SMEs). Since the late 1990s, a gap in innovation intensity has increasingly opened up between large companies and SMEs. While large companies allocate 3.8% of turnover to financing innovation activities, the figure for SMEs is only 1.4%.

The innovator rate measures the proportion of companies that have introduced at least one product or process innovation within a 3-year period. Overall, around 36% of companies were innovators in 2016, compared with 35% in 2015. This means that the decline in the innovator rate that has been observed for several years, which can also be seen in most other EU member states, did not continue in Germany for the time being.

The industry sectors electronics, metrology and optics as well as pharmaceuticals, chemicals and other vehicle manufacturing have the highest innovator rates. In a European comparison, Germany continues to occupy a top position for this indicator. In 2016, the German economy achieved sales of €719 billion with product innovations, around 3% more than in the previous year. The share of sales with new products in total sales was almost unchanged in 2016 compared to the previous year at 13.6%. The share of sales generated with product innovations is above average, especially in industries that are intensively determined by research and development (R&D) (vehicle manufacturing, electrical industry and mechanical engineering).

The investments of science and industry in R&D are reflected in economic returns when inventions become innovations that reach the market and diffuse widely. Market novelties represent a higher degree of novelty, as the corresponding innovation has not been offered on the market before. More than 8% of all German companies were the first to introduce market novelties in 2016. The sales generated with them amounted to around €154 billion. The share of market novelties in total sales was around 3% in 2016.

The international competitiveness of knowledge-based economies is reflected in trade in research-intensive goods. In 2016, research-intensive products accounted for 46% of total world industrial exports. Of these, 16.4% were advanced technologies and 29.6% were high-value technology. The share of research-intensive products in total industrial trade in goods has been increasing again since 2013. In 2016, Germany's share of global trade in research-intensive goods was 11.6%. In a European comparison, Germany thus occupies a top position.

However, with a global share of 14.6%, China is now the largest exporter of research-intensive goods.

Germany is considered one of the most innovative economies in the world: this is reflected not only in the innovation ranking according to the European Innovation Scoreboard (EIS) of the European Commission (EC), but also in the two international innovation indices, the Global Innovation Index (GII, Cornell University) and the Global Competitiveness Index (GCI, INSEAD and WIPO), in which Germany is ranked between fifth and ninth place and is on a par with the USA, Japan and Sweden, and ahead of China and South Korea.

Germany's particular strengths are highlighted as the high share in R&D expenditure of private business enterprises and its patenting activities (Fig. 18.1). In addition, the work of clusters is viewed positively. Switzerland leads various innovation rankings (BMBF, 2018).

Against this background, reference should also be made to the results of the current report of the EFI Commission 2019 (EFI, 2018 et seq.), which explicitly praises the High-Tech Strategy 2025 (Federal Government 2018; Bundesregierung (2018)) (adopted by the Federal Cabinet in September 2018): this formulates the goal of spending funds amounting to 3.5% of gross domestic product on R&D by 2025. It also refers to the importance of start-ups for the country's innovation capability and competitiveness: These pursue new business models, expand and modernise the range of products and services with their innovations. Start-ups from science play an important role in the transfer of knowledge and technology into practice. According to EFI, start-ups are also considered trend scouts and impulse generators for established companies. As cooperation partners of established companies, they contribute to the joint development and marketing of innovations.

Start-ups, and this is specifically emphasised in the EFI report, still have problems in Germany – especially in the growth phase – in obtaining venture capital. They also face specific challenges due to their size and their business models, which are partly set or influenced by legal framework conditions. Against this background, the Expert Commission makes the following recommendations, among others:

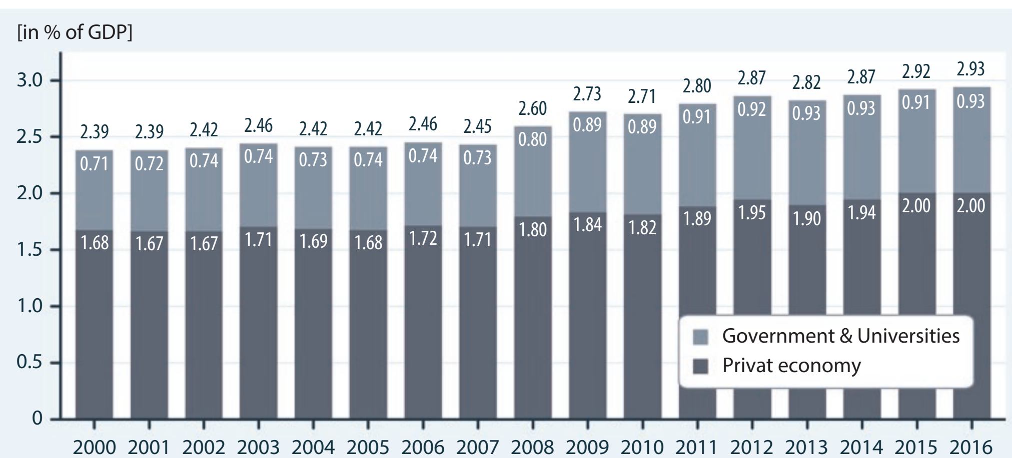


Fig. 18.1 Share of R&D expenditure in percentage of GDP and devided into public and privat spending. Higher amounts of privat R&D spending are accompanied by higher amounts of public spending as well. (Stifterverband für die deutsche Wirtschaft, 2016, p. 2)

18

- In order to promote start-ups from science, the start-up culture at universities must be further strengthened.
- Start-up education should be embedded in all degree programs.
- Universities and non-university research institutions should develop standard licence agreements for the transfer of rights to spun-off start-ups in order to enable start-ups to be licensed quickly.
- The framework conditions for private investment in start-ups are to improve further. Since there is a lack of anchor investors in Germany, the Expert Commission advocates providing incentives for institutional investors to invest more in venture capital. In addition, the VAT obligation for administrative services provided by fund managers should be abolished.

In countries such as the USA, Canada and Israel, functioning capital markets *(private equity markets)* for innovative companies have developed over decades. The success of these economic areas, especially in the pharmaceutical sector, but also in software/IT and the Internet, is largely due to these groups of actors. Interestingly, direct state intervention, subsidies or research funding in favour of new companies are of rather little importance in these economic areas. Instead, tax incentives on the investor side or the adaptation of capital market regulations to the needs of small and medium-sized enterprises (such as JOBSAct USA 2014) are used as instruments that can bring about enormous momentum.

The consideration of the EFI recommendations as well as the analogous adaptation of these exemplary, functioning innovation systems to the specific German and/or European conditions in each case are of decisive importance for the full exploitation of the potentials resulting from the life sciences for the bioeconomy.

18.5 Sustainable Finance

18.5.1 The Capital Market as a Driver of Sustainable Development

The publications of Sir Nicholas Stern, Chief Economist of the European Bank for Reconstruction and Development from 1994 to 1999 and Chief Economist and Vice-President of the World Bank from 2000 to 2003, in 2006 and 2009, which did nothing more than reverse the prevailing benefit-cost analyses of climate change mitigation, clearly made an impression on the financial community (Stern, 2006, 2009). Stern, for example, called for sustainability-oriented economics and posits that "greenhouse gas emissions represent the greatest market failure in the history of the world." The global economic costs of climate change without further climate protection measures, according to one result, will burden global economic output by around 5–20% by 2050.

The most important catalysts for *sustainable finance development* are therefore the Paris Climate Change Conference in December 2015, at which the 2-degree target for limiting global warming was agreed, and the international agreement on the 17 Sustainable Development Goals (SDGs). In the context of these two initiatives, numerous new developments have also been initiated in the financial market. For example, at the beginning of 2016, the G20 states established a Green Finance Study Group (since renamed the Sustainable Finance Study Group) to address environmental aspects in the financial sector. Decisive impetus also came from the Task Force on Climate-related Financial Disclosures (TCFD), based at the Financial Stability Board, which has been working intensively on the development of voluntary and uniform disclosures on climate-related financial risks. The debate was further intensified by the establishment of the High-Level Expert

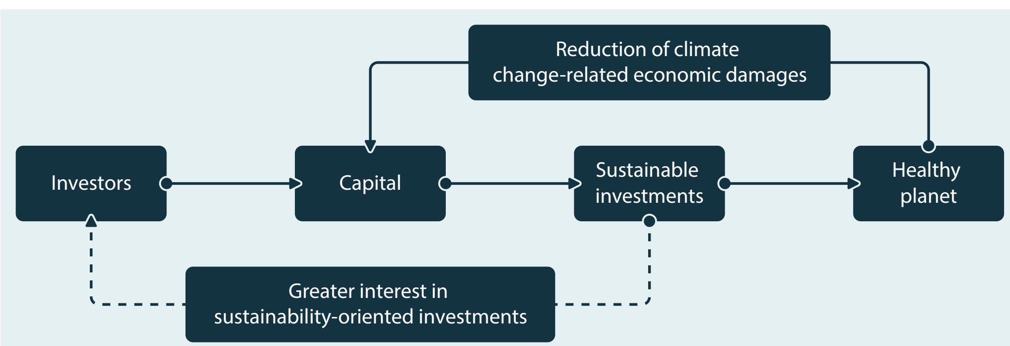
Group on Sustainable Finance (HLEG) by the European Commission at the end of 2016 (see also European Commission, 2012, 2013, 2014, 2015). The recommendations of these groups and bodies included the following

- the introduction of a *sustainable finance classification framework*,
- the revision of publication requirements,
- more transparent information for retail investors,
- the development of official European sustainability standards (e.g. for green bonds), and
- the stronger anchoring of sustainability aspects in the governance of financial institutions as well as in financial supervision.

Following on from this preparatory work, in 2018 the EC finally presented the EU Action Plan "Financing Sustainable Growth", which aims to direct capital flows towards sustainable investments in order to achieve sustainable and inclusive growth (European Commission, 2018) (▪ Fig. 18.2). It also aims to be able to manage the financial risks arising from climate change, resource depletion and environmental degradation, and social problems. Furthermore, the aspects of transparency and long-termism in financial and economic activities should be supported. The EU resolution on Sustainable Finance also commits the financial world to sustainability. It was adopted in the EU Parliament on 29 May 2018 by 455 votes (with 87 against and 92 abstentions). The report itself states that it is particularly important to have a policy framework that guides investments towards decarbonised, disaster-resilient and resource-efficient economic activities.

18.5.2 Sustainable Bioeconomy as an Investment Opportunity

A sustainable bioeconomy is seen as a promising investment opportunity by global financial markets: Private and institutional investors are increasingly interested in socially responsible forms of investment, also known as SRI *(sustainable and responsible investment)* or ESG-led investments, where ESG stands for *environmental-social-and-governance criteria,* i.e.: environmental, social and good corporate governance criteria. The focus is no longer solely on the desire for a clear conscience, which favors this investment segment. Rather, numerous investors are increasingly using the methodology of sustainability funds for the management of traditional investment funds: for example, sustainability criteria are also used as early warning systems by many fund com-



▪ **Fig. 18.2** EU Sustainable growth action plan – investing in a sustainable future for our planet. (Source: Illustration according to European Commission, 2018) panies such as DWS or Invesco Ltd. among others, in order to identify risks in good time before they are reflected in the quarterly reports of companies and thus in the share price (FNG, Berlin, n.d.).

In return for these investing strategies, securities of companies without corresponding sustainability efforts are restricted or sold off. Capital investments in the area of sustainable impact investing are growing steadily. According to the Forum for Sustainable and Responsible Investment (US SIF), at the end of 2017, approximately US$12 trillion in assets in the US were invested in SRI strategies. Numerous examples of this trend exist. For example, the World Bank announced at the end of 2017 that it would no longer invest in oil production projects or coal mining from 2019 onwards; only in exceptional cases to prevent social problems in poorer countries will this still be done in the future. The Norwegian parliament had already decided in mid-2015 to withdraw the sovereign wealth fund – with a volume of the equivalent of more than €800 billion one of the largest and most successful funds of its kind – from companies where climate-damaging coal transactions generate more than 30% of the business. At the same time, Allianz SE in Germany made the same strategic shift. In May 2018, Allianz followed suit and since then has refrained from individual insurance of coal-fired power plants and coal mining projects; by 2040, the company says it wants to have completely withdrawn from the coal business.

18.5.3 Significant Growth Potential of Sustainable Solutions

As early as 2010, Roland Berger estimated that the lead markets for environmental technology (including renewable energies, raw-material-efficient and energy-efficient products and processes, recycling and water treatment technologies) had a global sales volume of around US$ 1.7 trillion. By 2020, this figure is expected to reach around US$ 3.2 trillion, which would correspond to an average growth of 6.5%. In view of these targets, there are already numerous biobased solutions that make a sustainable bioeconomy an interesting investment with high returns. Analyses by the DIW, the Fraunhofer Institute for Innovation and Systems Research ISI and the strategy and management consultancy Roland Berger, commissioned by the Federal Ministry of Economics and Technology, show that from 2020 onwards environmental technologies will be more important in Germany than the entire automotive industry. These analyses once again demonstrate the effectiveness of "creative destruction" in Schumpeter's sense.

18.6 Biotechnology – Driver of Sustainable Problem Solutions

One of the key disciplines underpinning a new economic cycle is biotechnology, which is highly innovative. Due to its broad positioning, its numerous fields of application and methods, and its consideration of the findings of millions of years of evolution, it offers a promising problem-solving potential based on resource optimisation and cycle management (Heiden & Zinke, 2006). In this context, biotechnology itself represents the integration of many disciplines and in turn interacts with many areas of science and technology. It represents a cross-sectional discipline that has long since transcended the classical disciplinary boundaries (see ► Chap. 9). By integrating *proteomics, metabolomics, transcriptomics, genomics, genetic engineering,* biochemistry, microbiology, bioinformatics and digitalisation, it stands as a *pars pro toto* for living *open innovation* (Heiden et al., 2001). On the one hand, it deals with questions of basic research, and on the other hand with very concrete questions of industrial practice or societal needs in a changing world. Broad penetration in the sense of a sustainable transformation of society as a whole will only be achieved if it is possible to involve all relevant stakeholders at an early stage focusing on all their needs. The normative analogies between the risk assessment of civilian use of nuclear energy on the one hand and the use of biotechnology/genetic engineering on the other can be attributed to some extend to the failure to involve all stakeholders and represents an obstacle to innovation today.

Even today, sustainability is not only seen in a positive light, but is always associated with "cost driving": This was already noted by Dyllick et al. (1997): in 1995, around 77% of all companies surveyed on behalf of the European Commission stated that the legally induced environmental protection measures they had implemented had a cost-increasing effect. In ecologically particularly important industries the share of environmental protection investments of total investments ranged from 15% to 30%. As the Federal Statistical Office pointed out in 1996, current environmental protection expenditure in these sectors amounted to up to 5% of turnover. At the same time, however, 82% of all environmental protection investments in Germany in 1989 were still attributable to *end-of-pipe measures*. On the one hand, it is therefore not surprising that environmental protection measures are perceived by companies as a cost factor; on the other hand, however, this also disproves the frequently expressed prejudice that the presentation of the cost-increasing effect of environmental protection measures is purely a business defence strategy. In summary, additive responses (*end-of-pipe* or *add-on technologies*) to environmental protection requirements will probably always be a cost factor, but never a productivity factor.

By contrast, the situation is quite different with production-integrated environmental protection measures (PIUS), which reduce the use of raw materials and energy and, once implemented, cause lower running costs than *end-of-pipe technologies* (energy, material and personnel input). Production-integrated environmental protection measures can create both strategic and concrete competitive advantages. Environmental protection thus becomes a productivity factor (Bringezu, 1997).

However, this means for the understanding of **integrated or white biotechnology** that it can also be used in all other fields of application and contribute to sustainable development – for the company concerned as well as for society as a whole. And it is precisely this understanding that is reflected in the BIOECONOMY programs, which are being pursued with great verve by politicians and innovative companies worldwide.

The fascination and enormous potential of this technology can be seen in the interdisciplinary approach inherent in biotechnology, which has long since overcome the conventional boundaries of classical scientific fields. With its approaches, it will be possible to develop and establish energy- and resource-efficient processes and products on the market and to promote the change towards a sustainable society. Biotechnology is and will continue to be a driving force of a new, sustainability-oriented Kondratieff wave. This means that biotechnology is of a similar importance as it is currently attributed to digitalisation by some analysts and researchers. Perhaps we should even go as far as to describe this age as an era **of digitalisation and biologisation**.[1]

The success of the bioeconomy will be closely linked to innovations and research and development approaches in the field of digitalisation: On the one hand, this stands

1 Acatec prefers the concept of biological transformation.

for a comprehensive, currently only rudimentary, social change, on the other hand, for an industrial, in part quite revolutionary change. New digital technologies, such as cloud computing or big data, can realise a rapid networking of different industrial sectors and companies (SMEs, large companies and service providers): Material, machines and plants begin to communicate with each other in real time via the Internet in so-called smart production facilities *(smart factories)*, exchanging information and even coordinating complete manufacturing processes independently. At the same time, production and logistics can be linked along the entire industrial value chain. More resource- and energy-efficient production, process intensification, flexibility and individualisation (in manufacturing) will become possible, and this will significantly strengthen the competitiveness of companies (Fischer-Kowalski et al., 2014; Heiden & Zinke, 2006). Such objectives were already called for and published by the Enquete Commission "Protection of People and the Environment" of the 12th German Bundestag (1994): "Shaping the Industrial Society – Perspectives for a Sustainable Handling of Material and Substance Flows".

In such a networked world of business, new business models are also emerging at an enormous speed. Existing industry boundaries are being broken down, digital companies are conquering new markets and start-ups are challenging long-established market players in competition. In order to continue to survive in the market, it is particularly important for established companies to review the existing business model for possible potential for integrating these new technologies, to buy out start-ups if necessary and to develop completely new business models.

Schumpeter describes innovation as the creative destruction of what already exists (Schumpeter, 2006, 2008); and since all change brings with it resistance, for all the lip service paid to innovation in general, one should be prepared for the fact that innovations are not welcome in case of doubt. Thus, it is not surprising that D'Este et al. (2012) find that across industries, a strong relationship has been empirically established between the level of innovation activity and the extent of relevant financial, knowledge, market and regulatory barriers. For example, Hauschildt et al. (2016) in their book Innovation Management hold that the "history of innovation is a never-ending story of resistance to" the same (Hauschildt et al., 2016, p. 31). The authors sharpen their description of resistance to innovations in the following statement: "Resistance to innovations arises from the fact that the individual concerned is actually or supposedly unable to cope with these intellectual demands" (ibid., p. 40).

18.7 Will the New Kondratieff Wave Be a "Green" Wave?

The social insight into the urgency and necessity of transformation, as well as the availability and development of new key technologies (digitalisation, biologisation, environmental protection technologies …) will trigger a historically exemplary megatrend, which some authors already call a new, "green" (or sustainable) Kondratieff wave:

Five long growth waves can be identified since the Industrial Revolution at the end of the eighteenth century (see ◘ Figs. 18.3 and 18.4): the wave triggered by the steam engine, followed by the new wave triggered by the innovations of steel and railways. They were succeeded by chemistry and electricity, before petrochemistry and the automobile became established. The last wave so far was characterised by information and communication technologies.

Kondratieff waves	1st wave	2nd wave	3rd wave	4th wave	5th wave
Period	1780 - 1830	1830 - 1880	1880 - 1930	1930 - 1970	1970 till present
Basis innovation	Steam engine	Railway, steel	Electricity, chemistry	Automotive, petrochemistry	Information and communication technology, digitalization
Demand	Textile industry	Mass transport	Mass production	Individual mobility	Information, communication,-networking
Epoch	Early to late industrialization			Service economy	Knowledge society, Society of health and life sciences

Fig. 18.3 Kondratieff cycles. (Source: Own representation based on Bullinger, FhG)

18.7.1 Departure through Crises

Common to all emerging waves of growth is the crisis that precedes each one and leads to the breaking of the old cycle (see Fig. 18.4); from each crisis a new upswing emerges: be it the Panic of 1837, the Founders' Crisis of the late nineteenth century, the Great Depression of the 1930s, or even the two oil price crises of the 1970s of the twentieth century. The "creative destruction", as the Austrian economist Joseph Schumpeter put it, was always at the beginning of the new. Yet Nikolai Kondratieff already noted that a long cycle of growth, which permeates and transforms the economy and society, passes through a maturation phase, loses strength and finally ends in crisis. The newly created infrastructure remains and with the upswing of the next cycle the crisis is passed and survived.

The prerequisite for any new upswing are new underlying innovations and key technologies, which are carried across the board by growing demand. Demand, in turn, is driven by the productivity bottleneck factor. Only when this bottleneck factor has been overcome can new productivity gains be unleashed.

Clearly, crises are indispensable elements of our economic history: each of the Kondratieff cycles observed since the discovery of the steam engine at the end of the eighteenth century has ended in a crisis, followed by a long upswing. The resulting prosperity of a broad population over the past 200 years or so – especially in the industrialised countries – is probably unique in historical terms. Thus, one could agree with the statement of the Allianz Global Investors analysts (AGI, 2010) that the history of our prosperity is also the history of the associated crises.

The cycles described are thus always characterised by periods of technological upheaval and are similar in their consequences: old industries are being displaced by new ones; corporate cultures and processes change, new occupational fields are emerging and phases of long-term growth in prosperity lasting several years go hand in hand. In the past, these were always associated with rising CO_2 emissions, which will be different in the new cycle, as these develop-

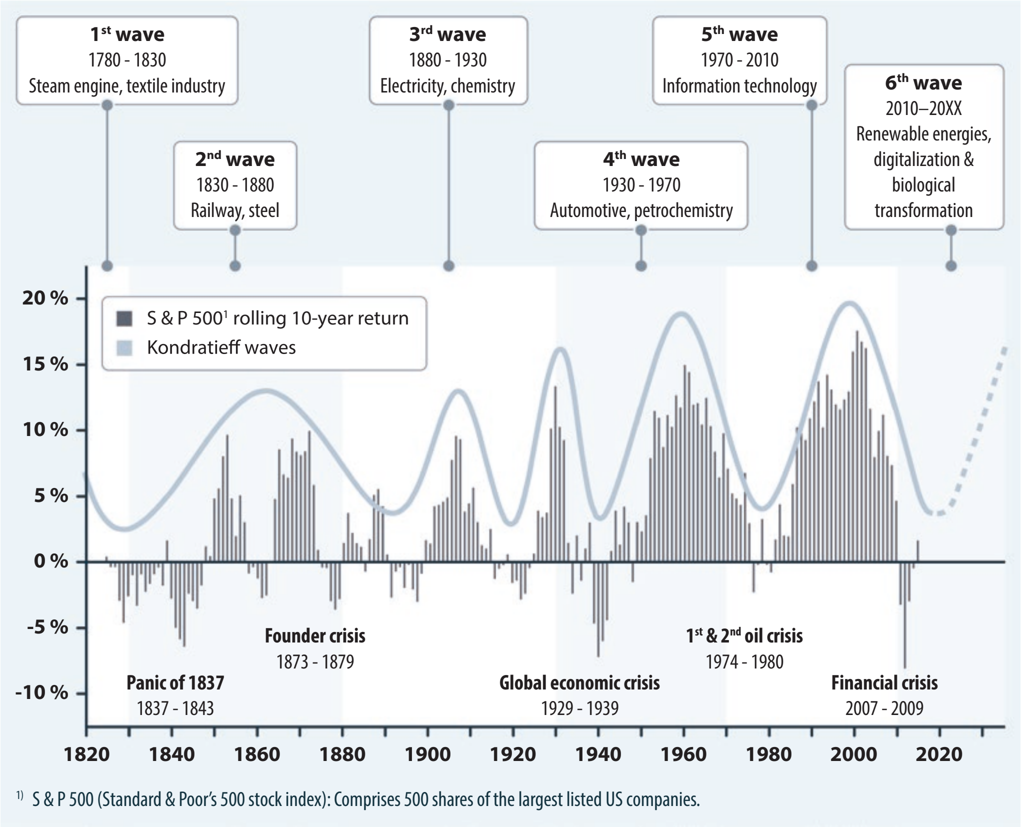


Fig. 18.4 Historical view of Kondratieff cycles: history of prosperity prosperity and associated crises. (Source: Illustration according to AGI, 2010)

ments focus on sustainable solutions and thus on decoupling prosperity and greenhouse gas emissions.

In the present and near future, we are experiencing changes in our knowledge-based society through innovations in the fields of communication technology, digitalisation, artificial intelligence and "biologisation" (biotechnology, *bioeconomy*), among others, which have already greatly changed our lives and will continue to do so in the future (see also Geels, 2005).

Moreover, we can attribute an important role of financial markets and their developments to each of the structural cycles considered: For example, high levels of debt, excessive speculation and inflated asset price bubbles played an important role, ultimately contributing to the termination of the respective cycles. Financial analysts even go so far as to attribute the decisive role in this downturn to them: At the same time, they also attribute to financial markets the role of accelerator of a new recovery[2]: after the crisis, entrepreneurs need a lot of money to spread and penetrate the more productive techniques in the market. Once the markets are developed, the demand for credit falls, real interest rates fall towards zero, and the process repeats itself. These cyclical processes with their different consequences are

2 For more information, see ► https://ch.allianzgi.com/en-gb/en-insights/market-updates/capital-markets-m-..onthly

now also the subject of popular business magazines and newspapers, such as Wirtschaftswoche or Handelsblatt (see, for example, Hanke, 2012 or Müller, 2010), whereby it is also emphasised that the view of economists on seemingly obvious analogies is quite differentiated.

18.8 Outlook

While in the previous economic cycles of the past 200 years the factor labour was the primary economic bottleneck factor, this role in the twenty-first century will be attributed to the bottleneck factors energy and raw material resources with their implicit environmental effects. This means that the focus is no longer on increasing labour productivity in order to secure our prosperity, but on increasing resource and energy productivity as a driver for securing quality of life, prosperity and peace.

Under the changed conditions of globalisation, demographic development, climate change and resource scarcity, as well as a growing sense of responsibility for the one world, growth will be generated in the future by sustainable solutions/innovations that contribute to the decoupling of quality of life (economic growth) and nature consumption (see Hennicke, 2010; Stern, 2006, 2009). This is precisely where biotechnology makes important contributions.

Bioeconomy and digitisation address all relevant megatrends through meaningful linkages, i.e. globalisation, urbanisation, demographic change, energy and resources, environmental and climate protection, health, mobility, knowledge-based society, and living and working (see Federal Government, 2018).

The success of this approach will essentially result from the successful participation of actors from the most diverse courses of life in society, thus addressing needs that exist not only at present but also in the long term and are also subject to enormous change in view of the global challenges facing society.

In order to fill such a far-reaching linkage with life in the long term, however, a courageous and formative policy is required that sets out to champion the issue, including through legislative, fiscal and interdepartmental – at both national and international level. The necessary instruments are well known. The urgency of such a call becomes apparent not only when looking at the distribution of R&D funds in the BMBF Report 2018, but especially when considering the situation of life science companies in comparison with the USA or other European countries.

Always keep in mind what Privy Councillor Johann Wolfgang von Goethe urged in his time: “It is not enough to know, one must also apply; it is not enough to want, one must also do.”

A sustainable bioeconomy and its underlying technologies will play the role of pacemaker and engine for establishing a major transformation. Digitalisation and biologisation, and especially their interconnection, are the drivers of a new dynamic of sustainably oriented growth, a “green” Kondratieff wave.

References

AGI (Allianz Global Investors Kapitalmarktanalyse). (2010). *Der 6. Kondratieff – Wohlstand in langen Wellen*. https://pfafi.de/wp-content/docs/4115722-1696571-AGI-Analysen—Trends-Der-6.-Kondratieff—Wohlstand-in-langen-Wellen.pdf

Aguilar, A., Magnien, E., & Thomas, C. (2013). Thirty years of European biotechnology programmes: From biomolecular engineering to the bioeconomy. *New Biotechnology, 30*(5), 410–425.

Bioökonomie (2012). Empfehlungen aus dem BioÖkonomieRat 04. Arbeitsperiode 2009–2012. *Weiterentwicklung des Förderinstrumentariums von öffentlicher und privater Forschung im Hinblick auf die Anforderungen der Bioökonomie-Empfehlungen des BioÖkonomieRats.* www.bioökonomierat.de. Accessed 30 Mar 2020.

BioÖkonomieRat. (2009a). Berichte aus dem BioÖkonomieRat 04. Arbeitsperiode 2009–2012. *Empfehlungen zum Aufbau einer wettbewerbsfähigen und nachhaltigen Bioökonomie – Beiträge der Industriellen Biotechnologie zum wirtschaftlichen Wandel in Deutschland; Positionspapier der AG Biotechnologie des BioÖkonomieRats*. www.bioökonomierat.de. Accessed 30 Mar 2020.

BioÖkonomieRat. (2009b). Empfehlungen aus dem BioÖkonomieRat 01. Arbeitsperiode 2009–2012. *Kompetenzen bündeln, Rahmenbedingungen verbessern,internationale Partnerschaften eingehen Erste Empfehlungen zum Forschungsfeld Bioökonomie in Deutschland*. www.bioökonomierat.de. Accessed 30 Mar 2020.

Blind, K., & Quitzow, R. (2016). Nachhaltige Innovationen. Aktueller Stand der Forschung und Ausblick aus innovationsökonomischer Perspektive. In G. Gordon & A. Nelke (Eds.), *CSR und Nachhaltige Innovation. Zukunftsfähigkeit durch soziale, ökonomische und ökologische Innovationen* (pp. 13–24). Springer Gabler.

BMBF. (2010). *Nationale Forschungsstrategie Bioökonomie 2030*. Unser Weg zu einer biobasierten Wirtschaft. bmbf.de/pub/biooeokonomie.pdf.

BMBF (Bundesministerium für Bildung und Forschung). (2018). *Bundesbericht Forschung und Innovation 2018. Forschungs- und innovationspolitische Ziele und Maßnahmen*. https://www.bmbf.de/upload_filestore/pub/Bufi_2018_Hauptband.pdf.

BMEL (Bundesministerium für Ernährung und Landwirtschaft). (2014). *Nationale Politikstrategie Bioökonomie. Nachwachsende Ressourcen und biotechnologische Verfahren als Basis für Ernährung, Industrie und Energie*. https://www.bmel.de/SharedDocs/Downloads/Broschueren/BioOekonomiestrategie.pdf?__blob=publicationFile

Bringezu, S. (1997). *Umweltpolitik: Grundlagen, Strategien und Ansätze ökologisch zukunftsfähigen Wirtschaftens*. R. Oldenbourg.

Bundesregierung. (2018). *Forschung und Innovation für die Menschen. Die High-Tech Strategie 2025*. https://www.hightech-strategie.de/files/HTS2025.pdf

D'Este, P., Iammarino, S., Savona, M., & von Tunzelmann, N. (2012). What hampers innovation? Revealed barriers versus deterring barriers. *Research Policy, 21*(2), 482–488.

Dyllick, T., Belz, F., & Schneidewind, U. (1997). *Ökologie und Wettbewerbsfähigkeit von Unternehmen*. Hanser Fachbuch.

EFI Report. (2018). *Gutachten und Studien*. www.e-fi.de/gutachten-und-studien/gutachten

Enquete-Kommission "Schutz des Menschen und der Umwelt" des 12. Deutschen Bundestages. (1994). *Die Industriegesellschaft gestalten – Perspektiven für einen nachhaltigen Umgang mit Stoff- und Materialströmen*. http://dip21.bundestag.de/dip21/btd/12/082/1208260.pdf

Enquete-Kommission "Schutz des Menschen und der Umwelt" des 13. Deutschen Bundestages. (1998). *Konzept Nachhaltigkeit – Vom Leitbild zur Umsetzung*. http://dipbt.bundestag.de/doc/btd/13/112/1311200.pdf

Europäische Kommission. (2005). Janez POTOCNIK, Europäischer Kommissar für Wissenschaft und Forschung, stellt erstmals in seiner Rede das Konzept "Transforming life sciences knowledge into new, sustainable, eco efficient and competitive products" vor, im Rahmen der "Conference on Knowledge-based bio-economy", Brüssel, September 2005.

Europäische Kommission. (2019). *Der Aktionsplan für Öko-Innovationen*. https://ec.europa.eu/environment/ecoap/about-action-plan/objectives-methodology_de. Accessed 05 Sept 2019.

European Commission. (1994). *Growth, competitiveness and employment: The challenges and ways forward into the 21st century*. https://publications.europa.eu/en/publication-detail/-/publication/0d563bc1-f17e-48ab-bb2a-9dd9a31d5004

European Commission. (2012). *Innovating for sustainable growth. A bioeconomy for Europe*. http://bookshop.europa.eu/en/innovating-for-sustainable-growth-pbKI3212262

European Commission. (2013). *Options for strengthening responsible research and innovation: Report of the expert group on the state of art in Europe on responsible research and innovation*. https://ec.europa.eu/research/science-society/document_library/pdf_06/options-for-strengthening_en.pdf

European Commission. (2014). *Bioeconomy information system and observatory project*. Set up of the Bioeconomy Observatory. Methodology Report. https://biobs.jrc.ec.europa.eu

European Commission. (2015). *The Paris Protocol – A blueprint for tackling global climate change beyond 2020*. https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1425546396765&uri=COM:2015:81:FIN

European Commission. (2018). *Financing sustainable growth*. European Commission Action Plan. https://ec.europa.eu/info/sites/info/files/180308-action-plan-sustainable-growth-factsheet_en.pdf. Accessed 05 Sept 2019.

E&Y Report (Ernst and Young). (2014). *1% für die Zukunft. Innovation zum Erfolg bringen*. Deutscher Biotechnologie-Report 2014. https://www.ey.com/Publication/vwLUAssets/ey-biotech-report-2014-1-prozent-fuer-die-zukunft/$FILE/ey-biotech-report-2014-1-prozent-fuer-die-zukunft.pdf. Accessed 05 Sept 2019.

Figueres, C. (2011). *CEO sustainability fourm*. Address by Christiana Figueres, Executive Secretary

United Framework Convention on Climate Change. https://unfccc.int/files/press/statements/application/pdf/110926_speech_ceo_sustainability.pdf. Accessed 05 Sept 2019.

Fischer-Kowalski, M., von Weizsäcker, E. U., Ren, Y., Moriguchi, Y., Crane, W., Krausmann, F., Eisenmenger, N., Giljum, S., Hennicke, P., Kemp, R., Romero Lanko, P., & Siriban Manalang, A. B. (2014). *Decoupling natural resource use and environmental impacts from economic growth: Report of the Working Group on Decoupling to the International Resource Panel*. http://www.gci.org.uk/Documents/Decoupling_Report_English.pdf. Accessed 16 Sept 2019.

FNG, Berlin. (n.d.). *Forum Nachhaltige Geldanlagen, Fachverband für Nachhaltige Geldanlagen in Deutschland, Österreich, Liechtenstein und Schweiz*. https://forum-ng.org/de

Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. *Research Policy, 31*(8–9), 1257–1274.

Geels, F. W. (2004). From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. *Research Policy, 33*(6–7), 897–920.

Geels, F. W. (2005). *Technological transitions and system innovations: A co-evolutionary and socio-technical analysis*. Elgar.

Geels, F. W. (2006). *System innovations and transitions to sustainability: Challenges for innovation theory*. Paper, presented at the SPRU 40th Anniversary Conference, 11–13 September 2006.

German Presidency of the Council of the European Union. (2007). *En route to the knowledge-based bio-economy*. https://dechema.de/dechema_media/Downloads/Positionspapiere/Cologne_Paper-p-20000945.pdf

Grin, J., Rotmans, J., & Schot, J. (2010). *Transitions to sustainable development: New directions in the study of long term transformative change*. Routledge.

Hanke, U. (2012). *Trendsetter Deutschland: Energiewende wird zum Kondratieff-Zyklus*. Wirtschaftswoche 15.06.2012. https://www.wiwo.de/politik/konjunktur/trendsetter-deutschland-energiewende-wird-zum-kondratieff-zyklus/6756334.html. Accessed 16 Sept 2019.

Hauschildt, J., Salomo, S., Schultz, C., & Kock, A. (2016). *Innovationsmanagement* (6. Aufl.). München.

Heiden, S., & Zinke, H. (2006). *Weiße Biotechnologie – Industrie im Aufbruch*. BIOCOM AG.

Heiden, S., Burschel, C., & Erb, R. (2001). *Biotechnologie als interdisziplinäre Herausforderung*. Spektrum Akademischer Verlag.

Hennicke, P. (2010). *Ressourcen- und Klimaschutz: Ökologischer Imperativ und ökonomischer Megatrend?* Wuppertal Papers 183. Wuppertal Institut für Klima, Umwelt, Energie. http://epub.wupperinst.org/frontdoor/deliver/index/docId/3623/file/WP183.pdf. Accessed 05 Aug 2019.

IIT (Institut für Innovation und Technik). (n.d.). *SystemInnovation*. www.iit-berlin.de/de/themenfelder/systeminnovationen. Accessed 05 Aug 2019.

Kompetenzzentrum Biointelligenz. (2019). *Die Biointelligente Wertschöpfung*. White Paper des Kompetenzzentrums Biointelligenz. Fraunhofer. https://www.iao.fraunhofer.de/images/iao-news/bio-intelligenz.pdf

Mietzsch, A. (2018). Biotechnologie: Wo bleibt die industrielle Revolution? In A. Mietzsch (Ed.), *BioTechnologie Jahr 2018* (pp. 33–42). BIOCOM AG.

Müller, A. (2010). Theorie der langen Wellen: Das Comeback von Kondratieff. *Handelsblatt* 18.04.2010. https://www.handelsblatt.com/politik/konjunktur/oekonomie/nachrichten/theorie-der-langen-wellen-das-comeback-von-kondratieff/3414216.html?ticket=ST-5480308-XddoQ4moHhjGNZp7sTMj-ap5

NSF Directorate for Engineering. (2010). *The role of the National Science Foundation in the innovation ecosystem*. https://www.nsf.gov/eng/iip/innovation.pdf

OECD (Organisation for Economic Co-operation and Development). (1998). *Biotechnology for clean industrial products and processes – Towards industrial sustainibility*. http://www.oecd.org/science/emerging-tech/1895218.pdf

OECD (Organisation for Economic Co-operation and Development). (2005). *The measurement of scientific and technological activities: Proposed guidelines for collecting and interpreting innovation data*. Oslo manual, third edition' prepared by the working party of national experts on scientific and technology indicators. http://www.oecd.org/science/inno/2367614.pdf

OECD. (2009). *Strategiepapier "The Bioeconomy to 2030. Designing a Policy" OECD 2010*. http://www.oecd.org/document/18/0,3343,en_2649_34537_44776082_1_1_1_100.html

Rennings, K. (2000). Redefining innovation – Eco innovation research and the contribution from ecological economics. *Ecological Economics, 32*(2), 319–332.

Röpke, J., & Stiller, O. (Eds.). (2006). *Theorie der wirtschaftlichen Entwicklung: Nachdruck der 1. Auflage von 1912*. Duncker & Humblot.

Schumpeter, J. A. (2006). *Theorie der wirtschaftlichen Entwicklung: Nachdruck der ersten Auflage von*

1912. Berlin: Duncker & Humblot. Herausgegeben und ergänzt um die Einleitung von Jochen Röpke und Olaf Stiller (Erstveröffentlichung 1911).
Schumpeter, J. A. (2008). *Capitalism, socialism and democracy*. New York: Routledge. (Erstveröffentlichung 1942).
SRU (Sachverständigenrat für Umweltfragen). (2013). *Sondergutachten – Den Strommarkt der Zukunft gestalten*. https://www.umweltrat.de/SharedDocs/Downloads/DE/02_Sondergutachten/2012_2016/2013_10_SG_Strommarktdesign_Eckpunktepapier.pdf?__blob=publicationFile&v=4
Stern, N. (2006). *The economics of climate change. The Stern review*. Cambridge University Press.
Stern, N. (2009). *A blueprint for a safer planet. How to manage climate change and create a new era of progress and prosperity*. Bodley Head.
Stifterverband für die deutsche Wirtschaft. (2016). *Forschung und Entwicklung in der Wirtschaft 2016*. https://www.stifterverband.org/forschung-und-entwicklung/fue-erhebung-2016#branchen
The Economist. (2015). *The process of invention. Now and then*. https://www.economist.com/science-and-technology/2015/04/25/now-and-then. Accessed 16 Sept 2019.
Thomas, R., & Ford, D. (1995). Technology and networks. In K. Möller & D. Wilson (Eds.), *Business marketing: An interaction and network perspective* (pp. 263–290). Kluwer.
UNWCED: United Nations World Commission on Environment and Development (1987): Our Common Future (Brundtland Report).
Vahs, D., & Brem, A. (2015). *Innovationsmanagement: Von der Idee zur erfolgreichen Vermarktung* (5th ed.). Schäffer-Poeschl.
WBGU (Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen). (2011). *Hauptgutachten – Welt im Wandel. Gesellschaftsvertrag für eine große Transformation*. https://issuu.com/wbgu/docs/wbgu_jg2011?e=37591641/69400318
Zahn, E., & Weidler, A. (1995). Integriertes Innovationsmanagement. In E. Zahn (Ed.), *Handbuch Technologiemanagement* (pp. 351–376). Schäfer-Poeschel.
Zapf, W. (1994). Über Soziale Innovationen. *Soziale Welt, 40*, 170–183.
Zinke, H., El-Chichakli, B., Dieckhoff, P., Wydra, S., & Hüsing, B. (2016). *Bioökonomie für die Industrienation. Ausgangslage für biobasierte Innovationen in Deutschland verbessern*. Bioökonomierat. https://biooekonomierat.de/fileadmin/Publikationen/berichte/Hintergrundpapier_ISA_Vero__ffentlichung.pdf

Stefanie Heiden

(born 1966) studied microbiology and biochemistry and received her PhD at the Max Planck Institute for Terrestrial Microbiology in Marburg. She has been working on sustainability-related issues of innovation research (I), technology management (T) and entrepreneurship (E) since the early 1990s; she has held the ITE Chair at Leibniz University Hannover since August 2019. As honorary professor, she represented the subject Industrial and Environmental Biotechnology at the University of Osnabrück from 2005 to 2019. She is active in leading positions at the interface of science, economy, society and politics, among others for the German Federal Environmental Foundation of the Federation of Industrial Research Associations "Otto von Guericke" e. V. In addition, she is a member of numerous committees, advisory boards and supervisory boards – among others: BMBF Coordination Group Biotech 2020+, Advisory Board of the Fraunhofer-Gesellschaft, Bioeconomy Council Working Group Industrial Biotechnology, University Council of Christian Albrechts University of Kiel, Central Committee of German Catholics, Supervisory Board of the Helmholtz-Centre for Environmental Research (UFZ) and Chairwoman of the Supervisory Board of BIOCOM AG.

Henning Lucas

(born 1985) studied materials science and engineering at the Technische Universität Berlin and the University of Michigan, Ann Arbor, from 2005 to 2013. From 2013 to 2019 he worked as a researcher at the Institute of Production Engineering and Machine Tools of the Leibniz University Hannover with a research focus on tailored surfaces and grinding. In addition to his research activities he coordinated the industrial workshop SMART Surfaces for 3 years during this time. Since 2020 he is working at the Institute of Innovation Research, Technology Management & Entrepreneurship located at the Leibniz University Hannover as well. His research focuses on the connection of digitalisation, biologisation and process chains to achieve sustainable production methods.