# Exploring innovation management strategies in the Flemish bioeconomy

# – An organizational innovation system perspective

Jonas Van Lancker

Thesis submitted in fulfilment of the requirements
for the degree of Doctor (PhD) in Applied Biological Sciences

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Innovatiestrategieën voor een meer biogebaseerde economie: een analyse vanuit het perspectief van organisatie-innovatiesystemen

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# Summary

The current fossil-based economy faces a number of challenges, such as an increasing and aging population, depleting resources and materials and a changing climate. Many countries around the globe believe that the development of a more bio-based economy can be one of the solutions to cope with a number of these challenges. This bioeconomy, defined as a collection of activities that sustainably produce biomass and transform this biomass into a range of products including food, feed, paper, biofuels, bioplastics and biopharmaceuticals, could greatly reduce our dependency on fossil resources such as oil and allow for the production of goods and services at a lower environmental cost.

Although many scholars from a broad array of scientific disciplines have been working for over 15 years on the development of knowledge and technologies to facilitate the transition towards the bioeconomy, it is still in its infancy. Many techno-scientific questions remain unanswered, but even more socio-economic questions are still open. One of the key socio-economic questions that has been severely under-researched is how organizations should configure their innovation management strategies in the bioeconomy context. In essence, the transition towards a more bio-based economy requires radical innovations implemented by traditional and new firms. Despite an overwhelming agreement on the importance of knowledge creation, research and development, and innovation to realize this transition, few innovation management studies have been performed with the bioeconomy as its subject. The overall aim of the research presented in this manuscript is to develop insights in how organizations can configure their innovation management strategies to better realize the transition towards a more bio-based economy and to derive implications for researchers, supporting businesses, and governments on how to develop a stimulating environment.

We use state-of-the-art knowledge on innovation management to investigate the innovation management strategies and practices of organizations in relevant sectors. First, using an extensive literature review, we identified five key contextual factors that affect the innovation behaviour of the firms that want to innovate towards the bioeconomy: (i) the need for radically new and disruptive innovations; (ii) the complex knowledge base these innovations will be built on; (iii) the necessity of cooperation between different actors in order to exchange knowledge and create the required new supply chains; (iv) the expected issues with commercialization of a large amount of new bio-based concepts; and (v) the complex and fragmented policies and legislation that regulate the bioeconomy.

Second, taking these five aspects as a basis, we developed the BioID model, a model containing guidelines and recommendations for innovation management in the bioeconomy, using a structured review of the innovation management literature. In the BioID model, we postulate the use of transdisciplinary innovation processes with open boundaries to include a network of diverse relevant actors, organized in a non-linear way to allow for iteration and feedback between different process phases and actors. We propose seven stakeholder groups that can be relevant in the bioeconomy context and discuss their potential contribution to the innovative firm. To foster interaction between innovative firms and these stakeholders, we advocate a layered network management scheme which divides stakeholders into a core group and a periphery group. Last, the model lists a number of organizational prerequisites that increase the capacity of organizations to develop such an open approach to innovation and implement it efficiently and effectively. These organization prerequisites are: (i) an innovation culture; (ii) leadership support; (iii) good project team configuration; (iv) a clear appropriation strategy; and (iv) adequate resources and capabilities.

Third, we introduce the novel concept of Organizational Innovation System (OIS). This theoretical-conceptual framework adds a micro level to the innovation systems theory based on the Open Innovation and related literature. It can be used as a guiding model for the design and/or analysis of radical innovation projects. The four main structural components of the organizational innovation system are discussed: (i) the innovation process; (ii) the actors; (iii) the innovation network; and (iv) the institutions. The conceptual framework identifies seven functions that an OIS can provide to the innovating organization, including providing opportunities, trends and ideas, reducing uncertainty about the innovative idea, and facilitate supply chain formation. Additionally, ten groups of system failures are listed, i.e. aspects that can hinder the organizational innovation system to work optimally, leading to subpar innovation performance. The combination of the main components, functions and system failure groups allows the analysis of innovation management strategies in different contexts, including the bioeconomy.

Fourth, in the main empirical part of the dissertation, we used a combination of the OIS framework and BioID model to analyse innovation strategies towards the bioeconomy in two very distinct contexts: (i) at the project level at a public research institute and (ii) at the organizational level at private firms. In the first empirical study, we analysed the idea generation phase of three innovation processes originating from a public research institute (PRI). We find that the open innovation approach, which was relatively new to the public research institute, produced a number of positive outcomes, such as increased resources, more and better ideas for innovation, legitimacy for the research, and increased reputation. However, the implementation of the open innovation approach was accompanied with a number of challenges. We found up to twenty-four factors contributing to these challenges, which can be grouped into five main groups: (i) factors related to the environmental context surrounding the PRI; (ii) factors connected to the configuration of the networks that were built by the case researchers; (iii) factors concerning the availability of internal resources; and (iv) internal capabilities; and (v) issues with the organizational structure, culture, and leadership.

In the second empirical study, we analysed the innovation management strategies of fourteen firms in several sectors relevant to the bioeconomy. We took a closer look at the view of the industry on the bioeconomy concept and the innovation management strategies applied in these firms. Most firms find the *bioeconomy* to be a vague concept that has limited practical use. As to the innovation strategies used, we found considerable levels of communalities regarding strategies across different firms, such as the strong focus on appropriation, the openness to external actors, and the emphasis on creating an innovation culture. Nevertheless, a number of differences exist, which relate mostly to how innovation is perceived in the different firms and how long ago the firms formalized their innovation management strategies.

Fifth, a reflective discussion is made that builds on the lessons learned. We elaborate on four main issues hindering the transition to the bioeconomy: (i) the ambiguous definition of the bioeconomy and related biorefinery and biomass cascade concepts; (ii) the lack of standardized measurement tools and methods for key bioeconomy aspects; (iii) the lack of insight on what contextual factors influence how innovation management should be approached in the bioeconomy; and (iv) the lack of knowledge on how innovation management strategies should be shaped at the organizational level in the bioeconomy. We conclude by formulating a number of recommendations for three of the most important actor groups in the bioeconomy transition. We posit six recommendations for policy makers that can help stimulate innovation towards the bioeconomy, we introduce ten good practices for innovation management in the bioeconomy context, and we suggest a number of recommendations for innovation management researchers on the bioeconomy, aggregated into three main groups.

# Samenvatting

Het huidige economische systeem gebaseerd of fossiele inputs wordt geconfronteerd met een aantal uitdagingen, waaronder een toenemende en verouderende bevolking, afnemende voorraden grondstoffen en materialen, en een veranderd klimaat. Veel landen geloven dat het ontwikkelen van een bio-economie één van de oplossingen kan zijn voor een aantal van deze uitdagingen. De bio-economie, gedefinieerd als een collectie activiteiten die biomassa op een duurzame manier produceren en transformeren in een range aan producten waaronder voedsel, voeder, papier, biobrandstof, bio-plastiek, en bio-farmaceutica, kan onze afhankelijkheid van fossiele inputs zoals olie sterk verminderen en kan zorgen voor de productie van goederen en diensten tegen een lagere ecologische prijs.

Ondanks de inspanningen van veel onderzoekers uit een brede waaier aan wetenschappelijke disciplines gedurende de voorbije 15 jaar rond het ontwikkelen van kennis en technologie die de transitie naar een meer bio-gebaseerde economie faciliteert, is de bio-economie nog steeds erg klein. Vele technisch-wetenschappelijke vragen zijn nog steeds onbeantwoord, en nog meer socio-economische vraagstukken blijven open. Eén van de socio-economische sleutelvragen waar op dit moment weinig onderzoek naar gebeurd, is hoe organisaties hun innovatie managementstrategieën moeten configureren in de bio-economie context. Om een transitie naar een bio-gebaseerde economie mogelijk te maken, zijn vele radicale innovaties nodig, geïmplementeerd door zowel traditionele en nieuwe bedrijven. Desondanks een groot consensus rond het belang van kennis creatie, onderzoek en ontwikkeling, en innovatie voor het welslagen van de transitie, zijn er nog maar weinig studies binnen het technologie en innovatie management domein met de bio-economie als onderwerp. De algemene doelstelling van het onderzoek in dit manuscript is het ontwikkelen van inzichten in hoe organisaties hun innovatie managementstrategieën kunnen configureren richting het realiseren van de transitie naar een meer bio-gebaseerde economie en zo implicaties voor onderzoekers en bedrijven afleiden, maar ook overheden ondersteunen bij het opzetten van een stimulerende omgeving voor innovatie.

We gebruiken de meest recente kennis rond innovatie management om de innovatie praktijken en strategieën te onderzoeken in organisaties uit sectoren relevant voor de bio-economie. Eerst, via een uitgebreide literatuurstudie, identificeren we vijf belangrijke contextuele factoren die een invloed hebben op het innovatiegedrag van bedrijven die willen innoveren in de richting van de bio-economie: (i) de nood aan radicaal nieuwe en disruptieve innovatie; (ii) de complexe kennis nodig om deze innovaties te realiseren; (iii) de nood aan samenwerking tussen verschillende actoren om de nodige kennisuitwisseling en configuratie van nieuwe waardeketens tot stand te brengen; (iv) de verwachte problemen met de commercialisatie van

een groot deel van de nieuwe bio-gebaseerde concepten; en (v) de complexe en gefragmenteerde wetgeving rond de bio-economie.

Twee, met deze vijf aspecten als basis, ontwikkelen we het BioID model, een model met aanbevelingen rond innovatie management in de bio-economie, gebaseerd op een review van de innovatie management literatuur. In het BioID model raden we het gebruik van een trans-disciplinair innovatieproces aan met open grenzen om de inclusie van externe actoren toe te laten, georganiseerd op een niet-lineaire manier die flexibiliteit en iteratie toelaat. We stellen zeven stakeholder groepen voor die relevant kunnen zijn in de bio-economie context en bespreken de potentiële bijdrage die ze kunnen leveren aan de innoverende organisatie. Om de interactie tussen de innoverende organisatie en de stakeholders te stimuleren, raden we een gelaagde netwerkstrategie aan die de diverse stakeholders onderverdeeld in een kerngroep en een periferie groep. Tenslotte lijsten we een aantal organisatorische vereisten op die de capaciteit van de organisaties om open innovatie toe te passen verhoogd. Deze vereisten zijn: (i) een innovatie cultuur; (ii) ondersteuning van het management; (iii) de juiste projectteam configuratie; (iv) een goede appropriatie strategie; en (v) voldoende middelen en capaciteiten.

Drie, we introduceren het nieuwe concept Organisatorisch Innovatie Systeem (OIS). Dit theoretisch-conceptueel framework voegt een micro niveau toe aan de Innovatie Systeem theorie, gebaseerd op de Open Innovatie en gerelateerde literatuur. Het concept kan gebruikt worden als een leidend model voor het design en/of de analyse van innovatieprojecten. De vier structurele componenten van het organisatorisch innovatie systeem zijn: (i) het innovatieproces; (ii) de actoren; (iii) het innovatie netwerk; en (iv) de institutionele arrangementen. Het conceptueel framework beschrijft zeven functies die een OIS kunnen aanbieden aan de innoverende organisatie, waaronder het aanreiken van opportuniteiten, trends, en ideeën, het verminderen van de onzekerheid rond een innovatief idee, en het faciliteren van het opzetten van de nieuwe waardeketen. Daarnaast worden ook tien groepen van potentieel systeem falen opgelijst, m.a.w. aspecten die de optimale werking van het organisatorisch innovatie systeem kunnen verhinderen. De combinatie van de structurele componenten, de functies en de groepen van mogelijks falen bieden een kader voor de analyse van innovatie managementstrategieën in verschillende contexten, waaronder de bio-economie.

Vier, in het empirische luik van deze thesis, gebruiken we een combinatie van het OIS framework en het BioID model om innovatiestrategieën te analyseren in twee specifieke contexten: (i) op projectniveau in een publieke onderzoeksinstelling en (ii) op bedrijfsniveau in private bedrijven. In de eerste empirische studie analyseren we de idee generatie fase van drie innovatieprocessen binnen een publieke onderzoeksinstelling (POI). De gebruikte open innovatie aanpak, die relatief nieuw was voor de publieke onderzoeksinstelling, levert belangrijke positieve resultaten op, zoals toegang tot meer middelen, meer en betere ideeën voor innovatie, verhoogde legitimiteit voor het onderzoek en verhoogde reputatie. Desondanks zorgde de implementatie van de open innovatie aanpak ook voor een aantal uitdagingen. Die uitdagingen kunnen in vijf groepen worden ondergebracht: (i) uitdagingen gerelateerd aan de omgeving van de POI; (ii) aspecten die te maken hebben met hoe de netwerken die de onderzoekers uitbouwden zijn geconfigureerd; (ii) uitdadingen die voortkomen uit de beschikbaarheid van interne middelen; en (iv) interne capaciteiten, en (v) uitdagingen met de structuur; de cultuur en het management van de onderzoeksinstelling.

In de tweede empirische studie analyseren we de innovatie managementstrategieën van veertien bedrijven in verschillende sectoren relevant voor de bio-economie. Daarnaast bekijken we het standpunt van de industrie ten aanzien van de bio-economie van dichterbij. De meeste van de bedrijven vinden de bio-economie een vaag concept met weinig praktisch nut. Wat betreft de toegepaste innovatiestrategieën, zien we een behoorlijk grote overeenstemming over de verschillende bedrijven, zoals een sterke focus op appropriatie, de openheid naar externe actoren, en de nadruk op het creëren van een innovatie cultuur. Desalniettemin kunnen een aantal verschillen worden opgemerkt, waaronder de perceptie op wat innovatie is en hoe lang geleden de innovatie managementstrategie werd geformaliseerd.

Vijf, in een reflectieve discussie kijken we naar de geleerde lessen, waarbij we dieper ingaan op vier aspecten die transitie naar de bio-economie in de weg staan: (i) de ambigue definitie van het concept bio-economie en gerelateerde concepten zoals bio-raffinage en biomassa cascade; (ii) het gebrek aan gestandaardiseerde meetinstrumenten en methodes voor belangrijke bio-economie aspecten; (iii) het gebrek aan inzichten rond welke contextuele factoren een invloed hebben op hoe innovatie management moet worden aangepakt in de bio-economie; en (iv) het gebrek aan kennis rond hoe innovatie management op het organisatorisch niveau moeten worden vormgegeven in de bio-economie context. We concluderen met een aantal aanbevelingen voor drie van de belangrijkste actor groepen in de bio-economie transitie. We formuleren zes implicaties voor beleidsmakers die het stimuleren van innovatie richting de bio-economie kunnen stimuleren, we introduceren tien *good practices* voor innovatie management in de bio-economie context, en we stellen een aantal aanbevelingen voor innovatie management onderzoekers in de bio-economie voor, onderverdeeld in drie grote groepen.

# List of abbreviations

| | |
|---|---|
| B2B | Business to Business |
| B2C | Business to Consumer |
| BioID | Bioeconomy Innovation Development |
| BU | Business Unit |
| CAD | Canadian Dollar |
| CEO | Chief Executive Officer |
| CIS | Community Innovation Survey |
| EBIT | Earnings Before Interest and Taxes |
| ERA | European Research Areas |
| ETP | European Technology Platform |
| EU | European Union |
| FP7 | Framework Programme 7 |
| IEA | International Energy Association |
| IIS | International Innovation System |
| IP | Intellectual Property |
| IPR | Intellectual Property Rights |
| IRR | Internal Rate of Return |
| IS | Innovation System |
| ICT | Information and Communication Technology |
| GIS | Global Innovation System |
| GM | Genetically Modified |
| GMO | Genetically Modified Organism |
| KBBE | Knowledge-Based BioEconomy |
| KPI | Key Performance Indicator |
| MLP | Multi-Level Perspective |
| NACE | Nomenclature statistique des Activités économiques dans la Communauté Européenne |
| NDA | Non-Disclosure Agreements |
| NGO | Non-Governmental Organisation |
| NIH | Not-Invented-Here |
| NIS | National Innovation System |
| NSH | Not-Sold-Here |
| OECD | Organisation for Economic Co-operation and Development |
| OIS | Organisational Innovation System |
| P&G | Proctor and Gamble |

| | |
|---|---|
| POI | Publiek onderzoeksinstituut |
| PPP | Public Private Partnership |
| PRI | Public Research Institute |
| PRO | Public Research Organization |
| R&D | Research and Development |
| RIS | Regional Innovation System |
| RIO | Return on Investment |
| SCI | Science Citation Index |
| SIS | Sectoral Innovation system |
| SSCI | Social Science Citation Index |
| TIM | Technology and Innovation Management |
| USA | United States of America |
| USDA | United States Department of Agriculture |

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# Chapter 1
# Introduction

**Abstract**

The transition towards a bioeconomy could greatly reduce our dependency on fossil resources such as oil and allow for the production of goods and services at a lower environmental cost. Although many countries support the development of the bioeconomy and many scholars from a broad array of scientific disciplines have been working for over 15 years on the development of knowledge and technologies to facilitate the transition towards the bioeconomy, it is still in its infancy. Many techno-scientific questions remain unanswered, but even more socio-economic questions are still open. In this dissertation, we focus on one of the key socio-economic questions that has been severely under-researched: how organizations should configure their innovation management strategies in the bioeconomy context. In this introductory chapter, we will elaborate on the importance and exact definition of a bioeconomy. We also specify the general aim of the research, its objectives, and the operationalization of these objectives into four main research questions. Additionally, we provide some first insights into the current state of the Flemish bioeconomy, the study area of this research.

# Chapter 1 - Introduction

## 1.1 The transition from a fossil-based economy towards a bioeconomy

Global trends cause a number of challenges for the fossil-based economic system. The world population is increasing and aging, the spending power per capita in developing countries is rising, our climate is changing, biodiversity is diminishing, and resource and material stocks are shrinking. Many policy makers and organizations worldwide such as the OECD, The European Union, The United States, China, Canada, Japan, and Brazil believe that the development of a *bioeconomy*, envisioned as an economy that relies on biomass inputs instead of fossil inputs to produce a variety of goods, can help alleviate or even eliminate a considerable amount of the challenges caused by these trends. For instance, breakthroughs in agricultural biotechnology, biopharmaceuticals, and biofuels and energy could help to provide adequate goods and services (most notably food, energy and healthcare) for a growing and aging population with more spending power, all with minimal negative impact on the environment (European Commission, 2012; OECD, 2009). In addition to these socio-ecological benefits, the development of a bioeconomy is also believed to yield a considerable number of socio-economic benefits such as economic growth, local and hard-to-relocate jobs, and energy security (European Commission, 2012; Boehlje and Bröring, 2011; Kircher, 2015; U.S. Administration, 2012).

The belief of policy makers in the bioeconomy is reflected in the considerable amount of policy support for the development of a bioeconomy around the globe. For instance, **Brazil**– the number one producer of sugar and the nation with large reserves of arable land – voiced the ambition in its bioeconomy strategy in 2007 to become the world's largest ethanol exporter in by 2025 by building 1 000 distilleries (Kircher, 2012; Staffas et al., 2013). **China** is putting special focus on biochemistry and life sciences in pursuit of a strong position in the bioeconomy (Staffas et al., 2013) by developing 20 biotechnology parks across the country with preferential policies regarding taxation and finance (Li et al., 2006). With 78 billion CAD, the bioeconomy in **Canada** is already larger than its automobile industry and has almost surpassed the Canadian oil and gas sector (Biotec Canada, 2008). In their bioeconomy vision text, they introduce a plethora of beneficial tax schemes and other measures to stimulate the transition towards a more bio-based economy, as well as a national program for biotechnology R&D partnerships worth 20 billion CAD. **The United States** have proclaimed the ambition to make 25% of all products bio-based by 2030 (Vandermeulen et al., 2010). To reach this goal, the US highlights five key areas for action: strengthening R&D; advancing from lab to market; reducing regulatory barriers; developing a bioeconomy workforce; and fostering partnerships (ibid). In terms of R&D support for the development of ethanol production from lingo-cellulosic feedstock alone, 385 million dollars will be invested on six biorefinery pilots and near commercial scale projects (Cologne paper, 2007).

The **European Union's** bioeconomy is estimated to have a market size of over 2 trillion euro and employs approximately 22 million people (Clever Consult, 2010; European Commission, 2012). The EU has put a number of different support systems and policies in place to further develop its bioeconomy. For instance, nine bioeconomy European Technology Platforms (ETPs) were set up and several research support grants in bioeconomy areas were developed under the commission's Framework Program 7 and Horizon 2020; an investment of 2.3 billion euro for the period 2007-2013 and a proposed budget of 4.5 billion euro for the 2014-2020 period (Clever Consult, 2010; European Commission, 2012; Kircher, 2012). The investments in direct research funding of the Horizon 2020 bioeconomy related areas are estimated to generate 130 000 jobs and 45 billion euro in added value by 2025 (European Commission, 2012). Besides these efforts to increase research investments and collaboration, the EU is also working on augmenting bio-based markets through the development of clear and unambiguous product standards, (sustainability) criteria and labels at different regulatory levels for bio-based products (European Commission, 2012), as well as on better communication with the public on bioeconomy topics (Clever Consult, 2010; Paula & Birrer, 2006), while also developing a more coherent policy framework and level playing field for all bio-based industries (European Commission, 2012).

Despite general agreement on the potential beneficial effects a bioeconomy could have on the problems the fossil-based economy is facing and the subsequent substantial global support for bioeconomy development, the transition towards the bioeconomy has been slow (McCormick and Kautto, 2013; Palgan and McCormick, 2016; Vandermeulen et al., 2012). Various estimates show that the current economy still relies heavily on fossil inputs. In 2010, calculations indicated that, in terms of products, today's economy in the European Union is only 5% bio-based, 12% of products (excluding energy use) in the USA are bio-based (Vandermeulen et al.,2012) and the Canadian bioeconomy amounts to 6.4% of total GDP (Biotec Canada ,2008). Assessments in 2010 show that only 8-10% of the European chemistry sector was bio-based, with even more limited shares in other bio-based markets (Vandermeulen et al., 2010). The International Energy Association (IEA) estimates that the share of biofuels (based on energy content) of the global transport fuel market to be 1% in 2007 (Cologne paper, 2007) and assessments in 2010 showed 20% of fine and specialty chemicals were bio-based globally (Vandermeulen et al., 2010).

## 1.2 Research on the bioeconomy: a dearth of studies on socio-economic topics

Many different technological, socio-economic and institutional issues are slowing down the development of the bioeconomy. Although topics related to the bioeconomy are being studied by a broad array of different scientific disciplines and approaches (Bugge et al., 2016; Pfau et al. 2014), the largest body of bioeconomy studies are conducted within the natural and engineering sciences (e.g. biotechnology or genetic engineering) (Bugge et al., 2016; Golembiewski et al., 2015; Kleinschmit et al. 2014). A literature analysis by Vandermeulen et al. (2011) illustrates this observation, showing that of the 790 articles found (mid 2010) with bio-based in the topic, only two are classified in the subject area of economics by the Thomson Reuters Web of Science search engine. Pfau et al. (2014), examining the conceptualization of sustainability in bioeconomy-related papers, also found that the large majority of studies on the bioeconomy is of a techno-scientific nature, describing biomass processing techniques, the production technologies of bio-based products, land use efficiency, (agricultural) production yields, or environmental impacts (Pfau et al., 2014). Hence, it is an established and recognized fact that, despite the wide recognition that, besides technological questions, mainly socio-economic and policy issues form significant hurdles on the road towards a more bio-based economy (e.g. Kircher, 2012; Kleinschmit et al., 2014; McCormick and Kautto, 2013; Mohan, 2016), very few socio-economic studies on the bioeconomy have been conducted (Golembiewski et al., 2015; Vandermeulen et al. 2011). Also, Kleinschmit et al. (2014), advocate an intensification of research in the economic theories (e.g. behavioural economics, resource economics, and ecological economics) and business administration veins such as sustainable supply chain management, corporate social responsibility, and (green) innovation.

As many fossil-based products currently do not have a genuine bio-based counterpart, many bioeconomy technologies are non-existent or still in pre-commercial stages, and the majority of the currently operational biorefineries are based on a single conversion technology and not on a cascading combination of technologies (McCormick and Kautto, 2013; Zwier et al., 2015), innovation management is regarded as one of the cornerstones to make the envisioned bio-based economy a reality by industry, policy and researchers alike (European Commission, 2012; Kleinschmit et al., 2014; McCormick and Kautto, 2013; Rönnlund et al., 2014). Despite the recognition of the importance of innovation management (e.g. European Commission, 2012; Keegan et al., 2014; McCormick and Kautto, 2013) to foster the growth of the bioeconomy, research on this topic in the bioeconomy context is scarce (Golembiewski et al., 2015).

## 1.3 Aim, objectives, unit of analysis, and research questions

### 1.3.1 Aim, objectives, and unit of analysis

The topic of innovation can be approached at many different innovation system levels, which can be aggregated to two general levels: the macro-meso level and the micro level. Research on the macro-meso level is concerned with innovation topics at the level of entire nations (e.g. Carlsson et al., 2002; Freeman, 1995), regions (e.g. Asheim et al., 2011; Cooke et al., 1997), or sectors (e.g. Faber and Hoppe; 2013; Malerba, 2002), often geared at formulating recommendations for policy (e.g. Collins and Pontikakis, 2006; Martin and Moodysson, 2013; Park and Lee, 2005). Studies at the micro level are focuses on topics related to individual innovative organizations or innovation projects, generally geared more towards developing managerial insights and implications.

Innovation management at the micro level is an intensely researched topic, which has branched out into many different specialized fields and subfields. Continuous new insights let to several different approaches to innovation management throughout the years.

The first generation is the *technology push* approach. Models within this approach follow a linear process to internally develop new concepts with a uni-disciplinary focus on science and technology, which are prone to failure due to late discoveries of commercial failures and reinventions of the wheel (Brem and Voigt, 2009; Rothwell, 1994; Van der Duin et al., 2007). Next, models from the *market pull* approach were prevalent. Innovation processes in this second generation were also characterized by internal, linear development paths, but the focus is on market and user needs (Caetano and Amaral, 2011; Gallagher et al. 2012; Rothwell, 1994). An important risk associated with this approach is becoming locked-in to a technology, while neglecting long-term R&D programs, leading to organizations losing their capacity to adapt to radical market or technological changes (Brem and Voigt, 2009; Rothwell, 1994). The early 1970s was the advent of the widespread use of the third generation of innovation approaches, the *coupled* approach. In coupled innovation models, innovation processes are essentially linear, but with some feedback loops between the R&D and the marketing department. Although there is an understanding that innovation is often the result from coupling market needs with technological opportunities, the focus of these models tends to lie on the development of the novel concept, with little consideration for organizational, institutional, legislative, and other necessary changes crucial to successfully exploit a developed concept (Rothwell, 1994; Van der Duin et al., 2007). The approach lost ground in the early 1980s to the fourth generation of innovation processes. The *integrated* innovation approach involves taking innovation projects out of the isolation of R&D departments, into cross-functional teams. Additionally, key suppliers and leading customers are integrated into the processes, which are now non-linearity and include more feedback, aimed at developing ‘total concepts’. (Rothwell, 1994; Van der Duin et al., 2007).

From the (mid-)1990’s onwards, the focus shifted towards a fifth generation of innovation models, with an emphasis on systems integration and networks, taking flexibly and speed of development as one of the primary goals (Rothwel, 1994; Van der Duin et al., 2007). These fifth, *system integrated* models take the ideas of the fourth generation further, increasingly integrating the internal process and expanding the external network of involved partners, fuelled primary by the advances in information technologies (Nobelius, 2004; Rothwel, 1994; Van der Duin et al., 2007). Some researchers (e.g. Nobelius, 2004) are suggesting a sixed generation of innovation models, driven by the ever increasing complexity of innovation management, further accentuating the need for innovation development in collaboration with internal and external actors (ibid). However, from the fifth generation of innovation models onwards, it is not always clear if these generations are truly new desirable generations, or mere expansions and intensifications of aspects already applied in generation four (Ortt and van der Duin, 2008; Rothwell, 1994). Regardless, the prevalent models from the (mid-)1990’s onwards share a strong focus on flexibility of the development process, interaction with various other internal departments (beyond sales and marketing), and collaboration with more types of external actors than just suppliers and customers.

An examination of the literature by Golembiewski et al. (2015) showed that only 12 publications are related to innovation management topics within the bioeconomy context. Of these 12 publications, nearly all are concerned with innovation topics at the macro-meso innovation system level, generally making conceptual contributions or formulating policy recommendations (e.g. Ahn et al., 2012; Dunham et al. 2012; Szogs and Wilson, 2008; Wield, 2013). Studies at the micro innovation system level are very scarce.

The focus of this dissertation is at the micro level, i.e. that of the individual organization, given the very limited amount of research at this level in this context, while the vast majority of innovation projects are initiated and developed at the level of individual organizations (Wang et al., 2012). **Hence, the overall aim of this dissertation is to better understand the innovation management strategies at the organizational level applicable in the transition towards a more bio-based economy.**

In other words, the unit of interest in this dissertation is the innovation management strategy of an organization, i.e. at the organizational level. We define an organization as “a legal entity consisting of individuals, employed to achieve a collective goal (Coase 1937; Kogut and Zander, 1996). All persons with an employment relationship and all official business units or subsidiaries are considered part of the organization”. Innovating organizations can be private firms, universities, public and private research institutes and any other organization a project aimed at developing an innovation. In this dissertation, we consider an innovation as "any concept that stems from an innovative idea, which is developed into an invention, but this invention cannot be called an innovation as long as the invention is not incorporated into the organization or introduced to and adopted by the market" (Bogers and West, 2012; Bruns et al., 2008; Kroon et al., 2008; Pullen et al., 2012; Vanhaverbeke and Cloodt, 2006). Further, the innovation management strategy is operationalized as "the overall strategy of how all aspects within an organization related to the development and commercialization of new concepts are approached and managed". It thus goes beyond the management of the innovation process and projects, as it includes organizational aspects such as organizational structure and culture.

The general aim of this dissertation is operationalized into the two main research objectives: (i) developing a conceptual model of and framework for analysis of innovation management strategies applicable in a bioeconomy context, and (ii) empirically exploring innovation management strategies both in a relevant academic and industrial setting. For the development of the first objective, we use in-depth multi-staged literature reviews to develop the conceptual model and framework for analysis. In order to develop the second objective, we use an abductive approach, more specifically a variant of extended case method (Danneels, 2002; 2003) to empirically explore the innovation management strategies applied in relevant settings. In other words, given the exploratory nature of the empirical research, we elected to first examine the relevant conceptual literature to help guide our case study analysis, rather than using an pure inductive (e.g. grounded theory approach) which is more aimed at new theory building (Danneels, 2002; 2003; Timmermans and Tavory, 2012).

### 1.3.2 Research questions and outline

The two formulated research objectives can be further translated into four specific research questions.

**RQ1: What is an effective and efficient configuration of an innovation management strategy in the bioeconomy context?**

Contingency theory suggests that there is no optimal strategy for all organizations, and that the *best* type of organization depends on how it is aligned with its environment (Lawrence and Lorsch, 1967; Ortt and van der Duin, 2008). This is no different for the innovation management strategy. How to approach innovation management depends strongly on the context, which includes internal contextual factors such as the type of innovation pursued (e.g. product, technology, market), the newness of the innovation (e.g. incremental, radical, disruptive), the type of organization (e.g. centralized, decentralized, functional, organic), and external contextual factors including the type of industry or the type of country (Ortt, 1998; Kotler, 2002;

Ortt and van der Duin, 2008). Hence, a one-size-fits-all approach innovation approach, i.e. an innovation management strategy that works under all circumstances, does not exist.

It is thus a fair assumption that the development of innovations in the context of the bioeconomy, which is a concept entailing a collection of various activities aimed at sustainably producing biomass and transforming this biomass into a range of products including food, feed, paper, biofuels, bioplastics and biopharmaceuticals[1], will also require an innovation management strategy that fits this specific context.

Therefore, in chapter 2 of this dissertation, a conceptual model for innovation management in the bioeconomy context is developed based on the rich knowledge and insights from the existing innovation management literature. Before studying this literature, we first take a closer look at the bioeconomy in order to identify which contextual factors will determine what innovation management aspects are (most) important and how the different aspects should be approached. In chapter 2, we elaborate on five such important contextual factors.

Based on these contextual factors, we determine that approaches from the aforementioned fourth generation onwards, i.e. an open, integrated, systemic approach to innovation management, can be considered most appropriate for the development of the required innovations in the bioeconomy context[2]. This approach to innovation has been the topic of different related innovation management research fields and subfields such as *Co-creation* (Payne et al., 2008; Prahalad and Ramaswamy, 2004), *University-Industry Collaboration* (Plewa et al., 2013; Tether and Tajar, 2008), and *Open Innovation* (Chesbrough, 2003; Enkel et al., 2009). Especially the recent open innovation approach is rapidly becoming a dominant approach for collaborative innovation in research[3] and practice (Jones et al., 2016). For instance, leading ICT firms Google, T-Mobile, Intel, Samsung and Qualcomm formed the Open Handset Alliance in 2007, birthing the Android operating system, and Nike and Apple are also combining their products and services to revolutionize the way people exercise (Han et al., 2012). In the medical sector, GlaxoSmithKline in 2007 and Pfizer in 2010 have both developed programs fostering partnerships (Schuhmacher et al., 2013). The open innovation approach has been advocated to be appropriate in contexts characterized by globalization, technology intensity, technology fusion, industry convergence, new business models, and knowledge leveraging (Golembiewski et al., 2015; Huizingh, 2011; Martin-De Castro, 2015). Moreover, the potential of open innovation as a suitable rationale for innovation development in the

[1] A more elaborate discussion on this definition of bioeconomy can be found in section 1.4 of this dissertation.

[2] In chapter 2 of this dissertation, we elaborate more on why these integrated, open approaches are best suited for innovation development in the bioeconomy.

[3] For an illustration of the rapid rise in popularity of the open innovation approach see, among others, Chesbrough (2012), Huizingh (2011), and Gassmann et al. (2010).

bioeconomy has been argued by among others, Kircher (2012), Bigliardi and Galati (2013), Golembiewski et al. (2015), and Boehlje and Bröring (2011).

The developed *BioID model* (Bioeconomy Innovation Development model) summarizes the basic characteristics of an innovation process and guiding principles and recommendations for innovation management in the bioeconomy context. In other words, it provides the main building blocks that are relevant to innovation management strategies in contexts characterised by the five contextual factors identified.

**RQ2: What conceptual framework for analysis can be used to examine the innovation management strategy of organizations developing innovations relevant to the bioeconomy?**

The empirical studies on the unit of analysis, i.e. the entire innovation management strategy at the organizational level in the bioeconomy context, requires a framework for analysis that looks at the entire innovation process and other relevant innovation management aspects in this context. Research on open innovation and other literature on collaborative research actors rarely takes such an inclusive approach, but rather focusses on specific stages of the process (e.g. idea generation (Salter et al., 2015) or Research and Development (R&D) (Bruns et al., 2008)) or on specific aspects linked to innovation (e.g. knowledge sharing (Bogers, 2011) or *absorptive capacity* (Patterson and Ambrosini, 2015; Spithoven et al., 2010)).

Hence, in chapter 3 of this dissertation, we make a synthesis of the innovation management insights currently scattered in numerous (empirical) studies and bring them together into a single, inclusive concept: the *Organizational Innovation System* (OIS), which is in turn used to develop a framework for analysis.

To structure the OIS, an innovation systems perspective is used due to its dynamic approach and holistic view on innovation (Budde et al., 2012), which aims to capture and understand the relations between different innovation actors, and by doing so, helps to identify system failures and deadlocks, rather than mere market failures as reasons behind innovation failure (Faber and Hoppe, 2013). Current research on innovation systems is mainly oriented towards different macro and meso levels (e.g. national, regional, sectoral, or technological innovation systems (Carlsson et al., 2002; Cooke et al., 1997, Malerba, 2002; Bergek et al., 2008). Also, the related literature on innovation ecosystems (Adner and Kapoor, 2010; Nambisan and Baron, 2013) is mainly concerned with the alignment structure and governance of a set of partners that need to interact to create a focal value proposition (Adner, 2017; Leten et al., 2013; Nambisan, 2013). Hence, we developed the OIS, the micro innovation system level, as a platform for the development of a framework for analysis that can be applied in many different innovation management contexts, including the bioeconomy.

The conceptualization of the organizational innovation system level and the framework for analysis is structured in congruence with that on the higher innovation system levels (e.g. Woolthuis et al., 2005; Bergek et al., 2008), i.e. by using structural components, supporting functions, and groups of system imperfections, allowing for a clear and accessible, though inclusive concept with a high level of comprehensiveness in the aggregated OIS-elements.

**RQ3: What factors influence the performance of innovation projects towards a more bio-based economy initiated by a public research institute?**

In chapter 4 of the dissertation, the OIS framework and the BioID model are used to empirically study a bioeconomy innovation project initiated and executed by a public research institute (PRI) in Flanders. More specifically, this case study looks to the success of an open innovation approach in this context and identifies which challenges were experienced by the involved researchers.

In the innovation system of a knowledge-based economy, public research organizations such as universities and public research institutes (PRIs) are important contributing actors by educating a skilled workforce and conducting (fundamental) scientific research (Etzkowitz et al., 2000; Huang and Chen, 2015). This fundamental knowledge and technology developed at these institutes is especially important in the bioeconomy transition, as many of the new bio-based concepts will be based on these breakthrough concepts (European Commission, 2012; Kleinschmit et al., 2014). However, much of the generated knowledge tends to remain trapped in the *ivory towers* (Chai and Shih, 2016; Saguy and Sirotinskaya, 2014) of these academic actors. Hence, the public research organizations have to find new methods to open their research activities to external actors, further incentivised by governments reducing structured funding due to budget pressures (Franco and Haase, 2015; Friesike et al., 2015), the requirements to form consortia that include a significant number of non-research actors in many prominent research funds, and the increasing market orientated science policy, requesting significant valorisation of research results beyond scientific publications (Perkmann et al., 2013; Robin and Schubert, 2013).

With this case study, we do not only provide additional insights into the suitability of PRIs – an important actor in the bioeconomy transition - to conduct open innovation research, we also offer among the first empirical insights on innovation management strategies in the bioeconomy context, while also providing a first step in the validation process of the OIS and BioID concepts.

**RQ4: How do firms configure their innovation management strategy in sectors anticipated to realize the bioeconomy transition?**

The OIS framework and BIO-ID are used in chapter 5 for the empirical analysis of the innovation management strategy of fourteen firms in sectors relevant to the bioeconomy located in Flanders. This exploratory case study research allows for further knowledge development on how innovation management is approached in the bioeconomy context, a scarcely researched topic. Moreover, the research also allows a better understanding into the view of the industry on the bioeconomy concept. Although the concept of bioeconomy has been introduced more than a decade ago (McCormick and Kautto, 2013; Vandermeulen et al., 2011), still no commonly agreed definition has been reached (Pfau et al., 2014; Vandermeulen et al., 2012). Especially the point-of-view of the industrial (sub)sectors that are supposed to lead the transition and become more bio-based, has generally been under-researched. However, to successfully realize such a transition from a fossil-based towards a bio-based economy, transition management literature and system innovation theory propagate the importance of a common vision, shared among all actors involved (Budde et al., 2012; Coenen et al., 2010; Smith et al., 2002; Woolthuis et al., 2005). Furthermore, this research also provides additional understanding as to the validity of the OIS and BioID concept.

In chapter 6, we look back on the conducted studies with a reflective discussion. We elaborate on our findings via four issues the bioeconomy is currently facing: (i) the ambiguous definition of the bioeconomy and the related concepts of biorefinery and biomass cascade; (ii) the lack of standardized tools to measure key bioeconomy aspects; (iii) the lack of knowledge on how innovation management should be approached in the bioeconomy context; and (iv) the lack of knowledge on how innovation management strategies should be shaped at the organizational level in the bioeconomy. Based on these findings, we formulate six recommendations for policy makers, ten good practices for innovation management that can aid industry in configuring high-performance innovation management strategies in the bioeconomy context, and recommendations for researchers on innovation towards the bioeconomy. The manuscript ends with concluding remarks in chapter 7. An overview of the different chapters in this dissertation and how they relate to the four main research questions can be found in figure 1.

In the remainder of this introductory chapter (section 1.4), we elaborate on the definition of the bioeconomy concept used in this work, as a consensus on a definition of the bioeconomy concept and which (sub)sectors are involved is still lacking (McCormick and Kautto, 2013; Pfau et al., 2014; Pülzl et al., 2014). In the final section of this introduction (section 1.5), we provide some information on topics relevant to the bioeconomy for the region of Flanders, Belgium, which is the geographical backdrop for the empirical analysis in this dissertation

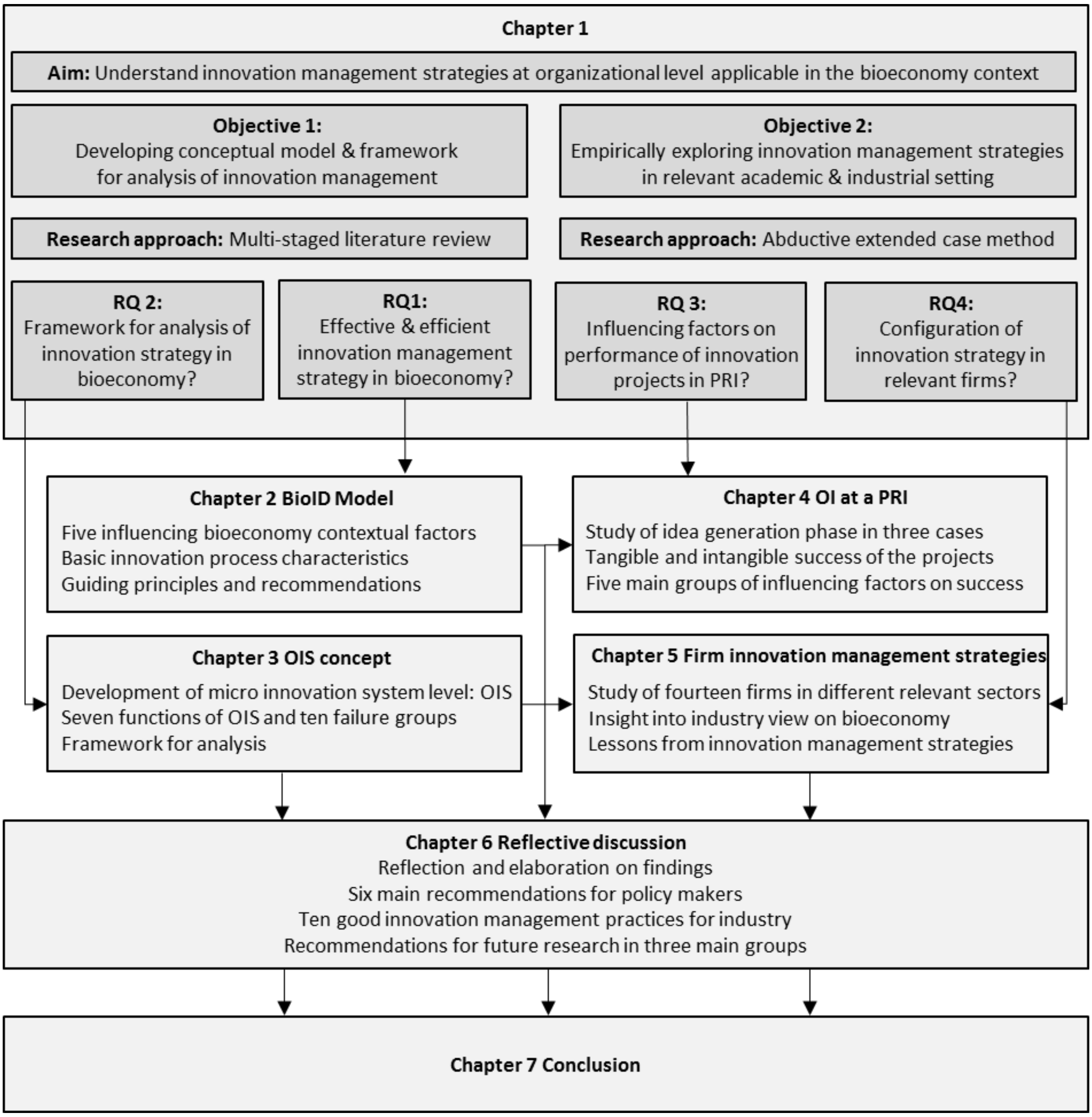


**Figure 1** Overview of the structure of the manuscript and relation between the chapters and research questions

## 1.4 Bioeconomy: a definition of the concept and delineation of involved activities

The use of the term bioeconomy and related concepts has risen rapidly since 2005 (Staffas et al., 2013; Pfau et al., 2014). However, a number of differences in perspective can be observed between various actors. The bioeconomy is considered by a number of authors, countries or organizations to be all biotechnological advances that contribute to solving global problems, while others focus on biotechnology in the life sciences and the application of biomass as a replacement of fossil materials (Pfau et al., 2014). In other words, the prefix *bio* refers in some perspectives to biotechnology while in others it is linked to the use of bio-resources (Kleinschmit et al., 2014). The OECD, the US, China, and Canada for instance approach the term from the first perspective, while the EU, a number of its member states, and authors such as Johnson and Altman (2014) and Nita et al. (2013) take the latter approach (Kleinschmit et al., 2014; Golembiewski et al., 2015).

Moreover, the use of terms such as *Bio-Based Economy* and *Knowledge-Based BioEconomy (KBBE)* (though complementary concepts) contributes to the ambiguity of the bioeconomy concept. The Knowledge-Based BioEconomy concept was launched by the European Union in 2005 (McCormick and Kautto, 2013; Golembiewski et al., 2015). This concept is essentially a synonym for bioeconomy but emphasizes the importance of biotechnology and life sciences to the development of this new economy (Clever Consult, 2010; Cologne paper, 2007; European Commission, 2005). Another concept which is treated as synonymous to the bioeconomy concept, is bio-based economy. However, Staffas et al. (2013) - before acknowledging the interchangeability of the two concepts - point out a difference: the bioeconomy is the biotechnological and life science part of an existing economy, whereas the bio-based economy refers to the transformation of the fossil-based economic system into an economic system based on biomass inputs.

Despite the apparent differences in nuance in the definitions utilized by the various actors concerned with the topic, a number of similarities can be distinguished in policy documents, scientific papers and popular articles. These similarities can be grouped into three key principles which could be considered the foundations of this vision on a new economy. The first key principle is that the bioeconomy will **rely on renewable biomass instead of finite fossil inputs** for the production of a wide range of value-added products such as food, feed, bio-based products and bio-energy (e.g. De Besi and McCormick, 2015; Johnson and Altman, 2014; OECD, 2009; Ollikainen, 2014; Pfau et al., 2014). The biomass feedstock will be sourced from the *traditional suppliers* of biomass, i.e. agriculture, forestry and fisheries, but will be supplemented by additional sources such as aquaculture (e.g. marine algae) and organic household, industrial and agricultural waste (Aguilar et al., 2013; OECD, 2009). The second key principle is the **biomass cascade for the production of these bio-based products in biorefineries** (e.g. De Besi and McCormick, 2015; EBP and SCAR, 2014; European Commission, 2012; McCormick and Kautto, 2013; OECD, 2009). This entails that biomass is initially processed into high value products (e.g. food and feed, pharmaceutical materials, industrial chemicals) and the residues are then used for lower value applications until a minimum of waste remains at the end of the process (EU SCAR, 2012; Fritsche and Iriarte, 2014; Keegan et al., 2013; Zwier et al., 2015). The third key principle, in part enabled by the first two principles, is one of **sustainability**. The bioeconomy is envisioned to be a greener economy, taking maximum biomass valorisation, renewability of inputs, zero waste, and circularity of the production chains as a starting point (European Commission, 2012; EBP and SCAR, 2014; EPSO, 2011; OECD, 2009; Schmid et al., 2012).

The bioeconomy is also related to the concept of circular economy. Geissdoerfer et al. (2017) define the concept based on several contributions including the Ellen MacArthur Foundation (2013), the European Commission (2015) and Lieder and Rashid (2016) as "a regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops." This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling. In the circular economy, two closed-loop cycles are defined: the biological cycle and the technical materials cycle (Ellen MacArthur Foundation, 2013). Hence, the circular economy entails the optimal use and re-use of all materials and resources, including non-biomass resources, whereas the bioeconomy is focussed on (and can contribute to) the optimization of the configuration of the biological loop (European Commission, 2015; Van Buggenhout et al.,2016).

For the purpose of this research, taking into account the aforementioned key principles and differences in definitions, we define the bioeconomy as "a collection of various activities that sustainably produce biomass and transform this biomass into a range of products including food, feed, paper, biofuels, bioplastics and biopharmaceuticals". In other words, the bioeconomy is not a sector, nor a collection of different sectors and subsectors. It is a set of activities that are or will take place in a range of the currently existing (sub)sectors. The terms bioeconomy and bio-based economy will be used as interchangeable synonyms and the circular economy concept is viewed as a complementary concept, based on similar principles, but that also moves beyond the biomass sphere.

These activities are performed in a number of different sectors and subsectors of the current fossil-based economy. We distinguish four main groups of the sectors and subsectors that can play an important role in the transition towards the bioeconomy. A first group is the **biomass producers**, i.e. agriculture, forestry, fisheries, and aquaculture. The second group consists of those sectors that have traditionally relied on biomass input for the production of their goods, the **traditional bio-based economy**. The most recognizable examples of sectors belonging to this group are the food and feed sector. All activities in these two groups can thus be considered an integral part of the bioeconomy. The third group of sectors are those who, in the current economic constellation, conventionally rely on fossil-based inputs for production, but could shift to biomass inputs. The most well-known and currently most established example of a sector in this group is the biofuel and bioenergy sector (Mc Cormick and Kautto, 2013). Other examples are biopharmaceuticals, bio-based (e.g. construction) materials, and bio-based chemicals. We label this third group of firms with bio-based activities in these sectors the **new bio-based economy**. The fourth group, which will play a crucial supporting role in the envisioned bioeconomy is the **waste management** sector, as they can facilitate to effectively and efficiently provide the biorefineries with the currently unused waste and by-product streams, as well as dispose of any residual biomass that may remain at the end of the biorefineries in a sustainable way. This conceptualization of the bioeconomy, with the relevant sectors and (sub)sectors, is schematically represented in figure 2.

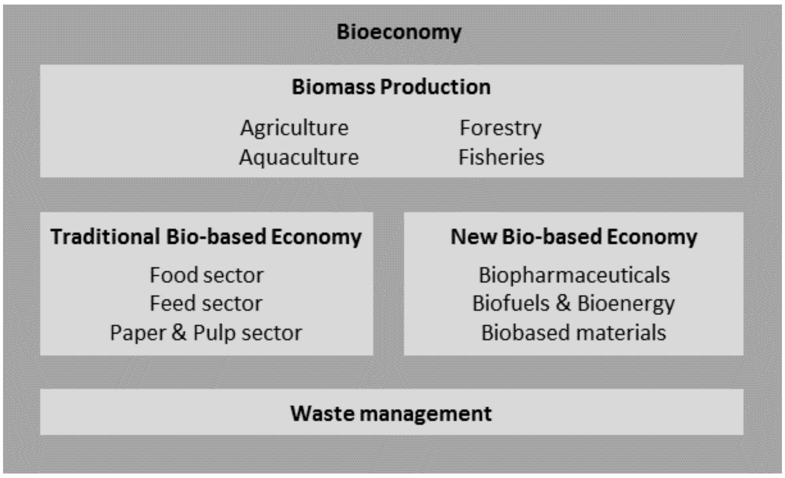


**Figure 2** Conceptualization of the bioeconomy and the four main groups of relevant (sub)sectors

## 1.5 Flanders as the study area for the empirical analysis

The empirical research in this dissertation is conducted in Flanders, the northern part of Belgium. As a region belonging to the European Union, it is part of one of the global leaders and pioneers in the development of the bioeconomy (McCormick and Kautto, 2013; Staffas et al., 2013). Moreover, it is a good example of a small European economy relying heavily on imported fossil inputs (Vandermeulen et al., 2011). It has therefore taken a keen interest in developing a more bio-based economy, with a strategy text that is in line with the EU documents on bioeconomy, emphasizes the importance of biorefineries, cascading biomass use, and closing material and nutrient cycles with close attention for the specific local contexts (Flemish government, 2014; Vandermeulen et al., 2010).

The Belgian bio-economy has been described as "geared towards the agro-food industry and bio-based chemical industries", as the turnover generated by the food, beverage and tobacco sector is above the EU average and has a turnover per capita employed in biochemical industries (here bio-based chemistry, bio-based pharmaceuticals and bio-based plastics) higher than 260 000 euro per capita (Ronzon et al., 2015). Analyses show that the bioeconomy in Flanders (excluding biomass production and the agri-food and feed industry) account for 1.5 to 1.8% of firm's gross margin in Flanders and 0.4% - 1% of total Flemish employment (Vandermeulen et al. 2011; Flemish Government, 2014).

Given the relatively low share of bio-based economy activities and the heightening attention and support for the bioeconomy on the European and Flemish policy level, it is a region expected to have many firms running innovation projects to develop bio-based applications. Research and development on bio-based products is well developed in Flanders, especially in the chemical sector, organized by both industry as well as research institutes (Vandermeulen et al., 2011). Moreover, there is a biotechnology and chemistry hub located in the city of Antwerp and a collective called the Ghent Bio-Energy Valley, which can become focal points for further bioeconomy growth in the region (Vandermeulen et al., 2012). Flanders is also a member of the BIG-C initiative (BioInnovation Growth mega Cluster) with the aim to foster innovation towards the bioeconomy (EBP and SCAR, 2014). In the next subsection (1.5.1) we provide some additional information on the size of the Flemish sectors relevant to the bioeconomy. In subsection 1.5.2, we give a brief overview of some of the innovation behaviour of the Flemish firms in these sectors.

### 1.5.1 The Flemish sectors driving the transition towards a bioeconomy

Table 1 gives an overview of the number of firms and their turnover in the sectors that are supposed to drive the development of the bioeconomy (excluding biomass production) according to the strategy texts and the definition of the bioeconomy developed in section 1.4. The data in this table is obtained from Statistics Belgium, the national institute responsible for collecting official national statistics and for the development of European statistics (http://statbel.fgov.be/). To operationalize the definition of the bioeconomy provided in section 1.4, the sectors and activities were translated to 18 level 2 NACE-codes, codes that are used to group organizations according to their economic activities (FPS Economy Belgium, 2017)[4].

**Table 1** Overview of number of firms and turnover in sectors relevant for the bioeconomy transition

| | **2014** | | | |
|---|---|---|---|---|
| | **Firms (freq.)** | **Firms (%)** | **Turnover (million €)** | **Turnover (%)** |
| Food and Beverage | 5 254 | 38.1 | 48 010 | 20.1 |
| Textile industry | 1 173 | 8.5 | 4 811 | 2.0 |
| Wood, Furniture, Pulp & Paper | 3 606 | 26.1 | 10 661 | 4.5 |
| **Traditional Bio-based Economy** | **10 033** | **72.7** | **63 482** | **26.6** |
| Chemistry and Pharmaceuticals | 545 | 3.9 | 56 711 | 23.7 |
| Potential producers bio-based materials | 1 855 | 13.4 | 15 361 | 6.4 |
| Electricity & waste management | 1 365 | 9.9 | 103 309 | 43.3 |
| **New Bio-based Economy** | **3 765** | **27.3** | **175 381** | **73.4** |
| **TOTAL relevant sectors** | 13 798 | 100 | 238 863 | 100 |
| **TOTAL all sectors Flanders** | 511 288 | - | 1 118 147 | - |
| **% trad. Bio-based Economy in Flanders** | 2.0 | - | 5.7 | - |
| **% new Bio-based Economy in Flanders** | 0.7 | - | 15.7 | - |
| **% total relevant sectors in Flanders** | 2.7 | - | 21.4 | - |

[4] A more detailed explanation on how the bioeconomy was operationalized can be found in annex 1 of the manuscript.

The data show that the traditional bio-based economy is three times as large as the new bio-based economy in terms of firms. However, roughly 70% of the total turnover in the bioeconomy sectors is achieved by the firms from the new bio-based economy and the waste management sector. This can likely be explained by the higher added-value created in e.g. the pharmaceutical and chemistry sector compared to the food and beverage sector.

The food and beverage sector is the by far the largest with 40% of the firms, followed by the wood-based industries (± 25%) and the other bio-based products group (roughly 13.5%). Chemistry and pharmaceuticals are the smallest group with just under 4% of firms, followed by the electricity and waste management sectors (9.9%). However, these small groups are responsible for the second largest and largest turnover of the bioeconomy sectors, 43% and almost 24% in 2014 respectively. The large food and beverage industry generates roughly 20% of the turnover, whereas the second largest cluster, the wood-based industries, only generate about 5% of total turnover. The same can be seen in the bio-based material group, which also generates relatively low turnover despite the relatively large sector in term of active firms. This indicates that the potential bioeconomy sectors consist for the most part of relatively small firms, with the chemistry and pharmaceuticals and the electricity and waste management groups as notable exceptions. These two clusters, with 104.1 million and 75.7 million euro average turnover per firm respectively, are defined by larger scale organizations.

Table 1 further shows that the sectors that are of interest for the bioeconomy represent roughly 3% of the Flemish active organizations and 21% of the total turnover generated by all Flemish firms in 2014. However, this is an overestimation of the bioeconomy in Flanders, as the NACE-nomenclature used to divide the firms into sectors does not allow a distinction between fossil-based and bio-based production (Ronzon et al., 2015). It is thus very difficult to further split the firms from sectors belonging to the new bio-based economy, into those firms with bioeconomy activities and those with traditional fossil-based activities. However, the Flemish bioeconomy account for at least 2% of all Flemish firm and 5.7% of total turnover realized in Flanders (i.e. the size of the traditional bio-based sectors), augmented by the biomass producing sectors (not included in this table) and a (small) part of the new bio-based sectors.

### 1.5.2 Innovation behaviour of firms in Flemish sectors driving bioeconomy transition

In this section, we provide first insights into the innovation behaviour of the firms belonging to the sectors that are of interest for the bioeconomy transition. This exploratory overview is based on date from CIS 2012 for Flanders. The Community Innovation Survey (CIS) is a harmonized questionnaire developed by Eurostat to gain more insight into the innovation activities across industrial sectors and countries in the EU member states (Evangelista et al., 2001). Data gathered through these questionnaires, which are send out in three year intervals, have been used in a large number of scientific studies (e.g. Faber and Hesen, 2004; Faems et al., 2010; Janeiro et al., 2013; Laursen, 2011; Laursen and Salter, 2006). For the 2012 survey, the response rate is approximately 45% or 794 firms for the sectors of interest for this study. More detailed information on the methodology of the study can be found in annex 1 of this dissertation and on the website of the institute responsible for the CIS survey in Belgium (BELSPO, 2016).

**Table 2** Number of innovators in sectors relevant for the bioeconomy transition

| | 2012 | | | |
|---|---|---|---|---|
| | **Firms (freq.)** | **Firms (%)** | **Innovators[1] (freq.)** | **Innovators[1] (%)** |
| **Food & Beverage** | 233 | 29.3 | 109 | 46.8 |
| **Textile industry** | 91 | 11.5 | 56 | 61.5 |
| **Wood, Furniture, Pulp & Paper** | 120 | 15.1 | 66 | 55.0 |
| **Chemistry & Pharmaceuticals** | 116 | 14.6 | 96 | 82.8 |
| **Potential producers bio-based materials** | 179 | 22.5 | 111 | 62.0 |
| **Electricity & waste management** | 55 | 6.9 | 24 | 43.6 |
| **TOTAL** | 794 | 100 | 462 | 58.2 |

[1] innovators: introduced product or process innovations or have ongoing project(s) or abandoned project during surveyed period

The number innovators per cluster, i.e. the organizations who had introduced product or process innovations, had ongoing innovation projects, or abandoned an innovation project during the surveyed period is shown in table 2. The data show that 58% of surveyed firms were innovators. The chemistry and pharmaceuticals appears to be the most innovative sector (82.8% innovators), followed by the textile industry and the potential producers of bio-based materials group (both ±62%), whereas the food and beverage sectors and the electricity and waste management group are scoring well below the average, 43.6% and 46.8% respectively.

For the remainder of this overview, the non-innovators, i.e. organizations who did not introduce a product or process innovation, are disregarded, as these firms would yield no further useful information on the innovation behaviour.

Table 3 shows that organizations often pursue both product and process innovations, combining both internal and external innovation. 70% of innovations have internally developed a product innovations, but well over half of the innovators (60%) have developed products with help from an external source. The external development of innovation is even more frequently used to develop novel processes (in 83% of the cases). The data further show that a considerable number of the innovators (78%) have introduced at least one radically new product innovation to the market during the surveyed period.

**Table 3** Types of innovation pursued by innovative firms in the sectors relevant to the bioeconomy

| | 2012[4] | | |
|---|---|---|---|
| | Firms (freq.) | Firms (total freq.) | Rel. amount (%) |
| **Product innovation internal** | 227 | 323 | 70.3 |
| **Product innovation cooperation** | 138 | 323 | 42.7 |
| **Product innovation copied[1]** | 57 | 323 | 17.6 |
| **External product innovation[4]** | 195 | 323 | 60.4 |
| **Process innovation internal** | 184 | 321 | 57.3 |
| **Process innovation cooperation** | 192 | 321 | 59.8 |
| **Process innovation copied[1]** | 74 | 321 | 23.1 |
| **External process innovation[2]** | 266 | 321 | 82.9 |
| **Radical product innovation[3]** | 251 | 323 | 77.7 |

[1] We combined the either goods and services introduced to market from external actors, modified or unmodified by the firm
[2] We combined the cooperation for innovation and the copied concepts introduced as innovations by the firm
[3] This aggregates all firms who answered yes to the question 'have you introduced a good or service that was new to the market?'
[4] n: 462

Table 4 shows that, of the innovating firms, almost 70% have cooperated with other actors to develop innovations. In terms of different partners, internal cooperation within the group and cooperation with suppliers are the two most used types of cooperation. Innovative efforts with government, public and private research institutes (29.2%), and cooperation with other firms in the industry (18.8%) are used least. When the innovators were asked to rate the importance of different sources of knowledge for innovation, internal knowledge was rated as medium to highly important by over 84% of respondents (table 4). In terms of external knowledge sources, suppliers (±73%) and customers (70.6%) were by far the two groups that were most often indicated as important knowledge providers. The knowledge source that was ranked as important least are the government and public research institutes, followed by universities and consultants and private labs, all under 30%.

**Table 4** Overview of cooperation with different types of actors and their importance

| | 2012[1] | | | |
|---|---|---|---|---|
| | Cooperated with other actors | | Deemed as important knowledge source[2] | |
| | Firms (freq.) | Rel. amount (%) | Firms (freq.) | Rel. amount (%) |
| **At least one actor** | 321 | 69.5 | - | - |
| **Within group[3]** | 180 | 56.6 | 415 | 89.8 |
| **Suppliers** | 245 | 53.0 | 336 | 72.7 |
| **Customers[4]** | 175 | 37.9 | 326 | 70.6 |
| **Other firms in industry** | 87 | 18.8 | 178 | 38.5 |
| **Consultant & private labs** | 153 | 33.1 | 128 | 27.7 |
| **Universities** | 172 | 37.2 | 144 | 27.7 |
| **Government, public & private research institutes** | 135 | 29.2 | 109 | 23.6 |
| **Conferences & other exhibitions** | - | - | 205 | 44.4 |
| **Journals & other publications** | - | - | 175 | 37.9 |
| **Industry associations** | - | - | 157 | 34.0 |

[1] n: 462, [2] Firms who answered average to great importance for the knowledge sources, [3] n 318, this represents the number of firms in a group structure, [4] This aggregates public and private customers

The innovators in the potential bioeconomy sectors tend to work with 1 to 2 different partners types (31.2%) or 3 to 5 different partners types (45,2%) (table 5). 21% works with a very diverse network of partners, with 6 to 7 of the different partner types from table 4 involved. Only a very small minority involved no partners in their innovation efforts (2.8%).

**Table 5** Number of different partner types involved in the innovation process

| | 2012[1] | |
|---|---|---|
| | **Firms (freq)** | **Rel. amount (%)** |
| **No partners involved in innovation** | 9 | 2.8 |
| **1 to 2 different partners types** | 100 | 31.2 |
| **3 to 5 different partners types** | 145 | 45.2 |
| **6 to 7 different partners types** | 67 | 20.9 |
| **TOTAL** | 321 | 100 |

[1] n: 462

# Chapter 2

# Managing innovation in the bioeconomy: An open innovation perspective

**Abstract**

The transition towards a bioeconomy is increasingly viewed by both policy makers and scholars as one of the primary ways to reduce our dependency on fossil resources. However, socio-economic research on the transition towards the bioeconomy at the firm-level remains scarce. Specifically, studies approaching the bioeconomy from the technology and innovation management (TIM) concepts are particularly uncommon, although the importance of knowledge generation and innovation is considered crucial to make the transition towards a greener economy. In this study, we take a first step in addressing this issue by developing a set of guiding principles for the management of innovation processes in the bioeconomy comprised in three key issues: the relevant stakeholder groups and their importance in innovation development within the bioeconomy, the innovation network strategy and management, and organizational features considered prerequisites for collaborative innovation. This called for an identification of influencing factors specific to the bioeconomy context and the establishment of basic characteristics of innovation processes in the bioeconomy. The five identified influencing factors, the basic innovation process characteristics, and the guidelines and recommendations presented in this paper are based on insights derived from a four-staged literature research of the bioeconomy and TIM literature. In particular, we focused on the Open Innovation approach because of the evident fit between this approach and the requirements for innovation in the bioeconomy.

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## Chapter 2 - Managing innovation in the bioeconomy: An open innovation perspective

### 2.1 Introduction

Increasing population, scarcity of resources and materials, environmental pressures, and climate change are issues that challenge our current fossil-based economy (Boehlje and Bröring, 2011; European Commission, 2012). To help address these issues, Europe, the United States and countries such as Japan, India, Brazil, and China are investing heavily into the transition to a more sustainable economy: the bioeconomy (McCormick and Kautto, 2013; Schmid et al., 2012). Since the increase in attention in the early to mid-2000's (McCormick and Kautto, 2013; Ollikainen 2014; Vandermeulen et al., 2011), the bioeconomy concept has been given various definitions and its conceptualization is still evolving (Pfau et al., 2014; Pülzl et al., 2014; Vandermeulen et al., 2012). However, three aspects are shared by the majority of the different conceptualizations and definitions. One, the bioeconomy will rely on renewable biomass instead of finite fossil inputs for the production of a wide range of value-added products such as food, feed, bio-based products and bio-energy (e.g. Johnson and Altman, 2014; OECD, 2009; Ollikainen, 2014; Pfau et al., 2014). Second, these products will be produced in biorefineries following a cascade principle in order to maximally valorise the available biomass (e.g. De Besi and Mc Cormick, 2015; Fritsche and Iriarte, 2014; McCormick and Kautto, 2013). This entails that biomass is initially processed into high value products (e.g. pharmaceutical materials, chemicals) and the residues are then used for lower value applications until a minimum of waste remains at the end of the process (Fritsche and Iriatre, 2014; Keegan et al., 2013; Zwier et al., 2015). Third, these two aspects enable the third somewhat encompassing aspect of sustainability. The bioeconomy is envisioned to be a greener economy, taking maximum biomass valorisation, renewability of inputs, zero waste, and circularity of the production chains as a starting point (European Commission, 2012; EBP and SCAR, 2014; EPSO, 2011; OECD, 2009; Schmid et al., 2012).

The bioeconomy can thus be considered a collection activities in different sectors and subsectors (e.g. food, feed, chemistry, energy, fuel, and pharmaceutical sector), working in conjunction to sustainably derive products from renewable biological resources originating from agriculture, fisheries and forestry (De Besi and Mc Cormick, 2015; Fritsche and Iriarte, 2014; McCormick and Kautto, 2013).

Bünger (2010) posits that over 90% of oil-based products could be replaced by bio-based alternatives and projections show that by 2030 one third of chemicals and materials and 50% of the pharma market will be bio-based (Cologne paper, 2007). Yet, few bio-based alternatives to the current fossil-based products are already available (Golembiewski et al., 2015), as illustrated by estimates in 2010 indicating that today's economy still relies heavily on fossil fuels with only 5% bio-based economy in the European Union and 12% (excluding energy use) in the USA (Vandermeulen et al., 2012). Moreover, the majority of the currently operational biorefineries are based on a single conversion technology and not on a cascading combination of technologies (McCormick and Kautto, 2013; Zwier et al., 2015).

Realizing the bioeconomy, with bio-based applications produced in biorefineries combining multiple conversion technologies, requires knowledge creation, research and development, and innovation as its major cornerstones (European Commission, 2012; Kleinschmit et al., 2014; McCormick and Kautto, 2013; Rönnlund et al., 2014). Despite the recognition of the importance of knowledge creation, R&D, and innovation (e.g. European Commission, 2012; Kleinschmit et al., 2014; McCormick and Kautto, 2013), managerial and economic work on how to develop the necessary (radical) innovations at the organizational or value chain level is scarce (Golembiewski et al., 2015). Existing publications on bioeconomy and bio-based topics mainly originate from governmental institutions (e.g. Biotec Canada, 2008; European Commission, 2012; OECD, 2009; U.S. Administration, 2012), often describing policy and strategic agendas (Golembiewski et al., 2015). The current bioeconomy related scientific literature primarily focuses on technical aspects (e.g., processing techniques) or consequences (e.g., environmental or social impacts) (Pfau et al., 2014). And although a number studies in literature on e.g. sustainable socio-technical transitions (e.g. Smith et al., 2010), sustainable business models (e.g. Nair et al., 2014) or sustainable business management (e.g. van Kleef and Roome, 2007) also approach bioeconomy issues from a socio-economic point of view, what is presently lacking is technology and innovation management (TIM) research guiding R&D and innovation efforts capable of realizing the future bioeconomy (Golembiewski et al., 2015). Yet, a large body of literature exists on technology and innovation management in sectors such as food and nutrition (e.g. Bigliardi and Galati, 2013; Khan et al., 2013; Sarkar and Costa, 2008), biotechnology (e.g. Fetterhoff and Voelkel, 2006; Holl and Rama, 2012; Stevens et al., 2013), and information and communication technology (ICT) (e.g. Bigliardi et al., 2012; Rohrbeck et al., 2009; West and Gallagher, 2006), containing insights and knowledge relevant to guide the development of innovations in the bioeconomy context.

This paper aims to present such a set of guiding principles and recommendations based on relevant insights from this technology and innovation management literature, aggregated into the BioID model, short for Bioeconomy Innovation Development model (section 2.4). In order to do so, in section 2.3, we first describe the specificities of an innovation process in the bioeconomy, based on five identified bioeconomy contextual factors that will determine the nature of innovation development in this context. But first, the methodology, a three-staged literature research, for the identification of these bioeconomy contextual factors, guiding principles, and recommendations is elaborated in the next section. The paper ends with a discussion on the contributions of the study to theory and practice in section 2.5 and some concluding remarks in section 2.6.

## 2.2 Research approach

The development of the guiding principles and recommendations to organize innovation processes within the bioeconomy is based on a three-staged literature research. In the first stage, we carefully examined the bioeconomy literature. Besides a search in scientific literature using the Science Citation Index (SCI) search engine, we also examined the grey literature on bioeconomy because many important documents on the topic originate from governmental institutions (e.g. BioteCanada, 2008; European Commission, 2012; OECD, 2009; U.S. Administration, 2012) published between the year 2000 up until the end of 2015 when the search was conducted. The keywords used in this search were different spellings of bioeconomy as well as different search strings of bio-based economy and knowledge based bioeconomy, as the definition of the bioeconomy is still evolving and many authors threat these similar concepts as interchangeable concepts or even synonyms (De Besi and McCormick, 2015; McCormick and Kautto, 2013; Golembiewski et al., 2015). We included articles from English peer-reviewed journals and English texts from international organizations (e.g. European commission, 2012; OECD, 2009) or nations (e.g. BioteCanada, 2008; U.S. Administration, 2012) that approach the bioeconomy from a socio-economic point of view. Work tackling a bioeconomy related topic from a purely techno-scientific perspective were excluded from the study. Based on the five identified influencing contextual factors and insights provided by the studied texts, the aim of this first stage was to identify the most relevant literature for the development of the recommendations and guidelines. The Open Innovation approach was selected as main vein of technology and innovation management literature for the development of the paper. A more elaborate discussion on the identified specificities of innovation processes in the bioeconomy as a result of stage one and the reasoning for selecting open innovation as the main theoretical backbone for the development of the guidelines and recommendations can be found in section 2.3.

In the second stage, an extensive literature review of the Open Innovation literature was conducted. A search for different variations on Open Innovation was entered into the Social Science Citation Index (SSCI) search engine for the years 2003 (when the term Open Innovation was first coined by Henry Chesbrough (2003)) to the end of 2015. In a first selection round, all articles published in peer-reviewed English-language journals with open innovation in the title, keywords or abstracts were withheld. In a second selection round, papers were selected for further analysis based on the title and abstract. Only papers on open innovation topics at the organizational level were included. In addition, we conducted backward citation searching of the reference lists of the included publications in order to identify further relevant publications in topics such as Innovation Adoption (e.g. Rogers, 1995; Frambach and Schillewaert, 2002), Business Model Innovation (e.g. Boons et al., 2013; Calia et al., 2007; Zott and Amit, 2010), Innovation Systems and related Transition Management (e.g. Geels and Schot, 2007; Geels, 2002; Smith et al., 2005). The same backward citation searching was applied in stage 1 on the bioeconomy texts in order to identify further relevant publications. During these two stages, over 200 publications were analysed. In the third research stage, the recommendations and guidelines were synthesized into the BioID model (figure 3) and discussed at length in individual interviews with eight innovation experts, to improve the validity of our analysis. The group of experts consisted of two innovation management researchers, one innovation consultant, three innovation managers, and one director of an innovation broker. Overall, these experts agreed with the majority of the findings and only provided a limited amount of additional information and suggestions (e.g. specific wording of certain results or comments on the presentation of the findings in the model).

### 2.3 Innovation development in the bioeconomy

Building on the work of Golembiewski et al., (2015) and other publications on the bioeconomy, we identified five important factors that will impact the implementation and management of innovation development processes in the context of the bioeconomy.

First, although some existing products and processes may only need some incremental, gradual innovations (Boons et al., 2013; European Commission, 2012), the transition towards the bioeconomy will mainly require diverse**, radically new and disruptive innovations** (Boehlje and Bröring, 2011; European Commission, 2012; Golembiewski et al., 2015; Kleinschmit et al., 2014), such as redesigned business models (Pülzl et al., 2014; Staffas et al., 2013), reconfigured supply chains (Boehlje and Bröring, 2011), and the setup of entirely new supply chains between organizations from sectors currently un-or only remotely related (FMER, 2011; Kircher, 2012).

Second, these innovations will be based on a **complex knowledge base**, from a variety of sciences and technologies (European Commission, 2012; Golembiewski et al., 2015) such as life sciences, agronomy, ecology, food science, social science, biotechnology, nanotechnology, ICT and engineering (European Commission; 2012).

Third, a large degree of **cooperation between different actors** will be required to develop this complex knowledge and to setup the integrated biorefineries that will cut across the borders of existing organizations, value chains and traditional sectors (Boehlje and Bröring, 2011; European Commission, 2012; FMER, 2011; Fritsche and Iriarte, 2014; McCormick and Kautto, 2013; Staffas et al., 2013). This cooperation with external actors is already implemented by a number of organizations that are currently developing different bioeconomy concepts. For instance, Cargill is developing renewable bindings for the paper industry in collaboration with suppliers, universities and scientific institutions. Sybimar, in addition to research partners and suppliers, involves end product buyers to develop biofuels from fish and food industry by-products. Borregaard, a large Norwegian firm running a spruce based biorefinery, mainly involve customers and research institutes in their innovation endeavours (EBP, 2014).

Fourth, the **commercialization and adoption** of new bioeconomy technologies and bio-based products can often be challenging both in a business to business context due to e.g. high switching costs or a lack of existing quality standards (Henchion et al., 2013), as well towards final consumers (Golembiewski et al., 2015; McCormick and Kautto, 2013; Rönnlund et al., 2014). Final consumers are, for instance, hesitant to embrace products generated from side or waste streams or products produced with technologies such as genetic modification (Frewer et al., 1997).

Fifth, the **complex and fragmented policy schemes** form an additional important challenge for the development of new bioeconomy concepts (European Commission, 2012). Not only are many of these new concepts expected to comply to a number of different policy schemes, e.g. food secure, climate change mitigation (Bigliardi and Galati, 2013), they are often also subject to schemes and regulation from different administrative levels. Moreover, some bio-based applications or biomass cascade steps are hindered or forbidden by current policy. For instance, in Europe, composting bio-based and biodegradable plastics at end of a biomass cascade is not permitted, even when these products comply with the composting standard criteria (Philp et al., 2013). Additionally, the required cooperation between firms from various sectors to create integrated biorefineries, can further amplify this legislative challenge, as these biorefineries will need to play by the rules and regulations of each involved sector.

With these five contextual factors in mind, the innovation process will have to be conducted using a transdisciplinary approach in order to obtain the diverse knowledge required to successfully assess the viability of innovative ideas, develop new bio-based concepts, set up integrated biorefineries, and alter existing regulations, standards and supporting infrastructure (Aguilar et al., 2013; European Commission, 2012; EU SCAR, 2012; Kircher, 2012; Ollikainen, 2014; Schaltegger et al., 2013; Schmid et al., 2012). In other words, linkages will have to be made across disciplinary boundaries and between academic knowledge and professional practice (Aguilar et al., 2013; EU SCAR, 2012; Hadorn et al., 2006; Lawrence and Després, 2004; Nowotny et al., 2003; Pohl, 2008, 2011; Veldkamp et al., 2009) in order to take into account the different, inseparable social, economic and technical aspects of innovation. Moreover, an innovation process in the bioeconomy should be a flexible, iterative process with feedback loops and reverse flows, in which the different phases are interconnected learning cycles, enabling repetition of certain process steps to adjust to unforeseen developments and mistakes (Berkhout et al., 2010; Bruns et al., 2010; Fetterhoff and Voelkel, 2006; Gallagher et al., 2012; Hadorn et al., 2006; Hermans et al., 2013; Kroon et al., 2008; Pohl, 2008, 2005; Veldkamp et al., 2009; West and Bogers, 2014).

This iteration is important between the three main phases; **the idea development phase, invention phase, and commercialization phase**[5], and between subphases. For instance, during the idea development phase, short feedback loops between the subphases is beneficial to distinguish viable from less viable ideas, thereby reducing uncertainty, which in turn positively contributes to the chances of a successful project outcome (Börjesson et al., 2006; Koen et al., 2001; Van der panne et al., 2003). This iteration during idea development may cost significant time, but taking adequate time to assess an idea's viability typically shortens the total innovation project time (Börjesson et al., 2006; Koen et al., 2001; Sandmeier et al., 2004). An example of iteration during phases of invention can be found at 3M, where a more tacky than sticky adhesive was developed for a project that eventually was never realized. The adhesive however, through a loop back to idea development phases became the linchpin-technology for the 3M Post-it notepads (Koen et al., 2001).

[5] The aggregation of a large number of innovation subphases into these three main phases which occur in every innovation process is the result of a thorough screening of the literature for communalities in different definitions of innovation (e.g. Bogers and West, 2012; Bruns et al., 2010; Kroon et al., 2008; Pullen et al., 2012) and different models of innovation processes (e.g. Bergek et al., 2008; Berkhout et al., 2010; Brem and Voigt, 2009; Bruns et al., 2010; Gallagher et al., 2012; Hansen and Birkinshaw, 2007; Koen et al., 2001; Rothwell, 1994; Sandmeier et al., 2004). The idea development phase groups actions that can identify opportunities, trends, and other aspects that can potentially spark new ideas, efforts related to idea generation, activities to concretize ideas and check their feasibility, and finally, an idea selection. The subphases with more emphasis on the techno-scientific aspects of developing the selected idea into a proof of concept, such as project design, resource acquisition, research and development activities, and real-life testing, are bundled in the invention phase. The commercialization phase entails efforts of a more socio-economic nature, such as demonstration activities, determining the marketing strategy, and making supply chain arrangements.

Finally, innovation processes in the bioeconomy should be **open to collaboration** within a network of diverse relevant stakeholders. For instance, the well-known *Connect and Develop* program by Procter and Gamble (P&G) taps into a wide network of government and private labs, academic and other research institutions, suppliers, retailers, competitors, development and trade partners, VC firms, and individual entrepreneurs for new ideas and business opportunities (Huston and Sakkab, 2004). Besides a great source for innovative ideas, such openness provides other general benefits such as (i) a spread of the costs of R&D (Chesbrough, 2012; Giannopoulou et al., 2011; Holl and Rama, 2012); (ii) an improved adaptation to dynamic market and environmental needs (Börjesson et al., 2006; Du et al., 2014); (iii) increased identification of potentially valuable opportunities for innovation (Huang et al., 2014); (iv) possibilities to expand to new markets (Kutvonen, 2011); and (v) decreased time to market (Chesbrough, 2012; Holl and Rama, 2012). Further, external stakeholders can provide access to complementary assets, financial resources and knowledge Chesbrough, 2012; Du et al., 2014; Schaltegger et al., 2013), and cooperation between organizations can facilitate the integration of new bio-based products in biorefinery value chains (Boehlje and Bröring, 2011; FMER, 2011).

With these contextual factors and innovation process characteristics in mind, an innovation approach that considers innovation as a holistic, collaborative effort is preferred because such an approach is especially useful to develop radical, complex innovations Bigliardi et al., 2012; Michelfelder and Kratzer, 2013) in contexts of increasing complexity and intensity of technology (Holl and Rama, 2012; Huizingh, 2011). This collaborative approach to innovation has been the topic of different related TIM research fields and subfields such as Co-creation (Prahalad and Ramaswamy, 2004; Payne et al., 2008), Innovation Systems (Cooke et al., 1997; Freeman, 1995; Malerba, 2002), and most recently, Open Innovation (Chesbrough, 2003; Enkel et al., 2009). Especially the recent open innovation approach is rapidly becoming a dominant approach for collaborative innovation[6]. It can be defined as "the use of purposive inflows and outflows of knowledge to accelerate internal innovation and expand the markets for external use of innovation" (Chesbrough, 2012 p.20). In other words, the boundaries between the firm and its surrounding environment are considered to be more porous which allows knowledge and innovation to move more easily between the two (Chesbrough, 2003). The approach has been advocated to be appropriate in contexts characterized by globalization, technology intensity, technology fusion, industry convergence, new business models, and knowledge leveraging (Golembiewski et al., 2015; Huizingh, 2011), making it a suitable central concept to develop the guiding principles and recommendations for innovation

[6] For an illustration of the rapid rise in popularity of the open innovation approach see, among others, Chesbrough (2012), Huizingh (2011), and Gassmann et al. (2010).

development in the bioeconomy. Moreover, the potential of open innovation as a suitable rationale for innovation development in the bioeconomy has been argued by among others, Kircher (2012), Bigliardi and Galati (2013), Golembiewski et al. (2015) and Boehlje and Bröring (2011). The guidelines and recommendations in section 2.4 for innovation management within the bioeconomy context based on the findings in the open innovation literature are aggregated into three topics, reflecting the main research areas: (i) Relevant stakeholder groups and their importance in innovation processes in the bioeconomy context; (ii) Innovation network strategy and management; and (iii) Organizational prerequisites facilitating (open) innovation. An overview of the different basic characteristics of an innovation process in the bioeconomy can be seen in the BioID model in figure 3. In the outer circle of the model, the five contextual factors are filled in. The next layer holds the different relevant stakeholder groups which we will elaborate on in the next section (2.4.1). The third layer of the model holds a number of important aspects related to the innovation network management strategy that are discussed in section 2.4.2. The innovation process, with the three main phases of an innovation process and their subphases, is depicted in the inner layer of the representation. At the centre of the schematic overview is a core component of organizational prerequisites, which are presented in section 2.4.3. To emphasize the flexible and iterative nature of the innovation process, the different components are represented in circles, connected by bidirectional arrows.

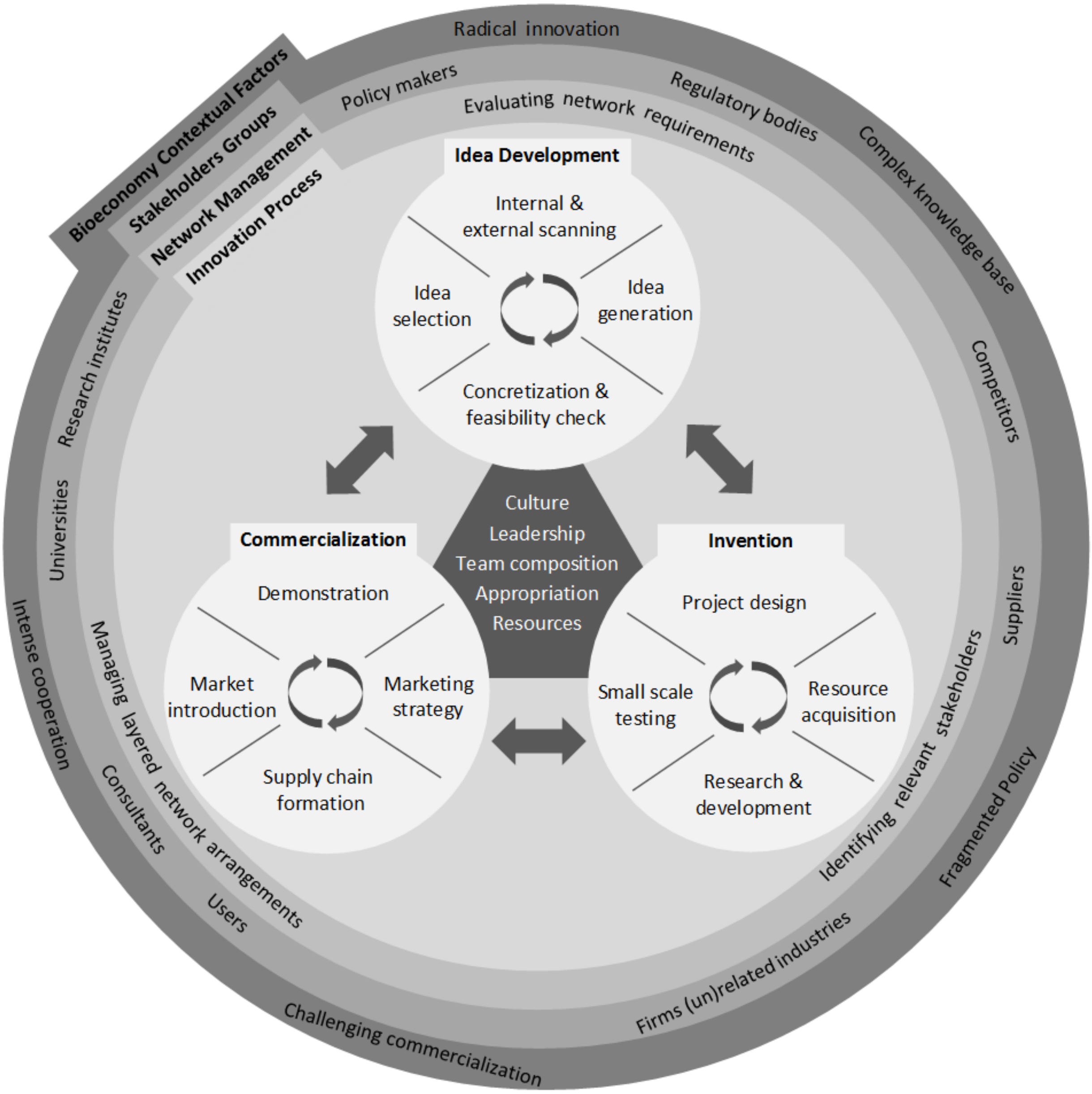


**Figure 3** Innovation model giving a schematic representation of innovation process in the bioeconomy context

## 2.4 Guiding principles and recommendations for innovation development in the bioeconomy

### 2.4.1 Relevant stakeholders groups

A first group of relevant stakeholders when developing innovations in the bioeconomy are **policy makers** or regulatory bodies. They can offer subsidies to develop the innovation or subsidize the utilization of the innovation (e.g. green energy certificates) and provide political support (Ritter and Gemünden, 2004). Moreover, close coordination with policy makers can help ensure conflicts with food security and safety are avoided (Bigliardi and Galati, 2013). Furthermore, these relations provide the innovating organization with channels to communicate problems experienced due to inadequate regulations, regulatory hurdles, or lack of level playing fields (Peerlings et al., 2012), e.g. the European targets on renewable energy that currently distort the market for biomass (European Commission, 2012). Being able to signal and thus potentially overcome such inadequate or lack of regulations is considered an important success factor when developing new bioeconomy concepts (Peerlings et al., 2012). Involving policy makers and regulatory bodies can also help the organization win the struggle for dominant design (Ritter and Gemünden, 2004), another important beneficial aspect given that many of the bio-based technologies and products are still in development stages (Golembiewski et al., 205) and the fight for what will be the new dominant design is yet undecided (European Commission, 2012; Kleinschmit et al., 2014).

A second group of stakeholders that can assist in this fight and aid in standard setting are **competitors** (Bigliardi et al., 2012; Laursen and Salter, 2013). In addition, collaboration with competitors can be beneficial for precompetitive research (Bigliardi et al., 2012; Laursen and Salter, 2013).

Access to complementary knowledge and technologies is crucial in the bioeconomy context (Golembiewski et al., 2015). Organizations developing new, more sustainable products and technologies will often need knowledge and skills outside their fields of expertise or core business (Boehlje and Bröring, 2011). For instance, chemical industries will need to learn to use bio-precursors delivered from biorefineries in bulk volumes, and those refineries must learn to use residual biomass. Farmers need economically viable logistic options to monetize the value of their residual biomass (Kircher, 2012). Contributions from **universities and research institutes** will often be the cornerstone for the necessary (radical) innovation in the bioeconomy (Boehlje and Bröring, 2011; Golembiewski et al., 2015; Holl & Rama, 2012), as they are considered to be the premier source of (new) more fundamental, scientific knowledge (Ritter and Gemünden, 2004; Spithoven and Teirlinck, 2006) necessary for radical innovation (Janeiro et al., 2013).

Working together with **suppliers** can reduce risks and lead time of product development as well as increase product quality (Bigliardi et al., 2012). Furthermore, they can provide new materials and components, offer expertise on the latest technologies (Du et al., 2014; Ritter and Gemünden, 2004), help identify potential technical problems early in the process (Du et al., 2014, and can be a low-risk gateway into information on the (innovation) activities of competitors (Bigliardi and Galati, 2013). But arguably the most prevalent reasons to include suppliers in the innovation process is to align the value chain of the new bioeconomy concept.

This realignment of existing value chains and building of entirely new chains will be inevitable to produce bio-based products in the envisioned integrated biorefineries. Hence, besides with suppliers, innovating organizations will have to engage in collaboration, partnerships or alliances with the other **actors in their value chain(s)** and with **organizations from previously unrelated industries** in order to maximally integrate the use of the available biomass (Boehlje and Bröring, 2011; FMER, 2011).

**Users and customers** integrated into the innovation process can help define new requirements of the innovation (Du et al., 2014; Ritter and Gemünden, 2004), provide market information (Bigliardi et al., 2012), and enhance the awareness and acceptance of the innovation among a broader public (Arnold and Bath, 2012). Additionally, involving users and customers can result in a larger number of innovation ideas (Du et al., 2014; Hansen and Birkinshaw, 2007).

A final, more heterogeneous relevant group of stakeholders are **consultants**. They can provide a specialized type of knowledge or skills such as process structuring, financial services, or legal and insurance services (Ritter and Gemünden, 2004). One type of consultant that is gaining importance are innovation intermediaries or brokers. The main services these intermediaries can provide are: identifying and recruiting partners (Almirall et al., 2014; Lichtenthaler, 2013), connecting innovative ideas and organizations (Almirall et al., 2014; Lichtenthaler, 2013; Mina et al., 2013), providing governance and structure during the innovation effort (Almirall et al., 2014), and supporting negotiations (Lichtenthaler, 2013).

### 2.4.2 Innovation network strategy and management

Opening up an organization to external stakeholders is not a binary choice between essentially closed or completely open innovation, but rather a spectrum of possible collaborative arrangements and strategies between the two extremes (Bahemia and Squire, 2010; Bellantuono et al., 2013; Chesbrough, 2003; Huizingh, 2011).

We suggest a dynamic, **layered innovation network** strategy. In this collaboration strategy, the innovation network consists of a smaller core group and a larger periphery. The stakeholders in the first group are strongly involved in the innovation process and knowledge is openly shared, while the periphery group is kept more at arm's-length, sharing knowledge and information less openly (Bahemia and Squire, 2010; Bogers, 2011; Michelfelder and Kratzer, 2013). This layeredness allows organizations to have a large heterogeneous network, which positively effects the development of radical innovations (Bahemia and Squire, 2010; Berkhout et al., 2010; Brettel and Cleven, 2011; Westergren and Holmström, 2012), while ensuring a more closed approach to networking, proven to have a beneficial effect on innovation performance (Michelfelder and Kratzer, 2013; Pullen et al., 2012). Moreover, the more closed approach can also help reduce the risk of knowledge theft or involuntary outgoing spillovers inherent to open innovation (Kleinschmit et al., 2014; Laursen and Salter, 2013; Sisodiya et al., 2013; Stevens et al., 2013).

The layered innovation network should be managed with **dynamism and flexibility** because both the level of openness and the importance of different stakeholder groups is not fixed. For instance, the degree of openness depends on the phase the innovation project. In early stages, i.e. idea development phases, participation with the innovation network will be more open to a broader range of diverse stakeholders in order to maximally explore their knowledge and absorb novel ideas (Huang et al., 2014; Spitsberg et al., 2013), whereas later stages of the innovation process (during invention and commercialization phases) are associated with more closed approaches to facilitate exploitation of the provided knowledge and resources (Bahemia and Squire, 2010; Cooke et al., 1997). Additionally, to which network layer a certain stakeholder belongs can also depend on the innovation project phase. For instance, during phases of invention, technology providers and upstream firms are likely to be closely involved, while downstream players come to the foreground during commercialization phases to get the innovation to market (Vanhaverbeke and Cloodt, 2006). Nevertheless, the innovating organization should strive to involve the outer layer of the network as much as possible. Non-confidential information about the innovation should be shared to help ensure that the innovation will meet stakeholder expectations and to help create legitimacy and support for the innovation (Bergek et al., 2008; Spencer, 2003). The importance of different stakeholder groups is also influenced by the degree of newness of the innovation; technological stakeholders are believed to be more important in processes of radical innovation and market stakeholders are thought to be more relevant for incremental innovation development (Brem and Voigt, 2009). Furthermore, stakeholder-importance is also dependent on the industry. For example, consumer product industries have a strong market flavour, while more science-based industries such as pharmaceuticals have a more technology focused mindset (Berkhout et al., 2010; Caetano and Amaral, 2011; Rothwell, 1994).

A majority of layered networks in innovation processes related to the bioeconomy will consist of a large amount of suppliers, other value chain partners, and organizations from other industries. Moreover, the organization should engage with a substantial amount of policy makers and regulatory bodies on different administrative levels to acquire subsidies and (legislative) support in the fight for dominant design. A number of potential users and customers should be included at an early stage in the innovation process to obtain knowledge about market preferences and requirements (Du et al., 2014) and to help alleviate potential adoption barriers. Additionally, involving some competitors at-arm's-length can be beneficial in the struggle for dominant design and standard setting. Depending on the ability of the organization to manage such a network of diverse stakeholders, it is worth considering involving an innovation intermediary or broker to assist with network management and coordination of the innovation process. Regarding the layeredness of the network, an innovating bioeconomy organization should generally closely involve suppliers, other chain partners and organizations from other industries, users, policy makers and regulatory bodies, and universities and research institutes during the idea development phase to help identify the most feasible and profitable ideas for innovation. During the invention phase, the users and customers, policy makers and regulatory bodies, processors and suppliers will be more in the periphery of the network. They should however still be consulted regularly, as user needs and preferences are dynamic (Gruner and Homburg, 2000) and standard are often developed parallel to the innovation (EPSO, 2011). The suppliers and processors will return into the core group to adjust the existing value chain or setup the new chain, while universities and research institutes will move more to the background during the commercialization phase. Competitors should best be kept in the periphery group to reduce chances of negative spillovers and knowledge theft. Figure 4 gives a representation of this difference in stakeholder involvement throughout the phases.

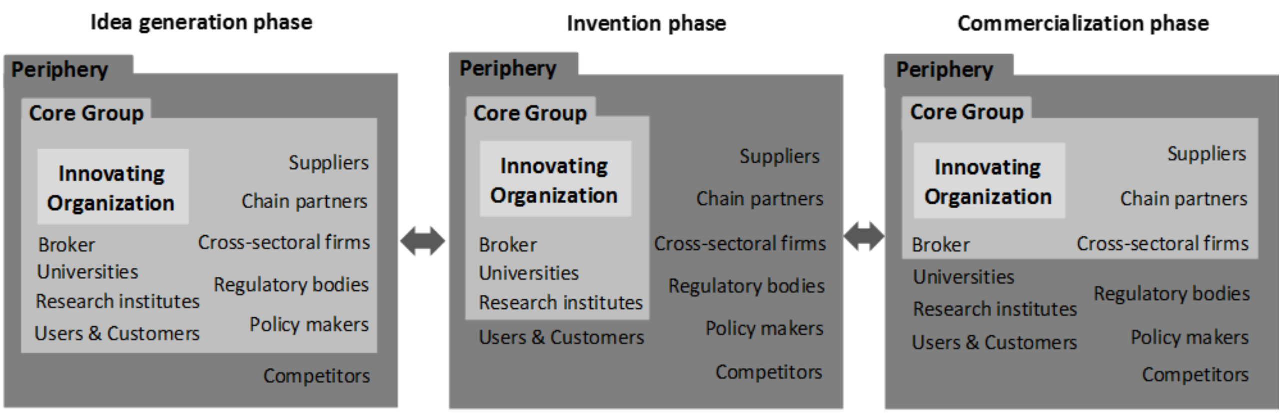


**Figure 4** Changing stakeholder involvement in innovation process using layered network strategy

### 2.4.3 Organizational prerequisites

Open innovation processes can be accommodated or hindered by a number of organizational characteristics (Galanakis, 2006; Sisodiya et al., 2013). We elaborate on five of these characteristics which can be considered prerequisites for the success of the open innovation efforts.

The organizational literature suggest that a strong **organizational culture** can contribute to better performance because it plays an important role in determining the working climate, strategy formulation, and the way organizations interact with customers, competitors and suppliers (Brettel and Cleven, 2011). A culture conducive to innovation is a prerequisite for the success of (open) innovation efforts (Giannopoulou et al., 2011; Van der Panne et al., 2003; West and Bogers, 2014). Creativity, receptiveness to new ideas, risk taking, and an entrepreneurial mindset (Brettel and Cleven, 2011) are all important attributes of such a conducive innovation culture. These attributes can be supplemented by a stern recognition of the collective nature of innovation efforts (Van der Panne et al., 2003), an attitude of openness (Ollila and Elmquist, 2011), and a willingness to strive for win-win relations with stakeholders (Chesbrough and Schwartz, 2007; Enkel at al., 2011). Furthermore, two important cultural barriers to open innovation must be combatted: the Not-Invented-Here (NIH) and the Not-Sold or Shared-Here (NSH) syndromes (Bellantuono et al., 2013; Burcharth et al., 2014; West and Bogers, 2014). The first is the negative attitude towards inbound open innovation activities (Burcharth et al., 2014). The resistance towards outbound open innovation activities is labelled the NSH syndrome (ibid). Some examples of how organizations can combat the NIH and NSH syndromes can, among others, be found in Koen et al. (2001), Burcharth et al. (2014), and Salter et al. (2014). For instance, Burcharth et al. (2014) found that professional training to improve the specific expertise of employees and training for innovation and creativity decreased the NIH syndrome. Also, flexible reward and promotion systems that support openness is considered beneficial to combat resistance to collaborative innovation (Salter et al., 2014). At P&G's Connect and Develop, it is engrained in the culture that an invention development process is only started from scratch when no applicable knowledge or technology is available elsewhere in the organization and no external partner has a relevant solution (Huston and Sakkab, 2004). Moreover, the reward system is designed to explore outside the organization, as it even favours innovations developed from outside ideas because these tend to reach the market quicker (ibid). Organizations developing innovation towards the bioeconomy should pay particular attention to combatting any feelings of Not-Invented-Here syndrome, because many new concepts in the bioeconomy will need a combination of technologies and knowledge from sectors and academic fields that are currently not connected and thus often not all present within the walls of a single organization. Moreover, limiting feelings of Not-Shared-Here can is also important in the bioeconomy context, as sharing your technology (and it subsequently being implemented by other organizations) can help your technology become the industry standard.

Another important factor is the **organization's management and leadership**. To increase the awareness of the importance of innovation among employees, leaders should demonstrate this importance in every decision (Koen et al., 2001). Also, it is the responsibility of leaders to find and fight any resistance to change in the organization (Giannopoulou et al., 2011). Herskovits et al. (2013) state that convincing senior management to embrace an open innovation culture and aiming for full recognition and support of open innovation practices within all levels of the organization are the most relevant requirements for the success of open innovation. The importance of senior management support as well as the significance of the organization's culture is further illustrated by the work of Nakagika et al. (2012) describing the open innovation efforts at Roche, one of the world's largest healthcare firms. They propagate demonstrating the value of open innovation to senior management and changing the organization's mindset to be the two most important aspects for open innovation to take hold at Roche (Nakagika et al., 2012).

The **configuration of the project team** also has an effect on the innovation performance of the organization. First, an R&D team with access to interdisciplinary knowledge, with both technological and commercial knowledge is recommended (Du et al., 2014; Van der Panne et al., 2003). The best way to realize this is to work with cross-divisional teams (Frambach al al., 1998; Grote et al., 2012; Van der Panne et al., 2003). Miller et al. (2007) even suggest that combining knowledge between internal divisions is more important than knowledge sharing between different organizations. Second, Kleinschmidt and Cooper (1995) state that R&D teams involved in several projects simultaneously are more successful than those that are not. Third, a successful open innovation project also requires team members who can operate in a boundary-spanning role, i.e. connect knowledge from different sources and find a way to combine it in new combinations (Chesbrough, 2012). Such *T-shaped managers* share knowledge with the team and the entire organization, while remaining heavily committed to their specific department or business unit (Hansen and von Oetinger, 2001).

The appropriability of IP and other outcomes from the innovation process can be an important issue in collaborative innovation efforts (Belderbos et al., 2013; Giannopoulou et al., 2011; Kleinschmit et al., 2014; Stevens et al., 2013). Therefore, an **appropriation strategy** suitable to an open innovation approach is an organizational prerequisite. It should include a large variety of appropriability methods, especially in organizations with a high degree of openness (Huang et al., 2014). Trademarks, (co)-patents, copyrights, non-disclosure agreements and confidentiality agreements are examples of formal methods of appropriation (Belderbos et al., 2013; Bogers, 2011; Huang et al., 2014; Laursen and Salter, 2013; Melese et al., 2009). Informal methods include secrecy, the complexity of design, and the benefit of lead times or first mover advantage (Huang et al., 2014; Laursen and Salter, 2013). Relying solely on informal appropriation methods requires a certain level of trust and will thus be more applicable in relations with familiar partners (Coenen and Díaz López, 2010; Faber and Hoppe, 2013; Michelfelder and Kratzer, 2013). Furthermore, in environments with strong competition and rapid technological change, lead times and first mover advantages can often dissipate quickly (Laursen and Salter, 2013). The choice of appropriation method is further influenced by the basis of the project and the type of actors involved. For instance, partnerships that are more market-based are best managed in a formal way, whereas a more loose project management positively affects science-based partnerships (Du et al., 2014). Also, more formal arrangements such as co-patenting should be employed when working with universities (Belderbos et al., 2013; Huang et al., 2014), but in intra-industry partnerships, co-patenting shows a significant negative affect on market value due to the high probability of overlapping exploitation of the co-owned knowledge (Belderbos et al., 2013). For organizations operating in a bioeconomy context, this suggests a flexible and dynamic appropriation strategy is best suited. In other words, the organization should be well versed and comfortable using an array of both informal and formal appropriation methods. Which methods are used in a certain situation depends on e.g. the type of innovation persuaded, the stakeholders involved, or the innovation process phase.

There are also a number of important preconditions related to the **organization's own resources and capacities**. When selecting innovation projects, the organization should not only consider the feasibility and profitability of the projects, but also the compatibility of the project with the organization's core competences, resources and business activities (Frambach et al., 1998; Van der Panne et al., 2003). Sisodiya et al. (2013) also found that a certain financial resource slack is beneficial to innovation projects, because it enables organizations to flexibly respond to opportunities and to changes in the innovation process. Previous engagement in innovation projects is also considered to be conducive for the organization's innovation skills and for the development of technological capabilities (Van der Panne et al., 2003). Creating new innovations is less and less considered to be the sole aim of internal R&D, but is in addition increasingly viewed as the primary generator of *absorptive capacity* (Cohen and Levinthal, 1990). Absorptive capacity is the ability of the organization to fully and successfully understand, evaluate and utilize the external knowledge provided by the stakeholders (Berkhout et al., 2010; Ulrich, 2011). Organizations who possess this capacity are more effective in collaboration (West and Bogers, 2014). It amplifies the benefits of external innovation sourcing on both innovativeness and financial performance (ibid). Furthermore, the broader the knowledge base, the more likely organizations will be able to source technologies and knowledge that are more distant from their own core competences (Laursen and Salter, 2013). These findings thus imply that an organization should not completely substitute their internal R&D activities with an external R&D system. Research by Berchicci (2013) confirms this, showing that firms with a combination of internal and external R&D perform better than those with more external than internal R&D activities. Moreover, firms with more internal R&D activities, i.e. more absorptive capacity, create more innovative output by utilizing a smaller share of external R&D than those organizations with lower R&D capacity (Berchicci, 2013). Another key factor in realizing the benefits of open innovation is relational capability (Sisodiya et al., 2013). Relational capability is the ability to create and manage the inter-organizational relationships between the different relevant stakeholders (Sisodiya et al., 2013). This includes the capability of the firm to quickly sort out the level of compatibility and complementarity with other stakeholders, its knowledge on effective communication patterns, on negotiation skills, and on conflict management techniques (ibid). Given that many of the innovations in the bioeconomy will be developed from a combination of distant knowledge and technologies provided by a large amount of diverse actors, both the development of adequate absorptive capacity and relational capability are of the utmost importance the innovating organization.

## 2.5 Discussion

Our analysis of the literature gives an overview of the important aspects for innovation management in the bioeconomy context, in accordance with the existing innovation management theory, strengthened and supplemented by a number of innovation experts. Based on five characteristics of the bioeconomy, we found that innovation processes in the bioeconomy are best considered as transdisciplinary endeavours, open to relevant stakeholders, with ample room for iterativety between idea development, invention, and commercialization. Successfully managing such innovation processes requires organizations striving to innovate towards the bioeconomy to be able to accommodate such an open approach to innovation. Among others, leadership should embrace innovation and openness, the organizational culture should reflex this, the available knowledge, expertise and technology needs to be scrutinized, and relational capability and absorptive capacity needs to be adequate. Based on these prerequisites, a layered innovation network should be configured. A natural first step of the iterative network management process is to analyse the needs of the project, followed by the identification of relevant actors, and activities to arrange the effective collaboration between the different network actors at the appropriate innovation process phase. These general guidelines and recommendations, combined into the Bioeconomy Innovation Development (BioID) model can serve as a solid basis for (innovation) managers with a non-TIM background, who often have little experience in open innovation (Rönnlund et al., 2014), but who are looking to engage in more open innovation efforts and for bioeconomy scholars from other fields with ambitions in TIM research. However, it cannot be considered a readily applicable one-size-fits-all guide to innovation management in the bioeconomy, as the bioeconomy is considered a collection of actions spanning across many different sectors and subsectors. Moreover, the transition towards the bioeconomy will consists of a collection of different innovations and innovation processes, including radical developments in new technology and radical product innovation, but also substantial and incremental changes in current business models and supply chains. Hence, the exact specificities of the innovation management strategy (e.g. level of openness, which stakeholders are relevant, which appropriation mechanism is appropriate, etc.) will be defined by the specific conditions (e.g. organizational characteristics, sectors involved, type of innovation developed) of the particular organization and project.

This paper contributes to the development of the bioeconomy by looking at the bioeconomy and its challenges from a currently underdeveloped managerial perspective (Vandermeulen et al., 2011). Specifically, the analysis of a large body of TIM-literature, with an emphasis on the leading field of open innovation, is the first step in addressing the gap between the recognition by many policy makers (e.g. European Commission, 2012; OECD, 2009) and scholars (e.g. Holl and Rama, 2012; Khan et al., 2013; Kleinschmit et al., 2014) that innovation is essential to the successful development of the bioeconomy on the one hand, and the very limited (scholarly) attention to technology and innovation management in the bioeconomy (Golembiewski et al., 2015). This study can initiate further research on innovation management in the bioeconomy, especially empirical and case-study work to further enrich our understanding on successful innovation management approaches in the bioeconomy. The paper also contributes to the open innovation literature by synthesizing the insights of many open innovation studies which, for the most part, focus on specific stages of the process rather than on the innovation process as a whole (e.g. R&D (Bruns et al., 2008)) and often only investigate specific aspects linked to innovation (e.g. knowledge sharing (Bogers, 2011) or absorptive capacity (Cheng and Huizingh, 2014; Spithoven and Teirlinck, 2006). Also, this synthesis contributes to alleviate the apparent struggle managers experience when implementing open innovation strategies (Almirall et al., 2014), which is reflected in the rather low success rate of open innovation found in different studies (up to 50% failures in inter-firm partnerships) (Michelfelder and Kratzer, 2013). Indeed, the important aspects, guiding principles and recommendations discussed in this work can also apply in other context besides the bioeconomy, so long as these context are characterised by similar contextual factors as identified in section 2.3. Although the BioID model will be largely applicable in these contexts, managers and scholars need to take into account that any deviation in the contextual factors can result in different levels of required alterations to the model.

## 2.6 Conclusion

Based on the rich valuable insights of previous technology and innovation management studies, this paper explored the most relevant aspects of innovation management in relation to the development of new concepts, i.e. products, processes, or technologies, in the emerging bioeconomy. The transition from our fossil-based economy to the bioeconomy will require radical and disruptive innovations, based on a complex knowledge base. Cooperation between organizations of different value chains and sectors will be a necessity, and the developed new concepts will have to fit into the currently complex and fragmented policy schemes and regulations, as well as overcome barriers related to adoption. Based on these contextual factors, we postulate innovation processes in the bioeconomy context should be transdisciplinary in nature, have open boundaries to include a network of diverse stakeholders, and be organized in a non-linear, flexible way to allow iteration and feedback between the different process phases; the idea generation phase, invention phase and commercialization phase. To meaningfully interact with op to seven relevant stakeholder groups, we propose a layered network management scheme, which divides stakeholders into a core group of important stakeholders and a periphery group containing less crucial actors. In order to be able to develop such an open innovation approach, a number of organizational characteristics are required. We identified and elaborated five groups of such prerequisites. With this work, we hope to provide practitioners with a set of guidelines and recommendations for innovation in the bioeconomy context, while also offering a contribution from a TIM-perspective to the bioeconomy transition, which is currently underdeveloped. These insights should be further tested and validated through follow-up case studies of organizations and start-ups which are currently taken the lead in this transition from a fossil-based economy towards bio-based economy.

# Chapter 3

# The Organizational Innovation System:

# A framework for radical innovation at the organizational level

**Abstract**

Most research on innovation management at the organizational level has typically been focused on one specific innovation project phase or innovation management concept. This has resulted in many valuable insights, though scattered in different (innovation) research fields and studies. With the development of the Organizational Innovation System (OIS), we bring together important insights from the Innovation Systems, Open Innovation and other related fields into a guiding concept useful for both innovation managers developing (radical) innovations and innovation scholars. In this paper, we define the OIS and its key structural components, and discuss the identified functions and categories of potential imperfections. With the OIS, we provide a holistic ,hands-on concept currently lacking in the open innovation approach. From the conceptualization, a framework for analysis is put forward which provides structure to the study of ongoing and finished innovation processes. Additionally, the development of the OIS is a first step in the development of a currently underdeveloped micro-level within the innovation systems perspective. The insights in OISs and the future insights derived from analytical efforts, will not only be beneficial for the performance of innovating organizations and organizational innovation systems but also for the performance of the higher, interconnected system levels.

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# Chapter 3 - The Organizational Innovation System:
# A framework for radical innovation at the organizational level

## 3.1 Introduction

Innovation is widely considered to be a key factor behind economic development and competitiveness for firms, regions, and nations (Frambach and Schillewaert, 2002; Reinders et al., 2010; Tödtling and Trippl, 2005). Furthermore, answering the rising demand for a transition towards an economy with more resource-efficient and sustainable production systems, fuelled by global issues such as the increasing resource scarcity, the growing world population, land scarcity and global warming, requires numerous innovations of different magnitude. Minor changes to existing technologies or products, i.e. incremental innovations, are one piece of the puzzle, but the most important driver in this transition are more radical innovations, i.e. new-to-the-world concepts. Successfully implementing these new concepts involves alterations to the core dimensions of the existing socio-technical-system, i.e. the stable configuration of linked and aligned dimensions: technology, user practices and markets, industries, infrastructure, policy, and techno-scientific knowledge, as well as alterations to the linkages between these dimensions (Farla et al., 2010; Geels, 2002; 2005; 2006; Kircher, 2012; Van Humbeeck, 2003). Consequently, these complex radical innovations have to be developed using innovation processes that take into account these multi-dimensional aspects (Bruns et al., 2008; Kroon et al., 2008).

However, the mindset of many (innovation) managers, researchers, policy makers and the general public is still dominated by innovation models stemming from approaches that either focus on a single dimension (the *push* and *pull* approaches) or on a very limited number of dimensions (the *coupled* approach) (Berkhout et al., 2010; Caetano and Amaral, 2011; Kroon et al, 2008; Rothwell, 1994; Tödtling and Trippl, 2005)[7]. These approaches and their uni-disciplinary models with closed boundaries and inflexible, linear trajectories without feedback are ineffective and no longer sufficient to systematically succeed in cost-efficiently delivering (radical) innovations (Bigliardi et al., 2012; Han et al., 2012).

One approach that is well suited as a theoretical background for the development of complex radical innovations is the innovation systems perspective because of its dynamic approach and holistic view on innovation (Budde et al., 2012). The innovation system construct has been developed to capture and understand the relations between producers, users, governments

[7] For a more elaborate description of the approaches, see chapter 1 and Rothwell (1994).

and institutions, and by doing so, helps to identify system failures and deadlocks, rather than mere market failures as reasons behind innovation failure (Faber and Hoppe, 2013). Consequently, within this paradigm, innovation is viewed as an evolutionary, non-linear and iterative learning process, which requires intense communication and collaboration between different actors in order to take into account the multi-dimensional aspects of innovation (Budde et al., 2012; Tödtling and Trippl, 2005; West and Bogers, 2014). Currently, research on innovation systems is mainly oriented towards the macro level (national innovation systems, NIS (e.g. Carlsson et al., 2002; Freeman, 1995)) and the meso level (regional innovation systems, RIS (e.g. Asheim et al., 2011; Cooke et al., 1997) and sectoral innovation systems, SIS (e.g. Faber and Hoppe; 2013; Malerba, 2002)). Another body of IS-research focusses on the system surrounding a particular technology (technological innovation system, TIS (e.g. Bergek et al., 2008; Carlsson, 1997)). Moreover, due to the globalizing economy, the international or global innovation system (IIS or GIS) is increasingly receiving attention (Balzat and Hanusch, 2004; Chung, 2002; Freeman, 2002; Fromhold-Eisebith, 2007; Walshok et al., 2014). The micro level however, that of the innovating organization, has received very little attention within the innovation system perspective). As a result, micro-level innovation managers are in need of hands-on models for innovation development (Berkhout et al., 2010) that bring together the many valuable insights currently scattered in different studies and different (innovation) research fields (Alänge, 2013).

In this paper, we develop this innovation systems micro level, the *Organizational Innovation System (OIS),* and develop a framework to analyse different organizational innovation systems. With the OIS, we aim to give a more holistic, comprehensive overview of important issues during a radical innovation project - from idea development to commercialization - based primarily on the innovation systems literature and open innovation literature, supplemented with insights from other related literature. Consequently, the organizational innovation system contributes to the innovation literature and practice in four important ways. First, the OIS provides the innovation systems perspective with a micro level that is currently underdeveloped. Second, the OIS-concept provides innovation managers with a more comprehensive guiding model for the development of complex radical innovations within the multidimensional, multi-stakeholder innovation systems context. These types of models are currently lacking in both the innovation systems and open innovation perspective (Giannopoulou et al., 2011). Third, by developing a framework for analysis, innovation managers and scholars can study and compare OISs, potentially leading to further valuable insights to increase innovation efficiency and efficacy of innovation organizations. The importance of improving efficacy and efficiency of innovation processes will only increase due to shortening product life cycles, increasing research and development costs, continuously decreasing innovation times and technology becoming increasingly complex (Drechsler and Natter, 2012; Holl and Rama, 2012; Ritter and Gemünden, 2004; Vanhaverbeke and Cloodt, 2006). Fourth, improved innovation performance on the organizational level will have a direct positive effect on the performance of related higher system levels, thus increasing growth of the related regions and nations. This is due to the interconnectedness and interdependence of the different system levels (Walshok et al., 2014) (figure 5).

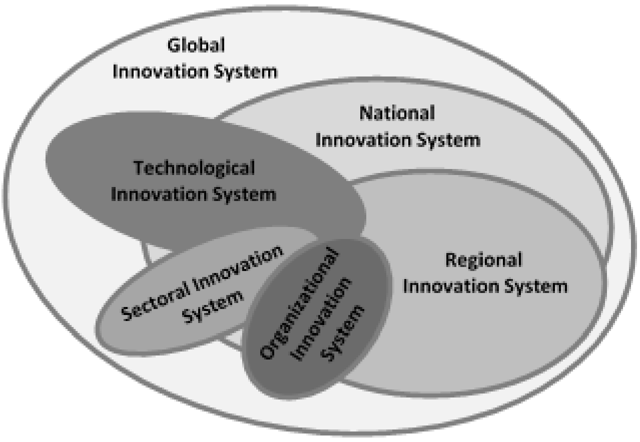


**Figure 5** Relationship between innovation systems levels (Adapted from Asheim et al., 2011)

An OIS is related to innovation systems at other levels in different ways. A TIS often cuts across several sectors, may have geographical dimension but is often international in nature (Bergek, et al., 2008). A sectoral system is embedded in one or more RISs and the regional innovation system is a sub-system of one or more national innovation systems (Asheim et al., 2011; Chung, 2002). An OIS is part of one or more SIS, which can have regional or national bounds, but it can just as well be international.

The paper continues in section 3.2 by defining the organizational innovation system and explaining how the OIS-concept is further conceptualised. Next, in section 3.3, the OIS is further developed by elaborating on its main structural components. In section 3.4, we define seven supporting functions of an OIS and in section 3.5, ten groups of potential system imperfections are developed. Based on these different OIS elements, the framework for analysis is formulated in section 3.6. The paper ends with a discussion on the implications of the OIS to theory and practice, potential paths for further research in section 3.7 and concluding remarks.

## 3.2 Defining the Organizational Innovation System

In order to define the organizational innovation system, we examined how the innovation system is conceptualised at the higher system levels. A NIS is shaped by the interaction between various agents within a nation, bound by nation-specified institutions and policies that influence a nation's capability to generate, produce and diffuse innovation (Fromhold-Eisebith, 2007; Groenewegen and van der Steen, 2006; Wang et al., 2012). The regional innovation system can be defined as an interrelationship of innovation actors and institutions in a particular region that enables the generation, diffusion, and appropriation of innovation (Andersson, 2013; Chung, 2002; Fromhold-Eisebith, 2007). The SIS is conceptualised as a network of agents interacting in a specific economic or industrial area under a particular institutional infrastructure, which are involved in the generation, diffusion and utilization of innovation (Coenen and Diaz Lopez, 2010; Malerba, 2002). A technological innovation system (TIS) is a network of agents in a particular area of technology that, within the boundaries of institutions, generate, diffuse and utilize technology (Bergek et al., 2008; Carlsson, 1997).

These definitions across the different analytical levels have four communalities, allowing us to give a general definition of an innovation system: (i) a complex of diverse innovation actors (ii) that work in collaboration (iii) on the generation, development and utilization of innovation, (iv) shaped by a number of institutions (Bergek et al, 2008; Carlsson et al., 2002; Coenen and Diaz Lopez, 2010; Guan and Chen, 2012). In line with this general definition of an innovation system, the organizational innovation system can be defined as an innovation network of diverse actors, collaborating with a focal innovating organization in an innovation process, to generate, develop and commercialize a new concept, shaped by institutions.

The four main structural components: (i) the diverse actors; (ii) the innovation network; (iii) the innovation process; and (iv) the institutions that contribute to the main goal of an OIS, i.e. the generation, development and commercialization of a new concept are further elaborated using insights from different relevant literature. We have collected findings of different scholars primarily from the innovation systems literature and open innovation literature. We selected the open innovation paradigm as a second primary theoretical background due to its complementarity to the innovation systems approach. This popular paradigm also places strong emphasis on the importance of a flexible and dynamic innovation process (Chesbrough, 2003; 2012). Additionally, open innovation strongly propagates collaboration, stressing the importance of opening up the organization to bring external knowledge and ideas into the organization, and also to commercialize internally developed ideas through outside channels (e.g. spin-offs, licensing) (ibid). Furthermore, open innovation is also viewed as a well suited approach to pursue the development of more radical types of innovation (Bigliardi et al., 2012).

However, although the majority of research on open innovation focusses on the organizational level, it rarely looks at the innovation process as a whole (West and Bogers, 2014) but rather focusses on specific stages of the process (e.g. idea generation (Salter et al., 2015) or Research and Development (R&D) (Bruns et al., 2008)) or on specific aspects linked to innovation (e.g. knowledge sharing (Bogers, 2011) or absorptive capacity (Patterson and Ambrosini, 2015; Spithoven et al., 2010)), resulting in a lack of models explaining how an open innovation process should be executed (Giannopoulou et al., 2011).

To increase comprehensiveness of the OIS-concept, insights from other related perspectives and constructs such as the Multi-Level Perspective (MLP) (e.g. Geels, 2006; Geels and Schot, 2007), Business Models (e.g. Bocken et al., 2014; Osterwalder and Pigneur, 2005) and Innovation Adoption (e.g. Hameed et al., 2012; Rogers, 1995) were incorporated. Subsequently, these insights were also used to develop the framework for analysis of organizational innovation systems. The analyses on the organizational level, which should yield insights in OIS performance, is primarily based on the prevalence of a number of supporting functions and the prevalence of a number of system imperfections. This is in congruence with the analytic methods used at higher system levels. On these higher levels, the primary aim of a significant number of studies is to analyse and compare different innovation systems and formulate policy recommendations to improve the performance of the innovation system(s) under study (e.g. Collins and Pontikakis, 2006; Martin and Moodysson, 2013; Park and Lee, 2005). The performance is either judged on the ability to perform seven supporting functions: entrepreneurial activities, knowledge development, knowledge diffusion, guidance of the search, market formation, resources mobilization and creation of legitimacy (e.g. Bergek et al., 2008; Hekkert et al., 2007), or on the prevalence of a number of system imperfections such as infrastructural failure or weak network failure (e.g. Carlsson and Jacobsson, 1997; Woolthuis et al., 2005).

We choose to develop the OIS-concept with both a number of supporting function and system imperfection categories for two reasons. First, this method of structuring and analysing has already yielded valuable insights and policy recommendations in studies on higher system levels. Second, thinking in terms of beneficial general functions within an organizational innovation system and disrupting imperfections, allows us to better bring together the many fragmented important aspects of innovation management into a limited amount of aggregated categories of importance. Consequently, a clearer, less complicated overview of important aspects throughout the whole innovation process can be developed, whereas other methods summing up every fragmented beneficial aspect would result in less hands-on, more complex models and concepts.

## 3.3 The structural components of the Organizational Innovation System

In the definition of an OIS established above, four main structural components are derived: (i) the innovation process; (ii) the actors; (iii) the innovation network; and (iv) the institutions. Since the 1980s, a significant increase in organizations engaging in external collaboration has been observed, causing organizational boundaries to blur (Gulati et al., 2012). Therefore, before exploring the structural components of the OIS, some elaboration on the focal point of the OIS, the innovating organization, is required. We consider an organization to be a legal entity of consisting of individuals, employed to achieve a collective goal (Coase 1937; Kogut and Zander, 1996). All persons with an employment relationship and all official business units or subsidiaries are considered part of the innovating organization. Consequently, in congruence with work on *Meta-Organizations* (Gulati et al., 2012), we consider all entities or individuals not employed by the organization to be external agents outside of the organizational boundaries (Dahlander and Gann, 2010). Innovating organizations can be firms, research institutes, governmental agencies or other institutes.

In order for an innovating organization to successfully develop (radical) innovations, **the innovation process** should be a non-linear and iterative learning process with intense communication and collaboration between different actors to take into account the multi-dimensional aspects of innovation (Budde et al., 2012; Coenen and Diaz Lopez, 2010; Tödtling and Trippl, 2005). The innovation process within the OIS concept is divided in three main process phases, as derived from the general consensus on the definition of innovation across the innovation literature. Innovation stems from an innovative idea, which is developed into an invention, and this invention cannot be called an innovation as long as the invention is not incorporated into the organization or introduced to and adopted by the market (Bogers and West, 2012; Bruns et al., 2008; Kroon et al., 2008; Pullen et al., 2012; Vanhaverbeke and Cloodt, 2006). Therefore, the three main innovation process phases are the idea development phase, the invention phase and the commercialization phase.

Each main phase contains a number of subphases. The idea development phase can be separated in activities that involve identifying potential sources of innovations, generating innovative ideas to exploit these trends and opportunities, judging the feasibility of these ideas and selecting the most attractive ideas for further development. The subphases with more emphasis on techno-scientific aspects, from project design to real life testing of proof of concepts, are bundled in the invention phase. The commercialization phase entails the more socio-economic phases towards end-user adoption such as demonstration activities and determining the marketing strategy. Figure 6 gives an overview of the three main phases with their subphases.

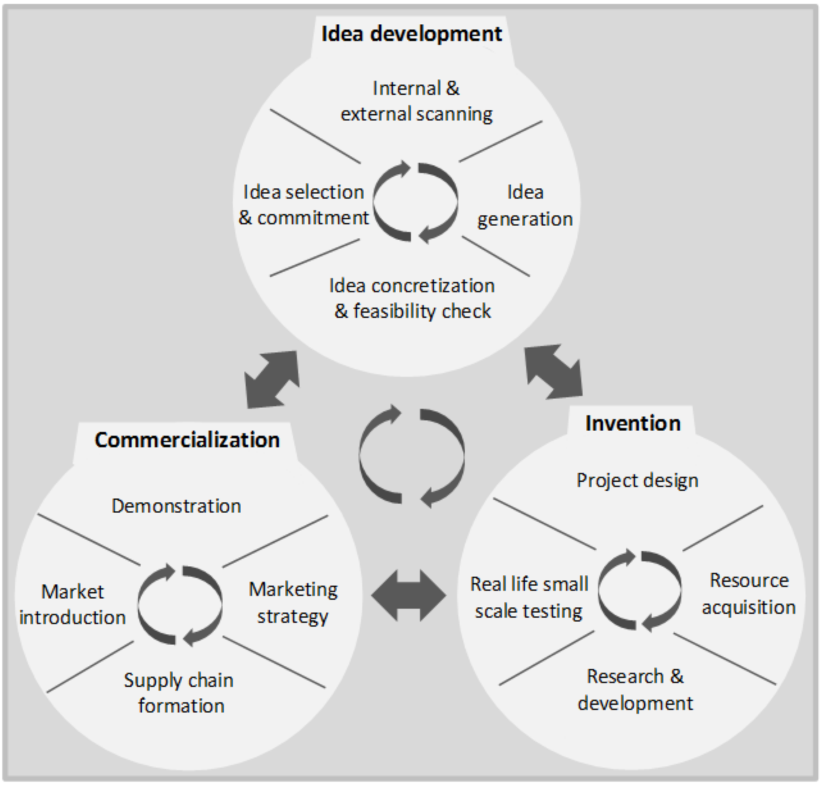


**Figure 6** Main and subphases innovation process

The relevant **actors** of the OIS are those groups or individuals who affect or are affected by the innovation process, i.e. those who have a certain stake in the innovation process (Freeman, 1984). These stakeholders can be divided into different stakeholder groups. The potentially relevant stakeholders for innovation projects include competitors, suppliers, intermediate users, end-users, industry associations, financial partners, universities and (private) research institutions, network organizations, government bodies, non-governmental organizations (NGOs), expert consultants, knowledge brokers, and firms from unrelated industries (Bogers and West, 2012; Bruns et al., 2008; Chesbrough, 2003; 2012; Huizingh, 2011; Laursen and Salter, 2006; Lichtenthaler, 2011; Nowotny et al., 2003; Pohl, 2005; 2011; Sarkar and Costa, 2008).

During all phases of an innovation project, the process should be systematically open to an **innovation network** consisting of representatives of these various relevant stakeholder groups, in order to access their different expert knowledge and other resources (Chesbrough, 2003; Gallagher et al., 2012; Malerba, 2002; Wetergren and Holmeström, 2012). However, participation with an innovation network is not a binary choice between essentially closed or completely open innovation. There is a spectrum of possible collaborative arrangements between those two extremes (Bahemia and squire, 2010; Chesbrough, 2003; Huizingh, 2011). The innovating organization should employ a dynamic, layered collaboration strategy. The layeredness entails that the innovation network can consist of two layers. The first layer is a smaller core group of stakeholders with whom the organization works in close collaboration, sharing knowledge openly (Bogers, 2011). The second layer consists of a larger periphery of diverse stakeholders that are less involved, though participate in the innovation process, with whom not all information is shared (ibid). The layered strategy allows organizations to have a large heterogeneous network which has a positive effect on the development of (radical) innovation (Bahemia and Squire, 2010; Berkhout et al., 2010; Westergren and Holmeström, 2012), while allowing a more closed approach to networking, proven to have a beneficial effect on innovation performance (Pullen et al., 2012). This layeredness is dynamic in time, depending on the stage of the innovation process. In an early stage, participation with the innovation network will be more open to the broad innovation network in order to maximally explore its knowledge and other resources, whereas stages of the innovation process involving more confidentiality necessitate more closed approaches to optimally exploit the knowledge and other resources (Bahemia and squire, 2010; Cooke et al., 1997). Besides the level of openness to the network, which stakeholders should be part of the core group and which belong in the periphery layer, is also dynamic and function of the innovation stage. For instance, during stages of invention, technology providers and innovative upstream firms will be closely involved, whereas during commercialization stages, downstream players come to the foreground to get the innovation to market (Vanhaverbeke and Cloodt, 2006). However, the periphery of the innovation network should be regularly consulted by sharing non-confidential information about the innovation. By doing so, the innovation network can act as a reference group, suggesting adjustments to be made to the innovation to better fit the external expectations. Furthermore, the whole innovation network, including the peripheral stakeholders, should help create legitimacy and support for the innovation. The process of legitimation entails the efforts and strategies to overcome the liability of newness of the innovation. These efforts can range from adjusting the innovation to fit the existing institutional framework (e.g. choosing to follow an established product standard or legislation) to creating a new institutional framework that fits the innovation specificities under development (e.g. establish new product standards or lobby for changes in legislation) (Bergek et al., 2008; Spencer, 2003).

**Institutions** form a key factor in systems theory that envisions the institutional context as a defining and structuring element of the system (Woolthuis et al., 2005). The dynamic layered collaboration scheme requires strong institutions within the OIS to efficiently and effectively collaborate with the stakeholders, as institutions shape the interactions between them, providing the stakeholders some sort of stability in the light of the intrinsic risk connected to innovation activities (Coenen and Diaz Lopez, 2010; Faber and Hoppe, 2013; Kaiser and

Prange, 2004; Malerba, 2002). A commonly used and accepted distinction is made between formal and informal institutions (Coenen and Diaz Lopez, 2010; Kaiser and Prange, 2004). Informal institutions influence social and economic life in a subtle, often intangible way (Coenen and Diaz Lopez, 2010). Examples include trust, habits, norms and values, beliefs, conventions, traditions, routines, and preferences (Coenen and Diaz Lopez, 2010; Faber and Hoppe, 2013; Geels, 2005; Huang et al., 2014). Formal institution are more formal and tangible, such as laws, regulations, contracts, standards, product specifications, and property rights (Coenen and Diaz Lopez, 2010; Faber and Hoppe, 2013; Huang et al., 2014; Kaiser and Prange, 2004). Hard institutions in the OIS level would include non-disclosure agreements, collaboration contracts, intellectual property(IP)-arrangements, written agreements about the distributions of the developed value, etc. that can facilitate the open sharing of knowledge and resources between the stakeholders (Bogers, 2011; Melese et al., 2009). Also, there needs to be an alignment in soft institutions such as beliefs, norms and values, and expectations between the different collaborating partners, supplemented by a certain level of trust.

Besides the importance of institutions on the OIS-level, the institutions of national (e.g. patent system, laws), sectoral (e.g. sectoral labour market) or other system levels can also influence how the innovating organization is shaped, how the relationships between organizations are formed and which innovative ideas are viable, consequently influencing the innovation process and the OIS as a whole (Malerba, 2002). In addition to these contextual institutions, other contextual factors such as the dimensions of the dominant socio-technical system, e.g. scientific, technical, political, cultural, industrial, and market aspects (Geels, 2005), and networks formed within the higher system-levels of which the organizational innovation system is a part, are linked and aligned to the existing technology (Geels, 2002), potentially influencing the OIS. Therefore, innovation efforts that do not take the interdependency between these different dimensions into account will face a number of barriers to market adoption (Farla et al., 2010). Such barriers, but also triggers for innovation processes may exist in each of the system levels (Faber and Hoppe, 2013). Consequently, innovation within the system perspective is seen as a multidisciplinary activity which has to take these different dimensions into account from the beginning of the process and throughout the whole innovation process (Kroon et al., 2008). To optimally do so, linkages should be made across disciplinary boundaries and between theoretical development and professional practice, transcending academic disciplinary structure (Hadorn et al., 2006; Pohl, 2005; 2011; Nowotny et al., 2003; Veldkamp et al., 2009).

In this multi-stakeholder, multi-dimensional setting, learning between collaborating partners plays a vital role, necessitating a process with frequent iteration and feedback in order to be able to repeat process stages to undertake corrections, adjust to unforeseen developments and correct mistakes (Bruns et al., 2008; Fetterhoff and Voelkel, 2006; Gallagher et al. 2012; Hermans, 2011; Van der Duin et al., 2007; Veldkamp et al., 2009). Therefore, the innovation process should be organized in a non-linear, iterative, flexible fashion with interconnected cycles (Arnold and Barth, 2012; Berkhout et al., 2010; Bruns et al., 2008; Gallagher et al., 2012; Kroon et al., 2008; Pullen et al., 2012; Van der Duin et al., 2007). To emphasize this non-linear, iterative character of the innovation process, it is depicted in figure 7 using looping and double arrows. Furthermore, to highlight that innovation processes do not consist of a fixed number of phases that follow each other seamlessly, the phases are placed in circles and depicted in a non-sequential order. Figure 7 shows a schematic overview of the OIS and its main structural components, within the higher system levels' contextual aspects which form its contextual boundaries.

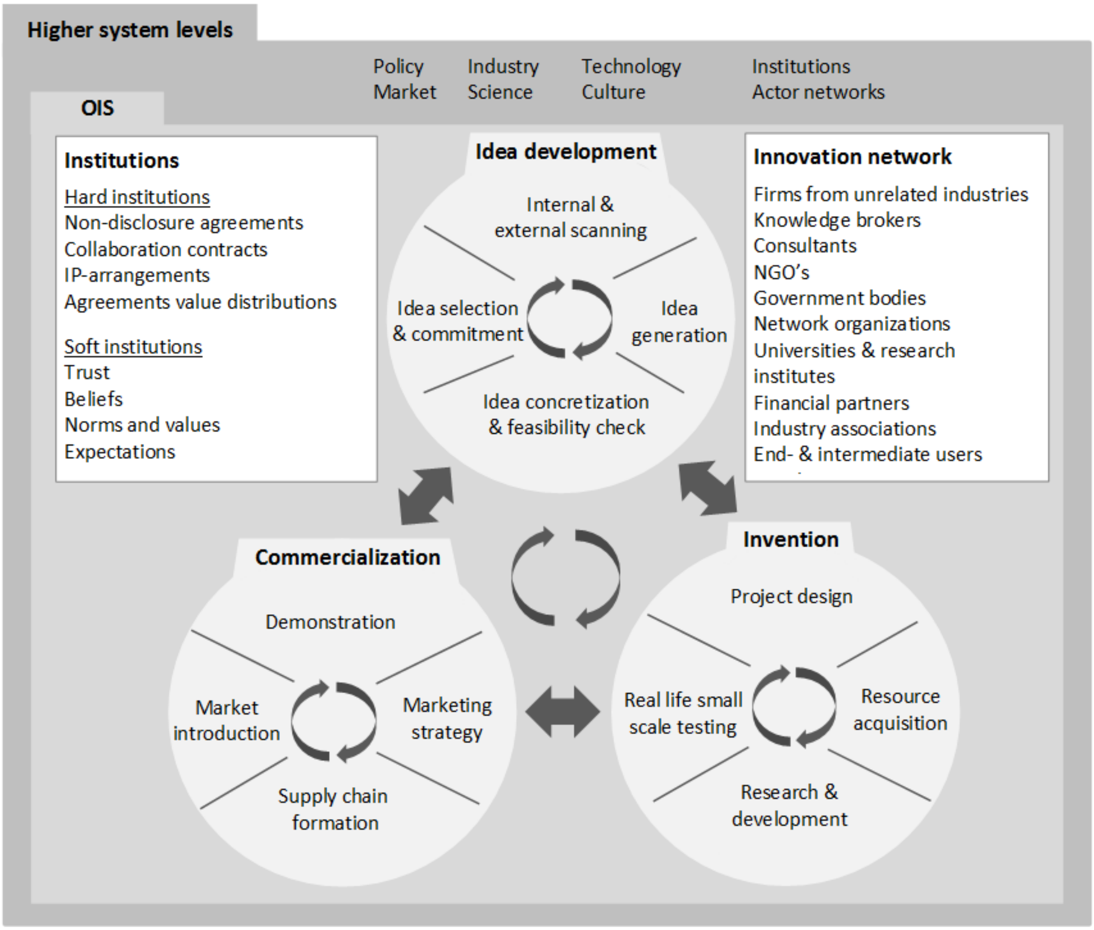


**Figure 7** Main structural components of the organizational innovation system

## 3.4 The supporting functions of the Organizational Innovation System

Seven supporting functions of an organizational innovation system are identified and developed, allowing a better understanding of how an OIS should be configured to maximise the chances of a successful outcome and facilitating the analysis of the performance of an OIS. These seven functions are: (i) provide opportunities, trends and ideas; (ii) reduce uncertainty about the innovative idea; (iii) provide complementary human and financial resources; (iv) act as a reference group during the innovation process; (v) create awareness, legitimacy and support for the innovation; (vi) facilitate market formation; and (vii) aid in supply chain formation. The further elaborating of the seven supporting functions is linked to the main innovation process stage in which the fulfilment of the respective function is most important. However, this does not imply that functions important in later phases should not be taken into account during earlier phases of the innovation process and vice versa.

### 3.4.1 Functions during the idea development phase

During the idea development phase, the OIS can play an important facilitating role. Firstly, regular interaction with diverse stakeholders will enable the organization to constantly and efficiently scan the external factors in search of inspiration for innovation (Börjesson et al., 2006; Maine et al., 2014). Furthermore, the network can aid in translating trends and opportunities into more and better ideas for innovation projects (Brettel and Cleven, 2011; Hansen and Birkinshaw, 2007; Sandulli et al., 2012). Third, stakeholders, by looking at an idea from their diverse expertise, can help identify the potential technical and socio-economic bottlenecks and inducing factors that will determine the attractiveness and feasibility of the ideas. Fourth, during the selection stage, the OIS can help safeguard that the idea with the highest value and potential win-win for the entire value chain and society is selected, rather than an idea with the highest added value for the single, innovating organization. The OIS should thus provide the innovating organization with insights in external opportunities and trends, more and better ideas to choose from and a multidisciplinary viewpoint on the feasibility of the ideas. This allows us to formulate the first two functions of the organizational innovation system; first, **providing opportunities, trends and ideas for innovation projects** and second, **reduce uncertainty about the selected innovation idea and subsequent innovation project**.

### 3.4.2 Functions during the invention phase

During the invention phase, the innovative idea is first translated into a project design. From this project design, it becomes fully clear which resources will be required to develop the innovation. These resources can be financial resources such as capital, infrastructure, machinery, lab equipment, etc. or human resources, i.e. people with the multidisciplinary knowledge, skills and/or knowhow to successfully develop a feasible idea into a marketable invention (Bigliardi et al., 2012; Holl and Rama, 2012; Rampersad et al., 2010; Sandulli et al., 2012). The OIS can play a significant role in the invention phase by providing the resources the innovating organization is lacking (Brettel and Cleven, 2011). This type of collaboration requires well formulated hard institutions with a clear division of tasks, roles, and responsibilities between the collaborating partners, as well as complementary soft institutions such as beliefs, expectations and trust. The third function of the organizational innovation system is thus to **provide the complementary financial and human resources** required to develop the invention. The fourth function of the OIS is a **reference function**. The periphery stakeholders should be used as a reference group to check if the development of the innovation proceeds in congruence with the wishes and needs of downstream stakeholders, the market and society.

### 3.4.3 Functions during the commercialization phase

The commercialization phase entails a number of actions with the ultimate goal to maximally increase the chances of market adoption, i.e. the decision of an individual or organization to make use of an innovation (Frambach and Schilewaert, 2002). The innovation characteristics that have a positive effect on the adoption decision include the perceived relative advantage of the innovation over the existing concepts, the perceived compatibility of the innovation with existing values, past experiences and needs of potential adopters, the perceived observability of the results of the innovation and the perceived trialability of the innovation. Negative effects on adoption include the perceived complexity, difficulty to understand and use the innovation, and the perceived uncertainty regarding the innovation (Arts et al., 2011; Frambach and Schilewaert, 2002; Frambach et al., 1998; Nooteboom, 1989; Rogers, 1995; Tornatzky and Klein, 1982). Consequently, efforts should be made to emphasize the relative advantage of the innovation, increase its compatibility, observability, and trialability, as well as reduce as much uncertainty and complexity as possible.

A way to increase compatibility is to take into account the needs and wants of the users and other stakeholders from the beginning of the process, in the idea development phase and throughout the invention process. Another important aspect to increase adoption chance is to organize demonstration and dissemination events on a regular basis. During these events, information about the innovation specifications, e.g. how it will work and what the benefits are or will be, are shared with the general public to reduce uncertainty and complexity of the innovation while also absorbing the feedback received from these events to further improve the fit of the innovation. Providing early and timely information is particularly important for highly innovative and discontinues new concepts to avoid harsh judgment by the market (Berkhout et al., 2010). These demonstration and dissemination events should also be organized as early as possible during the process and throughout the process. Apart from helping to reduce uncertainty, these events also help to create awareness for the innovation, and, with the correct communications, assures a certain familiarity with and acceptance of the new concept before it is even launched to market (Arnold and Barth, 2012; Spencer, 2003), which helps create legitimacy for the innovation. These type of activities, together with activities that help shape certain institutions in favour of the developing innovation, are all part of the OIS's fifth function; **creating legitimacy for the innovation**.

A sixth function related to the commercialization of the innovation is to **facilitate market formation**. Although some radical innovations could be directly diffused to the mass market, most will have to find their way to the mass market through a niche. These niches are markets where selection criteria are different from the dominant socio-technical regime (Geels, 2002; Hermans et al., 2013). There are two distinct types of niches: the *technological niche* and the *market niche*. A technological niche is deliberately created by actors to have spaces for experiments, pilot and demonstration projects, and often a first market for the developed new concept (Schot and Geels, 2007). Market niches are a select number of innovators and early adopters that have a positive attitude towards innovative features and can benefit from the innovation (Rogers, 1995; Walter et al., 2012). These niches serve as nursing markets which, through the spread of information, interaction and contamination effects, help bridge *the chasm* that exists between the niche markets and the mass markets (Bergek et al., 2008; Frambach et al., 1998; Moore, 1991). One example is T-City, Friedrichshafen in Germany. This city is a large test market and showcase for new technology from Deutsche Telekom (Rohrbeck et al., 2009). It is the task of the OIS to aid in setting up a technological niche and/or to help identify market niches, thus facilitating market formation.

The seventh and final function of the organizational innovation system is the **facilitation of the supply chain formation**. A lean supply chain that can effectively and efficiently assure quality products is beneficial for the adoption of the innovation. This supply chain can be formed with downstream stakeholders from the innovation network, or actors provided by stakeholders in the innovation network.

## 3.5 Organizational system failures

When an OIS-supported innovation project fails to get the new concept to market, this can be due to certain failures or imperfections in the organizational innovation system. Although some of the system imperfection categories on the OIS level are similar to the ones at higher system levels, their conceptualisation has to be altered to better fit the micro level. The potential failures on the organizational level are manifold, but can be categorised into ten different groups of imperfections (table 6), related to the one of the main structural components of the OIS or one of its supporting functions.

**Table 6** Summary of the possible organizational innovation system failure groups

| OIS failure groups | Explanation |
|---|---|
| Dimensional blindness failure | Overlooking of one or more dimensions or not focusing on one or more dimensions soon enough |
| Iteration failure | Improper balance between too much iterativety and too little feedback loops |
| Resource failure | Too few financial resources or human resources within the OIS to successfully generate, develop and diffuse the innovation |
| Representativeness failure | Improper stakeholder group representativeness, non-representative organization or individual for the group, or non-representative individual for the organization |
| Openness failure | Improper balance between consulting and participating with too many stakeholders and too few |
| Cooperation failure | Too few strong ties in the innovation network, leading to, for example, trust issues and difficulties in cooperation |
| Lock-in failure | Too many strong ties, leading to, for example, *group think*, resulting in myopia and inertia within the innovation network |
| Hard institutional failure | The lack or underdevelopment of formal arrangements, e.g. collaboration contracts, IP-arrangements and non-disclosure agreements |
| Soft institutional failure | The lack or non-alignment of informal arrangements, e.g. shared vision, social values, culture and norms, mutual trust, goals of the different partners and business models |
| Capacity failure | The lack of certain capacities of the innovation organization to maximally profit from the OIS, e.g. absorptive capacity or network management capacity |

The first two groups of failures relate to the organization of the innovation process. The first failure that can occur is that the innovation process was organized and ran without taking into account all system dimensions, thereby creating unsurmountable bottleneck(s), preventing the project to succeed. For instance, unidentified legislation or poorly investigated market demand can respectively make a potential innovation illegal or not attractive enough for potential adopters. Also, analyses of best practices in many firms and industries shows that aspects that become more important in later stages of the process (e.g. marketing and launch planning in the commercialisation phase), should already be taken into account at an early stage of the project and should be monitored throughout the whole process (Börjesson et al., 2006; Guiltinan, 1999). We categorize the overlooking and underinvestigating of one or more dimensions of the innovation system, or taking innovation aspects into account too late into the process **dimensional blindness failure**. Second, the flexible and iterative nature of the process could also cause problems. Too little iteration can be harmful and deadlock the innovation process or have it yield a suboptimal result. For instance, too little iteration during the idea development phase can cause the selection of a sub-feasible idea. This is due to the inseparability of the idea generation and idea concretization subphase, necessitating iteration (Koen et al., 2001). The feedback loops may take significant time but they typically shorten the total innovation project time because integrating the multidisciplinary knowledge helps to identify bottlenecks early, which in turn helps prevent late and costly changes, or even worse, product failures (Börjesson et al., 2006; Koen et al., 2001; Sandmeier et al., 2012). But iteration and flexibility between the main phases is just as important; when an idea proves not accomplishable during R&D, additional idea development should be organized to overcome the deadlock. However, too much iteration, for instance during the idea development phase with the goal to exhaustively check the feasibility of the idea, can cost precious time to market (Koen et al., 2001). Consequently, innovation projects can fail when the right balance in iteration is not found, causing an **iteration failure**.

The third category of failures is related to the functions of the OIS to provide complementary human & financial resources necessary for the innovation process to succeed. The provision of the skills, knowledge and expertise (human resources) is of particular importance during the idea development and the invention phase whereas providing the necessary financial capital is most important during the invention and commercialization phase. If the project is faced with a shortage of either of these resources, it can fail. We labelled these failures the **resource failure**.

The fourth category is the **representativeness failure**, one of the four groups linked to the innovation network. This type of failure can manifest itself in three ways. One, the network has to consist of an adequate number of stakeholders from all relevant stakeholder groups. Two, these stakeholders have to be representative for their group in terms of characteristics and opinions. Three, when the stakeholder is an organization, the individual representing the organization should be someone who articulates the opinion and actions of the organization (and not his own) and have a certain decision power within the organization. If this is not the case, the idea selection can, for instance, be based on opinions not shared by all stakeholders within the stakeholder group. Besides the representativeness of the stakeholders in the innovation network, the amount of participating stakeholders can also influence the successful outcome of the innovation project. Research shows that organizations that open up their boundaries to search for knowledge with a wide variety of stakeholders tend to be more innovative (Berchicci, 2013). However, at a certain point, due to increasing searching- and information costs, bargaining- and decision costs, and policing- and enforcement costs (Bruns et al., 2008), diminishing returns of this openness set in (Berchicci, 2013; Laursen and Salter, 2006). Thus, a balance has to be found between consulting and participating with too many stakeholders, resulting in too much lost time and resources, and consulting with too few stakeholders, which can lead to incomplete information or suboptimal partnerships. We label a failure to find this balance, resulting in a suboptimal OIS, an **openness failure**, the fifth category of imperfections. Two more possible network failures lay in an imbalance in the network between stakeholders with whom the innovation organization habitually cooperates and stakeholders with whom it is not or less familiar. The presence of familiar stakeholders helps to build trust and allows the network to gain new members, while new stakeholders bring in new ideas and impulses (Bahemia and Squire, 2010). Bahemia and Squire (2010) advocate a network consisting of small group of weak ties (at least 20% of the network) and a large group of strong ties to generate better and more radical innovations. Too few strong ties will lead to the sixth imperfection labelled **cooperation failure**, which include trust issues and difficulties in cooperation. On the other hand, too many strong ties will lead to lock-ins in thinking due to *group think*, resulting in myopia and inertia within the network (Nooteboom, 2000), which we name **lock-in failure**, imperfection number seven.

An additional source of potential failure in the organizational innovation system lies in contradicting hard and soft institutions. The hard institutions are deliberately created, on-paper rules that regulate the collaboration within the OIS (Edquist et al., 1998). For the OIS, these can be collaboration contracts, IP-arrangements and non-disclosure agreements. The absence of hard, formal institutions or inadequately developed hard institutions can, for instance, hinder the open sharing of knowledge between partners or the exchange of other resources and can lead to opportunistic behaviour. In congruence with Carlsson and Jacobsson (1997) and Woolthuis et al. (2005), we label the lack of or underdevelopment of hard institutions in the OIS **hard institutional failure**, the eight category of imperfection. The ninth failure group is the **soft institutional failure**, which refers to the lack of commonality between the actors in the innovation network in less formal institutional aspects. Examples of these soft institutional failures are a lack of shared vision, different social values, culture and norms, a lack of trust in one another, no alignment in the goals of the different partners and incongruence in business models (Carlsson and Jacobsson, 1997; Chesbrough and Schwartz, 2007; Pullen et al., 2012; Woolthuis, et al., 2005).

The tenth and final group of failures are the **capacity failures**. This group holds all shortcomings of the innovation organization in its capacity to innovate together with the innovation network. A first possible shortcoming is a lack of absorptive capacity, impeding the innovating organization to recognize and absorb external valuable resources. Absorptive capacity is defined as the capacity of an organization to recognize the value of new, external information and apply it to commercial ends (Spithoven et al., 2010; West and Gallagher, 2006). Organizations can develop this absorptive capacity by internally developing prior (technological) knowledge and expertise (Berchicci, 2013; Lichtenthaler, 2011). Another example can be the lack of network management capacity or relational capability (Sisodiya et al., 2013). The innovation organization needs to have the competences to build an innovation network, grow it, recruit potential partners and manage the different relationships between the actors (Bahemia and Squire, 2010; Mu, 2014; Ritter and Gemunden, 2004). The innovating organization can take this role on herself, or if she should lack these competences, employ a stakeholder that takes on the role of broker. These brokers are actors that grease the wheels of the innovation systems. They function as a bridging agent in the network, facilitating resource sharing between the different collaborating actors (Klerkx et al., 2009; Lichtenthaler, 2013). If the innovation organization neither has the network management capacities, nor recruits an organization that has, this form of capacity failure can hinder the success of the OIS.

## 3.6 Framework for analysis of the Organizational Innovation System

Based on the developed facilitating functions and system imperfection groups, organizational innovation systems can be analysed to acquire insights on how to improve or adjust the systems under study. Conducted from the viewpoint of the focal organization in the innovation network, the innovating organization, the OIS can be studied using the framework depicted in figure 8.

This seven step framework for analysis can be used to study an OIS both during an ongoing innovation process to make alterations to the OIS based on the resulting insights, as well as when the innovation project is finished to analyse the reasons for failure or success, resulting in insights useful in future projects. In the first step of the analysis, the innovation project to be studied is selected. In step two, the success of the project (thus far) is reviewed based on the predetermined key performance indicators (KPIs) such as time to market, number of products sold in first few months after launch, R&D costs, etc. In step three, the structural components of the OIS are described. Then, in step 4, an analysis is made of which functions were developed, underdeveloped and undeveloped. In step five, the project is reviewed to find system imperfections which have led to the un(der)development of certain functions, ultimately resulting in meeting or not meeting the KPIs or perhaps the failure of the innovation project. From the insights gathered in these previous steps, innovation management recommendations are formulated in step 6 and the OIS is altered accordingly should the project still be ongoing in step 7. Then, this process can be repeated starting from step 3 to further monitor the projects progress.

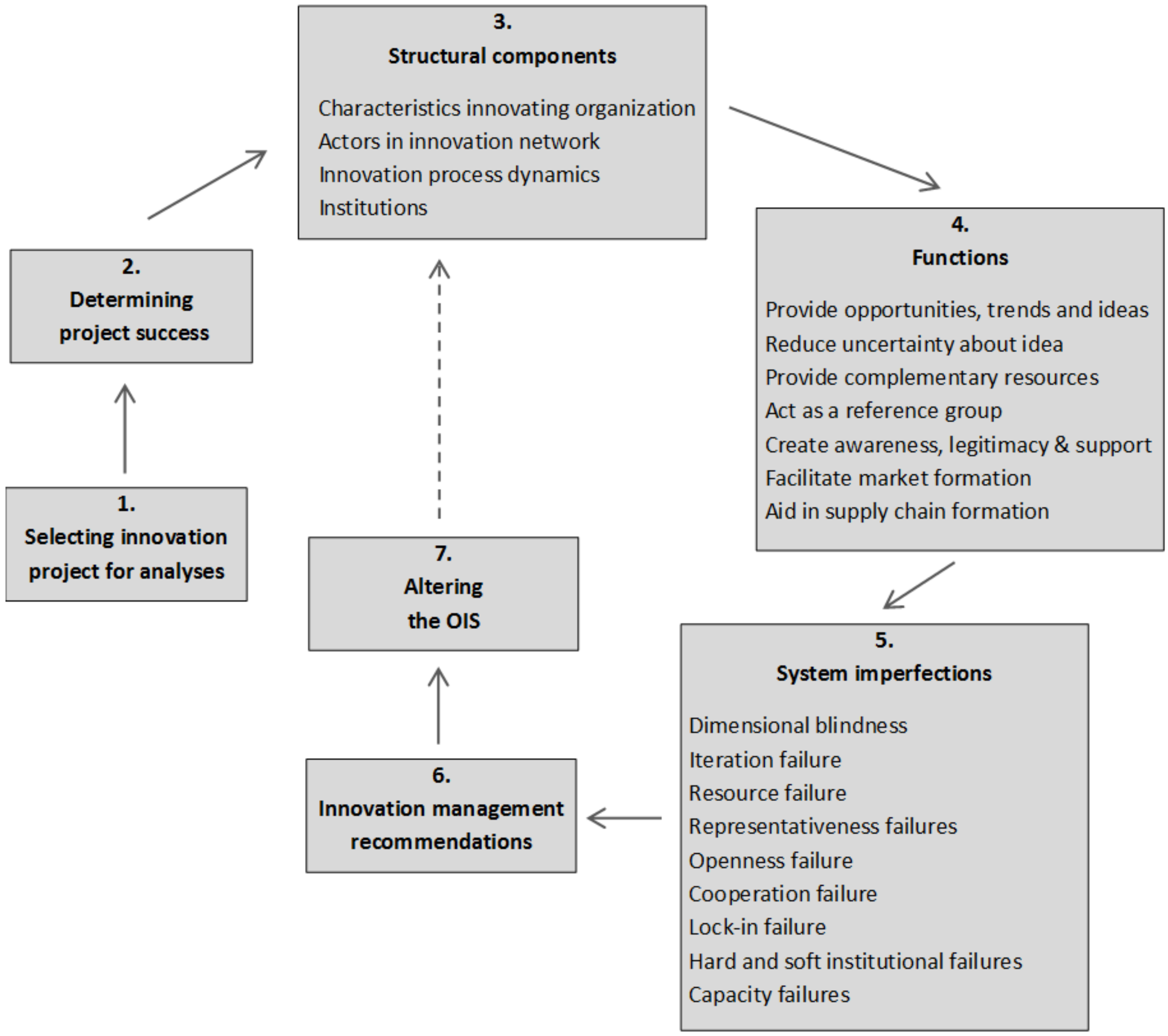


**Figure 8** Framework for analysis of organizational innovation system

## 3.7 Discussion

Changes in environmental conditions occur ever faster and product life cycles continue to shorten (Drechsler and Natter, 2012), making innovation efforts crucial to the survival of organizations. However, given the multidisciplinary nature of innovation (Kroon et al., 2008), the increasing complexity of technology (Holl and Rama, 2012; Ritter and Gemünden, 2004) and the tendency of firms and other organizations to focus on their core competences (Gulati et al., 2012), organizations are and will increasingly continue to open up their innovation processes to external stakeholders (Chesbrough, 2012). Therefore, in this paper, we developed the organizational innovation system concept to facilitate the execution and study of such open, collective innovation processes. An organizational innovation system contains a dynamic, layered innovation network of diverse relevant stakeholders, shaped by a set of formal and informal institutions. Through an iterative innovation process, it aids the focal innovating organization in generating, developing and commercializing innovations by providing the required supporting functions. However, diverse system imperfection can cause a suboptimal innovation process or even failure. Based on the structural components and functions of the OIS, ten categories of these potential imperfections are put forward. Furthermore, the elaborate conceptualization of the OIS concept allowed for the development of framework for analysis of organizational innovation systems.

With the development of the OIS concept, we contribute to the innovation management theory, in particular the Open Innovation and Innovation Systems perspective, in several important ways. First, we have made a synthesis of the innovation management insights which are currently scattered in numerous (empirical) studies and dispersed across different research fields (Open Innovation, Innovation Systems and other related concepts) and bring them together into a single, inclusive concept. Second, to the authors' knowledge, the organizational innovation system is among the first concepts that elaborates on innovation network configuration, institutional arrangements, and innovation process characteristics, while also commenting on the interconnection and interdependence between these different key innovation management aspects for the entire innovation process. Third, conceptualizing the OIS in congruence with the development of higher system levels (e.g. Woolthuis et al., 2005; Bergek et al., 2008), i.e. by using structural components, supporting functions, and groups of system imperfections, allows for a clear and accessible, though inclusive concept with a high level of comprehensiveness in the aggregated OIS-elements. Fourth, the organizational innovation system concept presented, offers a first step into the development of a currently largely overlooked and lacking micro level in the innovation systems perspective, while simultaneously providing the open innovation perspective with a concept explaining how radical innovation processes in a multidimensional, multi stakeholder context should be executed. Fifth, in addition to the conceptualization of the organizational innovation system, we further contribute to the innovation management theory through a framework for analysis, which provides a stepping stone for scholars who wish to study open, collective innovation processes from idea development to commercialization in an inclusive manner.

Besides these theoretical implications, the organizational innovation system presented also offers a number of practical contributions and implications. The OIS-concept can serve as a guiding concept or model for innovation managers to ex-ante organize their innovation processes. Guided by the OIS-model, innovation managers will look at the innovation process from a more holistic point of view. They will see the process as an iterative learning loop and will develop an innovation network with a layered innovation strategy to maximise both exploration and exploitation opportunities, while minimizing chances of negative externalities. The concept urges them to consider which stakeholders should be in the network and to which layer they belong, taking into account the phase of the innovation process and which supporting functions the innovating organization requires. Furthermore, innovation managers are encouraged to tailor their use of formal and informal institutions to best fit the situation. Furthermore, the groups of imperfections provide the managers with accessible categories of potential red flags. Using these imperfection categories in conjunction with the rest of the framework for analysis, innovation managers can critically analyse their ongoing innovation projects to rectify imperfections and other inefficiencies, or study past projects in search of best practices or lessons learned to increase efficiency and efficacy of future innovation efforts. However, when implementing the OIS concepts, managers need to take into account no one-size-fits all approach to innovation management exists. General innovation management concepts such as the organizational innovation system need to be configured to fit the specific context, depending on, for instance type of innovation pursued (e.g. product, technology, market), the newness of the innovation (e.g. incremental, radical, disruptive), the type of organization (e.g. centralized, decentralized, functional, organic), the type of industry, and the type of country (Ortt, 1998; Kotler, 2002; Ortt and van der Duin, 2008).

Despite its contributions to both theory and practice, this study is not without its limits. Although efforts were made to maximize the comprehensiveness of the aggregated system elements, the vast amount of innovation management studies in the numerous relevant research fields made it impossible for a completely comprehensive overview, especially in the elaboration on each system element. Therefore, the OIS can benefit from both further theoretical and empirical research on the topic. One valuable line of research could be on the further development of the different system elements, e.g. research on which aspects relate to *capacity failure* or which OIS activities can be labelled as part of the *facilitating market formation* function. Additionally, further research, especially empirical work, will be beneficial to not only illustrate and validate, but also to further develop the OIS-concept. Future research should also aim to critically review the different system elements as they are currently developed and will potentially reveal additional structural components, supporting functions, or failure groups. Furthermore, empirical research on organizational innovation systems will test the developed framework for analysis and contribute to its usability. Another research path on OIS can focus on the connection and interdependence between the different developed system elements, especially between the different functions and groups of systemic failures. Additionally, high potential lies in the development of archetypes of OIS. Similar to typologies of meta-organizations (Gulati et al., 2012), modes of open innovation (Lazzarotti and Manzini, 2009), or archetypes of open innovation users (Keupp and Gassmann; 2009), these archetypes of organizational innovation systems could be differentiated by differences in innovating organization characteristics (e.g. type, size, industry), innovation network structure, institutions used, or prevalent functions. Finally, although the link between the micro level of OIS and the higher system levels has been established in this work, future research can enrich the understanding on how the OIS influences the performance of the connected other systems and vice versa.

## 3.8 Conclusion

Many organizations are already implementing collaborative, open innovation activities with external partners. Although many success stories exists and these type of open innovation activities are associated with a substantial number of potential benefits, collaborating with external stakeholders often proves challenging. With the Organizational Innovation System, we provide a holistic concept that offers insights in stakeholder groups, network strategy, and institutional arrangements across the different innovation process phases. With the development of seven OIS functions, ten groups of potential OIS failure, and the framework for analysis, we aimed to further amplify the comprehensiveness and usability of the concept. The OIS can guide both (innovation) managers and scholars in the set-up of projects as well as in the analysis of ongoing and finished innovation efforts to help maximize the benefits and minimize the risk associated with open innovation.

# Chapter 4

# Bio-based open innovation projects at a public research institute – An analysis of innovation performance and its influencing factors

**Abstract**

Due to societal evolutions, public research organizations need to increasingly engage in open innovation processes besides classic collaboration with industry and public-private partnerships. In this study, the effectiveness of an open innovation approach is examined in three bio-economy cases set up by a public research institute, as well as the factors influencing the implementation of the approach. The results indicate that an open innovation approach can yield many beneficial outcomes in a public research context, despite a great many detrimental influencing factors. These identified adverse factors can be aggregated into five key areas, the organizational culture and structure being the most important influencing factor. The results and the derived implications contribute to the further understanding of managerial challenges experienced when implementing open innovation to practice, deliver insights towards the applicability of open innovation in a public research environment and provide a first understanding on how the approach performs in the context of the transition towards a bioeconomy.

This chapter is based on:

Van Lancker, J., Van Huylenbroeck, G., and Wauters, E. (2015). The Challenges of Implementing Open Innovation in a Public Research Institute. 26th ISPIM conference 2015.

# Chapter 4 - Bio-based open innovation projects at a public research institute: An analysis of innovation performance and its influencing factors

## 4.1 Introduction

In the innovation system of a knowledge-based economy, public research organizations such as universities and public research institutes (PRIs) are important contributing actors by educating a skilled workforce and conducting (fundamental) scientific research (Etzkowitz et al., 2000; Huang and Chen, 2015). However, a significant amount of the research results are not always directly relevant for or applicable in practice, and much of the generated knowledge tends to remain trapped in the *ivory towers* (Chai and Shih, 2016; Saguy and Sirotinskaya, 2014). To overcome this, public research organizations are increasingly setting up technology transfer offices and stimulating the creation of spin-off firms, as well as increasing the collaboration with external actors, predominantly with industry and government (Etzkowitz, 2003; Perkmann et al., 2013). These collaborative efforts have been and continue to be the topic of different research strands including *Triple/Quadruple Helix Innovation* (Etzkowitz, 2003; Villarreal and Calvo, 2015), *Public-Private Partnerships* (Jarvenpaa and Wernick, 2011; Stevens et al., 2013), *Co-creation* and *Co-production* ( Prahalad and Ramaswamy, 2004; Payne et al., 2008; Canhoto et al., 2016), and *University-Industry Cooperation* (Perkmann and Walsh, 2007; Franco and Haase, 2015). Although studies on these topics have yielded valuable insights, they are typically focused only on one specific mode of collaboration or on collaborative efforts with only one type of actor.

However, several societal evolutions drive universities and public research institutes to further pursue outward looking strategies consisting of a variety of external collaboration modes with increasingly diverse types of actors. First, technology is becoming more complex, multidisciplinary and dynamic, making it hard for a single organization to possess all the required knowledge and skills (Holl and Rama, 2012). Second, universities and PRIs are increasingly required to find alternative financing due to budget pressures on many public households (Franco and Haase, 2015; Friesike et al., 2015), resulting in more and more projects funded by non-governmental agents (König et al., 2013). Third, many prominent research funds demand the formation of consortia that include a significant number of non-research actors. Fourth, science policy is becoming more and more market oriented, requesting significant valorisation of research results beyond scientific publications (Perkmann et al., 2013; Robin and Schubert, 2013).

The *Open Innovation* (OI) (Chesbrough, 2012; Enkel et al., 2009) approach, which has evolved into a dominant rationale for technology and innovation management since Chesbrough (2003) coined the term in the early 2000's, can prove invaluable to universities and public research institutes, especially as a rationale when conducting more market oriented, i.e. innovation, research projects. Open innovation advocates opening up the organizational boundaries to source-in complementary external resources for innovation and source-out certain internal resources to be externally developed or commercialized through a diverse set of actors (Chesbrough, 2003; Chesbrough, 2012). It thus moves beyond specific modes of collaboration with a specific actor type, towards a more comprehensive approach of external collaboration. The approach has been associated with a considerable amount of benefits, such as access to complementary financial and human resources (Bigliardi et al., 2012; Bruns et al., 2010; Holl and Rama, 2012), cost and risk sharing (Bigliardi et al., 2012; Du et al., 2014; Sarkar and Costa, 2008), and reduced time to market (Chesbrough, 2012; Giannopoulou et al., 2011; Holl and Rama, 2012). Many success stories (e.g. IBM, Intel, Philips, Unilever, and Procter & Gamble (Chesbrough, 2012)) have been reported and the amount of research on the topic has vastly increased during the last decade (see e.g. Chesbrough, 2012; Gassmann et al., 2010; Huizingh, 2011).

However, organizations that have adopted open innovation strategies often struggle to manage the OI processes (Almirall et al., 2014; Lichtenthaler, 2011). Despite this observation and although it is recognized that implementing OI has a profound impact on the organization and its management systems (Chiaroni et al., 2010), research on managerial implications and challenges associated with implementing open innovation in practice is scarce (Bigliardi et al., 2012; Chesbrough, 2012; Firms et al., 2015; Giannopoulou et al., 2011; Salter et al., 2014; West and Bogers, 2014). Moreover, the empirical work that has been done on the topic of implementation of open innovation has mainly focused on private organizations (Rampersad et al., 2010).

In this study, an analysis is conducted of the idea development phase of three bioeconomy open innovation cases initialized and executed by a public research institute. The goal of the study is to gain insight into the achievability of market oriented research, initiated by and conducted within the structures of a public research institute. Specifically, we will focus on (i) the success of the open innovation approach in this setting, i.e. how did the cases perform in terms of beneficial tangible and intangible outcomes, and (ii) the factors influencing this success, with a special emphasis on the hindering factors and challenges experienced by the researchers. With this research, besides providing additional insights into the suitability of PRIs to conduct open innovation research, we also contribute to the knowledge on the open innovation approach in two important ways. First, we gain more insights in how the IO theory can be applied to practice, with special attention to the under-researched issue of which (managerial) challenges and underlying factors are associated with translating OI theories to practice (Bigliardi et al., 2012; Chiaroni et al., 2010; Salter et al., 2014). Second, the research increases the understanding on the suitability of an OI approach in the context of the public research sector, a topic thus far only scarcely studied from an open innovation perspective. Moreover, by selecting three cases that aim to develop concepts applicable in the bioeconomy context, we contribute to literature on this emerging, more sustainable economy. The bioeconomy is a rapidly developing cluster of organizations from different industries that are substituting their fossil-based input materials with biomass, fuelled by investments made by many important countries such as the European Union, the USA, Canada, Japan, India, Brazil and China (Kircher, 2012; McCormick and Kautto, 2013; Schmid et al., 2012). The transition towards this more sustainable economy will heavily depend on radical and disruptive innovation (Boehlje and Bröring, 2011; Golembiewski et al., 2015) developed in transdisciplinary, collaborative R&D efforts (McCormick and Kautto, 2013; European Commission, 2012; Van Lancker et al., 2016a). Hence, open innovation has been propagated by several scholars (e.g. Bigliardi and Galati, 2013; Boehlje and Bröring, 2011; Golembiewski et al., 2015; Kircher, 2012; Van Lancker et al., 2016a) to be a suitable approach for bioeconomy innovation. However, despite this recognition, technology and innovation management research on the subject of the bioeconomy, especially with a focus on open innovation, is currently almost non-existent (Golembiewski et al., 2015).

This paper continues with the introduction of the studied cases in section 4.2.1. Next, we elaborate on the research aim and the framework of Van Lancker et al. (2016b) selected for the analysis (4.2.2), the evaluation criteria (4.2.3) and the methodology for data collection and processing (4.2.4). In section 4.3, the results of the analysis are discussed in two sections. Section 4.3.1 presents an assessment of the performance of the open innovation approach for the three cases. In section 4.3.2 the influential factors are aggregated into five key areas and further discussed. Three general recommendations for the execution of open innovation in a research institute context are proposed and general conclusions are drawn in section 4.4.

## 4.2 The bioeconomy cases and research approach

### 4.2.1 Introducing the bioeconomy cases

The selected cases are initiated by a public research institute located in Flanders (northern part of Belgium) that conducts a mix of fundamental and applied research aimed towards the development of more sustainable agriculture, horticulture and fisheries.

The three cases are part of a larger four year biomass valorisation project with the general goal to develop innovative solutions for the valorisation of by-products and waste products originating from agriculture, fisheries, and the related processing industries. The specific goal of case A is to valorise residual plant-biomass into high-value applications such as food additives, bio-based chemicals or biomaterials. Similarly, the aim of case B is to develop production processes for high-value bio-based products from fisheries by-products. Case C aims to valorise biomass by-products into a high quality, agricultural-grade compost in order to help ensure closed nutrient cycles and the sustainable maintenance of soil fertility. According to the respondents, the selected technologies in the cases were at Technology Readiness Level[8] (TRL) 9 at the start of the project. In other words, the technologies were proven in an operational environment somewhere in the world. However, one has to take into account that these technologies had, at the start of the project, rarely been applied in the Flanders region and have not been used in the context of by-product and waste product valorisation, necessitating research to apply the technologies in this context. Besides the *innovation goal* in every case, the cases also have a *scientific goal*: the junior researchers involved in the project should graduate as PhDs by the end of the project.

Each case is assigned one junior researcher (full time allocation) and one senior researcher (20-30% time allocation), who conduct the bulk of the research, largely independent of the other cases. These six researchers, working at one of the three techno-scientific research units (hereafter Unit A, B, and C[9]) within the institute, are complemented by two researchers from the socio-economic Unit D[10]. The role of these latter researchers was to offer support and assistance on socio-economic topics to the case-researchers. Together with an additional researcher from Unit A, who fulfils the role of project coordinator, these eight researchers form the core research group. Additionally, the cases could obtain guidance and assistance from a large advisory committee consisting of thirty senior researchers from the four different units of the PRI. A schematic overview of the project's structure can be found in table 7.

[8] The TRL qualifications of the European Commission for H2020-projects was used for this qualification.

[9] Research in Unit A is mainly concerned with agricultural engineering, product quality and innovation, and food safety. The research topics in Unit B are related to animal husbandry, aquatic environment and quality, and fisheries and aquatic production. The research on crop protection, plant growth and development, crop husbandry, and applied genetics, are handled in Unit C.

[10] Research in Unit D is focusses on socio-economic topics related to agricultural and farm development, and rural development.

The project proposal defined an innovation process consisting of two iterative cycles. The proposal emphasizes the collaboration and participation with internal and external stakeholders, as well as the iterativeness between the two cycles and the phases within the different cycles. The first cycle is an exploratory cycle, budgeted to take one year. The aim of this cycle is to identify the valorisation trajectories with the highest potential and to develop a diverse network of potentially relevant stakeholders. In the second cycle, the selected valorisation trajectories are then developed and prepared for market introduction, in collaboration with the innovation network and was planned to take three years.

**Table 7** Overview of project structure, involved researchers and time allocation

| Project structure | Type of researchers involved | Allocated time |
|---|---|---|
| **Project coordinator** | Senior researcher Unit A | One workday a week allocated |
| **Advisory committee** | Six case researchers<br>Two researchers Unit D<br>Project coordinator<br>Thirty senior researchers | Meetings once a year |
| **Core group** | Six case researchers<br>Two researchers Unit D<br>Project coordinator | Monthly – bimonthly meetings |
| **Socio-economic support** | Junior Researcher Unit D<br>Senior researcher Unit D | Full time<br>20-30% time allocated |
| **Case A** | Junior Researcher Unit A<br>Senior researcher Unit A | Full time<br>20-30% time allocated |
| **Case B** | Junior Researcher Unit B<br>Senior researcher Unit B | Full time<br>20-30% time allocated |
| **Case C** | Junior Researcher Unit C<br>Senior researcher Unit C | Full time<br>20-30% time allocated |

### 4.2.2 Research aims, methodology, and framework for analysis

In this study, we focus on the first cycle of the bioeconomy innovation project: the idea development phase. This process phase, which entails activities such as idea generation, idea concretization, idea selection, and project planning (Grote et al., 2012; Schiele, 2010; Van Lancker et al., 2016a), is also known as the *Fuzzy Front End* of innovation (e.g. Koen et al., 2001; Sandmeier et al., 2004; van den Ende et al., 2015). The term hints to the often mysterious, erratic, highly informal nature and the high level of uncertainty associated with this early innovation phase (Grote et al., 2012; Koen et al., 2001; van den Ende et al., 2015), making it a challenging phase to organize and manage (Sandmeier et al., 2004). Yet, proper management of the idea development phase is of crucial importance for successful innovation (Bocken et al., 2014; Stevens, 2014) because this phase is often costly and time consuming (Sandmeier et al., 2004), and making the right choices in this stage avoids expensive alterations later in the project (Koen et al., 2001).

Our first objective is to analyse how successful this open innovation approach was in terms of tangible and intangible outcomes, reflecting on the benefits of this approach for the cases, the involved researchers and the research institute during this idea development phase. Second, we aim to identify factors and challenges that impact this success.

We adopted an extended case study logic. Because the main aim of this study is to explore on open innovation aspects in an under-researched context, we feel that the logic behind this method, which aims to reconceptualise and extend theory (Danneels, 2002; 2003), fits the goals of this research better than pure inductive methods. Burawoy, who developed this method, stated the following: "The generation of theory from the ground up was perhaps imperative at the beginning of the sociological enterprise, but with the proliferation of theories reconstruction becomes ever more urgent. Rather than always starting from scratch and developing new theories, we should try to consolidate and develop what we have already produced." (Burawoy, 1991: 26).

Hence, in this study, we examine the literature relevant to the goal of the study, i.e. primarily open innovation, to develop a labelling scheme to add to the framework for analysis guiding our empirical exploratory analysis, which helps us to fill gaps, elaborate the meaning and extant the coverage of the open innovation concept (Daneels, 2002; 2003).

As to the framework for analysis, several frameworks have been developed to evaluate and analyse collaborative research and innovation efforts (e.g. Hegger et al., 2012; Walter et al., 2007), all with different foci, goals and underlying theoretical assumptions (Schmid et al., 2016). One type of frameworks is process-centred, using success indicators that capture the quality of the collaborative process, whereas a second type - outcome-centred frameworks - aim to verify whether the expected benefits or goals of the research effort have been reached (ibid). Given our dual objective, an analytical framework is required that accommodates this dual goal. Van Lancker et al. (2016b) offers such a general framework. This seven-step framework was adapted to provide a structure for our analysis (figure 9).

The first step in this framework is the selection of the cases for analysis. Step two entails determining the success of the cases based on key evaluation criteria, followed by an analysis of the structural components of the cases in step three. Based on the results of step two and three, an assessment can be made of the beneficial functions and of the system imperfections in step four and five. These findings allow us to formulate recommendations in step 6 (Van Lancker et al. 2016b).

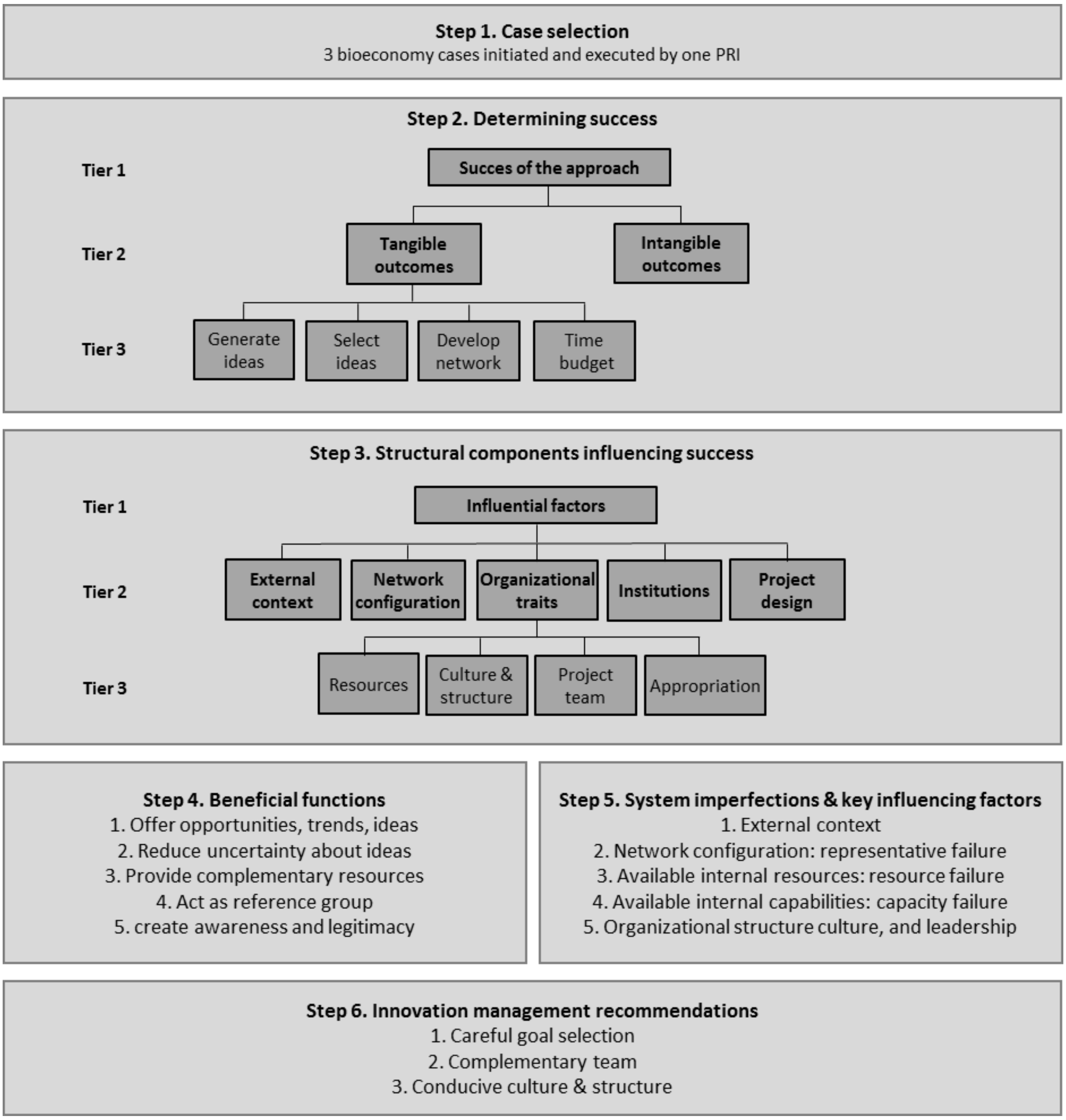


**Figure 9** Framework for analysis of the case studies (adapted from Van Lancker et al. (2016b))

However, due to the vast number of potentially influencing variables and varying goals of innovation projects, no set of commonly accepted, reliable criteria exists in the literature on collaborative research actions such as open innovation, participatory research, or university-industry cooperation (Blackstock et al., 2007; Schmid et al., 2016) that could be readily applied for this study. Therefore, we have created a three tier labelling scheme with predefined criteria for the second and third step of the analysis (see figure 9). The first tier of the scheme related to the main research questions, i.e. (i) the success of the open innovation approach and (ii) the factors influencing this success. Hence, all data related to the success of the approach was aggregated in this tier 1 label to be further analysed in the second step of the research framework. For the second step of the research framework, we defined two key success criteria for the idea development phase: *tangible outcomes* and *intangible outcomes* (tier 2 labels). The project proposal was consulted to help determine more specific criteria for success. Four *tangible outcomes* were identified and added as tier 3 labels: (i) generate feasible ideas for innovation, (ii) select one or more of these ideas to be further developed; and (iii) develop a diverse stakeholder network able to contribute to the innovation project; (iv) within the budgeted one year time period. Regarding expected *intangible outcomes*, the proposal is less clear. we left room for outcomes to come up from the data and did not predetermine any intangible outcomes.

Similarly, all data related to the influencing factors was grouped in the tier 1 label on influencing factors for further analysis in step 3 of the research. Four subcategories of structural components were predetermined to serve as subcategories of potential influencing factors to be analysed in step three of this study (tier 2 labels). These four subcategories are based on the organizational innovation system concept (Van Lancker et al., 2016b) and the innovation management recommendations in the work of Van Lancker et al. (2016a) on open innovation in the bioeconomy context. Both of these studies are based on extensive literature review of the open innovation approach, supplemented by other relevant research topics such as innovation systems, innovation adoption and business model innovation (Van Lancker et al., 2016a,b). The four subcategories are: (i) organizational traits; (ii) network configuration; (iii) innovation process dynamics; and (iv) institutional arrangements related to the network and the project. Of these four subcategories, only the *organizational traits* category is further subdivided in more specific criteria at the third tier based on the different organizational prerequisites put forward in Van Lancker et al. (2016a): organizational culture and leadership, team composition, appropriation strategy, and available resources. As also encouraged while using the extended case method, we decided to leave room for criteria and concepts to emerge from the data in order to avoid being limitative by overlooking important concepts and criteria (Blackstock et al., 2007; Triste et al., 2014;). Through iterative loops between the data collection and analysis, the initial labelling scheme was slightly altered to the final scheme shown in figure 9 and the questions in the guideline for the semi-structured interviews was also adjusted to accommodate the advancing insights gained (Danneels, 2002).

### 4.2.3 Data collection

Data for this study was gathered combining four ways of qualitative data collection. The first is participant observation, which was possible because the first author of this paper was responsible for providing the socio-economic support to the three cases and was therefore involved in the project on a regular basis, while the two other authors were a member of the advisory committee. Second, information was gathered through observation of a number of interactions between the case researchers and their stakeholders. Third, a document analysis was conducted of a large number of internal documents (e.g. project proposal, meeting reports, and presentations) and external publications related to the project. Fourth, we conducted 11 interviews with key involved researchers. These in-depth, semi-structured interviews (45 minutes to 2.5 hours in length) were all recorded (except one) and transcribed. The interviews consisted of a series of common questions which were related to the evaluation criteria (see 4.3.2.), but also a number of specific questions tuned to the specificities of the case or the expertise of the interviewee. Moreover, we allowed for additional topics to come up during the interviews. An overview of the different interviewees, their level of involvement in the cases and job title in the research institute can be found in table 8.

**Table 8** Overview of the interviewed researchers

| Involvement in the cases | Function in research institute |
|---|---|
| Principal researcher Case A | Junior researcher Unit A, PhD-candidate |
| Principal researcher Case B | Junior researcher Unit B, PhD-candidate |
| Principal researcher Case C | Junior researcher Unit C, PhD-candidate |
| Secondary researcher Case A | Senior researcher Unit A |
| Secondary researcher Case B | Senior researcher Unit B |
| Secondary researcher Case C | Senior researcher Unit C |
| Project Coordinator | Senior researcher Unit A |
| Member advisory committee | Research coordinator, General Management Unit |
| Member advisory committee | Senior researcher Unit C |
| Member advisory committee | Scientific director Unit B |
| Member advisory committee | Scientific director Unit A |

The field notes from the observation and participation, the documents, and the interview transcripts were analysed in NVivo 11, enabling us to label, structure and classify the data (Triste et al., 2014). The data was systematically categorized into the different evaluation criteria described in section 4.2.2 using a three step process. First, the data was labelled into one of the two main category groups, i.e. success of the approach or influencing factors (tier one). Second, each of these data fragments were further divided into a more specific tier two category. In the third step, each fragment received the matching third tier label. Data fragments that could not be included into a tier two or tier three label, were given a new label and then closely examined to determine if these different fragments could be clustered into new relevant criteria and concepts.

**Table 9** Schematic overview of tangible and intangible outcomes linked to the bioeconomy innovation cases

| **Tangible outcomes** | **Case A** | **Case B** | **Case C** |
|---|---|---|---|
| Goal i: Generate innovative ideas | Function 1: Network aided in generating of significant number of ideas | Function 1: Network aided in generating limited number of ideas | Function 1: Network aided in generating large number of ideas |
| Goal ii: Select feasible idea(s) | Function 2: Network aided in selecting two promising ideas | Function 2: Network aided in selecting one promising idea | Function 2: Network aided in selecting five promising ideas |
| Goal iii: Develop innovation network | Start: Small, homogeneous network<br>End: Significant, heterogeneous network | Start: Very small, homogeneous network<br>End: Small, homogeneous network | Start: Significant, heterogeneous network<br>End: Large, heterogeneous network |
| Goal iv: Finish phase within one year | Finished slightly past budgeted one year | Finished slightly past budgeted one year | Finished within budgeted one year |

| **Intangible outcomes** | **Beneficial to the cases** | **Beneficial to the entire public research institute** |
|---|---|---|
| | Function 3: Network providing complementary resources | Increased brand awareness & strengthened network position |
| | Function 4: Network acting as a reference group | Increased internal networks within the institute |
| | Function 5: Network aiding in creation legitimacy and support | Improved capabilities and knowledge of the involved researchers |

The design of the study ensured validity through a number triangulation techniques (Strauss and Corbin, 1998; Patton, 2002). For instance, data triangulation was achieved by using different types of respondents (e.g. difference in project involvement and in disciplinary background) and data (e.g. project documents and interview data) (Franco and Haase, 2015). Methodological triangulation was achieved through the four different methods of data gathering, increasing the probability of an in-depth understanding (Blackstock et al., 2007). Additionally, we summarized our first analysis of the data in an extensive presentation which was presented to the respondents in a validation process, to reduce the chance of researcher bias (Plewa et al., 2013).

## 4.3 Results and discussion

### 4.3.1 Success of the open innovation approach

The analysis of the tangible and intangible outcomes of the cases indicates that an open innovation approach can be a worthwhile approach to conduct applied research within public research institutes. A schematic overview synthesizing the outcomes linked to the cases can be found in table 9.

#### *4.3.1.1 Tangible outcomes*

In terms of tangible outcomes, all case were able to generally meet the four predefined goals in the project proposal related to the idea development phase, i.e. (i) generating feasible innovation ideas; (ii) selecting one or more of these ideas for further development; (iii) developing an innovation network consisting of diverse stakeholders; (iv) within the budgeted one year time period.

All cases were able to significantly grow their networks (goal iii). The network provided five out of the seven functions an organizational innovation system can provide (Van Lancker et al. 2016b). A first function was providing a considerable amount of opportunities, trends and ideas with the potential of becoming marketable concepts, which was beneficial towards reaching goal i, i.e. generating innovative ideas. Second, the network helped to reduce uncertainty about these opportunities and potential innovative ideas, aiding in successfully reaching the second goal of the idea development phase. Although the opportunities and ideas were generated, further developed and selected, using a variety of open innovation activities to interact with stakeholders, the most commonly used activities were outside-in open innovation activities (Enkel et al., 2009). For instance, the most important outside-in activity was bilateral talks with stakeholders to exchange knowledge and ideas. Also, group discussion with representatives of different stakeholder groups were used by case A and C to discuss the feasibility of different ideas. Additionally, but to a lesser extent, coupled open innovation activities were implemented, e.g. the case-researchers performed research for network partners and engaged in joined research with some of their partners, which enabled them to gain additional knowledge to base their idea selection on. Activities in which knowledge or technology was shared with external partners, i.e. inside-out open innovation activities, were rarely used at this stage of the research (Enkel et al., 2009).

The project researchers decided to publish one report per case containing the insights and findings of the idea development phase before putting more emphasis on activities in the second research cycle. The publication of these reports can therefore be considered to mark the end of the idea generation phase. Based on the publication process of these reports, it can be concluded that case C completed the idea generation phase within the budgeted one year period. The two other cases took somewhat longer to complete their report, but only exceeding the predefined deadline by a few weeks (goal iv).

*4.3.1.2 Intangible outcomes*

The three remaining functions provided by the networks can be considered more intangible outcomes (see also table 9). The third important function of the networks, was providing the researchers with complementary resources. Not only did the researchers gain access to a number of financial resources (e.g. joint research at facilities of network partners), the networks also transferred a substantial amount of human resources (i.e. knowledge and expertise). For instance, besides expanding their techno-scientific knowledge through the interaction with their networks, the involved researchers also gained knowledge on which socio-economic factors influence an innovation effort and how to address these factors. Also, the researchers gained a better (practical) understanding of the relevant sectors and actors.

*"I now have a better idea of what the concerns are in different sectors and actor groups. Maybe not immediately useable in this project, but in other projects."* (Senior researcher)

*" … And I notice that I now have vague ideas [of what actors wants], which I will remember throughout the rest of the project, and when I ever find a relevant molecule, I now know where to go.*" (Senior researcher)

The close involvement of stakeholders results in a group that can be consulted throughout the research process, functioning as reference group.

*"You involve stakeholders into your thinking process. At the end [of the process] they will then be ready to handle and utilize the innovation. …….. Moreover, you really consider what people expect from the innovation and enable them to actively correct certain functionalities or let them point out a certain aspect they want you to include in your research*." (Senior researcher)

This fourth function, together with the fifth provided function: the generation of support and legitimacy for the results of the research and for similar bioeconomy innovation efforts, are very important for the later stages of the project (Van Lancker et al., 2016b). Researchers can consult the network to ensure the innovation optimally fits the external expectations, and the network can assist in overcoming the liability of newness (Bergek et al., 2008; Spencer, 2003), increasing changes of acceptance of the new concept before it is even launched to market (Arnold and Barth, 2012; Spencer, 2003; Van Lancker et al., 2016b).

Besides these beneficial outcomes contributing to the project, the open innovation research approach also generated outcomes beneficial to the PRI. First, the expansion of the different networks and the close stakeholder interaction brought the PRI improved ties with a number of key stakeholders, as well as augmented *brand awareness* and reputation in the different stakeholder groups. The strengthened network position of the institute has already catalysed the writing of a number of project proposals with different actors from the networks and will continue to contribute to increased chances of being solicited for new research consortia on similar topics. This quote reflects the importance of this outcome.

"*I feel that the project has already succeeded, just because of all the trust we have built and the follow-up trajectories we have generated*." (Senior researcher)

Second, the project approach also contributed to the strengthening of internal networks within the research institute. Much of the research in the PRI is conducted within separate research units, resulting in four somewhat isolated silos. The cases were an illustration of the positive effect of more internal cooperation and have contributed to alleviate the walls between the units, resulting in increased insights of what expertise is present in the different units.

*"I used to think that one of the sites of the institute was only capable of research involving dairy products. I would have never thought it was a place where biomass for the bioeconomy could be processed for different applications."* (Senior researcher)

Third, through the intense cooperation with a larger number of more diverse stakeholders, the researchers improved their networking capabilities. Additionally, applying this open innovation approach resulted in a strengthening of the belief among the researchers in the beneficial contribution of such an approach, or as one of the senior researchers stated:

*"Now you know, if it [a project] is not demand-driven, if they [relevant stakeholders] are not interested and it is not economically feasible, you will not be able to do anything with it."*

Moreover, many of the interviewed researchers indicate that they now take socio-economic factors into account and consider a stronger involvement of diverse stakeholder groups more often when designing new projects. The case researchers can contribute to future benefits for the PRI. In addition to acting as bridge builders, spanning the internal boundaries between the different research units and the external boundaries, they can be ambassadors or champions promoting open innovation (Chesbrough and Crowther, 2006; Klerkx et al., 2010).

### 4.3.2 Challenges and influencing factors

Despite the apparent positive effects and success of the approach, represented by the great number of intangible beneficial outcomes and the fact that the predetermined goals were reached, there are a number of indications that hint to challenges experienced throughout the execution of the idea development phase. For instance, two out of the three cases took longer than the budgeted time to finish the idea development phase. Also, while Case C had little trouble identifying five promising aspects to tackle, case A selected two research paths to further develop, and case B struggled to select one feasible idea. Additionally, there is a notable difference between the network size and composition of the different cases. Case B had the smallest network by the end of this phase, with little diversity in terms of types of stakeholders represented. In contrast, case C was surrounded by the largest network with the most diverse stakeholder representation (see table 9). Although more and larger is not always better, a large number of the interviewed researchers expressed their concern about the composition of the networks and its effect on the decision making process during this phase and the further execution of the project. A small, less diverse network forced some researchers to rely more on existing internal knowledge, literature reviews, and internal availability of technology to decide on research paths than they would have liked.

*“We had to conclude the idea development phase ourselves mostly. We did not really succeed in delineating research questions together with industry. It has been a major concern. Because you had to work demand-driven and have not completely succeeded.”* (Senior researcher)

Twenty-four aspects that influence the general results of the idea development phase or help to explain the difference in outcomes between the three cases could be identified from the data. Figure 10 gives an overview of these aspects and depicts the relationship between them. It also schematizes which aspects impacted the general success of the idea development phase, and which can help to explain the difference in outcomes between the cases. Closer analysis revealed that the twenty-four aspects can be aggregated into five key areas which are at the root of all influential aspects or most significantly influenced the outcomes. These five key areas are: the external context, the network configuration, the available internal resources, the available internal capabilities, and the structure, culture and leadership of the PRI.

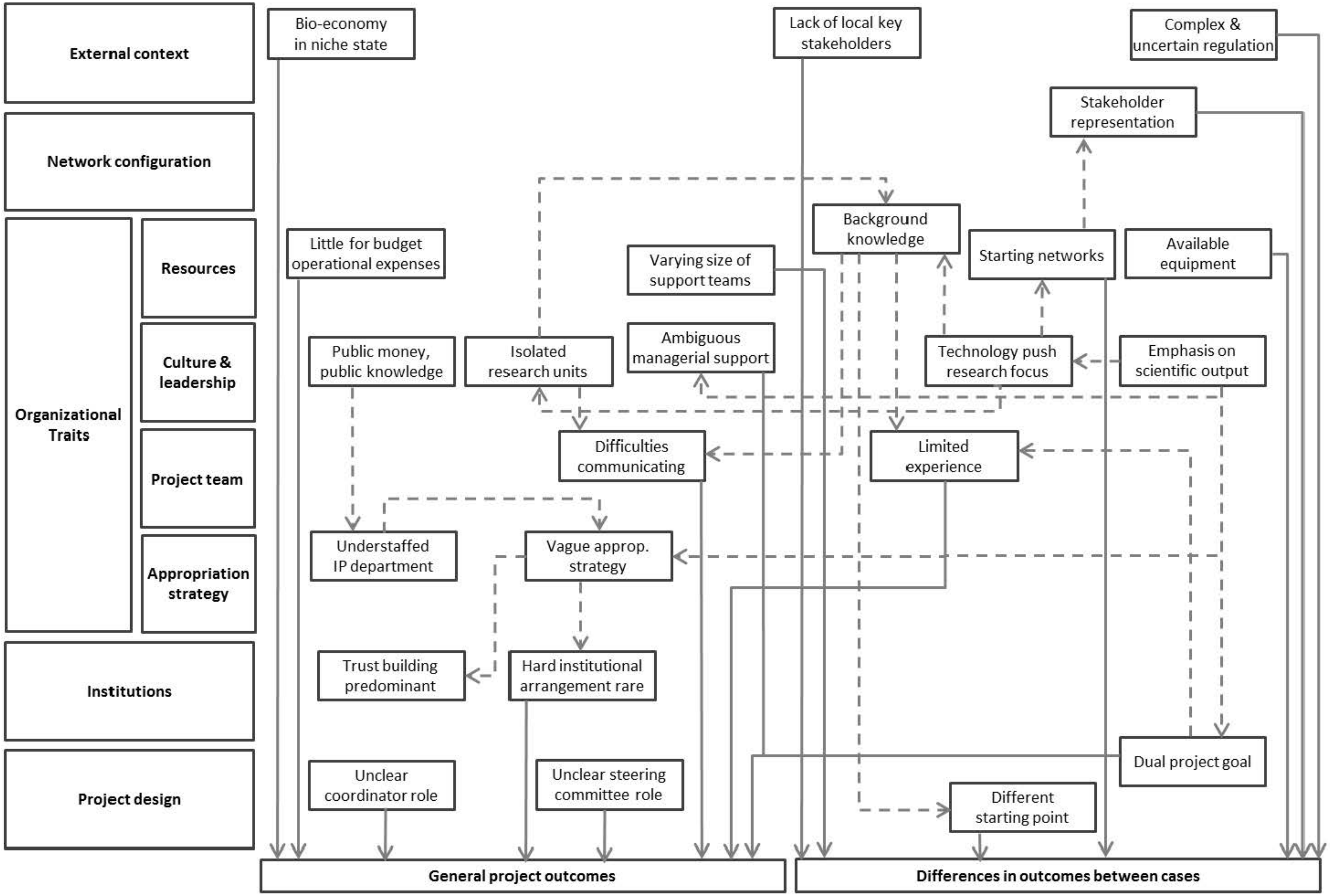


**Figure 10** Overview of the different identified aspects explaining the general outcomes and the differences between the cases. Full lines represent a direct relation to either the general project outcomes or difference in outcomes. Dotted lines represent an indirect relation.

#### *4.3.2.1 Key area one: External context*

Three aspects related to the external context surrounding the project help to explain the difficulties experienced while developing the networks and the differences in size and configuration between the cases. A first influencing aspect is that the **bioeconomy is still in its infancy**. Although interest in innovating towards this greener economy is growing, the real success stories of bioeconomy innovations are still scarce, bottlenecks are still plentiful, and customers looking for bioeconomy concepts only form a small niche. This was regarded as one of the reasons for the experienced lack of enthusiasm and motivation of many stakeholders to invest in bioeconomy development paths. A second, somewhat related, aspect is a **lack of key local stakeholders**.

*"I strongly feel that we are missing key players to realize these innovations. It requires specific knowledge that is not available in Flemish organizations."* (Senior researcher)

The importance of geographical proximity has been shown in previous research to facilitate knowledge transfer and encourage learning effects (Broström, 2010; Knoben & Oerlemans, 2006; Steinmo and Rasmussen, 2016).

A third contextual factor is the **uncertain and complex policies and regulations**. This was an especially prevalent issue in case B. The feedstock used in this case, i.e. fisheries by-products, stemmed predominately from non-commercial fish that was being discarded at the time, but would have to be landed due to a change in European regulation (discard ban). The exact implementation of this discard ban was unsure at the time. The Flemish fisheries sector refused to accept these impending regulatory changes and would not cooperate with any attempt to facilitate the implementation of these rules, including this project.

*"The willingness of the sector to change? Zero. They were going to make that legislation go away, so in effect, there was no problem [of large amounts of unvalorized fish], and no need to solve it."* (Junior Researcher)

#### *4.3.2.2 Key area two: Network configuration*

There is a noticeable difference in configuration between the networks surrounding the different cases. Case C managed to develop the largest network, a balanced and heterogeneous group of all different actor groups. Case A also had a rather large network, but more skewed towards certain stakeholder groups. Case B engaged with the lowest number of stakeholders. Further, the case B network is very homogenous, with a very large component of research institutes and universities, while other important stakeholder groups are only represented by one or two actors, if at all. The **difference in stakeholder representation** can help explain the difference in time spent on the idea development phase, as the researchers from the cases with more homogeneous networks expressed a lack of confidence and hesitation when selecting ideas due to knowledge and information blind spots, partly caused by lack of stakeholders to provide it.

*"There is a risk that we value the opinion of one stakeholder too much, and maybe they are not always right, causing us to emphasize the wrong aspects in our research."* (Senior researcher)

Furthermore, the difference in size of the networks and its *representative failure*, is argued to be a potential cause of innovation project failure (e.g. Van Lancker et al., 2016b) and can also help explain the difference in generated ideas, as previous research states that collaboration with a network of diverse actors contributes to translating trends and opportunities into more and better ideas for innovation (Brettel and Cleven, 2011; Hansen and Birkinshaw, 2007; Sandulli et al., 2012).

*4.3.2.3 Key area three: Available internal resources*

Another aspect explaining the difference in network development between the cases is the **size of the networks at the start of the project**. These networks were relatively small in all three cases, but differences were already present: Case C had an already considerable stakeholder network of heterogeneous stakeholders (research institutes, farmers, composting firms, policy makers, interest groups, etc.), whereas Case A and case B had considerable smaller networks. Further, Case A and B's networks were more homogeneous, mainly including other research institutes and sector federations. This order of network size remained the same at the end of the idea generation phase, indicating that these starting networks served as a stepping stone for further network development. The same holds regarding the heterogeneity of the networks, hinting that the starting networks also influenced the difference in stakeholder representation between the different cases.

*"The expansion of our network went really quickly because we could start from an existing network and from some basic trust that was already build through the related work we had been doing the years before*." (Junior researcher)

"*Detecting the hindering factors was relatively easy because we already had a lot of good relations with farmers thanks to the related research the PRI has been doing the past years."* (Junior researcher)

Another noticeable difference in available intangible resources between the cases was the existing internal **background knowledge**, both on the research topic and on the research approach.

*“Bioeconomy, bio-based economy, etc., these are all terms I was only really confronted with in relation to the project, not before.” (Senior researcher)*

*“This was a completely new research approach for us. And the problem statement was also new.”* (Senior researcher)

Specifically, the knowledge on the relevant topics for case B was very limited, due to focus on other fishery-related research topics by unit B. Research on topics related to the goals in case A was still in very early stages at Unit A, with a few finished projects prior to the start of this one. Unit C did have a rich background in compost research, resulting in significant amount of knowledge on the topic to start from.

A first aspect which influenced the difference in outcomes between the cases related to the available background knowledge, is the **different starting point** of each case. Case C could immediately focus on a specific application (i.e. composting), while the two other cases had a much broader starting scope. With the input materials, processing techniques, or final products not determined in the research proposal, the researchers of case A and B had to explore more possibilities before being able to focus on technological questions and influential contextual factors (e.g. industry requirements, availability of feedstock, market conditions, and legal and policy limitation) of a specific feasible application. This can be considered part of the explanation why case C was able to finish the idea generation phase faster than the other two cases, as well as the difference in network size and ideas generated.

“*It is hard to have a debate with possible market actors if you do not have anything concrete yet. …. If some things are fixed, you can go to potential clients to look for feedback.”* (Junior researcher)

*“Working on a more specific problem would have been better.”* (Senior researcher)

A second factor related to this difference in background knowledge explaining the difference between cases, is the difference in **support within the units**. In case B, only the two case researchers spent a significant amount of time on this case, whereas case A could regularly count on two additional researchers from the unit contributing some of their time and knowledge to the case. Case C even has a small team of seven researchers (including the two main researchers assigned to the case) with complementary knowledge and expertise on the production and application of compost and its effects on the soil.

In addition to this difference in intangible resources, a difference could also be observed in **available** tangible resources (i.e. **equipment and machinery**) between the different cases. Unit C had a state-of-the-art composting site and most relevant equipment and technologies available for the researchers to conduct their research. The case A researchers also had a good amount of relevant technologies and equipment available both on lab-scale as well as on small pilot scale. Case B however, although the researchers could utilize resources from unit A, had the least relevant equipment and technologies available at their research site.

A considerable amount of the case researchers feel that the amount of available resources, especially the intangible resources, played an important role in the outcomes of the project.

*"How we did things was very strongly influenced by the starting situation here; the knowledge and the contacts available. If I were to start [the project] now, I would be able to go much faster thanks to the knowledge and networks that was build the past year."* (Junior researcher)

*"You should be able to focus on one specific application, really focus on this one case and completely develop it, but we did not dare make that decision because we were too insecure, we had to little indications."* (Senior researcher)

Moreover, the project was somewhat under-budgeted. It was predominantly allocated to personnel-costs, leaving **little budget for operational expenses**. This, according to some of the researchers, influenced the general outcomes of the project.

*"But then the financing discussion begins, and if you have only limited funds to pay for it, certain things become very difficult", "The part of the budget designated to operational expenses was perhaps a bit limited to set up big plans."* (Senior researcher)

The assessment has merit, as insufficient resources has been reported to be among the most frequent obstacles encountered when trying to interact with private businesses (Franco and Haase, 2015). Van Lancker et al. (2016b) also posits *resource failure*, i.e. the lack of adequate resources to develop the novel concept, as one of the major potential flaws in an organizational innovation system causing project failure.

#### *4.3.2.4 Key area four: Available internal capabilities*

Another potential cause for the imperfect execution of innovation projects put forward in the OIS-framework, is *capacity failure*, defined as the lack of certain capacities, skills or capabilities of the innovation organization to maximally profit from the network constellation (Van Lancker et al., 2016b). Within the three cases, this capacity failure has manifested itself primarily in a lack of absorptive capacity and a shortage of relational capability.

First, absorptive capacity, enabling an organization to better interpret external information and improving the translation of the information to the organization's needs (Berchicci, 2013; Chesbrough, 2012), has often been linked to more successful inbound open innovation efforts (Spithoven and Teirlinck, 2015; Lichtenthaler, 2011). This capacity is acquired when sufficient and solid internal (technological) knowledge stores on relevant topics prior to collaboration with external sources are present (Cohen and Levinthal, 1990; Spithoven and Teirlinck, 2015). The data (see 4.3.2.3) show that background knowledge on relevant topics was somewhat lacking in some of the cases, creating low absorptive capacity. The importance of this capacity, together with the importance of adequate resources for innovation efforts has also been shown in the context of SMEs, where Saguy and Sirotinskaya (2014) state that low absorptive capacity, limited financial resources, inadequate human resources and competencies, and an insufficient knowledge base have been reported as barriers for the implementation of OI activities.

Second, despite all senior case researchers having ample techno-scientific knowledge, they had only limited knowledge on how to scientifically investigate the relevant influential socio-economic factors. Additionally, the research team had only **limited experience** with the implementation of the more open, iterative and transdisciplinary approach propagated, which is very different from the traditional technology push way projects are predominantly designed.

*"Normally it works like this: you write a project, and maybe you need some co-financing, so you contact a few stakeholders and see if they are interested. So there is some interaction if you need some expertise, but if you have the necessary knowledge in-house, you will involve them scarcely."* (Senior researcher)

*"You used to do research aimed at publishing as much as possible and defend [a PhD-thesis] at the end, then you invite a few stakeholders to disseminate your results."* (Senior researcher)

"*Interaction with stakeholders used to be something we were obligated to do, to make sure the numbers added up, but nothing more."* (Senior researcher)

As a result, the researchers were not used to involving different types of stakeholders into their research processes, causing uncertainty of what input to expect from the stakeholders and how to correctly interact with them, which in turn led to challenges developing the required network, generating ideas, and gathering knowledge for idea selection. The importance of the capability to successfully build relationships or *relational capability* has already been linked to improved efficacy of inbound open innovation efforts (e.g. Sisodiya et al., 2013). Further, assisting in the execution of an open approach was also new to the involved researchers from the socio-economic unit, adding to the unfamiliarity with the open innovation approach propagated in the project. Moreover, the decision to let the cases be primarily conducted by junior researchers, PhD-candidates, is another element adding to the relative inexperience of the project team in certain areas. One of the involved researchers touches on one of the issues that the appointment of inexperienced juniors caused:

*"It is somewhat dangerous to place the responsibility to innovate on PhD-students. That is a difficult hurdle to tackle for them. They have just graduated and have little background. This does not make it easier to generate trust between them and industrial players."*

Previous research on university-industry collaboration has shown that seniority is often positively related to collaboration (e.g. Boardman and Corley; 2008; D'Este and Perkmann, 2011), as more experienced researchers likely have larger networks and better reputations (Perkmann et al., 2013).

Besides the choice to appoint PhD-candidates as the principal executing researchers, the unfamiliarity within the research institute with the open innovation approach can also be an explicatory factor for the unclear definition of the tasks and **role of the project coordinator**. These were never formally determined, nor was the time available for the person to coordinate this project ever formalized. This created uncertainty regarding what the coordination role entailed and caused the involved researchers to have different expectations. Many researchers envisioned a coordinator with a plethora of tasks such as: help identify and contact relevant stakeholders, facilitate the formation of the networks, be the principal contact for internal and external stakeholders, take care of PR and communication, be the frontrunner of the project, motivate and assist the involved researchers, coordinate the research efforts within the project and seek synergies between the cases. This interpretation of the coordinator role requires close to a fulltime job, but once the project started, it became clear that only 20% of the coordinator's time was allocated to this innovation project. As a result, the coordinator was forced to assume a more reactionary, administrative coordination role, rather than a proactive role which all involved researchers agree on, would have been beneficial to the projects outcomes. König et al. (2013) also stresses the importance of a successful and efficient project management in such complex and transdisciplinary research, which is often difficult to handle even by one person.

*"In the beginning there was a lot of tension regarding what the role would look like, it was completely unclear.", "The coordinator did a great job if you take into account the constraints. She took a lot of weight of our shoulders, but I missed some help guarding the methodology, seeking synergies between the different cases, transferring knowledge, etc."* (Senior researcher)

Another influencing factor that can be at least partly explained by the scientific research tradition, is the choice to install an advisory committee consisting of all senior researchers. Although the involved researchers, as well as other members of the advisory committee, feel that it is a good institute to report the progress of the project, the interviewees indicate that working with such a committee in this innovation context, felt somewhat artificial.

*“To me it seems a little artificial, if you have a problem at a certain point, you are not going to wait until the next advisory committee to ask for help. You go to your supervisor or directly to the co-worker that can help you and ask him.”* (Junior researcher)

Additionally, similar to the role of the coordinator, the **role of the advisory committee** was not formally defined. This, besides the large size of the committee (over thirty researchers) and the infrequent meetings (only once a year), contributes to the sentiment of the interviewees regarding the format as a forum for discussion and knowledge transfer, which can be summarized as *“*a passive, one-way-street with little input*”*. Furthermore, there is little reward for the members of the committee to very actively collaborate and invest time into a project they are not evaluated on.

*“If they do not get any return for what they put in, the driver to put much effort into it is small.”* (Senior researcher)

The functioning of the advisory committee could have been improved if a number of academic incentives could have been clearly included (e.g. co-authorship on publications) into the proposal or collaboration and innovation key performance indicators (KPIs) are valued more within the organization, thereby motivating committee members to more actively contribute to the project (Debackere and Veugelers, 2005). Alternatively, the committee, as suggested by some of the researchers, could have been reduced to a small number of key senior researchers (e.g. scientific directors) that meet on a regular basis, who could in turn suggest the right expert senior researcher to assist with the problem at hand.

#### *4.3.2.5 Key area five: Organizational structure, culture and leadership*

The last key area groups the influencing aspects related to the way the PRI is structured, the culture within the organization and the leadership style. This is the most prevalent group because these aspects either directly influence the outcome of the project or are at the root of numerous other influencing factors.

The researchers working at the studied public research institute aim to deliver results that have societal relevance and are applicable to the real world. These results are generated through studies conducted in congruence with the highest standards of scientific research. Besides this goal to deliver relevant results, the researchers, not unlike those working at other scientific research organizations, also aim to publish their studies in peer-reviewed academic journals. Consequently, the goals set by the PRI, the subsequent KPIs, and the goals pursued by the researchers are dual, still with a significant **focus on scientific output** (e.g. scientific publications, PhD-graduates, conference attendance).

This focus on scientific output can help explain the choice for **a dual goal project design**, i.e. publish papers and deliver PhD-graduates on top of the innovation goal of developing novel concepts. This dual goal design is considered to be problematic by all junior researchers and a number of the seniors. The combination of an innovation goal and scientific goal created a tension between research actions, leading to uncertainty on which actions to focus on. This was challenging for both the case researchers as well as for the supporting researchers from the socio-economic unit. The latter had to limit their support to guiding the innovation processes and providing socio-economic knowledge and tools ad hoc, whereas the case researchers indicate that more hands-on help (e.g. doing cost/benefit analysis for them) would have been beneficial to the project.

*"You notice throughout all cases that it's a difficult balance between the needs of the project and doing PhD-worthy work."* (Senior Researcher)

*"Developing an innovation useable in practice does not always correspond to what has to be done to get a PhD. For a PhD, you generally focus on one specific aspect, whereas for an innovation you have to take a lot of aspects into account and have to work multi-disciplinary. You need more than just technical knowledge. You also need knowledge on how to develop relationships with stakeholders, but also on logistics, economics and legislation."* (Junior researcher)

Additionally, the goal to deliver four PhD-graduates by the end of the project is one of the major motivations to appoint junior researchers to key positions in the project, which contributed to the limited availability of the required capabilities and capacities to fully profit from the stakeholder interaction (see 4.3.2.4). Moreover, the dual goal design, emphasizing the importance of scientific output in an innovation oriented project, added to the goal divergence that already often exists within and across different actor types (Almirall and Casadesus-Masanell, 2010). This goal divergence is often discussed in light of cooperation between academia and industry actors, where academia favours in-depth understanding in a specific area to publish the results, whereas industry seeks applicable discoveries that generate return on investment and increase profits ( Goduscheit and Knudsen, 2015; Melese et al., 2009; Saguy and Sirotinskaya, 2014; Stevens et al., 2013). The dual goal fuelled the potential misalignment between goals of the researchers and the involved stakeholders. Previous research has already identified that a lack of goal complementarity has a negative influence on collaboration (Bogers, 2011; Chesbrough and Schwartz, 2007; Pullen et al., 2012). The importance of a common, shared purpose or goal among the actors in the network is also stressed in the influential literature on innovation ecosystems (Adner and Kapoor, 2010; Nambisan, 2013; Nambisan and Baron, 2013).

The emphasis on scientific output also contributed to the fact that the PRI's research projects are usually executed using **technology push type approaches**, with rather linear trajectories, limited collaboration with external and internal actors, and a focus on a limited amount of disciplines. The *publish or perish* dogma forces researchers to keep their work secret until submitting to a journal, and a narrow and uni-disciplinary framing of the articles increases the likelihood of acceptance, fuelling a culture of working in isolation and closed disciplinary thinking (Friesike et al., 2015; Saguy and Sirotinskaya, 2014). Although the level of collaboration has improved throughout the years, amongst others through the creation of a dedicated research coordination department, interdisciplinary strategic working groups and thematic committees, the **four different units** continue to function as somewhat **isolated silos**.

*"Ten years ago, one department did not even know how many researchers were working in the other departments, let alone knew what they were working on."* (Senior Researcher)

This project was the first time the four units explicitly worked together in one project. This lack of internal cooperation contributed the limited background knowledge, as it does not promote the development of skills associated with relational capability (see 4.3.2.4). Additionally, it can help explain the **difficulties in communication** between the case researchers and the socio-economic researchers, at least in the beginning months of the projects. The socio-economic researchers lacked the vocabulary to effectively deliver their message to the techno-scientific case researchers and vice versa.

*"In the beginning of the project, we just did not understand each other. That was a big problem. ….. It created confusion, causing us to work differently than it was perhaps expected.*

The isolated structure further manifested itself during the project. For instance, during the span of the idea development phase, several other projects were initiated in one of the involved units that could have been relevant for one of the cases developed in another unit. This information was not shared by researchers from the former unit and was only discovered by chance by the junior case researcher of the latter unit late in the idea development phase. Another illustration of this lack of collaborative attitude is that sometimes visits to relevant stakeholders were planned by case researchers from one case without notifying the other researchers who clearly could also have potentially benefited from contacts with these stakeholders. Another reason for the relative absence of a collaborative reflex can be the competitive way of evaluating the units. The different units are compared to one another based on key performance indicators (KPIs) and part of the units' financing is coupled to this comparative result. This impedes the sharing of information and knowledge with *competing* researchers from other units.

This, together with the emphasis on the scientific output, helps explain the non-conducive **ambiguity in the management's attitude** towards the goal and approach of the project. For instance, management of one of the units regularly emphasized the scientific goal of the project, pushing the researchers in that case to stop consulting stakeholders and start doing experimental work, as management felt the idea generation phase would not yield publishable results.

*"The researcher is first and foremost a PhD-candidate, she has to be able to graduate and convince a jury of [the scientific worth of] the followed trajectory."*

Also, the involvement and interest in the projects progress of the management in general seemed limited, illustrated for instance by the very irregular attendance of the management at advisory committee meetings.

The importance of a suitable organizational structure and culture, as well as management support towards collaborative efforts have been discussed in previous studies covering different technology and innovation management topics. For instance, Lichtenthaler (2011) found that barriers to open innovation are often cultural, which has been frequently reemphasized in other scientific studies (e.g. Chesbrough, 2012; Enkel et al., 2011). Dodgson et al., (2006) and Thong and Lotta (2015) report that the key to open innovation success was cultural change and managerial support. Giannopoulou et al. (2011) emphasizes leaders should support and motivate people with every mean they have to get involved with OI and find and fight any resistance to change to increase chances of successful implementation. Also, the importance of flexible evaluation and promotion systems that reward open innovation activities is highlighted in the work of Salter et al. (2014) and Chiaroni et al. (2010). Such rewards systems help academics value patents and related outcomes besides traditional academic outcomes, making them more likely to consult with private firms (Perkmann et al., 2013). Furthermore, Bocken et al. (2014) in his work on the fuzzy front end of innovation, also notes the importance of a supportive innovation culture and high involvement of senior management. This is increasingly understood within the PRI, as efforts are already being made by the management of the PRI to meet more often and exchange knowledge, as well as to reduce structures that could cause feelings of competition between units (e.g. by remove administrative and financial divisions).

*"We used to have this system of performance indicators, but we have changed that last year. We want to be one institute, and no longer put checkmarks next to each unit's name. We definitely do not want to couple it with levels of financing anymore. It created an unhealthy competition and an unhealthy push for more publications."*

Besides the emphasis on scientific output and the subsequent focus on a technology push research approach, the second major influencing trait related to culture, leadership and organization at the PRI is the public nature of the institute. Being primarily funded by public government funds, the predominant aim of the research performed at the institute is to contribute to the general knowledge of society as a whole. As a result, it is difficult conduct research that might only benefit a select number of actors. Several of the involved researchers indicated that this made it hard to decide how close they could cooperate with specific stakeholders.

*"It is sometimes difficult because we feel like we cannot work directly, one on one, with firms."* (Junior researcher)

The fact that this ***public money equals public knowledge*** attitude stifles innovation and collaboration with more profit oriented organizations has also been argued by other authors such as Saguy and Sirotinskaya (2014) and Melese et al. (2009).

As a result of, the PRI has little history protecting knowledge and a somewhat **vague appropriation strategy**. The following quote illustrates that the PRI is even somewhat averse towards intellectual property (IP) protection.

*"When I started here over a decade ago, even starting to think about a patent was like cursing in front of the Pope. Now, this has improved."*

Moreover, the PRI has no funds budgeted towards intellectual property protection. The PRI has no real tech-transfer service or department dedicated to IP protection. Instead, IP protection is one of the tasks of the afore mentioned research coordination department. However, this department is rather small, staffed by only two people, and has a number of other tasks besides IP protection such as coordinate research, assist with interactions between researchers and external parties, provide support in contracts with different funding agencies, etc. The interviewees almost unanimously agree that this **department** is **understaffed** for the supporting services it is supposed to provide. Additionally, with only a limited amount of resources designated towards IP protection, developing a strategic plan and educating the organization about this plan, is challenging.

*"Tech-transfer, we do not have that here. It is not the goal of the institute to put products to market. I can relate to that. …. But if you have totally no idea on how to protect your IP, how to handle it, and how to potentially valorise is, it becomes very difficult because our researchers are not informed."* (Senior researcher)

*"If researchers are not interested in these issues [IP protection] themselves, they just publish without wondering about such things."* (Senior researcher)

The importance of a clear IP framework and agreements on the appropriability of the generated IP from the start of a project has been repeatedly reported to be of utmost importance in collaborative innovation efforts such as PPP (e.g. Stevens et al., 2013), university-industry partnerships (e.g. Perkmann et al., 1013) and open innovation in general (Giannopoulou et al., 2011).

The limited attention to appropriation by the PRI contributed to the lack of knowledge and awareness of the project team to institutional arrangements when collaborating with their stakeholders. Only a very limited set of institutional arrangements were used to arrange the exchanges between researchers and their stakeholder. The **most important** one was **trust**. All researchers almost unanimously agreed that this is the basis for starting a meaningful relationship, and that other types of arrangements are required once trust is established to discuss aspects related to the idea generation phase. Non-disclosure agreements were sometimes used, whereas more extensive contractual agreements were rarely demanded. Yet, although such soft institutional arrangements indeed proved to be sufficient in most cases for this research phase, sometimes collaboration was slowed or halted by the lack of **knowledge on hard institutional arrangement**, i.e. IP protection and contracts.

*"We were able to get a meeting with a very big multi-national organization. They indicated their potential interest. But it takes very long to sort out all the IP documentation. This makes it almost impossible to work with such a partner given our time constraints."* (Senior researcher)

## 4.4 Conclusions and recommendations

By generating (fundamental) knowledge and educating the workforce, universities and other public research institutes have always been one of the cornerstones of the innovation system. Currently, these PRIs are expending their role through the development of technology transfer offices, the stimulation of spin-off firms, and the execution of applied innovation research, increasingly moving beyond university-industry collaboration and public-private partnerships to collaborate with a more diverse set of stakeholders, as open innovation systems with diverse interactions with different organizations are key to the knowledge based economy (Giannopoulou et al., 2011). This work set out to better understand the feasibility of such applied innovation research projects initiated and executed by a PRI, evaluate the usefulness of an open innovation approach in this setting, and gain insight in the factors influencing its implementation and its success.

The results indicate that an open innovation approach can prove very beneficial both on the research project level and on the research institute level, given the many positive intangible and tangible outcomes. This is despite the many factors that were experienced as challenges by the researchers. These twenty-four influencing factors, except for those related to the external context, can all be linked to the organizational traits of the public research institute, specifically to the culture, leadership, and organization of the institute. Even the issues grouped in the other key areas have, at least in part, a root in the institute's culture or organization.

Consequently, despite the apparent success of open innovation approach, the many challenges originating from the organizational traits leads us to conclude that projects using such approaches would continue to struggle if the traditional configuration of public research institutes persists. Based on the insights from this study, three general recommendations can be formulated which could help alleviate potential sources for struggles when implementing open innovation activities in a PRI context.

The first recommendation is to carefully consider the goal of the project. A first aspect here is internal agreement within the PRI on the project goal. A dual goal design, with an ambitious innovation and scientific goal, proved difficult to accomplish. One of the two goals should have been clearly prioritized; if the innovation goal was the priority, the publication of scientific publications should have been viewed as a nice added benefit and vice versa. Additionally, the project goal should be connected to the already available knowledge and expertise within the organization. The present background knowledge can serve as a base to hit the ground running and help establish absorptive capacity. Moreover, when operating within, or at least at the fringe of, existing knowledge in the organization, the likelihood of knowing a first set of key stakeholders is higher. Second, external agreement on the goal of the project needs to be achieved. In other words, all actors involved in the projects need to be on the same line as to what the exact aim of the collective effort is. This is of special importance in the context of science-based actors, i.e. public research organizations, collaborating with more market-oriented actors, as their goals are often divergent.

Second, we recommend building a well-balanced, complementary project team. For these types of projects, the team should possess adequate technical and socio-economic knowledge on the relevant domains, as well as capabilities to interact with stakeholders. Involved researchers can still be experts in specific fields, but there should also be a number of *T-shaped researchers* involved. These T-shaped researchers, in analogy with T-shaped managers (Hansen and von Oetinger, 2001), are researchers with a deep knowledge of one relevant domain and a good understanding of a wide range of other relevant domains. These profiles are argued to help connect information and knowledge from different research domains, as well as from internal and external sources, contributing to idea generation and cooperation (Chesbrough and Crowther, 2006; Chesbrough, 2012; Hansen and von Oetinger, 2001). Especially for project coordinators in innovation efforts with broad scopes, a person with such a profile could prove a paramount driving force for success.

The third, and perhaps most significantly, is creating an organizational culture, structure and leadership style conducive towards innovation. General organizational support has often been argued to be a positive influential factor on the outcome of (collective) innovation projects (e.g. Chiaroni et al., 2010; Enkel et al., 2011; Giannopoulou et al., 2011; Naqshbandi et al., 2015; Saebi and Foss, 2015). For public research organizations to more actively participate in innovation, a new mindset is required in which academia does not only consider itself an intellectual centre and generator of knowledge, but also a contributor to innovation (Saguy and Sirontinskaya, 2014). Changing this mindset and implementing more open innovation approaches, necessitates the full support and recognition of management (Herskovits et al., 2013; Nakagaki et al., 2012). Furthermore, isolation between different units should be combated, more external cooperation should be promoted, and the importance of innovation output should be recognized in the reward system. Rewards systems in most organizations are still designed around closed models of innovation, resulting in individuals who tend to see external knowledge as second best (Salter et al., 2014). Introducing criteria during personnel or unit evaluation related to internal and external cooperation, as well as innovation outputs, makes its importance more explicit and can be conducive towards the intended behaviour. Increased (internal) cooperation will improve absorptive capacity (Cruz-González et al., 2015), relational capability, and generate more interdisciplinary knowledge among researchers, the latter conducive to increased chances of publication of research results given the growing number of interdisciplinary research journals (Friesike et al., 2015). More (external) collaboration and emphasis on innovation necessitates a clear appropriation strategy delineating the different modalities of collaboration and distribution of knowledge. Such clear arrangements on what types of knowledge can be shared, which should be protected and what the general rules are when interacting with external actors, could have yielded more fruitful collaborations, as various studies have emphasized the importance of developing a clear IP framework from the start of collaborations (Chesbrough, 2012; Enkel et al., 2011; Giannopoulou et al. 2011; Stevens et al., 2013). The strategy could include approaches that stipulate protection of information of specific results by collaborators, while the general conceptual principles and knowledge can be published to contribute to society's knowledge stores. Alternatively, Mesele et al. (2009) suggests an arrangement of confidentially, with public research organizations granting reasonable publication delays to allow firms time for patent filing. Not only does a clear appropriation strategy help reconcile the needs of public research organizations and those of profit oriented organizations, it also helps researchers cope with the *paradox of disclosure*, i.e. the fine balance between revealing enough of the innovative idea to generate the interest of the potential partner, but also safeguarding enough details for the idea not to be stolen (Salter et al., 2014).

With these results, we contribute to the knowledge on open innovation, because the application of the approach in the public research context has only been rarely studied. The research further contributes to the open innovation literature and practice through the identification of a substantial number of factors which can influence the success of an open innovation approach, another topic only scarcely covered. By focusing on a number of struggles the researchers faced when implementing the open innovation practices, we take a first step in answering the calls of Chesbrough (2012), Bigliardi et al. (2012) West and Bogers (2014), and Goduscheit and Knudsen (2015) to investigate the limits, problems and managerial pitfalls related to open innovation. We were able to do so by selecting cases that were not *best-practice* cases, but rather *average* cases in terms of open innovation performance, which diminishes problems with the *halo effect* (Grönlund et al., 2010).

The identified factors, mainly related to the external context, the network configuration, the availability of internal resources, the capabilities, and the organizational structure, leadership and culture, largely correspond to issues already argued to be influential in private organizations in other, more theoretical work on open innovation. However, the public nature of these PRIs and universities, together with the historic emphasis on the development of deep scientific knowledge seem to be two factors that further challenge the implementation of open innovation.

This research also contributes to the knowledge on the emerging bioeconomy. The development of this more sustainable economy, where fossil-based inputs are substituted by biomass inputs, will rely heavily on radical and disruptive innovation (Boehlje and Bröring, 2011; Golembiewski et al., 2015). Although open innovation has been propagated by several scholars (e.g. Kircher, 2012; Biliardi and Galati, 2013; Golembiewski et al., 2015; Boehlje and Bröring, 2011; Van Lancker et al., 2016a) to be a suitable approach for the required innovation efforts, it has not been widely explored. With this work, we offer first empirical insights on this topic which was thus far non-existent (Golembiewski et al., 2015).

The models of Van Lancker et al. (2016a,b) were used to develop the research design of this paper. We can conclude from this research that these models were a proficient starting point for the analyses of innovation development processes in the bioeconomy context. The study does however reveal that the organizational innovation system (Van Lancker et al., 2016b) could benefit from additional system failure categories (e.g. unconducive firm culture) or existing system failure categories could be expended upon (e.g. Capacity failure).

# Chapter 5

# Towards a more bio-based economy – Empirical investigation of firm level innovation management strategies

**Abstract**

Although the bioeconomy concept has been introduced over a decade ago, the concept still does not have a commonly agreed definition, despite the importance of such a shared understanding of the concept between the different relevant actors to the transition effort. The view on the bioeconomy economy of the industry in particular has been under-researched. Hence, the first objective of this study is to examine the view of this actor group on the bioeconomy concept. Additionally, we studied the innovation management strategies applied in the different sectors relevant to the bioeconomy, as not much is currently known on this important topic in the bioeconomy context. An in depth analysis of fourteen case studies show that most firms find the bioeconomy to be a vague concept that has limited practical use. Innovating towards a more bio-based economy is not a priority for the majority of the firms. As to the innovation management strategies, we found considerable levels of communalities regarding strategies across different firms, such as the strong focus on appropriation, the openness to external actors, and the emphasis on creating an innovation culture. Nevertheless, a number of differences exist, which relate mostly to how innovation is perceived in the different firms and how long ago the firms formalized their innovation management strategies.

# Chapter 5 - Towards a more bio-based economy – Empirical investigation of firm level innovation management strategies

## 5.1 Introduction

Many governments around the globe are investing heavily into the transition towards a bioeconomy. The bioeconomy is described as an economy which relies on biomass instead of fossil inputs as input for the production of diverse bio-based goods. The transition towards a more bio-based economy is advocated to help combat climate change, alleviate the increasing resource scarcity, and aid in ensuring food security, while also providing local, hard-to-relocate jobs (European Commission, 2012; Boehlje and Bröring, 2011; Kircher, 2015). However, although the concept of bioeconomy has been introduced more than a decade ago (McCormick and Kautto, 2013; Vandermeulen et al., 2011), still no commonly agreed definition, nor agreement on which (sub)sectors belong to the bioeconomy has been reached (Pfau et al., 2014; Vandermeulen et al., 2012). Related concepts such as bio-based economy, knowledge based bioeconomy, green economy and circular economy, which are sometimes used as synonyms, add to the ambiguity of the bioeconomy concept. Additionally, the view on bioeconomy often differs within and across different stakeholders groups, i.e. policy makers, scholars, and industry. Therefore, the first goal of this study is to gain additional insight into the different views on the bioeconomy from an industrial perspective. A number of studies have already been conducted on the difference and communalities in the definitions and conceptualizations of different countries and scholars (e.g. Aguilar et al., 2013; Kircher, 2012; Pfau et al., 2014). However, the point-of-view of the industrial (sub)sectors which are supposed to lead the transition and become more bio-based, has generally been disregarded. However, to successfully realize such a transition from a fossil-based towards a bio-based economy, transition management literature and system innovation theory propagate the importance of a common end-goal (Budde et al., 2012; Coenen et al., 2010; Smith et al., 2002; Woolthuis et al., 2005). Sharing a common vision among all actors involved is a vital factor in the transition effort.

Despite the ambiguity in the definition of the bioeconomy concept, there is general agreement that the road towards the bioeconomy will be paved by knowledge creation, research & development and innovation in different knowledge and technology fields (European Commission, 2012; Kleinschmit et al., 2014; McCormick and Kautto, 2013; Rönnlund et al., 2014). This is echoed by the heavy investments of many countries into support schemes for technology development and innovation towards the bioeconomy. For instance, Canada has implemented a national program for biotechnology R&D partnerships worth 20 billion CAD (Biotec Canada, 2008), the USA is investing 385 million USD in six biorefinery pilots, and the EU has developed several research support grants in bioeconomy areas under the European Commission's Framework Program 7 and Horizon 2020 (Clever Consult, 2010; European Commission, 2012; Kircher, 2012). However, despite the wide acknowledgement of the importance of innovation, research and development, and knowledge creation for the development of the bioeconomy (e.g. European Commission, 2012; Keegan et al., 2014; McCormick and Kautto, 2013), empirical research on how firms are approaching their innovation efforts to develop bioeconomy concepts are currently virtually non-existent. Research within the technology and innovation management (TIM) perspective on the bioeconomy is scarce and the little research that has been conducted, has largely focused on theoretical contributions (e.g. Golembiewski et al., 2015, Van Lancker et al., 2016a). Therefore, the second main goal of this paper is to examine the innovation strategy of firms in sectors that can be considered relevant to the bioeconomy, based on the organizational innovation system framework developed by Van Lancker et al. (2016b) in order to gain insights into successful innovation approaches in this context.

To accomplish both goals, interviews were conducted with innovation managers of 14 firms of various sizes and activities considered to belonging to the bioeconomy (see section 5.2). These interviews yielded an industry perspective on the bioeconomy concept (section 5.3.1) and valuable insights on the different important aspects of innovation management in this context (section 5.3.2). From these results, communalities and differences are derived and discussed in section 5.4, and conclusions drawn in section 5.5.

## 5.2 Research goals and methodology

The two main goals of this study are to gain insights in how industrial actors are looking towards the concept of the bioeconomy and to investigate how industrial actors organize their innovation efforts in this context.

Similar to the methodology in chapter 4 of this research, we adopted an extended case study logic. Because the main aim of this study is to explore on open innovation aspects in an under-researched context, we feel that the logic behind this method, which aims to reconceptualise and extend theory (Danneels, 2002; 2003), fits the goals of this research better than pure inductive methods. Burawoy, who developed this method, stated the following: "The generation of theory from the ground up was perhaps imperative at the beginning of the sociological enterprise, but with the proliferation of theories reconstruction becomes ever more urgent. Rather than always starting from scratch and developing new theories, we should try to consolidate and develop what we have already produced." (Burawoy, 1991: 26).

Hence, in this study, we examine the literature relevant to the goal of the study, i.e. primarily bioeconomy literature on the one hand, and open innovation literature on the other, to develop a framework for analysis that helps us guide our empirical exploratory analysis which, in turn, helps us to fill gaps, elaborate the meaning and extant the coverage of the open innovation concept (Daneels, 2002; 2003).

The first main research goal, to gain insights in how industrial actors are looking towards the concept of the bioeconomy, was translated after the literature review into three important aspects: (i) the definition of the bioeconomy by the respondents; (ii) the significance of the bioeconomy for the activities of the firm; and (iii) the innovation efforts made by firms interested in the bioeconomy.

Second, regarding the second research goal, i.e. investigate how industrial actors organize their innovation efforts in the bioeconomy context, the starting base for the framework for analysis were the theoretical insights in previous work on the organizational innovation system concept (Van Lancker et al., 2016b) and the innovation management recommendations applied to the bioeconomy (Van Lancker et al. 2016a). In both more conceptual papers, an extensive literature review was performed on the concept of open innovation, supplemented by topics such as innovation systems, innovation adoption ,and business model innovation (Van Lancker et al., 2016a,b).

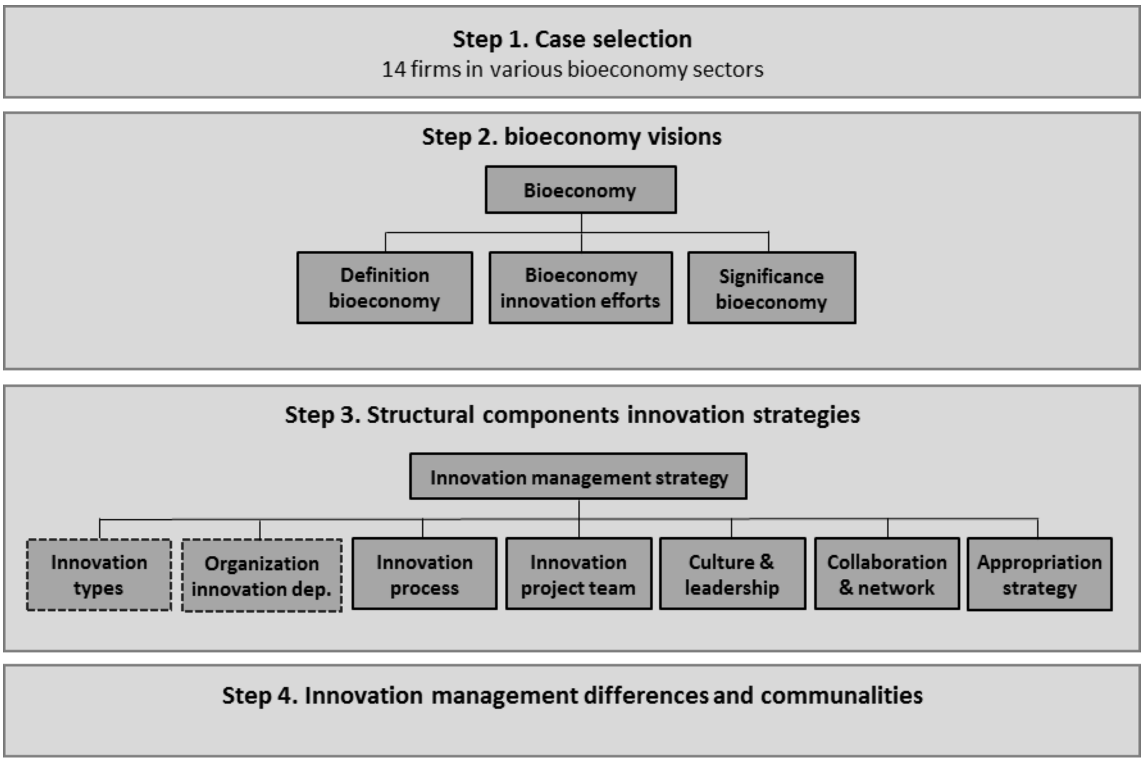


**Figure 11** Analytical framework for the case studies (Adapted from Van Lancker et al. (2016b)). Codes depicted using dotted edges come up during the data collection.

Through iterative loops between the data collection and analysis, sufficient room was left for aspects and concepts emerging from the data in order to avoid being limitative by overlooking important concepts and criteria (Blackstock et al., 2007; Triste et al., 2014). This resulted in the following seven aspects discussed in section 5.3.2: (i) innovation types; (ii) organization of the innovation department; (iii) innovation process; (iv) innovation project team; (v) organizational culture and leadership, (vi) collaboration and innovation network; and (vii) appropriation strategy and institutional arrangements. This led to the finalized framework for analysis summarized in figure 11, where the 'innovation types' and 'organization of the innovation department' were the two main aspects not in the initial framework.

The primary data for the analysis was collected through interviews with innovation managers from firms with activities in (sub)sectors that potentially belong to the bioeconomy. To construct a sample, a number of inclusion criteria were applied. First, the firm had to have activities in one of the (sub)sectors defined in chapter 1 of this manuscript. These sectors are food and beverage, textile, wood processing, paper and pulp, furniture manufacturing, chemistry, pharmaceuticals, manufacturing, energy production, and waste management[11]. Second, the firm had to either be a member of one of the associations grouping firms emphasizing sustainability or be in a Flemish, Belgian or European database listing firms with bioeconomy activities. Third, the firm has to explicitly mention sustainability, bioeconomy, or similar concepts on their firm website. Fourth, the firm has to be an innovator, illustrated by the emphasis on research and development and innovation in the firm's communication. If the firm complied with three out of these four criteria, it was considered for inclusion in this study. Our intention with this sample was not to be exhaustive or fully representative, but to collect viewpoints from very different firms with respect to size, activities and organizational structure.

In total, 17 innovation managers from 14 different firms of various sizes and with different activities were interviewed. From these 14 firms, one was a small start-up, employing only two people; five firms are large firms, with 350 to 2 100 employees and a turnover of 200 to 750 million euro; and five are very large corporations with up to 12 000 employees and 4 billion turnover. The final three firms are large conglomerates, employing between 90 000 and 150 000 people and generating a turnover between 30 to 150 billion euro. The firms predominately have activities in the food and feed sector, the chemistry sector, and the construction materials sector. Some of the firms, generally the smaller firms, are concentrated on activities in one or two of these sectors, whereas the very large firms and conglomerates have activities in several different sectors, even beyond those identified as potential bioeconomy sectors. An overview

[11] For an elaborate description of these sectors, see annex 1.

of the interviewees' official job title and a general description of the firms can be found in table 10.

**Table 10** Overview of the interviewed managers and the studied firms

| Firm | Interviewee | Job title | General description of the firm | |
|---|---|---|---|---|
| | | | **Firm size** | **Industrial activity** |
| 1 | A | CEO | Small start-up<br>2 employees | Chemistry |
| 2 | B | Fundamental Research | 200-750 million euro turnover<br>350-2 100 employees | Food and Feed |
| 3 | C | Corporate Technology Manager | 200-750 million euro turnover<br>350-2 100 employees | Chemistry |
| 4 | D<br>E | Partnership Coordinator<br>Long Term Innovation Manager | 200-750 million euro turnover<br>350-2 100 employees | Chemistry |
| 5 | F | R&D Director Applications | 30-150 billion euro turnover<br>90 000-150 000 employees | Agro-food<br>& sectors beyond bioeconomy |
| 6 | G | Business development manager | 1-4 billion euro<br>4 000-12 000 employees | Food and Feed |
| 7 | H | Director External Affairs | 1-4 billion euro<br>4 000-12 000 employees | Construction |
| 8 | I<br>J | Innovation Management<br>Vice President | 30-150 billion euro turnover<br>90 000-150 000 employees | Chemistry |
| 9 | K | Division Scientist | 30-150 billion euro turnover<br>90 000-150 000 employees | Chemistry<br>& sectors beyond bioeconomy |
| 10 | L | Product development manager | 1-4 billion euro<br>4 000-12 000 employees | Construction |
| 11 | M<br>N | Director Intellectual Property<br>R&D director | 1-4 billion euro<br>4 000-12 000 employees | Chemistry |
| 12 | O | Director Engineering | 200-750 million euro turnover<br>350-2 100 employees | Potential bioeconomy sector[1] |
| 13 | P | Business developer | 200-750 million euro turnover<br>350-2 100 employees | Agro-food industry |
| 14 | Q | Technology & Innovation Manager | 1-4 billion euro<br>4 000-12 000 employees | Chemistry<br>& sectors beyond bioeconomy |

[1] A more exact description of the activities of this firm would jeopardize the guarantied anonymity

The in-depth, semi-structured interviews (1h30 to 2h30 in length) were all recorded and transcribed. The interviews consisted of a series of common questions which were designed to cover the different aspects defined in the research framework, but also a number of questions related to the specificities of the firm. Moreover, we allowed for additional topics to come up during the interviews.

Besides the interviews, a document analysis was conducted of a large number of documents from the studied firms. These documents were either internal documents provided by the interviewees or documentation freely available through the internet. Only documents concerning the firm's products or services portfolios, innovation strategy, or bioeconomy efforts were withheld for further analysis.

The documents and the interview transcripts were analysed in NVivo 11, enabling us to label, structure and classify the data (Triste et al., 2014). The data was systematically categorized into the different aspects described (see figure 11). For this purpose, first, the data was labelled into one of the two main category groups, i.e. bioeconomy or innovation strategy (tier one). Second, each of these data fragments were further divided into a more specific tier two category. Data fragments that could not be included into one of the labels were given a new label and then closely examined to determine whether these fragments could be clustered into new relevant criteria and concepts.

## 5.3 Results

### 5.3.1 Industry view on the bioeconomy concept

A considerable amount of the interviewees regard the bioeconomy as an ill-defined, hollow *container concept* with unclear boundaries and of no real practical use. For them, it is more a concept created by policy makers to frame certain legislative decisions and financial support structures rather than a concept following an industrial logic. The lack of a clear definition is reflected in the wide variety in definitions of the bioeconomy concept given by the interviewees. Some of the interviewees define the bioeconomy similar to many policy makers (i.e. the definition in section 5.1); "all activities that use biomass to produce value-added goods and services". Using this definition, the firms belonging to the agro-food industry, felt that they inherently belong to the bioeconomy, as the input for the production of their goods originate from natural sources. However, many go beyond this, as they are increasingly trying to valorise their by-products, which some add to the definition of bioeconomy.

*"You mentioned valorisation of waste products. We have a different definition for that. We do not have any waste streams, we have many side streams, and valorising those steams is very closely examined."* (Interviewee F)

A small number of innovation managers added the requirement of green processing, i.e. environmentally friendly production methods, to the definition of the bioeconomy. Other interviewees consider bioeconomy to be closely related to sustainability, although in two different ways. One group of firms treat the bioeconomy as synonymous with sustainability, but view sustainability exclusively from an ecological point of view. In other words, this group consider themselves as firms with bioeconomy activities because they are making efforts to reduce their environmental impact, labelled by them as increased sustainability. A second group views sustainability as a combination of economic, societal and ecological aspects. As they invest heavily to improve at all three aspects, they take bioeconomy activities into consideration to improve on their ecological impact.

One firm considers themselves to be part of the circular economy. In this firm, efforts are made to reuse and recycle as many of the end-of-life goods as possible. For them, the bioeconomy is part of this, as they also repurpose biomass waste. Closing cycles was also mentioned by three other firms as part of their definition of bioeconomy.

*"For us, Bioeconomy is very closely related to circular economy, which puts much emphasis on zero waste. Reusing everything as much as possible. ………. In nine out of ten projects we take this into account. I feel that it is almost a prerequisite to initiate a project."* (Interviewee G)

*"We look at it [the bioeconomy] as closing cycles as much as possible. Reusing waste that is created by agriculture."* (Interviewee B)

Partly related to the ambiguous definition of the bioeconomy concept, many interviewees felt uncomfortable stating that their firm did or did not belong to the bioeconomy. Indeed, when confronted with this question, they often debated to define the bioeconomy. Phrases similar to "If by bioeconomy, you mean [definition x], then we are part of it, but if you mean [definition y], I am not so sure" were commonplace. Only half of the interviewed innovation managers believed strongly that their firms have a bioeconomy profile, while one feels the circular economy is a better concept to describe the rationale behind their activities, and two others believe that they really do not belong to the bioeconomy. The remainder of the respondents argued they had some bioeconomy activities, although these described activities did not really correspond to activities which could be included into the definition provided in section 5.1.

Another issue mentioned with regard to the bioeconomy which is also related to the unclear definition, is the limited marketability of the concept. Innovation managers state that it is hard to easily and quickly (e.g. in a commercial) explain what the bioeconomy is to consumers and why it is important that their product is bio-based. Additionally, they emphasize that the demand for their bio-based goods is fuelled by the specific or additional functionality of these goods compared to fossil-based alternatives, rather than because of the fact the projects are bio-based.

*"If I had to make an estimation, then I would say that 90% of our bio-based products are being sold because of their functionality, and not because of the fact that they are green or renewable. That is often only a second argument."* (Interviewee C)

A final issue which was stressed in relation to the marketability of the bioeconomy, is the cost aspect. Especially with low oil prices, competing with commodity fossil-based goods is very difficult for bio-based alternatives which often cost significantly more to produce.

*"Unfortunately it is still the case that, especially with the current low oil prices, natural resources are a lot more expensive than crude oil. This makes it not easy. Especially if it is a one-on-one substitute for an oil-based product, than it is often very difficult."* (Interviewee C)

However, a number of the firms say that there is a growing demand from their costumers for more (ecologically) sustainable goods, made with green processing technologies if possible.

Despite the afore mentioned practical issues with the bioeconomy concept, the large majority of the interviewed firms have a plethora of innovation projects related to the bioeconomy currently in development. A difference can be observed between how these bioeconomy projects are implemented into the innovation activities of the sampled firms. For those firms considering themselves inherently part of the bioeconomy, these innovation projects are being developed at all organizational levels, i.e. the corporate, division, and business unit level (see also section 5.3.2.2 on the different innovation department levels), while for those firms who state to have only a limited amount of bioeconomy activities, bioeconomy research is more often executed at the corporate level, i.e. the long term development level. Additionally, for the firms who feel they belong to the bioeconomy, improving the *bio-based level* of products or services is inherently included in almost every innovation project. In contrast, the firms with limited bioeconomy activities efforts often do not have bio-based products as a goal in the majority of their innovation projects. Instead, these types of firms will, for instance, try to optimize the supply chain of a new application by valorising as many waste and side streams as possible or attempt to use green processing techniques during production to gain additional income or develop new markets.

### 5.3.2 Innovation management strategies

All of the interviewed firms have an innovation strategy, which is very often closely related to and aligned with the general mission, vision and general strategy of the firm. Most of these firms couple formal goals to the innovation strategy such as a fixed percentage of firm's growth generated by innovations developed during the last five year, or a ratio of the number of successful innovation projects versus the total number of projects initiated.

For the vast majority of the firms, the innovation strategy is formally established in written documents to provides clarity and guidance for the employees. However, two groups can be distinguished, one with an innovation strategy that has been established for many years and a second group with an only recently (all within the last four years) formalized or rethought innovation strategy. The formal innovation strategy discusses different key aspects of innovation management, including the types of innovation pursued at the firm, the organization of the innovation departments and innovation development, the innovation process, the involvement of external actors, and the appropriation strategy. In what follows, we discuss how these different aspects are approached by the interviewed firms.

#### *5.3.2.1 Innovation types*

The innovation efforts are often divided and structured according to different attributes of the pursued innovation. In the interviewed firms, this division is made based either on time horizon, the novelty of innovation, orientation of the innovation, or a combination of the three. In terms of time horizon, two to three levels can generally be distinguished: short term innovation (up to 2 years of development), medium term innovation (2 to 5 years), and long term innovation (5 years and more). In the firms where only two time horizons exist, the medium term is most often combined with the short term, i.e. short to medium term innovations. The respondents distinguish between two to four different degrees of novelty. In general, innovations can be divided into three degrees of novelty: disruptive innovations, i.e. truly *new-to-the-world* concepts, radical innovations (concepts new to the firm, market or industry) and incremental innovations or small changes to existing concepts. In some firms, the disruptive and radical innovations are grouped together, whereas in other firms, the incremental innovation group is further divided into incremental innovation, e.g. a variation on an existing product, on the one hand, and service, tech support or troubleshooting, i.e. small performance tweaks or small changes in appearance of products on the other. A final division is made in the orientation of the innovation. An innovation can either be an internally oriented innovation, i.e. an innovation to improve the firms' performance, or an externally oriented innovation which is focused towards the market and the customer.

#### *5.3.2.2 Innovation department configuration*

All firms, except the small start-up firm, have a separate department aggregating staff working on the development of novel concepts. The exact name of these departments varies, going from *Research, Development, Research & Development, to Innovation Development*. For the remainder of this paper, we will refer to these departments as *innovation departments*.

Excluding the start-up firm, all interviewed firms have a decentralized innovation department. The innovation subdepartments and their responsibilities can be linked to three levels, closely related to the administrative levels of the firms. The highest administrative level is the corporate level. This is the level of the CEO, other top management, and the aggregated administrative services supporting the different divisions and business units. The business unit (BU) level is the lowest level. A BU is a specific site of a firm, for instance a factory or a sales office. A number of business units can be grouped into a division, often based on communalities between the business units such as geographical location, products, background technology or activity. At this intermediate level, the leadership and shared services of a group of BUs is aggregated.

At the corporate level, four main innovation tasks can be distinguished. One, this highest innovation management level is responsible for the general management of the innovation activities of the firm. This includes bringing structure to the innovation activities, coordinating the innovation activities at the different lower levels, determining the budgets for the innovation activities at the lower levels, and defining the innovation agenda (i.e. which central topics or key technologies will be the focus of innovation efforts for the following years) after consulting the various innovation subdepartments. Two, this corporate innovation level is responsible for monitoring and analysing the innovation activities, using the afore mentioned formal innovation strategy goals (if explicitly available) to assess the necessity of altering the innovation strategy. Three, they provide support to the innovation subdepartments at the lower organizational levels. For instance, many interviewed firms have central a legal department or intellectual property department which provides services and knowledge to the subdepartments. Additionally, they provide decision support on innovation projects selection (especially when these projects involve significant investments or high uncertainty) and aid in connecting the different innovation subdepartments at the different levels. Four, this highest innovation department level is often responsible for the development of long term, more fundamental and disruptive innovation projects that are that are still far away from commercialization. As this type of projects is often associated with long development times and high levels of uncertainty, the return on the investment (if any) can often only be reaped after many years. By lifting the burden of this investment to the corporate level, the cost of development is not attributed to one division or BU, avoiding the division or unit rushing the development to make sure the project does not negatively influences their bottom line for too many years. This type of innovation projects in most cases only involves a small share of the total innovation projects of a firm.

*"There is a danger that the divisions will concentrate themselves on optimizing existing processes, closer to their daily operations. Therefore, more radical innovation is governed from a central budget. Those divisions are all responsible for their own EBIT. And research is a cost, and it can sometimes take a long time before it returns something. Often you have to wait four or five years. And also, there is more risk associated with this type of innovation, so it is approached more from the corporate level."* (Interviewee J)

The majority of the projects (between 65 and 95%), related to the development of radical, medium term innovation projects and incremental short term innovations, happen at the division level or the business unit level. Several reasons were mentioned for structuring the innovation efforts in this decentralized way.

The most often mentioned reason is the available of detailed knowledge at these lower levels on the technologies, products and needs of the (local) customer, the latter believed to lead to faster detection of changes in the markets. Also, the firms often establish innovation subdepartments close to different well-established universities and research institutes or close to relevant industrial clusters to facilitate cooperation and knowledge spillovers. Another reason for decentralization is the difference in local legislation. For instance, one firm has innovation activities that are conducted in an innovation department outside of Europe because of the more lenient legislation regarding genetically modified organisms outside of the EU. An additional, somewhat related reason for is the difference in innovation support schemes between countries. Many interviewees indicate that they have different innovation departments in different countries to maximize the governmental support for their innovation projects.

More pragmatic reasons were also mentioned. A number of the firms, especially the big conglomerates we interviewed, have activities that do not share many communalities. Therefore, they feel it is irrelevant to centralize innovation efforts, because the profit of potential knowledge sharing or economies of scale is limited. Also, a considerable amount of the interviewed firms' growth is realized through mergers and acquisitions. These acquired firms often already had an innovation department, and it was simply kept active after the merger.

*"If you really look at what an acquisition entails, then the first step is integrating the finances, then the commercial and operational synergy, etc. and, in all honesty, the research and development is not the aspect that is prioritized to align."* (Interviewee P)

*5.3.2.3 Innovation process*

Many of the interviewed firms have a formalized innovation process, i.e. a fixed number of steps or phases to go from opportunity and trend identification to a launched product or operational technology. Although not a pure dichotomy, two different approaches can be observed in the philosophy behind the innovation process management. One group of firms follows a rigid philosophy. In these firms, the innovation projects move through stage-gate-like phases, each with strict timings and predefined deliverables. The progress of the projects is relatively firmly guarded by innovation committees consisting of executives who rigorously make a go/no-go decision based on the predetermined objectives. Contrastingly, the second group of firms have a more laissez-faire philosophy. For these firms, the process is a guiding tool to aid in the development of new concepts.

*"You do not want to guide the outcome, but you do want to guide the process."* (Interviewee G)

In this second type of innovation processes, progress is monitored, but the judgment whether or not to continue with the development is based more on the experience and instinct of the evaluators than on formal criteria. In this philosophy, projects that are not completely going according to expectations, are sometimes redirected towards a different application or previous process steps are repeated in search of better solutions.

The design of the innovation processes varies widely between the different firms in terms of number of phases and names of the phases. Moreover, some firms several innovation processes, one for each the type of innovation. However, these innovation processes all include stages that can be put into the three general aggregating phases, proposed by Van Lancker et al. (2016a,b): an idea development phase, an invention phase, and a commercialization phase[12]. The idea development phase includes all phases that are related to the identification, generation, and evaluation of innovative ideas. *Exploration, Discover, Screen,* and *Idea generation* are examples of phases from innovation processes of the interviewed firms that can be considered part of the idea development phase. Activities and phases related to the (technical) development of the innovative idea are aggregated in the invention phase. Examples from the interviewed firms include the *Create, Dealmaking,* and *Lab-scale testing* phases. The commercialization phase groups the different phases concerned with getting the created new concept to the market. *Harvest, Evaluation,* and *Refine* are three examples of phases that can be considered part of the commercialization phase.

One clear communality in the interviews is that the innovation managers heavily focus on the idea development phase. They indicate that they often have *fool-proof, tried and tested* processes as part of the invention and commercialization phases, i.e. to get an idea developed and to market. However, the idea development phase remains a hard to manage stage with three apparent challenging aspects: opportunity identification and idea generation, idea consolidation, and feasibility assessment of the ideas.

*"The hardest part is how to get from trends, opportunities and vague ideas to concrete ideas. That fuzzy front end, how are you going to manage that?"* (Interviewee E)

The first challenging aspect the innovation managers focus on is developing ways to better identify opportunities and generate more and better ideas for innovation. To do so, almost all firms have a hybrid approach to opportunity and idea identification. They look for technological and scientific prospects (technology push approach), but also consider the possibilities offered or presented by clients and the markets (market pull approach). Moreover, they use both internal sources to provide potentially innovative ideas, as well as methods for external idea sourcing. One often applied method is appointing specific technology scouts. These scouts stay up to speed about the latest developments in certain appointed technology areas and

[12] More information on these three general phases can be found in chapter 2 and 3.

assess how the firm can benefit from these developments. Another method used in a number of firms, is regular scans of the scientific publications databases and relevant scientific conference attendance by the innovation personnel Similarly, a number of firms have specific idea development employees or teams for different product lines, technologies, or businesses. Another implemented method is improving the ties between e.g. the sales department and sourcing department on the one hand, and the innovation department on the other hand in the hope of gaining better insights into the latest evolution in customer needs and in upstream value chain changes. Also, many firms strongly invest in incentive schemes stimulating innovation, often involving methods to also motivate employees outside the innovation (sub)departments to submit their ideas for innovation. Such incentives can be financial, e.g. small cash rewards for feasible ideas, but also through intangible rewards such as recognition and appreciation for their contributions (see also section 5.3.2.5 on culture and leadership). Additionally, some interviewed firms strongly encourages a culture of experimentation. In one firm, an employee can bring together a small team of relevant co-workers to do some small tests before ever bringing the idea to a committee to be assessed. In another firms, small basic tests are sometimes performed as part of the idea generation process. Finally, many firms also invest in internal idea competitions; events where employees can pitch their idea to an innovation committee. The ideas deemed most feasible are withheld for further development.

A second challenging aspect the interviewed innovation managers are paying much attention to, is the idea consolidation, i.e. the effective collection and centralization of all innovative ideas. Although nearly all innovation managers emphasize this issue, it is more prevalent the more decentralized the innovation department is, as the dispersion of different innovation activities across different corporate levels and often different geographical locations frequently causes suboptimal communication between the innovation subdepartments. Two methods aimed at improving the internal exchange of knowledge and ideas were frequently mentioned by the respondents. First, many firms strongly encourage interaction between employees. They install internal networks or communities, often around a certain topic, with people from the different innovation subdepartments, sometimes including personnel from other departments. Also, the development of personal networks is often encouraged through, for instance, indicators for internal knowledge sharing in the personnel evaluation procedure. Additionally, some firms have a small number of innovation centres where researchers working on all different types of innovation are in the same building to promote communication and knowledge sharing. Second, a number of the firms have invested in information software solutions, aimed at information, knowledge and idea integration, storage, and distribution between subdepartments. These solutions range from a simple spreadsheet to file an idea, i.e.

a single page standardized template, to an integrated digital environment used for the entire innovation project management, including the idea collection.

The third challenging area is the development of methods and criteria for feasibility assessment of an innovative idea. Many of the firms have formal feasibility assessments, based on fixed criteria, often at different stages in the innovation process. In these firms, an innovation committee consisting of senior scientists and management commonly decides whether a project can proceed to the next phase. Most of the interviewed firms without such formal feasibility assessments, have recently developed such an approach, because they felt the ad hoc decision making led to too many unprofitable and unsuccessful projects. However, despite this observation, many of the respondents admit that, although taking into account the criteria official, the decision to pursue an idea or to give the green light to a project to go to a next phase, is still very often predominantly based on the gut feeling of the committee members.

*"… but claiming that we continuously work with these tools, templates and criteria, no. And you notice that during a meeting, we still often use our gut feeling to decide.*" (Interviewee L)

Although the emphasis on certain criteria differs between firms, three general criteria are almost always used in the feasibility assessments. The first criterion is economic feasibility. Specifically, the required investment for development, the internal rate of return (IRR), and the return on investment (ROI) are the most observed indicators. Related to this economic feasibility, the size of the potential market was also frequently mentioned.

*"People have to fill in a template. An Excel sheet, one page. We call this a business case. And at the end of the page you have a number. And that number needs to be significant. The output needs to be significantly higher than the input in terms of resources."* (Interviewee B)

The second common criterion is strategic fit. Many of the interviewed firms will not pursue a proposed idea that does not adequately fit into the innovation and/or general strategy, even if it is financially interesting. Related to this second often heard criterion, some firms also consider whether the novel concept will *cannibalize* existing activities. In other words, if the new idea threatens to considerably undermine sales of existing products or means replacing significant (technological) investments, it will not be developed, or be postponed. A third often mentioned criterion freedom to operate and patentability of the novel concept. It is thus not only important to be able create exclusivity through intellectual property rights (IPR), it also entails an examination of the prior art; finding out whether similar concepts have been protected. With limited freedom to operate, certain right would have to be acquired before the idea could be developed, potentially impacting the feasibility of the idea.

*5.3.2.4 Innovation project team*

In the large majority of interviewed firms, the innovation projects are executed in selected project teams. Most of the interviewed firms do not have a fixed guideline team configuration. The selection of relevant profiles for each team is thus determined ad hoc, depending on the type of innovation pursued. However, one position that is often not filled ad hoc, is the project manager or team leader. In a considerable amount of the interviewed firms, a number of employees are thoroughly trained in project management for this role. The remainder of the project team is generally filled by employees with techno-scientific backgrounds. Although it depends on the type of project, employees with an economic profile (e.g. sales personnel) are not regularly involved in the projects. Yet, in some firms, these economic profiles are added to the project team when the project advanced further in development, or are consulted at certain points in the project. Beyond that, the firms rely on the economic profiles in the innovation committees evaluating the progress of the projects to provide the economic information.

*"For the real innovation work, no commercial profiles are involved. But commercial profiles attend the monthly progress meetings. So you could say that those teams are multidisciplinary. But definitely from phase 3, and even from the lab phase. And during upscaling more and more production people and engineers get involved."* (Interviewee C)

*5.3.2.5 Organizational culture and leadership*

The backbone of many of the innovation strategies of the interviewed firms is the development of a conducive culture, leadership style and environment to innovation. To help accomplish this, most firms opt for a flat organizational structure of the innovation department , with as few hierarchical levels as possible. This is especially reflected in the decision structure related to innovation. These flat structures allows for clarity on who has the power to make a decision about innovation projects, leading quicker, more agile decision making in reaction to environmental changes and opportunities. The same clarity is importance for the decision power of continuation or termination of existing projects. This way, the chance of missing opportunities due to indecision or late decision is reduced, as well as the chance of investing in projects that will most likely not end successfully.

*"One of the problems before was that nobody knew who was allowed to make a decision to develop a breakthrough innovation. Now we have emphasized this more, it is more clear. And there is local empowerment to make decisions."* (Interviewee O)

This empowerment of certain individuals does not mean that the interviewed firms are managing their innovation departments very strictly with a *do-as-I-say* management style. Most firms adopt a guiding, facilitating management style. With this style, they want to provide structure, boundary conditions and clarity on which aspects are important, but leave enough room for the innovation personnel to be creative in their innovation efforts.

*"We only want central coordination. We want to know what ideas the business units are developing in order to have a birds-eye view. This way, we can provide guidance."* (Interviewee O)

*"… That is what management should do. They need to guide, adjust, influence, coach, but they do not need to be closely involved with the projects. That is for the people who are in the field. Finding budgets, hiring the right people, finding the right contacts, that is what a manager does. That is something completely different than saying: these are your objectives, you completed this many, and then grade you. It does not work like this."* (Interviewee K)

Related to this facilitating style of management, the leaders and the management in many of the interviewed firms are incentivized to be supportive of the innovation efforts and recognize its importance. This aspect is emphasized by a large number of the respondents as crucial to motivate the staff to invest in innovation, in particular if the aim is to also engage people into the innovation effort that do not have innovation related activities in their job description.

*"…. Because it is not only the people from research and development that have to innovate, it is also the people from marketing, sales, manufacturing, everybody has to be aware that innovation is a must."* (Interviewee K)

The engagement of every employee in innovation is an explicit goal in the innovation strategy of a considerable number of the interviewed firms. By including employees from other departments with a plethora of different educational background, the firms want to create a richer and more diverse idea pool, with out-of-the-box solutions and original commercialization pathways. Related to this point, many of the firms emphasize the importance of giving employees the opportunity to be creative. Some of the firms try to achieve this by allowing people to make mistakes and by not judging them when one of their ideas is not feasible or ends up not working.

*"Let people do their thing, especially, allow them to make mistakes, and do not judge them. It is emphasized that managers have to allow their employees to make mistakes to allow them to learn from them."* (Interviewee K)

Other firms go further, and install policies that allows employees to work on something unrelated to their day-to-day job a given percentage of their time. In this *free* time, creative thinking about how to make things better for the firm or its customers is encouraged.

*"In this percentage of free time, they are given the opportunity to search for things that are outside of their direct objectives."* (Interviewee K)

An additional important aspect related to innovation culture implemented by a large number of the studied firms, is recognition of innovation success and a reward system for successful innovation efforts. Small cash prizes for contributing an innovative idea with potential, innovation days with awards for exceptional innovation projects, and/or exclusive honorary titles for researchers who have significantly contributed to the firm's innovation efforts are a some examples from the interviewed firms.

*"We have a strong recognition culture. [……] We have achievement awards, with big project that need to be nominated. These are then judged by a committee. They got such an award. That is full blown. Plus, all managers learn to recognize a job-well-done. They learn how to manage their team and how to give feedback."* (Interviewee F)

Moreover, some of the interviewed firms have two separate function ladders, one for the innovation staff and one for the other employees. The ladder for the innovation staff holds positions equivalent to the *regular* function ladder in terms of regard and rewards, but the function descriptions differ significantly. The positions for the innovation profiles, for instance, contain less managerial, administrative and supervisory activities, allowing the innovation researcher to keep developing their knowledge and stay active in the field in a more senior position. In this system, researchers can choose to develop a career more related to a scientist, with job titles such as *(chief) principal scientist*, or develop a more corporate profile, with *chief technology officer* (CTO) as one of the highest job titles.

*"It quickly became clear that you need to have your own human resources department within the innovation department. That someone hired for his knowledge who likes to develop ideas, but who is not really strong at managing people, also needs a way to advance in the firm."* (Interviewee F)

A final often mentioned aspect related to innovation culture, is investing in people. For many of the interviewed firms, being an innovative firm starts at the hiring process. Many of the firms pay special attention to specific skills when hiring new employees. For some firms characteristics such as creativity, open-mindedness, etc. are required for every position, and not only really for innovation positions. One firm even pays specific attention to find a balance of different profiles within their innovation department. They believe that the interaction between the right mix of gender, age, mindset, and educational background can cause discussions, fuelling creativity, leading to more and better ideas.

*"We strive to achieve complementarity between our employees. On all levels. Knowledge, gender, age. We have millennials here, but also people that are older. And they all get a say. Because they all have different a philosophy and way of thinking."* (Interviewee B)

In addition to attracting the right people, most of the firms also spend a significant amount of resources to further develop the skills of their employees through training and education. After hiring the right people and developing their knowledge and skills, many interviewed firms also pay close attention to retaining their employees as long as possible.

*"Finding the right people is very important. For instance, in our business innovation department, we have people with enthusiasm, drive as well as people who try to connect. We also spend a lot of attention to how people are feeling. We try to ensure people can contribute, that they feel involved. We pay a lot of attention to giving courses and training. We really try to invest in our human capital."* (Interviewee G)

*5.3.2.6 Collaboration and innovation network*

All interviewed firms are collaborating with external partners. However, the openness of the firms can be considered a spectrum with different levels of openness, as the number of external actors involved, as well as the modes of collaboration used differ greatly between the studied firms. Moreover, a number of the innovation managers mentioned that, although they work very openly with external partners, they sometimes opt to deliberately work behind closed doors to keep the development of certain innovations secret and the knowledge internal. This is most often the case when key knowledge is being developed, i.e. technology or products very close to the core activities defining (the future of) the firm. However, when deciding whether or not to collaborate with external partners, most innovation managers follow a similar rationale: the closer to market launch the project gets, the less likely the firms engage in a collaboration and the less partners will be involved in the development process.

When the firms do choose to collaborate with external actors, universities and customers the two most often mentioned. Other actors mentioned are suppliers, firms from other sectors, consultants with specific expertise, policy makers, and sector federations. Another type of actor that was sometimes mentioned are small start-up firms with specific knowledge or technology. On interaction with competitors, the opinions differ. Some firms opt to not work with competitors, as they feel the risk of knowledge theft and spillover of ideas is too high. Alternatively, a number of firms work together with competitors on carefully selected projects, generally aimed at precompetitive research, industry standard setting, or developing innovations that would significantly alter (a part) of the sector.

*"Yes definitely, that happens. We are currently conducting co-research with our two biggest competitors. We call that pre-competitive research. Because this has advantages for all parties involved."* (Interviewee B)

The firms collaborate with these different actors in a wide variety of modes. One of the most often mentioned collaboration mode is through consortia for the development of subsided research and development projects (e.g. FP7 or Horizon 2020). The most common actors involved in this type of collaboration are other firms and universities. Besides working together in these consortia, the interviewed firms also work with universities and other research institutes through shared or sponsored PhD grants or through student graduation theses. With other firms, some of the firms set up joint research projects, joint research facilities, or joint ventures. Two firms even have joint researchers, i.e. researchers that spend some of their time at one firm and the rest at the other. Furthermore, the firms often license-in relevant technology from other firms when necessary and sometimes even acquire firms with potential high impact knowledge or technologies through takeovers. One firm also buys product lines from other firms because they supplement the core offering of the firm, while these products are at the fringe of the portfolio of the owner-firm.

To interaction with customers, one often mentioned collaboration mode is *A days in the life*, i.e. a period of time in which employees visit customers and learn about their life (B2C) or processes (B2B). One B2B firm also has *alpha* and *beta* clients, who gain access to new developments before the official market launch. In return, the innovating firm gets access to the operations of clients to learn about customer needs and to measure the performance of their new concepts in real life situations. Additionally, the firms with B2B activities frequently often work in a one-on-one collaboration with a specific customer to develop a solution for their specific problem.

Interaction with government agencies and policy makers often takes the form of consortia, but some firms also develop public-private partnerships or make lobby efforts to, for instance, pinpoint legislative bottlenecks or to plead for (financial) support of certain research topics.

Additionally, some of the largest interviewed firms organizes web-based open innovation contests or crowdsourcing campaigns. In these contests, the firms post a number of problems or questions they face, and anyone with a potential solution can submit it, often in return for a cash reward. Also, a number of the firms deposit a specific amount in innovation development funds or in a reserve they use to act as venture capitalists for small start-ups developing technology or products relevant for their business. Furthermore, symposia are organized on certain topics they want to make progress on, and everyone who has relevant knowledge on the topic can come and present their contribution.

Most of the modes of interaction mentioned in the above paragraph can be considered outside-in open innovation activities. In other words, these are efforts to internalize knowledge that is available external to the firms. Some, such as creating research consortia, can be considered as a coupled open innovation activities, in which both internal information is shared and external information is internalized (Enkel et al., 2009). A small number of firms also mentioned specific inside-out open innovation activities. One of these inside-out modes is out-licensing, i.e. selling the right to use an intellectual property protected concept to an outside firm. Another example is contract research, where the firm does research (i.e. provides internal knowledge and equipment) for another firm in return for payment. Finally, one firm installed some of their testing equipment at the research facilities of the sector federation.

Interaction with these different actors through the above mentioned modes can have a great many benefits. The organizational innovation system framework (Van Lancker et al., 2016b) suggest seven beneficial functions a group of actors supporting the innovating firm can provide. These seven functions were all mentioned during the interviews. The most often mentioned function is that these actors provide additional insights in trends, offer ideas for innovation, or help pinpoint innovation opportunities. The second most often mentioned function of the networks was the provision of resources. As previously mentioned in the above paragraphs, the firms often count on external actors to provide both complementary tangible resources (e.g. technology or equipment) and intangible resources (e.g. knowledge, skills and expertise). A third function mentioned by some of the firms is the reduction of uncertainty regarding potential ideas. Fourth, some of the firms collaborate with external partners to create a first market. Through the interaction with these partners, some initial turnover is guaranteed which serves as a stepping stone to gain the desired market share. A number the interviewed firms involve external partners to setup a new effective supply chain (function five) for the innovation, often taking fair value distribution and efficient resource use along the chain into consideration. Sixth, a few innovation managers also mentioned the reference function of a network containing a variety of external stakeholders. These managers connect with externals on a regular basis during the innovation process to ensure the development of the concept still conforms to the needs and expectations of the relevant stakeholders. The seventh function, creating legitimacy for the innovation, was mentioned by only one interviewee.

*"It is important to go into a dialogue rather early, because before you know, an opinion is formed. And that is not always the right opinion. And that's when the problems begin. Look at the problems with genetically modified organisms in Europe."* (Interviewee J)

*5.3.2.7 Appropriation strategy and institutional arrangements*

One final aspect that is included in the innovation strategies of many interviewed firms, is an appropriation strategy including a number of institutional arrangements. Although a variety of institutional arrangements were mentioned by the interviewees, three types of arrangements were mentioned most. The first type are the non-disclosure agreements (NDAs) and secrecy agreements, often related to collaboration with external partners in the start-up phases of the innovation process, i.e. phases related to the idea development phase, or at the beginning of collaboration negotiations. The second type are contracts. In this type, all arrangements that specify a *quid-pro-quo* relationship between the partners are included, e.g. joint development agreements, or agreements with universities to do specific tests. The third most often mentioned type of arrangements are IP-agreements. These agreements specifically stipulate each partners' rights to the intellectual property developed in the projects, and can also specify what IP-protected knowledge or technology each partner contributed to the project. Another arrangement that was sometimes mentioned by the interviewees is exclusivity. In such agreements, the firm grants the collaborator(s) exclusive access to the technology or product for a certain period of time, or sometimes even indefinitely. One interviewee also mentioned that they draft specific agreements with universities on publishing. At the beginning of the project, the university and firm agree on what information can be published in journals and what remains proprietary. They also discuss if certain delays for publication are required to, for example, increase the first-to-market advantage or not jeopardize a patent application.

Most of the interviewed firms rely heavily on these hard institutional arrangements to interact with external actors. Many of the firms have employees specialized in partnership agreements and intellectual property rights, or even entire departments to manage these issues.

*"We have a central legal department. And within R&D we have a legal attorney. There are clear guidelines on how to, for instance, handle NDAs: when that is required, who can sign one etc. Formal guidelines exist on these issues."* (Interviewee H)

*"We have a network of IP coordinators. Each BU has one."* (Interviewee M)

This does not mean that trust is not an important part of the partnerships in these firms. Many of the respondents indicate that a certain level of trust is required to start negotiating and sharing knowledge, but the more concrete and potentially profitable a project becomes, the more written agreements are required. However, two of the interviewed firms have a mostly trust-based appropriation strategy. They rely on trust and other soft institutional arrangements when developing innovation with other partners, only putting things in writing when demanded by the other parties, or when required (e.g. in in government supported consortia). These interviewees indicate that they have only rarely encountered issues with this approach so far.

Both approaches thus seem to have merit and can be successfully used when collaborating. The respondents indicate that selecting the right way to institutionalize the cooperation is difficult, context specific balancing act. Innovation is often about speed, being quicker to the market with a novel concept than your competitors. Negotiating terms and filling in all the right paperwork to ensure an airtight collaboration agreement can be time consuming task.

*"[Working without hard institutional arrangements] is a strong expectation. But you cannot exaggerate these thing. There is a certain point where too many NDAs and other arrangements become counterproductive. It can lead to situations where you cannot talk to anyone anymore."* (Interviewee H)

Also, as innovation involves creativity and freedom to think outside the box, it is always difficult when drafting agreements to find the right balance between leaving enough space to be creative and firmly predetermining the conditions of the partnership.

## 5.4 Discussion and conclusion

### 5.4.1 Industry perspective on bioeconomy

All firms included in this study are part of sectors that can be considered potential bio-based economy sectors. Moreover, based on their specific activities and produced goods, all firms can be considered to, at least in part, belong to the bioeconomy or have activities aligned with the bioeconomy philosophy as defined in section one of this paper. Despite this and the efforts made in the selection process, a considerable number of the interviewed innovation managers indicate that they do not consider their firms to have (many) bio-based activities. One of the main reasons behind this apparent discrepancy, seems to be the definition of the bioeconomy. The interviewees not only feel that the bioeconomy is ill-defined by policy makers, the results also show that the different interviewed firms define the bioeconomy in a variety of ways. Figure 12 puts the views on bioeconomy from interviewed firms on a spectrum, with the traditional, fossil-based economy at one end and the circular economy, a holistic approach to material use which aims to maximally valorise, use and re-use of all resources (including biomass) at the other.

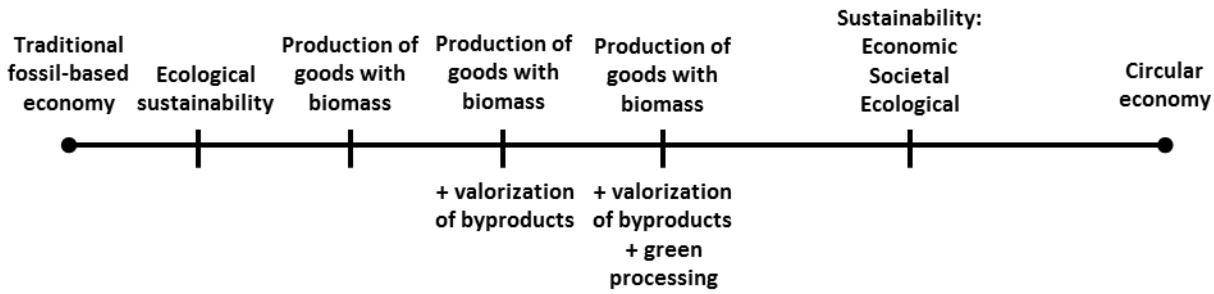


**Figure 12** A spectrum of views on the bioeconomy in industry based on the interviewed innovation managers

This plethora of different definitions observed, confirms the findings of Vandermeulen et al. (2011) who also found that some industrial actors include solar or wind energy in bioeconomy, as well as expand the definition by including terms like energy-efficiency and sustainability. Of these different definitions, only a limited number of firms defined the concept in line with the definition of policy makers, i.e. a definition containing the three key principles outlined in section one of this paper. Although increased sustainability is one of the three key principles, considering oneself as a (partly) bioeconomy firm because efforts are made to reduce ones environmental impact is a somewhat limited view on the bioeconomy concept. The efforts made do reduce the environmental impact are often not bio-based, nor (completely) in line with the cascade principle. Moreover, the fact that the bioeconomy is inherently a more (ecologically) sustainable economy, has been recently questioned by researchers such as Zwier et al. (2015), Staffas et al. (2013), and Pfau et al. (2014). The firms looking even beyond bioeconomy towards a circular economy, are following the latest developments in the views of policy makers and scholars, who are increasingly emphasizing the importance of a circular economy and the close connection and complementarity of the bioeconomy in the development of this circular economy (Philippides et al., 2015; Kircher, 2015; Viaggi, 2015).

A second explanatory factor for the fact that the firms do not identify themselves with the bioeconomy, is the apparent indifference towards the concept of bioeconomy. For the majority of the interviewed firms, becoming a more bio-based firm is not a priority in their general, nor innovation strategy. For them, the bioeconomy concept is a concept that is not easy to apply or commercialize. The latter coincides with a study of Vandermeulen et al. (2012) in which CEOs state that education of the consumer is still required to further convince them of the opportunities and benefits of a bioeconomy. For many firms, being more bio-based is not a goal, but a potential means to an end. Increased bio-based products, green processing technologies and valorisations of by-products and waste streams are used to either enhance their sustainability or meet customer requirements, ultimately leading to increased profitability. However, although the interviewed firms appear to be not really concerned with the bioeconomy concept, the interviews do show that the large majority of the firms are concerned with their ecological impact and take steps to reduce detrimental effects of their activities on the environment.

### 5.4.2 Innovation management strategies

In terms of the innovation strategies employed by the interviewed firms, a number of interesting communalities and differences can be observed. The differences in the strategies seem to not be influenced by the amount of bioeconomy activities of the firms. Firms with a strong emphasis on bioeconomy (and sustainability) generally show as many similarities in their innovation approach with firms with less bioeconomy ambitions as they show differences. With this dataset, it is however difficult to identify what the underlying cause of these differences could be. Some could be related to the sectors the firms are active in, to the size of the firms, to the type of activity (producer or service provider), or to the type of market served (business to business versus business to consumer). The interviewed firms are too heterogeneous in these aspects to be able to say which of these aspects are playing a role.

Regardless, two interesting differences could be observed between the firms. The first is the difference in definition of innovation. Although most firms consider innovation to be the successful commercialization of a new concept, there is a difference in what the firms consider an innovation, especially in terms of novelty. For instance, one firm considers the growth of the firm through the duplication of activities in another geographical region as part of the innovation activities, where most others do not really consider this as being part of the innovation definition. Some firms consider small changes to the appearance of their products (e.g. colour change) to be an incremental innovation, where others view this as a mere product alteration. For the latter firms, an incremental innovation involves an alteration to the product, technology or service which (slightly) enhances or changes its performance. Additionally, some firms view the implementation of existing technology into the firm as breakthrough, i.e. radical innovation, whereas most of the interviewed innovation managers consider radical innovation to be the development of concepts that are considerable improvements on existing concepts or new to the market/industry concepts.

The second interesting difference is in the age of the formalized innovation strategies of the interviewed firms. Of the interviewed firms, roughly half has a formalized innovation strategy that has been established for a considerable time now. The other half however only formalized their innovation strategy very recently (less than 2 years ago) and/or altered their formalized strategy significantly in the last few years. This last group of firms all formalized their informal strategy recently with the goal of offering clarity and structure to their employees regarding the innovation efforts, because most of these firms felt that opportunities were missed and innovation efforts were uncoordinated. By offering a number of formalized guidelines, they want to create a clear rationale for innovation within their firms. Besides all firms having a similar goal in mind leading them to formalize their innovation strategy, it is also striking that the alterations made to the innovation strategies are all along the same line. The changes in the strategies almost always include: increased consistency between the different strategy aspects, increased openness to external stakeholders, ways to improve internal communication, decentralization of research activities, a hybrid innovation approach combining market pull and technology push, and efforts to develop an innovation culture.

Interestingly, with these changes, these firms have created innovation strategies that are very similar to those of the firms with long(er) standing, formalized innovation strategies.

This, together with the long term business success of these firms with long standing strategies, seems to indicate that the communalities in their strategies can be considered potential key components to innovation success. Although the results show that none of the innovation strategies of the interviewed firms are the same, seven interesting similarities and trends can be distinguished. First, all firms have a well thought out innovation strategy that is formalized in one way or another. Moreover, these strategies are, in most cases, a holistic rationale which takes into account many different aspects important to innovation development, and try to find a logical coherence between these aspects. This finding is in line with the arguments made in the work of Van Lancker et al. (2016b) for an innovation system approach in which the different innovation management aspects are well though-out and complementary. Additionally, Knoskova (2015) found that corporate strategic orientation and highly developed innovation processes are clear success factors for radical innovation development. Jones et al. (2016) also found that that having a disciplined and defined innovation strategy across the firm strongly impacts innovation success.

Second, the innovation strategies have a strong focus on cooperation with external partners. Although there is a big difference between the openness of the firms, not only in terms of the amount of stakeholders and the number of different stakeholder types, but also on the different collaboration utilized, all firms are opening up their boundaries in one way or another. This trend towards open innovation (Chesbrough, 2003) has been observable both in theoretical research on innovation management as well as in practice. The use of open innovation strategies were already prevalent before Chesbrough's seminal work in 2003 on the topic (77% of European firms in 2001) (Greco et al., 2016), but rose to even higher levels, to around 90% of European firms (Cricelli et al. 2016). Open innovation has repeatedly been associated with increasing innovative performance (e.g. Berchicci, 2013; Chen et al., 2016) and long-term improvement in firm profitability (e.g. Noh, 2015). However, this positive effect has its limits, as the benefits of opening up the firm diminish with increasing openness and at a certain point, become negative (e.g. Berchicci, 2013; Laursen and Salter, 2006).

Third, despite this increasing openness, the *traditional partners* for innovation, i.e. customers and universities, are still the partners that are most often mentioned by the interviewees as key partners for their innovation efforts. This result is in line with Chesbrough and Brunswicker's (2014) findings that co-creation with customers and consumers was the top-rated open innovation practice, followed by informal networking and university research grants in second and third place. Brettel and Cleven (2011), based on work of other scholars, also strongly emphasize the beneficial contributions of involving customers and universities in the new product development process. The beneficial aspects of user integration on enhanced awareness of the innovation and increased acceptance stressed by Arnold and Barth (2012) further illustrate the importance of opening up the firm to their customers and users. And although the recent work of Chen et al. (2016) show that collaboration with value chain partners has the strongest effect on the innovation performance of a firm, the interaction with universities is found to be the second most important partner.

Fourth, in terms of modes of collaboration, the firms use far more ways to transfer in information from the outside of the organization, than they use inside-out collaboration modes. This finding is in line with Chesbrough's (2012) observation that the outside-in part of open innovation receives the greatest attention in both the academic world and industry practice. The inside-out branch is less explored and less well understood (Chesbrough, 2012) which could help explain why firms are not as eager to share their own knowledge, skills, and intellectual property rights.

Fifth, the strategies also put a lot of emphasis on the appropriation strategy of the developed knowledge and innovation from the projects. In many of the firms, the ways to interact with external parties is well-defined, and the different arrangements that can be used easily available. In some firms, specialists and even whole departments are retained to ensure the fruits of the innovation effort are reaped by the firm. The importance of capturing value of the innovation process, especially when the process is opened up to external contributors (Belderbos et al., 2014; Bughin et al., 2008; Chesbrough, 2003), has been considered to be a pivotal point of innovation management by many scholars (e.g. Huizing, 2011; Giannopoulou et al. 2011). The results show that the majority of the interviewed firms rely on hard institutional arrangements to accomplish this, rather than on trust and other soft institutional arrangements such as secrecy and time to market.

Sixth, many of the strategies include formal innovation processes for the development of different types of innovation. In most firms, a hybrid approach is used, combining technology push and market pull aspects. This result confirms the work of Brem and Voigt (2009) and Berkhout et al. (2010), who build on the work of Rothwell (1994), which has established that firms are increasingly looking for different sources of ideas to develop into novel concepts. The emphasis within these innovation process descriptions is heavily on the early stages of the process; the stages involving idea development. This finding is not unsurprising, as significant research on the management of these early stages continues. These stages, often referred to the fuzzy front end of innovation (Koen et al., 2001; Bocken et al, 2014), are highly informal, knowledge intensive, erratic and have a high level of uncertainty (Van den Ende et al., 2015;

Thanasopon et al., 2016). Despite all the attention given to this fuzzy front end, there is still only limited understanding of how these initial stages should be organized (Bocken et al., 2014).

Seventh, the innovation strategies often start at the culture and the leadership style of the firm. Many strategies include ways to create an innovation culture, i.e. allow for creativity, entrepreneurship and risk taking. Moreover, a supportive leadership style, where managers leave room for error and give responsibility and decision power to employees is included in a large number of strategies. This supportive leadership has also been argued to be crucial for employees commitment to a firm's innovative vision by a number of scholars (e.g. Chesbrough and Crowther, 2006; Enkel et al., 2011). Additionally, a number of firms take this even further and start at the employment policy. They look for people with the right knowledge and educational background, but at least and sometimes even more importantly, the right (character) traits to complement the team and fit the firms' innovation culture. Also, implementing a reward and promotion system that is more conducive to innovative behaviour, such as the ones described by the innovation managers, has also been argued to be of importance by Salter et al. (2014). The importance of a climate conducive to innovation and a matching leadership style has been found and argued to be principal driving forces for success in innovation endeavours (e.g. Brettel and Cleven, 2011; Bigliardi and Galati, 2013; Enkel et al., 2011; Thong and Lotta, 2015; Giannopoulou et al., 2011). Naqshbandi et al. (2015) found that organization culture is an important predictor for open innovation and a hierarchy culture retards both in- and out-bound open innovation. Indeed, as many of the of the innovation managers also stated, a recent study of Jones et al. (2016) shows that respondents overwhelmingly agreed that innovation is everyone's job.

With this study, we provide insights into the industry's view on the bioeconomy, which can aid in the development of a generally accepted and supported definition of the concept, an essential prerequisite for the successful transition towards this more bio-based economy. This research further contributes to the bioeconomy progress by investigating how innovation efforts are managed in firms within the bioeconomy sectors, an important topic that has currently only scarcely and theoretically been studied.

Additionally, this work is a first step in verifying the theoretical models developed in two papers of Van Lancker et al. (2016a,b), as it is among the first to use the models as frameworks for analysis. We found during the research that these models were adequate to structure the research and serve as a starting point for the topics during the analysis. The Organizational Innovation System framework for analysis (Van Lancker et al., 2016b) could however benefit from further elaborating on firm traits, which are better developed in Van Lancker et al. (2016a), where they are discussed as organizational prerequisites to aid in successful innovation development. The fact that the model holds in most firms strengthen our belief that the two models can be used to also ex-ante organize innovation development in general, and in the bioeconomy context in particular. With this findings, we thus also contribute to general innovation management knowledge as these models can be used as guiding principles to help overcome the many challenges with implementing open innovation that still exist and assist in setting up strategies on how to effectively manage these collaborative activities (Almirall et al., 2014; Lichtenthaler, 2011).

# Chapter 6

# Reflective discussion:

# Innovation management in the bioeconomy

**Abstract**

In this chapter, we reflect on the studies reported in the previous chapters of this dissertation. We compare the main findings and lessons learned across the chapters and with recent relevant literature, grouped into four issues hindering the transition to the bioeconomy: (i) the ambiguous definition of the bioeconomy and related biorefinery and biomass cascade concepts; (ii) the lack of standardized measurement tools and methods for key bioeconomy aspects; (iii) the lack of insight on what contextual factors influence how innovation management should be approached in the bioeconomy; and (iv) the lack of knowledge on how innovation management strategies can be shaped at the organizational level in the bioeconomy. Based on this reflection, we formulate recommendations for three of the most important actor groups in the bioeconomy transition. We posit six recommendations for policy makers that can help stimulate innovation towards the bioeconomy, we introduce ten good practices for innovation management in the bioeconomy context, and we suggest a number of recommendations for future research on innovation management aggregated into three main groups.

## Chapter 6 - Reflective discussion: Innovation management in the bioeconomy

### 6.1 Introduction

Many policy makers and scholars around the world agree that a transition of our fossil-based economy towards a bio-based economy could help alleviate a considerable number of current global challenges, including the increasing and aging world population, climate change, loss of biodiversity, and the depletion of many resources and materials. Moreover, they belief that the development of a bioeconomy can also create economic growth, local and hard-to-relocate jobs, and energy dependence (European Commission, 2012; Boehlje and Bröring, 2011; Kircher, 2015). In spite of this recognition, its institutionalization in vision documents, and substantial investment support from governments, the bioeconomy is still in its infancy. In this chapter, we reflect on our the main findings, results and contributions of the conducted research in this dissertation comparing them cross the different chapters and relate it to the most recent literature on the topics, aggregated into four main issues slowing the bioeconomy transition.

A first issue that remains unclear, even after more than a decade-and-half of extensive attention to the concept, is what the bioeconomy exactly entails. McCormick and Kautto (2013) show that the definitions of the bioeconomy are evolving and vary depending on the actor. The lack of consistency in the bioeconomy definition has been echoed in many other works, such as De Besi and McCormick (2015), Pülzl et al. (2014), and Golembiewski et al. (2015), and some critics even argue that the bioeconomy is just old ideas put into a new concept (Pülzl et al., 2014). The existence of various similar and related concepts (e.g. knowledge based bioeconomy, bio-based economy, and green economy) and the different ways they are implemented further add to the lack of clarity surrounding the bioeconomy. In section 6.2.1, we will elaborate further on the issues related with the ambiguous definition of the bioeconomy.

A second issue to the development of the bioeconomy is the lack of standardized tools to measure key bioeconomy aspects. Consistent and accurate figures on bioeconomy aspects are very important for policy makers and industrial players to make well-founded decisions. In section 6.2.2, we focus on three key aspects that currently lack tools for measurement: (i) the size of the bioeconomy in a given nation or region; (ii) the available biomass; and (iii) the environmental sustainability assessment of bioeconomy value chains.

Given the current lack of bio-based products and the limited availability of commercially viable bio-based technologies, innovation is regarded as one of the keys to make the envisioned bio-based economy a reality (European Commission, 2012; Kleinschmit et al., 2014; McCormick and Kautto, 2013; Rönnlund et al., 2014). Despite the recognition of the importance of innovation, a third issue is the lack of knowledge on how innovation management should be approached in the bioeconomy context. Therefore, in chapter 2 of this research, we identify five contextual factors from the bioeconomy literature up to 2015: (i) the need for radical innovation; (ii) the need for a broad and complex knowledge base for these innovations; (iii) the need for collaboration to develop these innovations and set up new supply chains; (iv) the complex and often incoherent legislation and policy regarding bioeconomy topics; and (v) the difficulties in commercializing bio-based products. We elaborate further on these five factors in section 6.2.3.

A fourth issue is the lack of knowledge on how innovation management strategies should be shaped at the organizational level in the bioeconomy, as not much research on technology and innovation management has been done in this context (Golembiewski et al., 2015). In section 6.2.4, we will discuss the innovation management strategy components that appeared to be the most important throughout the different studies performed in this dissertation: (i) opening up the organization using a layered collaboration scheme; (ii) four important organizational traits conducive to (open) innovation; and (iii) the innovation process configuration.

Based on our findings, we formulate recommendations for three actor groups that are of major importance in the bioeconomy transition. In section 6.3.1, we elaborate on six recommendations for policy makers. We introduce ten good practices for innovation management in section 6.3.2 that can aid industry in configuring high-performance innovation management strategies. In section 6.3.3, a number of recommendations for researchers on the bioeconomy and innovation are formulated. This paper ends with concluding remarks in section 6.4.

## 6.2 Four major issues hindering the development of the bioeconomy

### 6.2.1 Ambiguous bioeconomy definition

Researchers, policy makers and business actors adopt different conceptualizations and definitions of the bioeconomy. Although the definitions given by the researchers all have a basis close to that within global vision statements, i.e. containing the three key principles outlined in chapter 1 of this dissertation[13], the boundaries of the concept vary across researchers and similar variation is observed among the innovation managers. Some

[13] The first key principle is that the bioeconomy will rely on renewable biomass instead of finite fossil inputs for the production of a wide range of value-added products such as food, feed, bio-based products and bio-energy. The second key principle is the cascade principle for the production of these bio-based products in biorefineries. These two key principles enable the third somewhat encompassing principle of sustainability. The bioeconomy is envisioned to be a greener economy, taking maximum biomass valorization, renewability of inputs, zero waste, and circularity of the production chains as a starting point.

researchers consider only new bio-based products, e.g. bioplastics, to be bioeconomy and the traditional sectors such as food and feed as non-bioeconomy sectors. In contrast, other researchers include wind- and solar energy production, whereas policy makers and scholars in general do not consider this to be bioeconomy activities. Also, a number of concepts which are related to, but slightly different from the bioeconomy (e.g. bio-based economy, circular economy) are also mentioned by a large number of the researchers and seem to contribute to the differences in definitions. Similarly, the results from chapter 5 also show considerable variation in how innovation managers from the private sector view the bioeconomy, going from "every effort made to increase my ecological sustainability is part of the bioeconomy" to "the bioeconomy is part of the circular economy". This observed discrepancy in definitions among industrial actors coincides with the findings of Vandermeulen et al. (2011), which is, to our knowledge, one of the few works that examined the vision of the industry on the bioeconomy. In contrast with the researchers, only a limited number of innovation managers define the concept in line with the definition of policy makers. These results illustrate that there is a certain divide between how different important actors define the bioeconomy concept. This divide has also been mentioned by McCormick and Kautto (2013) and Golembiewski et al. (2015), and has also been observed by Hodgson et al. (2016), who found that the different relevant stakeholder groups have different perspectives on the bioeconomy and what is required for its development.

Despite the apparent difference in perspective between and even within stakeholder groups, most stakeholders agree that the future bioeconomy will be more sustainable than our current fossil-based economy and will aid in combating climate change ( EBP and SCAR, 2014; European Commission, 2012; OECD, 2009; EU; Schmid et al., 2012; EPSO, 2011). Indeed, the survey-based study of Hodgson et al. (2016) shows very clearly that climate change was an important driver for bio-based innovation. Our results coincide with this finding, as the interviewed researchers and innovation managers tend to attribute the bioeconomy with the capability to increase the sustainability of economic activities, especially the ecological sustainability as many interviewees even mention solar and wind energy production and input reduction as bioeconomy activities. For one group of interviewed innovation managers, their efforts made to increase their sustainability were the sole argument for them stating their organizations belong (partly) to the bioeconomy.

However, for a number of scholars, the evidence with which the concept is defined as sustainable is a root for concern. One potential issue with bioeconomy sustainability is the probable significant increase in land use required to deliver the required amounts of biomass (Pfau et al., 2014; Shortall et al., 2015), even if land that is currently deemed suboptimal for agricultural production is used to grow bioeconomy feedstock crops (Kircher, 2015). Another aspect that can help combat excessive land use in the bioeconomy is the biorefinery concept, coupled with the biomass cascade concept advocating to use all currently wasted biomass, including crop residues currently left on the fields. This could be a rich source of feedstock, as the amount of bio-waste is estimated to be up to 138 million tons per year in the EU, and 30% of all food produced in developed countries is discarded (European Commission, 2017). Sander and van der Hoeven (2008) estimate that agricultural residues could amount up to 10 billion tonnes in 2015, sufficient to cover 15% of the world energy needs. However, the detrimental effect of removing crop residues from fields on soil fertility and resilience to flooding should be taken into account when considering using this residues as a feedstock (De Meester et al., 2011; Schmid et al., 2012). Besides the likely required increase in land use, De Meester et al. (2011) emphasize that the agricultural phase is often the main contributor to the environmental impact of bio-based products with fertilizer and pesticide use, the use of water, and diesel consumption for machines. Kircher (2015) follows this reasoning, stating that the production of biomass is not without emissions at all. Given the limited arable land, higher agricultural yields will be pursued, possible leading to increased use of resources (De Meester et al., 2011) and extension of the industrial monocultures and genetically modified crop varieties (Zwier et al., 2015). These genetically modified (GM) crops bring us to another potential issue regarding the sustainability of the bioeconomy, as the effect of the increased introduction of such modified organisms into the environment on biodiversity and biosecurity are unknown, even leading to a *bio-ecology vision* on bioeconomy which rules out the use of certain biotechnologies such as GM crops (Bugge et al., 2016).

As previously mentioned, the biorefinery concept and associated biomass cascade concept are considered by a large majority of actors to be key concepts to the advancement of a sustainable bioeconomy (Devaney et al., 2017; McCormick and Kautto, 2013; Palgan and McCormick, 2016). Despite this agreement, also across opposing bioeconomy visions (Shortall et al., 2015), the development of biorefineries has been slow and have not reached industrial scale, stuck at demonstration or semi-commercial scale (McCormick and Kautto, 2013; Palgan and McCormick, 2016). In the scientific literature that deals with the biorefinery concept, there seems to be a consensus on the meaning of the concept as encompassing a sustainable production process where biomass is first processed into high value products (e.g. pharmaceutical, industrial chemicals) while the residues are used for lower value applications until a minimum of waste, or even zero waste, remains at the end of the process (e.g. De Besi and McCormick, 2015; Kamm and Kamm, 2004; Matharu et al., 2016; Odegard et al.2012; Palgan and McCormick, 2016 Viaggi, 2015). The biorefinery concept is thus closely related to the circular economy concept, with circular flows of materials and zero-waste as important aims of these concepts (Devaney et al., 2017; European Commission, 2012; Viaggi, 2015).

To determine which bio-based products are considered high value products, the biomass cascade comes into play. This cascade is a pyramid of possible uses for the available biomass, going from high value at the top of the pyramid to the lowest value applications at the bottom. Valorising biomass in biorefineries following such a cascade approach increases the chance of reaching maximum valuation from the harvested biomass (De Besi and McCormick, 2015; De Meester et al., 2011; Odegard et al., 2012). In order to establish sustainable biorefineries, value in these cascades should be interpreted as a combination of economic, environmental, and social value. However, it is very often only the economic value that is taken into account (De besi and McCormick, 2015; Odegard et al., 2012). Hence, in many cascades, biopharmaceuticals and chemical compounds are considered high value applications, followed by materials, and fuels are often at the lower end of the pyramid. Despite food and feed applications have nonetheless often been placed as the top priority for biomass cascading (e.g. European Commission, 2012; Mc Cormick and Kautto, 2013), the emphasis on economic value could be problematic for social and ecological sustainably. Additionally, truly closing cycles, i.e. bringing nutrients back to the agricultural soils, is only rarely mentioned in the current conceptualizations of the biomass cascade. Especially when agriculture intensifies to meet biomass demands and agricultural residues are used as biomass feedstock, the nutrient cycles need to be adequately closed (Viaggi 2015). In other words, the conceptualization of the biomass cascade concept, which will drive the development of biorefineries, needs more attention to truly yield sustainable value chains in the bioeconomy. For instance, biorefineries could consider adding soil improvers, such as compost (Viaene et al., 2016) as a valorisation option for residual biomass at the end of the refinery.

In summary, the bioeconomy concept has the potential to greatly contribute to a more sustainable society. However, the lack of a clear, unambiguous definition for the bioeconomy concept hinders its development. Indeed, many of the interviewed researchers as well as the innovation managers view the bioeconomy as a policy-imposed concept that is too vague and broad to be really useful in practice. This is in line with the findings of several scholars, who consider the bioeconomy more as a *master narrative* (Bugge et al., 2016) that is currently only evolving on a strategic level, which lacks a comprehensive and common definition (Golembiewski et al., 2015). The lack of a clear definition also contributes to critique on the concept, principally on the sustainability of the concept.

Therefore, we recommend efforts are made to clearly define the bioeconomy, biorefinery and biomass cascade concepts (section 6.3.1.1). We encourage policy makers to develop a platform that gathers all relevant stakeholders to debate on the different concepts, taking the sustainability and operationalizability of the concept into account. This way, a consensus can be reached between all relevant parties, contributing to a shared vision and common goal, advocated as a paramount factor for success of transition efforts (e.g. Budde et al., 2012; Farla et al., 2010; Lopolite et al., 2010; Smith et al., 2010).

### 6.2.2 Lack of standardized tools to measure key bioeconomy aspects

A first key aspect that requires robust measurement tools is the size of the bioeconomy in a certain nation or region. To a large extent due to the lack of an agreed upon definition of the bioeconomy concept, it proves difficult for researchers to operationalize the concept (Staffas et al., 2013). As was also the case in this dissertation, researchers that want to measure the size of the bioeconomy, need to first delineate the concept. Often, a consensus of elements from the different definitions found in policy text and other scientific papers is applied. Then, researchers need to decide which sectors to include and which to leave out of the study. Not only is there no consensus on which sectors are considered part of the bioeconomy and which are not (e.g. retail, restaurant and catering industry), some researchers also elect to leave certain sectors which are generally considered to be bioeconomy sectors (e.g. the food sector or the primary sectors) or certain biomass applications (e.g. bioenergy) out of the analysis (Carrez and Soetaert, 2002; Efken et al., 2016; Vandermeulen et al., 2011). Further, there are different units to express the size of the bioeconomy. Some studies use employment figures, others use gross margin, turnover, or market value of bio-based products (see also Vandermeulen et al., 2011).

Moreover, the databases used for statistical purposes are incomplete or not adjusted for this type of research. For instance, the official statistics offices of nations, which are, in general, reliable sources, do not take into account very small, micro firms and use extrapolated numbers from stratified random sampling for certain sectors (Efken et al., 2016). Furthermore, these databases do not allow for an easy distinction between bio-based and non-bio-based firms in the *new bio-based sectors*, e.g. chemical or pharmaceutical sector (see also chapter 1) (ibid). At the moment, no official (e.g. governmental) body exists that groups organizations with bio-based activities. This issue is illustrated in both chapter 1 and 5. In chapter 1, we tried to narrow down the bioeconomy firms using the NACE nomenclature. Although the NACE-codes are sufficient to identify the *biomass providers* (i.e. the agricultural, fisheries, and forestry firms) and the firms belonging to the *traditional bio-based economy* (e.g. textile firms or pulp and paper firms), the codes are not sufficient to truly separate the organizations with bio-based activities from those without in the *new bio-based economy* group, despite going deep into the subcodes of the NACE system. In chapter 5, we expanded on this way of identifying bioeconomy firms by using databases of NGOs that aggregate organizations with bio-based or sustainability (innovation) activities and by scanning the websites of the selected organizations for signs of activities related to the bioeconomy. As the results in chapter 5 show, this still was not enough to get a sample of truly bio-based firms.

Besides correctly identifying bio-based firms, a lack of consistent estimates on the availability of biomass further hinders the current measurement efforts. Papers reviewing studies on the availability of biomass conclude that the broad variety of underlying assumptions leads to a very wide range of estimates on both the current biomass availability, ranging from less than 50 to several hundred exajoule (EJ) on global level, as well as the future availability (Hennig et al., 2016).

A third issue with measuring tools in the bioeconomy is concerned with the environmental sustainability assessment tools of bioeconomy value chains. An analysis of Cristobal et al. (2016) shows that, similar to the measuring tools of the other bioeconomy aspects, environmental assessments of bioeconomy value chains is still incipient and limited to (too) few impact categories, barring a few exceptions such as liquid biofuels and biopolymers. Although limiting the number of impact categories facilitates the data collection, assessment and interpretation of the results, such an approach can lead to inaccurate and misleading conclusions (Cherubini and Stromman, 2011). This is true not only for the sustainability assessments, but also for the analyses of the available biomass and for measuring the size of the bioeconomy.

Because having accurate and correct figures is crucial when making business and policy decisions, we recommend increased efforts to develop standardized methods and tools to measure these three key bioeconomy aspects (section 6.3.1.2)

### 6.2.3 Contextual factors influencing innovation management in the bioeconomy

Before developing the conceptual model for innovation management, five factors were identified based on literature on the bioeconomy that can have an influence on the configuration of innovation management strategies in the bioeconomy context in chapter 2 of this dissertation: (i) the need for radical innovation; (ii) the broad and complex knowledge base these innovations will be based on; (iii) the need for collaboration to develop these innovations and set up new supply chains; (iv) the difficulties in commercializing bio-based products; and (v) the complex and often incoherent legislation and policy regarding bioeconomy topics. The empirical studies and recent literature indicates that these five contextual factors are indeed at play in the bioeconomy context.

The development of the new concepts related to the bioeconomy will involve significant innovation, requiring radical changes in the production process or even completely new production processes. Moreover, integrating these bio-based production processes into successful biorefineries will require a complete radical system innovation across different firms and sectors (Boehlje and Bröring, 2011; Mohan, 2016; Rönnlund et al., 2014; Vandermeulen et al., 2012). Our empirical work indicates some efforts of radical bioeconomy innovations. Data from the Community Innovation Survey (CIS) in chapter 1 show that efforts are made to develop radically new concepts and the interviewed innovation managers (chapter 5) indicate that many of their bioeconomy related innovation developments take place at the corporate innovation level. These projects are executed at this highest firm level because the risks associated with the radicalness of these projects are considered too high to be developed at the division or business unit level.

The development of new bioeconomy concepts will require knowledge from many different research fields (factor 2). For instance, not only the core technological knowledge is required to invent a bio-based substitute, but also socio-economic knowledge is necessary to assess the marketability, as well as knowledge on agricultural and other biomass sources. Further, developing bioeconomy concepts also requires technological knowledge on other biorefinery processes to integrate them into a zero-waste cascade solution. Knowledge on sustainability assessment is also essential to analyse the sustainability of the new innovation, not to mention knowledge on legislation.

With such a variety of complex knowledge required and the necessity to set up new value chains integrating previously unrelated sectors into biorefineries, bioeconomy firms will need to open up their firm boundaries to collaborate with other relevant actors (factor 3) (Boehlje and Bröring, 2011; Hodgson et al., 2016; Odegard et al., 2012). This collaboration between different knowledge fields has been observed before: e.g. in the chemical sector which is increasingly using technologies from neighbouring disciplines such as biotechnology and agriculture, in strategic alliances between food companies and cosmetic or pharmaceutical firms, and in increased investments from the energy sector in the field of bio-based materials (Boehlje and Bröring, 2011). Ghisetti et al., (2015) also firmly state that eco-innovations require more knowledge from outside the traditional industrial knowledge fields in which the innovators operate, and the necessity to collaborate with external partners, specifically partners from outside the supply chain (e.g. research institutes, universities and competitors). Further, Nakagaki et al. (2012) state that the biological science is becoming too complex for one firm to effectively innovate, necessitating partnerships. Sandulli et al. (2012) also emphasise that innovation in emerging industries (such as bio-based industries) is likely to benefit and thus occur in open innovation configurations. In the empirical research of this dissertation, indications of the increased importance of knowledge and collaboration were also observed. Although universities and customers remain the most important knowledge providers and most preferred collaborators, the interviewed innovation managers in chapter 5 mention a wide range of different actors and point out the increasing importance of including more diverse actors into the innovation process. The interviewed researchers (chapter 4) also indicate that their techno-scientific knowledge alone is insufficient to develop a viable bio-based concept, and that information from different actors (e.g. industry and policy makers) is required to successfully identify viable ideas.

The fourth factor, the complex and fragmented policies on bioeconomy related subjects, has been repeatedly argued to (negatively) influence the development of the bioeconomy. The researchers in chapter 4 specifically mention the complex and uncertain regulation as being a barrier to their innovation processes. Further indications of these legislative issues can be found in chapter 5, where the interviewees are mentioning policy makers as an important partner in innovation and mentioning the legislative climate as a key determinant when choosing the location of innovation (sub)departments. One innovation manager even specifically mentioned the biotechnology legislation (GMO). This coincides with Vandermeulen et al. (2012), who stressed that the strict legislation on GMOs can be detrimental for the development of the bio-based economy. Also, Khan et al. (2013) elaborates on the difficult, time and resource consuming task of acquiring proof for health claims of functional foods (a potential valorisation option for certain biomass). A recent study by Hodgson et al. (2016) also show that the installation of more standards and regulations is considered important by German, Italian, and Spanish bioeconomy actors. Also, Pitkanen et al. (2016) in their case studies on green innovations found that, besides some conducive policy measures, a considerable number of regulatory barriers exist which retard the development of new bio-based concepts. One example of such conducive policy measures is the significant support for bioenergy production through subsides. However, this support, which does not exist for other bio-based applications, does not allow a level playing field between different applications, an issue that is even recognized by the European Union itself (European Commission, 2012). A study by Viaene et al. (2016), investigating the barriers for compost use and production, a potentially important bioeconomy application to close cycles, further shows a considerable amount of legislative issues barring the use of compost in agricultural settings.

The data of this research also suggests that the firms in the sectors relevant to the bioeconomy are faced with the fifth influencing factor, i.e. the difficulties with commercialization of bio-based concepts. The CIS data in chapter 1 indicate the importance of including customers in the innovation process. Also, some of the innovation managers interviewed in chapter 5 indicate that the bioeconomy concept and the benefits from bio-based products are too difficult to explain to consumers. Boehlje and Bröring (2011) and Golembiewski et al. (2015) also state that the more disruptive an innovation is the less likely it is to get adopted because of some hard to overcome hurdles both in the B2B and the B2C markets. Moreover, although consumers are increasingly interested in sustainability and more sustainable production methods, studies show that a higher risk perception exists and that there is still only limited acceptance among consumers and users of products attained from residual biomass or through biotechnological processes (Ekman et al., 2013; Jensen et al., 2011; Paula & Birrer, 2006; Siegrist, 2008; Verbeke, 2007). Besides acceptance issues, cost issues also hamper commercialization. The interviewed innovation managers mention the higher cost of the bio-based applications compared to their fossil-based counterparts. The statement of one of the managers corresponds with what Kircher (2015) recently stated; most bio-based products are faced with a cost handicap, and the vast majority of sales of the bio-based products are based on the added or unique benefits the bio-based products offer, and not on ecological considerations. The high production costs are mainly due to the logistical cost (Correll et al., 2014; Hennig et al., 2016; Johnson and Altman, 2014). To solve this logistical cost issue, the bioeconomy products could be produced in many small to medium sized plants close to where the biomass is available, i.e. rural areas, rather than in a few big plants needing large amounts of biomass shipped over large spans of land or sea (Johnson and Altman, 2014; Kircher, 2015). However, this limits the potential beneficial economies of scale, which again negatively influences the economic competitiveness with classic fossil-based production plants (Kircher, 2015). A large, high-yield monoculture cultivation surrounding the plants, such as the corn to ethanol production in the US could offer a solution as they would generate larger supplies of affordable biomass (Correll et al., 2014), but can cause ecological issues. Another potential solution is installing biorefinery plants, combining different applications, thus boosting productivity of the plants and generating more revenue streams from the same biomass (Kircher, 2015; Palgan and McCormick, 2016). However, how biorefineries using a biomass cascade rationale should be operationalized remains unclear (see also section 6.2.1). Moreover, many of the biorefinery technologies are still in a research stage and very few actors have successfully combined several technologies into a commercially operating biorefinery. In addition, the cost gap between bio-based and fossil-based concepts is currently even further widened by the low oil prices (Palgan and McCormick, 2016), which was also mentioned by some innovation managers as a hindering factor for the development of the bioeconomy and the commercialization of bio-based products. Yet another option to combat the higher costs compared to fossil-based products is asking a premium for the bio-based goods. However, if one cannot convince customers that the bio-based products have considerable benefits, the willingness to pay a premium for bio-based products will be low, especially for products with only limited better or unique attributes.

Based on these findings, we formulate four recommendations to policy that can help innovating organizations cope with the above mentioned factors; (i) continued investment and support for research and development of bioeconomy products, technologies, and integrated biorefineries (see 6.3.1.3); (ii) support for the development of collaborative efforts within the bioeconomy and investments in projects aiming to improve the outcome of such collaborative endeavours (see 6.3.1.3); (iii) the implementation of measures targeting the cost handicap of bio-based products and market development for these product (see 6.3.1.5); and (iv) further advancement of the comprehensiveness and cohesion of policy and legislation regarding bioeconomy topics (see 6.3.1.4).

### 6.2.4 Innovation management strategies at organizational level in bioeconomy context

#### *6.2.4.1 Opening up the organization using a layered collaboration scheme*

The results of our research show that open innovation, i.e. opening up the organization to bring external knowledge and ideas into the organization, and also to commercialize internally developed ideas through outside channels (e.g. spin-offs, licensing) (Chesbrough, 2003; 2012), is an innovation management rationale implemented by a considerable amount of organizations. All interviewed firms in chapter 5 open up their innovation efforts to external actors in some way. However, this may be an overrepresentation as shown by the data from chapter 1 that indicates that only about 60% of the surveyed firms developed products with external help and 82% of the firms developed novel processes with aid from external sources. These numbers are in line with those of other studies such as Chesbrough's (2003) seminal work (77% in 2001). The percentages remain stable on very high levels of around 90% after a steep increase measured in 2004 (Greco et al., 2016). The somewhat lower numbers in chapter 1 might be explained by the inclusion of some sectors that are characterized by lower rates of open innovation, such as the food sector (Arcese et al., 2015), and the exclusion of some sectors that are considered early adopters of open innovation, e.g. the ICT sector (Bahemia and squire 2010, Dodourova and Bevis, 2012).

As argued in chapter 2 within the BioID model and the OIS concept (chapter 3), the layered collaboration strategy is a good approach to opening up organization's innovation processes in a flexible and dynamic manner. With this strategy, an organization does not fully open up its innovation department to external partners. Instead, depending on the type of project, the degree of novelty of the innovation, the industry involved and the project phase of the innovation development[14], the organization dynamically chooses if and to what extent collaboration with external actors is required. In this strategy, the innovation network consists of two layers, a smaller core group of actors and a larger periphery layer. Actors in the core group are strongly involved in the innovation process, while the actors in periphery group are

[14] See chapter 2 and 3 for an extensive elaboration

involved more at arm's-length. Indeed, too much openness has proven to be suboptimal. Several studies (e.g. Berchicci, 2013) since the work of Laursen and Salter (2006) have reaffirmed that diminishing returns exist with increased external actor involvement and at a certain point, involving more external actors has a negative effect on innovation performance, due to transaction costs, slower progress and potential knowledge theft (Bruns et al., 2008; Caetona and Amaral, 2011; Frishammar et al., 2015).

Toyota (Dyer and Nobeoka, 2000), Telia, KPN and Philips (Bogers, 2011) are all examples of firms using this type of flexible collaboration strategy. The work of Lazzarotti and Manzini (2009), suggesting four types of innovation modes based on the number of partners involved and the number of phases opened also hints at this layered and dynamic approach to open innovation. Further indications of the merit of this approach can be found in the results of chapter 5, where many innovation managers described their approach to open innovation as dynamic and flexible. They state collaboration with external actors occurs often, but the number of actors involved varies. For most of the firms, the openness also diminishes the closer the project comes to commercialization. Also the innovation managers indicated they still often develop innovation behind closed doors, without involvement of external actors, especially when core technologies or products are being developed. This latter flexibility can also be seen in chapter 1 of this research, were the CIS data from 2012 show that organizations often combine both internal and external innovation development.

The innovation process can be opened up to a plethora of different external actors, especially in the development of new bio-based products and technologies. In both theoretical chapters 2 and 3, we elaborated on the general and specific potential contributions of up to eleven different relevant actor groups. The CIS data and chapter 5 (innovation managers) show that cooperation with suppliers, customers and users, and universities and research institutes are most commonly used. Especially the involvement of lead users and customers has been widely accepted to be critical for innovation success (Laursen, 2011; Martin-De Castro, 2015). Gesing et al. (2015) also stress the contributions market partners (also called value chain partners), i.e. suppliers and customers, can make to the innovation process. Bocken et al. (2014) finds that these market partners are collaborated with most, in 60% of their studied cases. Universities and research institutes, also called science-based partners, has been and continues to be important partners for collaboration (Chen et al., 2016; Gesing et al., 2015). Chen et al. (2016) finds that collaborations with value chain partners have the strongest effect on a firms' innovation performance followed by science-based partners, thus concurring with our findings.

The other potential relevant actor groups were all mentioned, but not as often as the market partners and science-based partners. One group we expected to be mentioned more often, are the consultants, specifically innovation intermediaries, as they are getting a considerable amount of attention in the OI literature (e.g. Giannopoulou et al., 2011; Gomez et al., 2016; Iturrioz et al., 2015; Lichtenthaler, 2013; Ollila and Elmquist, 2011). Such intermediaries can be considered bridge builders, brokering the collaboration between different parties in the innovation process (Iturrioz et al., 2015; Lichtenthaler, 2013; Ollila and Elmquist, 2011). The fact that they are not mentioned more often, might mean that the researchers and innovation managers interviewed feel they possess adequate in-house capabilities to develop their networks themselves. This limited use of intermediaries is also seen in Chesbrough and Brunwicker's (2014) study where open innovation intermediary services are rated lowest in importance.

*6.2.4.2 Key organizational attributes*

The empirical chapters (4 and 5) of this research show that a **conducive organizational culture to (open) innovation and strong leadership support** are two of the most paramount prerequisites for innovation success discussed in the BioID model (chapter 2). In chapter 4, the three cases show that several of the barriers experienced during the idea development phase of the projects are related to issues concerning the leadership and culture at the public research institute. In chapter 5, the majority of the innovation managers discussed the firm's culture and leadership and its importance to innovation development at length. Also, for a great number of the firms that recently adjusted their innovation management strategy, the lack or improper innovation culture was a main conduit for the change. These findings correspond with recent studies based on large surveys of Naqshbandi et al. (2015) who find organizational culture to be a huge predictor of open innovation and Knoskova (2015) who finds the ability to manage open innovation and support entrepreneurial culture to be two important success factors for radical innovation. Also, case studies of, for instance, Nakagaki et al. (2012) at Roche, Kirschbaum (2005) at DSM and Thong and Lotta (2015) at Orion also show the importance of senior management involvement and a strong innovation culture.

One specific aspect concerning leadership and culture that was found to be important in both empirical chapters is the hierarchy structure. In the research institute, functional silos exist, each with its own hierarchical structure, overviewed by a managerial unit, which caused some issues when implementing open innovation. The interviewed firms in chapter 5 all have relatively flat structures in their innovation departments, or have recently adopted a structure with little hierarchical levels, further indicating strong hierarchy is detrimental to (open) innovation. Naqshbandi et al. (2015) and Thong and Lotta (2015) came to similar conclusions regarding hierarchy culture. A second specific aspect related to culture and leadership that was found important in both empirical chapters is engaging people with the right mindset and investing in their development. Denicolai et al. (2016) also found that the investment in people is key for a firm's dynamics and capability to self-renew. The need for specific training and management of R&D personal when adopting open innovation activities is also emphasized by Michelino et al. (2015). It has moreover been repeatedly found and argued by researchers that in order to successfully embrace open innovation as a firm, one needs employees with an open, entrepreneurial mindset, who can see the value of open innovation and do not perceive seeking solutions outside of the firm as an admission of failure (Nakagaki et al., 2012; Lichtenthaler, 2011; Salter et al., 2014).

Besides leadership and culture, chapter 4 and 5 show that the development of a **dynamic, well thought-out appropriation strategy** is an essential part when conducting innovation. Not only were the lack of experience with institutional arrangements and the lack of an established appropriation strategy two important issues in the PRI case studies (chapter 4), the innovation managers also almost unanimously discussed the importance of proper strategies for appropriating new knowledge and concepts originating from their innovation processes. This should come as no surprise, as many scholars agree on the importance of an appropriation strategy, especially when innovating with external partners. When external partners are involved, firms are faced with the paradox of openness, i.e. they have to reveal some parts of their knowledge to obtain knowledge, but also cannot reveal too much not to risk theft by external partners, specifically competitors (Gould, 2012; Laursen and Salter, 2014). The recent study of Veer et al. (2016) for instance shows that firms engaging in R&D cooperation face significantly more risk of imitation than those who do not, in all development phases, from all potential collaboration partners, except universities and research institutes. Belderbos et al. (2014) found similar results, as they state that the risk to miss appropriation is more pronounced in intra-industry partnerships than in inter-industry partnerships and collaborations with universities. Such knowledge theft or imitation can be mitigated by the instalment of an appropriation strategy in advance of the collaboration (Henttonnen et al., 2016). As argued in earlier studies (e.g. Dahlander and Gann, 2010; Veer et al., 2016), we found that the interviewed firms dynamically use both formal and informal institutional arrangements to protect their knowledge and innovation development. However, the interviewed firms generally relied more on the formal arrangements than on the informal ones. The finding of Veer et al. (2016), that intellectual property rights generally work better to protect against imitation than the other formal arrangements, might provide us with an explanation of why patenting was the most mentioned appropriation tool mentioned by the interviewed innovation managers.

In the analysis of the interviews with the innovation managers and the three studied PRI cases, we also found indications of the significance of **sufficient resources and capabilities**. One of the important capabilities is what researchers call absorptive capacity. Essentially, it can be defined as a firm's ability to successfully benefit from the knowledge and insights from external partners. However, this capacity has been divided into four major elements by scholars: acquisition (identify and procure external knowledge), assimilation (analyse, understand and interpret external knowledge), transformation (recombine and convert external knowledge) and exploitation (effective application of and learning from external knowledge) of the external knowledge and insights (Patterson and Ambrosini, 2015; Martin-De Castro, 2015; Miller et al., 2016; Spithoven and Teirlinck, 2015). We found in chapter 5 that many of the interviewed innovation managers were deeply involved in developing processes and tools to improve the absorptive capacity of their firms. Especially the acquisition and assimilation of the external knowledge appears to be a challenging endeavour, as many of the managers are investing considerable time in setting up systems to support the idea development phase, including feasibility assessments of ideas for innovation (see also section 6.2.4.3 on the innovation process).

The absorptive capacity concept is complex and dependent on a number of different aspects. A first aspect is the adequate investment in internal research and development in order to have sufficient background knowledge to absorb external knowledge. This has been repeatedly found in case study research (e.g. Dodgson et al., 2006) as well as in studies based on large surveys (e.g. Chen et al., 2016; Martinez-Senra et al., 2015; Spithoven and Teirlinck, 2015). In the studies conducted in this work, hints of the importance of internal innovation development can also be found. All interviewed firms of chapter 5 have internal innovation developments and the lack of background knowledge, in part due to limited prior research, is found to be one of the major barriers to open innovation in the PRI cases of chapter 4. Besides the resource investment in internal R&D, absorptive capacity also depends on human capital (Spithoven et al., 2011; Spithoven and Teirlink, 2015). Here, the importance of cultural elements, especially attracting the right employees is crucial. Additionally, a proper regime of appropriation within the firm is also important to enhance absorptive capacity (Patterson and Ambrosini, 2015). In addition to the afore mentioned four dimensions, Enkel and Heil (2014) also examined maintenance, i.e. the ability to communicate and store the external knowledge, as a dimension of absorptive capacity (Denicolai et al., 2016), which is also stressed by Chiaroni et al. (2010) and Cruz-Gonzales et al. (2015). Regardless of whether this is a part of the absorptive capacity concept, we found evidence of the importance of the maintenance of knowledge in our empirical work, especially in chapter 5. Indeed, many of the innovation managers are investing significant time and resources in developing and improving idea and knowledge management systems to improve knowledge preservation and inter/intra-departmental communication, as they feel much of the external (but also internal) valuable knowledge and ideas is too tacit, resulting in lost opportunities.

Besides absorptive capacity, we also want to emphasize relational capability, i.e. the capability to integrate stakeholders in a meaningful way (Sisodiya et al., 2013; Michelino et al., 2015; Vaquero et al., 2016). Vaquero et al. (2016) further divides this capability into stakeholder identification capability, stakeholder interaction capability and stakeholder integration capability. The importance of relational capability is reflected well in chapter 4, as the limited experience with open innovation left the researchers with little skills to efficiently identify and interact with stakeholders, leading to underrepresentation of certain stakeholder groups in two of the cases. The interviewed firms also show signs of paying specific attention to augmenting their relational capability. For instance, one firm has a specific director external affairs. Also, a clear appropriation strategy can also be beneficial for constructive relations with external partners, as it is important to select the right mode of collaboration depending on the goal of the project and the involved partner(s) (Enkel et al., 2011).

A final organizational trait that deserves attention is the innovation **project team composition**. We saw in chapter 4 that the configuration of the research teams was somewhat suboptimal, with junior researchers with little experience and relevant background knowledge, backed up by senior researchers who also lacked the relevant relational capabilities to compensate for the inexperience of the PhD-researchers. The importance of specific knowledge and experience, through project team selection is also illustrated in chapter 5, as most firms choose which researchers will handle a project ad hoc, in function of the necessary knowledge for the specific project. Another important aspect regarding team configuration evident from both empirical chapters of this work, is the importance of experienced project team leaders. The lack of experience of the project coordinator in the PRI cases proved to be detrimental, and in chapter 5, many of the firms train employees to become highly experienced in project management and act within their field of expertise. Previous research also shows the importance of project managers. For instance, Thong and Lotta (2015) shows that Orion even introduced scientific project leaders that work in parallel with existing task-oriented project managers to further enable open innovation.

One organizational aspect that was not included in the BioID model, nor highlighted in the OIS concept, but is shown in the empirical chapters of this dissertation to be important an important prerequisite is the **organizational structure**. In chapter 4, we found the structure of the PRI led to somewhat isolated silos, which in turn contributed to a number of barriers for open innovation. The indications of the importance of the proper organizational structure for (open) innovation is even more evident in chapter 5. Here, a large part of the interviewed innovation managers talked a considerable amount of time on how the innovation department was structured and how it related to the other departments and activities. The data shows that most of the organizations opt for a decentralized organization of the innovation department. This entails that often the innovation department is split into one unit at the corporate level of the firm and several other subunits divided on either the various organizational levels (e.g. division or business unit level), geographical locations, innovation types, technology (or knowledge) clusters, or a combination of these aspects. Linked to these innovation subdepartments, a number of firms have some support activities linked to the department. Examples of such supporting services are legal teams that aid in contract drafting and IPR submissions or human resources that are specifically focused on motivating the innovation researchers. The importance of a proper organizational structure that facilitates innovation has long been recognized, in closed innovation settings but also in open innovation settings (Bianchi et al., 2016; Enkel et al., 2011; Giannopoulou et al., 2011; Saebi and Foss, 2015). However, with decentralized innovation department structures comes the risk of disconnected subunits, similar to those found at the studied PRI. Hence, to counteract this risk, many of the studied firms are heavily investing in knowledge management systems to gather knowledge and innovative ideas. The importance of this internal knowledge was already discussed in relation to absorptive capacity, and is also illustrated in chapter 1, as the CIS data show that 84% of the respondents found internal knowledge to be important for their innovation development processes. Also, in literature, these observed organizational measures to stimulate (open) innovation have been discussed; e.g. the importance of human resource management practices including rewarding and incentive systems, and communication management systems (Bianchi et al., 2016; Chiaroni et al., 2010).

#### *6.2.4.3 Innovation process configuration*

In both the OIS concept and the BioID model, we strongly emphasize the importance of a structured innovation process. Many innovation management scholars have argued this to be an important enabler for (open) innovation. Recently Knoskova et al. (2015) found highly developed innovation processes for radical innovation in the almost 400 surveyed firms. Jones et al. (2016) who emphasizes that adding discipline and structure to innovation management processes will be paramount in the face of chaotic changes. We also observed the importance of a structured innovation process in chapter 5, as the large majority of the interviewed firms have a formalized innovation process with defined phases, or switched to a formalized innovation process recently when updating their innovation strategy. In the discussion on the innovation process in chapter 2 and 3, we stressed three specific innovation process attributes:

the different phases and subphases, the importance of iteration and the importance of flexibility.

To develop the innovation process phases in our model, we looked at a considerable number of innovation models in the literature. It quickly became clear that strong differences exist between the number of phases and the names of the phases between the different models. This difference in number and names of innovation phases was also observed in chapter 5, where no two of the studied firms had innovation processes with the same amount of phases, let alone the same names for these phases. Therefore, we decided to work with three main phases which aggregate a set of phases related to the same goals. The first main phase is the idea development phase, in which all phases related to identifying ideas and assessing the viability of these ideas are grouped. The second main phase, the invention phase, groups all phases related to getting the viable idea to a proof of concept, i.e. the technological development of the new concept. Finally, the commercialization phase entails all phases to get a proof of concept successfully to the market. The plethora of different phases described by the innovation managers can all be placed within the three main phases defined in chapter 2 and 3.

The subphases that were by far discussed the most by the innovation managers in chapter 5 are those belonging to the idea development phase. The interviewees indicated that these phases are the most challenging and the most difficult to manage. This is not unexpected, as scholars in the innovation management literature often refer to this early innovation phase as the fuzzy front end (Börjesson et al., 2006; Koen et al., 2001; Sandmeier et al., 2004). If innovation managers focus on improving the effectiveness of these early phases of the innovation process, significant time and costs can be saved in latter phases (Thanasopon et al., 2016). In part due to the hard-to-manage, fuzzy nature of these initial phases, the focus of the analysis in chapter 5 was the idea development phase of the cases in the PRI setting. In congruence with the innovation managers, the researchers responsible for the case studies in this chapter also struggled with this innovation step. The innovation managers (and the researchers of the PRI), indicate that they had issues regarding three main aspects of the idea development phase: (i) idea identification; (ii) feasibility assessment of ideas; and (iii) idea consolidation. This is also recognized by van den Ende et al. (2015) and Thanasopon et al. (2016) who point out that two of the main difficulties in this phase are increasing the quantity and novelty of ideas and successfully reducing the ideas to those useful to the firm’s strategy. To increase the number of ideas, organizations often count on external actors. Empirical research of Salter et al. (2015) shows that openness indeed contributes to the success of *ideation*, but only up to a certain point due to increasing integration and approval costs. Another possibility to increase the number of ideas is to allow for creativity, which is argued by a number of the innovation managers in chapter 5. However, as they also state, structuring the innovation processes requires a delicate balance between providing a somewhat rigid context and allowing freedom to be creative, especially in the idea development phase (van den Ende et al., 2015). A second difficult aspect is the assessment of the ideas. According to findings of Thanasopon et al. (2016), uncertainty about the feasibility of ideas is the most important contributor to the difficulty of this main innovation process phase. One way to reduce this uncertainty is to develop structured assessments with key indicators. Each idea is than scrutinized through this assessment. Only a minority of the interviewed firms had such a structured assessment, but the implementation of such tools for assessment is on the rise, as indicated by a number of the innovation managers. However, the innovation managers with structured assessment did admit that many of the go/no-go decisions were still based on gut feeling rather than on the results of the assessment. Opening up to external actors can also help reduce uncertainty, as they can provide information on the different evaluation factors (Thanasopon et al., 2016). However, the afore mentioned results of the study by Salter et al. (2015) need to be taken into account.

With regards to the importance of flexibility and iteration, we noted during the interviews that only a minority of the firms still use rather linear innovation models with stage gates guarding the completion of every process step. Most firms however implement a less rigid, more dynamic process. Indeed, the unidirectional linear path is an archaic and flawed representation of how innovation should be approached in the rapidly changing economy (West and Bogers, 2014). In a considerable amount of the innovation processes in the studied firms, there is plenty of room for creativity and experimentation. However, this flexibility diminishes the closer the concept gets to market. This coincides with the rigidity of the process observed in these firms; in the starting phases, the process aspects are envisioned as guidelines and good practices to help the innovation staff, whereas in the later stages, these aspects are more strict procedures for development and commercialization. We also found that in terms of iteration, this most often happens within the main phases, i.e. the subphases of the three main phases are often repeated until a satisfactory result is achieved. Iteration between main phases generally only happens when failure occurs, i.e. when the developed invention cannot be successfully commercialized, it is sent back to the invention phase to revamp it, or even sent back to idea development to see if another commercialization path can be pursued.

**Table 11** Overview of main findings, lessons learned and recommendations

| **Main findings and lessons learned** | **Recommendations**[1] |
|---|---|
| • Ambiguous definition of bioeconomy of biorefinery and biomass cascade across relevant actor groups.<br>• Bioeconomy not inherently sustainable. | (P) Support efforts to reach consensus among all relevant actors on clear definition of bioeconomy, biorefinery, & biomass cascade concepts, also accounting the sustainability & operationalizability. |
| • Lack of standardized measurement tools & methods for key bioeconomy aspects e.g.: bioeconomy size, biomass availability, & sustainability of bio-based products & processes. | (P) Support efforts to develop standardized methods & tools to measure key bioeconomy aspects. |
| • Innovation management strategies at the organizational level will be influenced by:<br>○ the need for radical innovation;<br>○ the broad & complex knowledge base required for radical innovation development;<br>○ the need for collaboration for radical innovations & new supply chain development. | (P) Support for R&D on bio-based products, technologies, & integrated biorefineries.<br>(P) Support development of collaborative efforts within the bioeconomy.<br>(P) Invest in projects aiming to improve the outcome of collaborative endeavours.<br>(I) Open the organization to external partners. |
| • Innovation management strategies at the organizational level will be influenced by complex & often incoherent legislation & policy on various bioeconomy topics & in different sectors. | (P) Efforts increasing consistency & cohesion of policy & legislation regarding bioeconomy topics. |
| • Innovation management strategies at the organizational level will be influenced by difficulties commercializing bio-based products and technologies. | (P) Implement measures targeting cost handicap of bio-based products & enable market development for these products. |
| • All interviewed firms have longstanding formal innovation management strategies or recently developed formalized strategies.<br>• Many interviewed firms have key performance indicators coupled to the strategy. | (I) Formalise the innovation management strategy.<br>(I) Couple key performance indicators to the formalized strategy. |
| • Majority of interviewed firms have formal innovation processes for each type of innovation.<br>• Many interviewed firms have key performance indicators coupled to the innovation processes. | (I) Formalise the innovation process for each type of innovation.<br>(I) Couple key performance indicators to the formalized innovation processes. |
| • Interviewed firms & analysed PRI cases handle external collaboration dynamically, flexibly, & pragmatic.<br>• Partners involvement in projects is decided ad hoc, depending on, e.g. type of project or process phase. | (I) Consider open innovation as a means to an end, not as an end goal.<br>(I) Develop a strategy for open innovation, e.g. the layered network management scheme. |
| • Lack of appropriation strategy caused a number of challenges in the PRI cases.<br>• Vast majority of interviewed firms have a well-thought-out appropriation strategy.<br>• A number of firms employ appropriation experts to handle arrangements with external partners.<br>• The firms use a plethora of different institutional arrangements, depending on type of partner. | (I) Structure appropriation of knowledge & technologies into an inclusive appropriation strategy. |
| • Lack of organizational culture & management style conducive to innovation is at core of great number of challenges experienced by PRI case researchers.<br>• Development of innovation culture is backbone of innovation strategy in many interviewed firms. | (I) Develop a culture conducive to innovation & open innovation.<br>(I) Ensure adequate levels of absorptive and desorptive capacity, as well as relational capabilities. |
| • Many interviewed firms have decentralized innovation departments, with specific benefits.<br>• Organizational structure of PRI caused great number of challenges experienced by PRI case researchers. | (I) Configure the organizational structure to facilitate innovation, e.g. a decentralized innovation department if the resources of the firm allow it.<br>(P) Reconfigure the business model of public research institutes and universities. |
| • Concept of innovation and open innovation is not defined the same by scholars and industry. | (R) Define the key innovation management concepts innovation and open innovation. |
| • More research is needed on innovation on higher system levels.<br>• More research is needed on many innovation topics at the organizational system level. | (R) Continued research on higher innovation system levels in the bioeconomy.<br>(R) Continued research on many innovation topics at the organizational innovation system level. |

[1] Before each recommendation, the main actor to which the recommendation is addressed, is indicated: (P): Policy, (I) Industry, and (R) Research

## 6.3 Recommendations for policy, industry and research

Based on these findings and lessons learned, six recommendations to policy makers are formulated, ten good practices for industry are developed and two main groups of recommendations for researchers on innovation management in the bioeconomy are discussed. An overview of these recommendations can be found in table 11.

### 6.3.1 Policy recommendations: six ways to stimulate bioeconomy innovation

#### *6.3.1.1 Facilitate the development of unambiguous definitions for bioeconomy and related concepts*

A first recommendation is to start a process or support processes aimed at developing a clear and unambiguous definition of the bioeconomy concept and the related biorefinery and biomass cascade concepts. Such processes should involve all actors relevant to this transition, i.e. policy makers, scholars, the different industries, and representatives of civil society and consumers. This way, public, private, and civil society stakeholders can negotiate and compromise to reach consensus on a holistic, sustainable bioeconomy development (Devaney et al., 2017). Through several iterations, two key aspects should be clarified. First, the stakeholders should agree on whether related concepts to the bioeconomy, such as bio-based economy, knowledge based bioeconomy, green economy are considered synonyms of bioeconomy or treated as different concepts. Second, the stakeholders should clearly delineate which activities and (sub)sectors are included in the bioeconomy. Is the restaurant and catering sector part of the bioeconomy, are the primary sectors part of the bioeconomy, is any research on biotechnology a bioeconomy activity, is solar and wind energy part of the bioeconomy, are all examples of questions in need of clarification.

Once consensus is reached on the definition of the bioeconomy, similar processes are required to reach agreement on how the biorefinery concept and the biomass cascade principle will be approached. Currently, no broadly agreed upon definition of the biorefinery concept and the related biomass cascade concept exists (McCormick and Kautto, 2013; Palgan and McCormick, 2016), with many ranking in as many stakeholders groups, each putting their most (economically) valuable application first. We plead for absolute clarity on how to approach the cascading of biomass through biorefining. Although we are not experts on the topic of cascading use of biomass, we suggest that the approach can be built on three essential foundations; food-first, zero-waste solution, and the current local optimum. Specifically, we agree fully with the recommendations of many policy makers that food (and feed) applications should always be considered first and foremost before using the biomass for another purpose. Also, we believe in the biomass should be cascaded until no waste remains at the end of the refinery process. However, these two foundations are not achievable in every situation. Some types of biomass might not have a food application (yet), or still have a considerable amount of wasted biomass at the end of the valorisation process. Local specificities of different regions can also limit the possible application options of certain types of biomass. Hence, it is possible that in one region only a small-scale plant with limited refinery steps is possible, while in others regions large plants can be built that cascades similar biomass into many different applications. For each region and each type of biomass, all options of biorefinery should be explored to identify the current local optimum, taking into account the economic, social and environmental consequences of the different scenarios (EU SCAR, 2012; European Commission, 2012). This local optimum should be re-evaluated regularly, as new technology development might enable new biorefinery options with more total value. Indeed, biorefining is still a young field, with research and development still at initial stages (McCormick and Kautto, 2013). Hence, given the limited technological advancement, single application refineries are currently the optimum in many regions. Such refineries should be build, as cascading is a mean to valorise as much of the available biomass as possible, and not an end goal (Odegard et al., 2012). They should however be built with a certain flexibility to include cascading steps as new technologies emerge. This is not only important for the zero-waste solution, but also to reduce overall cost of the process (De Meester et al., 2011; McCormick and Kautto, 2013). Besides building on the three afore mentioned foundations, we also want to stress the importance, especially when residual agricultural biomass is concerned, of including soil improvement application (e.g. compost) into the cascade in order to ensure closed nutrient cycles, essential for continuous bio-based production (Viaene et al., 2016).

With the recommendation to clearly define these different key concepts, we reinforce the recent call of Palgan and McCormick (2016) and others before them to improve alignment on the visions and goals related to the bioeconomy and biorefineries. The unambiguous definition of these key concepts should however not result in additional rigid rules or regulations. We picture this as a guiding set of recommendations, agreed upon by all relevant societal actors, which puts all these actors ‘back on the same page’. In transition theory, such a shared vision or common goal is believed to guide the innovation pathways towards the desired envisioned future (e.g. Budde et al., 2012; Farla et al., 2010; Lopolite et al., 2010; Smith et al., 2010). In other words, it should provide innovators with ample direction, while also allowing plenty of room to experiment and meander down different development paths.

*6.3.1.2 Facilitate measurement of key bioeconomy aspects*

A second recommendation to policy makers is to facilitate efforts that facilitate the measurement of key bioeconomy aspects, specifically the size of the bioeconomy, the availability of biomass, and the sustainability of single technologies or multiple technologies coupled in biorefineries. With this recommendation, we follow the calls of, among others, Vandermeulen et al. (2012), Staffas et al. (2013), Hodgen et al. (2016), and Hennig et al. (2016), that effective measurement tools on these aspects are needed given their importance for the success of the bioeconomy.

One possible tool is a registry for bio-based firms. Chapter 1 shows that the current NACE nomenclature is not sufficient to adequately distinguish firms with bio-based activities from firms without such activities, especially in the new bio-based economy (sub)sectors. Chapter 5 illustrates that relying on un-regulated registries is also insufficient to develop a correct and complete database of bioeconomy firms. Therefore, it is recommended to develop a mandatory system that unequivocally aggregates the bio-based firms. The NACE system can be used, if a number of specific codes that represent different bio-based activities are added. An example that could be followed is the Global Trade Analysis Project (GTAOP), which has been modified to incorporate a number of key bio-based activities in the parent sectors (Philippidis et al., 2016).

To facilitate the development of standardized measurement tools for the bioeconomy, policy makers can support efforts that developed such tools and methods. In these tools and method, decisions need to be made on which parameters (e.g. GDP, employment, turnover) are used for measuring the size of the bioeconomy in a certain region. Also, which types of biomass are considered when analysing biomass availability, and in which unit the availability will be expressed needs to be decided. With regards to sustainability, agreement must be reached on which method of analysis is used to measure the sustainability of bioeconomy processes and which and how many parameters are included into these analyses.

Reaching consensus on these issues can lead to reliable, standardized and repeatable methods for data collection and analysis on these topics. Ideally, these methods are adopted by all regions and nations with profound bioeconomy ambitions. The implementation of such harmonized methods would be an enormous step forward for the bioeconomy development, as it allows for easy comparison between different studies which is currently very challenging (Cristobal et al., 2016; Efken et al., 2106; Hennig et al., 2016). With such harmonized studies, policy makers can better assess the viability of a bioeconomy, monitor the growth of the bioeconomy, assess the sustainability of certain technologies and refinery options, and get a better indication whether or not their policy measures are working (Hennig et al., 2016).

*6.3.1.3 Continuous investment in research and industry collaboration*

Despite significant investments in the development of new technologies, the bioeconomy is still in its infancy. Scholars, policy makers, and industrial players all agree that governments should continue investing in research and development aimed at bioeconomy advancements. A first topic requiring further investment is the development of bioeconomy products, technologies, and integrated biorefineries. We have already indicated that bio-based products cannot compete on production cost with their fossil-based counterparts due to a lack of high performance technologies and biorefineries. Hence we share the analysis of, among others, Kleinschmit et al. (2014), Hellsmark et al. (2016), Hodgson et al., (2016), and De Besi and McCormick (2015) that further investments into technological development are paramount. A recent study of Pitkanen et al. (2016) on green innovation also emphasised the importance of a certain level of technological development as a critical initiator for the studied cases.

Second, echoing the conclusions of several other researchers (e.g. De Besi and McCormick, 2015; Kircher, 2012; Kleinschmit et al.,2014; Ollikainen, 2014), continued support is needed to enhance learning and collaboration between different bioeconomy actors (i.e., policy makers, industry, scholars, and the general public) and between actors in different bioeconomy sectors. The development of the bioeconomy and specifically of the high-performing biorefineries will require collaboration between many different industries, requiring several different technological and socio-economic knowledge, approached in inter- and transdisciplinary ways (European Commission, 2012; Pfau et al., 2014; Ollikainen, 2014). The research of Hodgson et al. (2016) shows that the surveyed bioeconomy stakeholders rank the stimulation of industrial symbiosis as an intervention of very high importance. Additionally, specific attention is needed to further bridge the gap between research institutes and industrial players, which has also been emphasized by, among others, De Besi and McCormick (2015) and, more recently, Hodgson et al. (2016).

Third and related to the previous recommendation, we believe investment is required to further the development of our understanding of how innovation management should be approached and how the different relevant actors can work together and collaborate to foster the bioeconomy transition. Although much work on innovation, open innovation and related concept of collaborative efforts has been done, very little studies have focused on these topics in the bioeconomy context. Indeed, the little work that has been done on the issue of (collaborative) innovation in the bioeconomy is largely focused on higher system levels, i.e. on the national and regional level. The studies on the bioeconomy on the firm or consumer level are still low (Golembiewski et al., 2015). It led Boehlje and Bröring (2011 p11,13) to posit the following questions that need to be addressed: “What are key determinant of success in bringing disruptive innovation to market in this industry? What are the opportunities for collaborative activities? What is the role of open innovation in the emerging bioeconomy?" Rönnlund et al. (2014), in their case study research, show that one of the obstacles in the Nordic bioeconomy is a lack of experience in open innovation among multiple involved parties. The studies in this dissertation give first insights into answers on the above mentioned and other relevant questions with regards to innovation management in the bioeconomy, but more research is needed to decisively find good practices and recommendations.

*6.3.1.4 Developing conducive and coherent policies and legislation*

Another area that needs important consideration is the policy and legislation concerned with bioeconomy topics. First, the legislative framework should be adjusted to be more conducive towards developing all bio-based applications. Although proactive policy measures such as subsidies can have a profound beneficial impact on the development of technology, e.g. bioenergy from biomass, but also solar and wind energy (Hellsmark et al., 2016), the bioenergy subsidies cause a lack of level playing field between the different bio-based applications. (De Besi and McCormick, 2015; Viaene et al., 2016). This has distorted the market of biomass towards energy applications (Carus et al., 2011), and can act as a disincentive for firms to invest in other bio-based applications. Indeed, Pitkanen et al. (2016) found that the conducive policy measures and the financial support was a key aspect initiating a great number of the studied projects. Thus, well-balanced support for other bio-based applications besides biofuels, which can complement the biofuel application in cascading biorefineries perfectly, is crucial for their development (Kircher, 2015). However, policy makers should take care to not lock into a particular system or technology and locking out future opportunities when designing such policy schemes (McCormick and Kautto, 2013).

A second area that needs attention are the existing regulatory barriers. One of the issues here is the fragmented nature of the regulation, legislation and policy schemes (e.g. food security, climate change mitigation, waste treatment) concerned with bioeconomy topics, making it a very complex issue. Moreover, as the development of biorefineries is expected to often cut across various state borders (Devaney et al., 2017; Ollikainen, 2014), these refineries will need to comply with regulations from different administrative levels, which are currently sometimes contradictory. Another issue relates to existing legislation on different governmental levels that hinder the development of the bioeconomy. Two examples of regulatory barriers to bioeconomy development mentioned by the interviewed researchers from chapter 4 are the Novel Food legislation and the Waste Treatment legislation. Although these laws are of course beneficial and important to help ensure public health and safety, they do (often unnecessarily) add costly test procedures or permit applications for the development and commercialization of bio-based products. For instance, as many of the biomass waste and side streams of farms and firms are still considered waste by law, they can only be transported by a licensed waste treatment transport firm. In the article of Viaene et al. (2016), this additional cost of having to use such a licensed agent was listed as an important bottleneck that hinders the on-farm production and application of compost. Hence, we follow Hodgson et al. (2016) with his call for the development of an inclusive, balanced and stable policy framework for the bioeconomy, preferably at the highest administrative levels.

#### *6.3.1.5 Market and awareness stimulations*

Our fifth recommendation to policy makers is to facilitate processes educating the consumer and general public on what the bioeconomy entails and on the beneficial aspects of the development of this greener economy. With this recommendation, we support the call of some of the interviewed innovation managers in this work and the CEOs interviewed in the work of Vandermeulen et al. (2012) who state that higher social awareness among the public is required. Hodgson et al. (2016) also found that a considerable amount of respondents perceive both a lack of legitimacy for bio-based products and a lack of efforts on combatting the resistance to change as obstacles to the advancement of the bio-based economy.

Besides efforts to raise awareness and thus help to create legitimacy, we also recommend aiding in the development of markets for the bio-based products. Hellsmark et al. (2016) found that a lack of niche markets is a considerable challenge in the development of advanced biorefineries. The importance of the development of new markets has previously been emphasized by, among others, Boehlje and Bröring (2011), McCormick and Kautto (2013), and De Besi and McCormick (2014). A first example of how policy makers can stimulate markets is by aiding in the creation of new markets through green public procurement (De Besi and McCormick, 2015; Kleinschmit et al., 2014). A second way is to help the process of industrial standard setting and labelling for these new bio-based products (Ghisetti et al., 2015; Hodgson et al., 2016; Kleinschmit et al., 2014). Third, policy makers can aid in the development of commodity markets, which are currently lacking for a number of biomass inputs to the biorefineries (Hennig et al., 2016). A fourth and final example of a conducive measure is setting progressive, short and medium term targets for bio-based applications, which could help achieve significant penetration of these greener products and technologies (Hellsmark et al., 2016).

*6.3.1.6 Reconfigure the business model of public research institutes and universities*

Policy makers should re-evaluate the business model and, consequently, the organization and configuration of public research organizations[15] (PRO), especially public research institutes. It has been repeatedly stressed that public research organizations are a key driver for innovation, as they create a highly educated workforce and conduct (fundamental) research crucial for radical innovation. The role of universities and public research institutes is especially important in the development of bioeconomy innovation (Ghisetti et al. 2015), as these types of green innovations rely on complex, often fundamentally new knowledge and technology. Hence, public research organizations should be optimally configured to fully take up this role in the innovation system, which is often not the case (Miller et al., 2016; Weckowska, 2015). This was illustrated clearly in chapter 4, where several organizational and cultural factors hampered the effective use of open innovation activities in the studied PRI. The inability to successfully share, let alone commercialize the knowledge and technology developed at these public organizations is not only a missed opportunity for firms and society that could benefit from these novel insights, but also for the public research organizations. As many public households are reducing their structured, guaranteed funding towards these research organizations (Franco and Haase, 2015; Friesike et al., 2015), they must look for alternative funding, e.g. selling knowledge and technology.

To effectively tap into this alternative funding source, as well as into other funding (e.g. through collaborative research consortia), public research organizations should adopt a number of open innovation good practices to relegate certain barriers that currently exist. A first good practice is to truly embracing open innovation in the organization. In order words, leadership needs to be convinced of the benefits of opening up the PRO and commercializing certain knowledge. Second, the importance of this needs to be reflected in the vision of the PRO, which results in KPIs measuring the performance of these types of activities. Third, separate management for different types of research should be implemented. Of course, PROs should still invest in basic research, i.e. fundamentally ground-breaking studies. These activities, with research still very far away from being useable, commercialized concepts, should be managed differently than those aimed at developing concepts that are closer to market. For the latter type of projects, we turn to the findings discussed in this dissertation, specifically in section 6.2.4 and chapter 4. Avoiding a dual goal design (strong scientific and strong innovation goal), assigning researchers with adequate background knowledge and relational capabilities, and assigning an experienced, preferably *T-shaped* project leader are three important aspects in

[15] Public research organizations is defined as all organizations that perform research activities that are at least partly funded by public resources. This includes universities, other institutes for higher education, as well as public research institutes.

this regard. A fourth good practice is the development of supporting services for these types of collaborative innovation projects. A good number of public research organizations have knowledge and technology transfer offices, which can be a good basis for the development of the required services. However, these transfer offices are currently not always functioning properly, and can even be a barrier to an effective transfer of knowledge and technology, through aggressive IPR or bureaucracy (Weckowska, 2015). Weckowska (2015) argues that a transfer office can play five key roles: encouraging disclosure of potentially marketable inventions, managing the IPR, identifying licensees or investors, securing resources for IP development and exploitation and intermediate among scientists, firms and other relevant actors. Indeed, with these supporting functions, as also illustrated in chapter 4, a public research organization could increase their open innovation effectiveness. A final suggestion to further facilitate the sharing of knowledge and technology is the involvement of what Perkmann and Schildt (2015) call a boundary organization. This intermediate firm can act as a go-between in projects involving public research organizations and several firms. Specifically, these firms can repackage and anonymize (sensitive) information and knowledge between the collaborators, enable goal complementarity and help setup an appropriate structure for the specific situation (ibid).

### 6.3.2 Industry recommendations: 10 good practices for innovation in the bioeconomy

We recommend firms from sectors relevant to the bioeconomy to consider investing in bio-based substitutes for their products and services. Not only are policy makers heavily investing into bioeconomy innovation schemes, consumers also are increasingly concerned with the (ecological) sustainability of the goods and services they purchase (Verbeke, 2007). The development of the bioeconomy is still in an early stage, making investments in these often radically new technologies and products that often rely on never before used biomass inputs a risky undertaking. On the other hand, the bioeconomy offers immense first mover advantages for many firms.

In this research, we have developed the BioID model to provide firms with guidelines and recommendations for the development of innovation in the bioeconomy, based on relevant knowledge in this context. The model was a first step to offer innovation management guidelines and recommendations in this context, which have largely been confirmed in the empirical research in this dissertation and in the most recent research on Technology and Innovation Management.

Both the theoretical and empirical work in this dissertation allows us to formulate ten recommendations for innovative firms that want to optimize their innovation management strategy for innovation towards the bioeconomy. However, before listing these recommendations, we first want to emphasize that an *optimal* innovation management strategy is context specific. Indeed, for the development of the BioID model, we first looked which contextual factors can affect the innovation management strategy in the bioeconomy. Many scholars have emphasized the context specificity of innovation management (Bigliardi et al., 2012; Guertler et al., 2016; Sisodiya et al., 2013; Thanasopon et al., 2016), finding ground in contingency theory that states there is no best way to organize, and any one way of organizing is not equally effective under all conditions (Bahemia and squire, 2012). Such influencing contextual factors include sector characteristics (Huizingh, 2011; Tanguy et al., 2016), market and customer characteristics (Guertler et al., 2016), regulations (Gassmann et al., 2010), and firm size (Michelino et al., 2015; Tanguy, 2016). Hence, the following recommendations can be considered more as *good practices* rather than *best practices*, in other words, well-established, market-proven practices that work in a wide variety of firms in different environments, but sometimes need to be fine-tuned for the specific firm (Slowinski and Sagal, 2010).

A first good practice is formalizing the innovation management strategy. This strategy should be inclusive and holistic, as innovation development is a systemic process, where each element of importance should be considered and coherent (Bigliardi et al.2012; Lazzarotti and Manzini, 2009; van Hemert et al., 2013). These different elements of an innovation strategy include: the configuration of the innovation process, the openness of the firm, the network strategy, the appropriation strategy, the firm's culture, and the firm's organizational structure.

Second, we recommend coupling key performance indicators to the formalized strategy to be able to objectively measure the performance of the implemented strategy. It does however have to be taken into account that it is sometimes difficult to determine the actual value of the innovation strategy outcomes, as some beneficial innovation outcomes are rather intangible and/or have a long time horizon (Traitler et al., 2011). However, especially in the bioeconomy context, it is worth considering both a short term and a long term profit orientation. Indeed, as many of the developments in the bioeconomy will involve radical, if not completely disruptive innovations, especially if fully integrated biorefineries are aimed for, firms should apply a long term profit orientation for bioeconomy innovations. These profits can be significant as a result of being first to the market and the gained reputation as a bio-based products authority.

Good practice three is formalizing the innovation process for each of the different types of innovation pursuit. Developing different subphases framed within the three main innovation phases described in chapter 2 and 3 i.e. idea development, invention, and commercialization. Ensuring adequate levels of iteration and flexibility are built into the phases to avoid false-positives but also false-negatives. This way a maximum of valuable ideas are pursued and unpromising ideas are weeded out early. The research in chapter 5 showed that this iteration and flexibility is especially important in the early phases of the project, i.e. idea development and early phases of invention, whereas during later stages of invention and during collaboration, the process can be somewhat more rigid. Here, similar to the formalized general innovation strategy, KPIs should be established to measure the efficiency and effectiveness of the formalized innovation processes.

Opening up the firm to collaboration with other relevant parties has been repeatedly shown to increase innovation performance, most recently by e.g. Cheng and Huizing (2014) and Noh (2015). However, this does not imply that a firm should be completely open to external input and share all internal knowledge and technologies with external partners. Hence, a fourth good practice is to apply a dynamic, layered collaboration strategy, in which open innovation is considered a means to an end, and not a goal. Indeed, firms should carefully consider on a case-by-case basis whether an innovation project should be opened up towards external actors, and if so, which types of actors will provide the required input for that specific project. This way, the possible ineffectiveness of opening up the innovation projects due to increased time and costs spend on searching and partnering can be avoided (Greco et al., 2016; Sisodiya et al., 2013). This pragmatism in the level of openness is not only relevant for outside-in open innovation, but also for coupled and inside-out open innovation. Texas Instruments generated hundreds of millions of dollars in annual licensing (Lichtenthaler, 2009), and IMB earned more than 1.2 billion dollars by licensing its technologies (Noh, 2015), illustrating that inside-out open innovation can contribute considerably to the profitability of the firm, and can even aid in setting industry standards (Lichtenthaler, 2009). However, one must carefully consider which technology and knowledge can be out licensed, as revealing too much of a firm’s core capabilities and technologies can weaken a firm’s competitive advantage.

In the bioeconomy context, collaboration with three groups of external actors are of specific interest. First, universities and public research organizations, as they are important sources of the type of radical new knowledge and technology required to develop bio-based alternatives, especially in science-intensive (bio-economy) sectors such as the chemistry and pharmaceuticals sector (Perkmann and Schildt, 2015). Second, intra and inter-sectoral firms, who can provide new knowledge and technology, adequate biomass input, and/or assist to develop high-performance biomass cascades using multi-valorisation biorefineries (Palgan and McCormick, 2016). Third, costumers and the general public. We have discussed earlier (section 6.3.1.5) how a lack of public acceptance of bio-based applications can hinder the commercialization of green innovations. Consequently, we have recommended policy makers in the previous section to support efforts aimed at increasing public acceptance, but the involved firms and sector organizations should also contribute to actions augmenting perception towards the bioeconomy innovations

Good practice five is developing a strategy for these open innovation activities. We have advocated the layered network scheme as a good way of managing the interaction with external partners in chapter 2 and 3, and the results of chapter 5 indicate that this type of network scheme is also often used in practice. In this layered network scheme, the external organizations engaged in the innovation process can be divided into two groups, a small core group and a large periphery. Which actor belongs to which group, should be flexibly and dynamically managed, as it is a function of the type of project and time. In other words, the importance of the different partner groups can depend on the type of innovation pursuit and on the innovation phase of the project. An elaboration on this, as well as an illustrated example can be found in chapter 2.

A sixth good practice is to structure the appropriation of knowledge and technologies into an inclusive appropriation strategy. We recommend an appropriation strategy which includes a large variety of appropriation methods. This way, the firm has both formal and informal institutional arrangements at its disposal, allowing the selection of the most appropriate method, depending on the type of innovation pursuit, the partner(s) involved, and the customs in different sectors (Gesing et al., 2015; Salter et al., 2014). A firm can also consider adding *free revealing* to the strategy, i.e. sometimes not protect certain knowledge and sharing it. The benefits of free revealing include an increase in reputation among peers and customers as well as the establishment of standards and a *dominant design* (Von Hippel and Von Krogh, 2006). Moreover, it can be used to speed up the development process of disruptive innovations. A recent example is Tesla, who freely revealed all their patents related to electric car technology for others to use as a basis to further develop the technologies (Tesla, 2017).

The development of a culture that supports innovation and innovation development with external partners is good practice number seven. A number of measures can be taken to enhance this (open) innovation culture. First, the management and leadership of the organization needs to fully support innovation efforts and demonstrate the importance of innovation. Second, the research of chapter 5 shows the importance of a guiding, facilitating management style, with clarity on who has the power to decide on innovation investment. Third, the organization needs to hire employees with the right mindset and skillset for creativity and innovation. Once hired, the firm needs to keep investing in its employees through training programs. Fourth, the firm needs to grant adequate space and stimuli to its employees to be creative and experiment with new ideas. Financial incentives, a high tolerance for failed ideas and experiments, and recognition of exceptional innovative feats are all examples of incentives to enhance creativity and entrepreneurship found in chapter 5. Fifth, chapter 5 further teaches us the importance of involving every employee in the innovation efforts, as employees from other departments can provide an alternative view on problems faced in the innovation efforts.

Good practice number eight is to ensure the firm has adequate levels of absorptive and desorptive capacity, as well as relational capabilities in order to fully maximize the opportunities open innovation can provide for a firm. Related to these adequate capabilities, the firm also needs sufficient resources and knowledge. It allows firms to successfully develop relationships with external actors (relational capabilities), use the knowledge and technology obtained from outside the firm (absorptive capacity), and valorise knowledge and technology outside of the firms through e.g. licencing (desorptive capacity).

However, Chesbrough and Schwartz (2007), Grönlund et al. (2010), and Cheng and Chen (2013) all emphasize the importance of core capabilities, i.e. core technology and knowledge that offers the firm competitive advantage, leverage in open innovation deals, and absorptive capacity. Hence, good practice nine is to never fully outsource innovation activities. The complementarity between internal and open innovation activities has often been found in previous research (Chen et al., 2016; Chesbrough and Crowther, 2006; Martinez-Senra et al., 2015), and the fact all of the interviewed firms in chapter 5 still have in-house innovation departments despite (often heavy) investments in open innovation, is a further indication to that. With regards to core knowledge and technologies, we want to stress the importance of flexibility, as they can quickly become core rigidities that hinder innovation (Grönlund et al., 2010; Cheng and Chen, 2013).

The tenth and final good practice is to carefully configure the organizational structure to facilitate innovation. If the resources of the firm allow it, a decentralized organization structure, with proper tools for communication in place, can provide a number of benefits for innovation (see also chapter 5). Additionally, the innovation department and subdepartments can be closely supported by units that help them with appropriation issues and even be backed by a human resources department that is tailored specifically to their needs.

The ten good practices illustrate that organizing for open innovation requires a business model that is fully geared towards it (Bianchi et al., 2016; Chesbrough and Schwartz, 2007; Saebi and Foss, 2015). If the business model is not transformed to completely embrace innovation and its different modes, a firm will never entirely succeed at reaping all benefits of collaborative innovation, and will likely even experience only adverse effects of introducing open innovation activities.

### 6.3.3 Recommendations for research on innovation management in the bioeconomy

#### *6.3.3.1 Define key innovation management concepts*

In section 6.2.1 we have discussed how the current ambiguous definition of the bioeconomy, biorefinery and biomass cascade concepts create issues for research. Besides these concepts, a number of concepts in the innovation management literature also generate disagreement. Here, we will elaborate on two of the most important ones, innovation and open innovation.

Although a considerable number of innovation scholars state that one can only call a new concept an innovation once it has been introduced to the market (Bruns et al., 2008; Bogers and West., 2012; Kroon et al., 2008; Pullen et al., 2012), a substantial number of people, including (innovation) managers, consider newly developed concepts which are not commercialized yet (i.e. inventions) to also be innovations. Moreover, the novelty of the innovation is also a source of differences. This was very apparent in the interviews with the innovation managers in chapter 5. Some interviewed firms consider duplication of activities in other regions as innovation, where most do not. Some consider very small aesthetic changes to products incremental innovation, where others view it as a mere product alteration. A number of studied firms view the implementation of existing technology into the firm as breakthrough, i.e. radical innovation, whereas most define radical innovation differently. Bogers and West (2012; 2014), in two of their publications also express their concern for the difficulty to draw hard lines as to what constitutes an innovation and for the tendency in open innovation to use the concept of innovation in a way inconsistent with earlier work in innovation management.

The second important concept in innovation management and core concept in this dissertation that has been a topic of debate ever since it was introduced is *open innovation*. One of the most often cited critiques on open innovation is that of Trott and Hartmann (2009), who find the concept to be *old wine in new bottles*, arguing that firms have been opening up their boundaries far longer than the advent of the open innovation concept (in Chesbrough (2003)). They give examples of scholars before 2003 (e.g. Rothwell and Zegveld, 1985; Rothwell, 1992; Tidd, 1999) who advocate a collaborative approach to innovation. The anecdotal work of Spencer (2012) on the longitude problem also shows that open innovation practices already existed even in the 18$^{th}$ century. Although this critique has merit, we agree with Grönlund et al. (2010) and Huizingh (2011) in their defence of the concept, that open innovation encompasses, connects and integrates a range of existing activities and research veins into a single term, offering a more holistic perspective on external collaboration, allowing us to rethink the design of innovation strategies in a networked world. Hence, the research on open innovation has grown immensely since its introduction. However, like with other broad concepts such as bioeconomy, the open innovation concepts lacks a precise definition (Dahlander and Gan; 2010). A clear example of how a lack of clear definition can influence the knowledge development of a concept is how the development of the IPod by Apple is considered a closed innovation development by Almirall and Casadesus-Masanell (2010) and a prime example of open innovation by Rohrbeck et al. (2009). The main issue with the open innovation concept is that, especially during the early years of research on the subject, it is not entirely clear which collaborative modes are part of open innovation and which are not.

For some scholars (e.g. Von Hippel, 2005), all modes of collaboration which involved a knowledge source outside of the firm's boundaries, are considered open innovation. This includes open source development of new concepts, where the knowledge and development is shared free of charge and anyone can develop the concepts further (e.g. the Linux operating system). However, Chesbrough (2012) himself has expressed that these types of free sharing collaboration modes are outside the realm of open innovation. For him, open innovation has to have a component of intellectual property protection in order to aid in the commercialization of the developed knowledge (Chesbrough, 2012). Since then, a number of scholars have expanded on the difference between open innovation and open source innovation (e.g. Wilkham, 2013; Euchner, 2013). However, the risk to further blur the boundaries of the concept remains. For instance, scholars (e.g. Kim et al. 2016) are including activities that connect different (sub)units of the same organization (*closed inbound innovation*) into the concept. We clearly observed the same ambiguity in the interviews with the innovation managers of chapter 5. For instance, some also defined internal cooperation into their open innovation definition.

We therefore recommend that the concepts of innovation and open innovation are further refined to remedy the adverse effects that this ambiguity can have on the development of knowledge on these topics.

*6.3.3.2 Research on higher innovation system levels in the bioeconomy context*

We further recommend research towards innovation management in the bioeconomy context using multi- and even transdisciplinary approaches. As both our and other research has shown, innovation management in the bioeconomy characterized by strong interdependencies and contextual aspects. Hence, the involvement of scholars from different innovation research streams, and even actors from industry and other relevant stakeholder groups, will enhance our current knowledge on the topic and contribute to identifying influencing factors that currently elude us.

Specifically, a first specific recommendation concerning innovation in the bioeconomy context is further research on the higher system levels. As mentioned in chapter 3 and other work on innovation systems, the different innovation system levels are intertwined and interdependent. This interdependence is especially prevalent in the bioeconomy. Although the national, sectoral, and technological innovation systems perspectives could provide interesting insights into the current state of a specific country, sector or technology (Hodgson et al., 2016), we follow De Besi and McCormick (2015) in believing that the regional innovation system is the most relevant approach to study the higher system levels in the bioeconomy context. This because the biorefineries require a combination of different (bio)technologies, cutting across different sectors. Additionally, the development of bioeconomy concepts depends heavily on the availability of adequate volumes of biomass. To achieve these volumes, national borders will often be crossed. Therefore, studying the innovation systems of regions with high bioeconomy potential might deliver more valuable and applicable results than studies on other system levels.

*6.3.3.3 Continued research on innovation management at the micro system level*

The research in this dissertation has set the first steps in understanding innovation management strategies at the micro innovation system. Hence, besides research on the higher system levels, more conceptual, qualitative and quantitative research on the micro level is needed to fully understand how to configure innovation management strategies that consistently, effectively and efficiently delivers novel bio-based products and technologies.

Our research set out to explore the innovation management strategies in the bioeconomy context. Our results seem to indicate that the currently employed innovation management strategies do not really differ significantly from strategies observed in the fossil-based context. However, especially taking into account the methodological difficulties, more research is required to gain more insights as to whether the bioeconomy context merits different bioeconomy innovation strategies. In this context, an interesting future research approach is comparative case study analyses between bioeconomy projects and fossil economy projects with a number of similar traits.

We primarily looked at the level of the organization. Our research shows, especially in chapter 5, that many of the firms are not (entirely) focussed on bio-based activities or innovation related to the bioeconomy. Hence, also in part due to the ambiguous definition of bioeconomy and the lack of tools to adequately identify bioeconomy firms (see also section 6.2.1 and 6.1.2), it is currently difficult to develop a sample that truly relates only to bio-based activities, causing methodological issues. Therefore, we recommend examining bioeconomy innovation activities at the project level, of which it is often more clear whether they belong to the bioeconomy, until definitions and tools are established to allow the study of the firm level with limited chances of biases. This also answers the call of Bahemia and Squire (2010) for more research on the project level and how different types of innovation projects require different management strategies.

Related to the OIS concept, our empirical research gives a first indication of the validity of the concept, showing it can adequately be used as a guiding concept for analysis. However, we recommend more research using the OIS framework to further increase the inclusivity and comprehensiveness of the concept, both in the context of the bioeconomy as well as in other innovation contexts. This is also the case for the BioID model. More empirical research is required to further identify the areas that need further development in the model. Also, research using the model in contexts with influencing factors similar to those of the bioeconomy, can give additional insights into the applicability of the BioID model in contexts beyond the bioeconomy.

Besides new empirical studies, both the BioID and OIS concepts, which are currently conceived as concepts providing the main building blocks and general guidelines and recommendations that are applicable for each case within the contextual scope of the concepts, can also benefit from additional extensive literature reviews on related research strands such as strategic alliances, supply chain management and participatory research, which all have inter-organizational relationships and collaboration as their focus (Bahemia and Squire, 2010). Besides these research topics, the research on innovation ecosystems can prove especially valuable in providing a considerable amount of additional knowledge and insights, specifically on the governance of the innovation network, and the reconciliation of the individual actors and the goal of the network (Adner and Kapoor, 2010; Nambisan, 2013; Nambisan and Baron, 2013), which can be integrated to further strengthen the concepts.

This conceptual research needs to be supplemented by empirical research to gain more insights into the specific implementation of the building blocks and general guidelines and recommendations. In other words, future research has to be done to better understand which innovation management configurations are successful in different specific innovation endeavours within the bioeconomy context. Two examples from general innovation management literature of interesting topics that merit further research also in the bioeconomy context are the demand of Perkmann and Schildt (2015) to further investigate which mechanisms, tools, activates and techniques are applied to select ideas and concepts for further development, and to the request of Veer et al. (2016) to work on the further development of clearly structured innovation processes.

A final recommendation for future research on innovation management, especially in the bioeconomy context, relates more to quantitative studies. We recommend the use of fourth generation metrics for these types of studies, i.e. metrics that still take into account inputs and outputs (generation one and two metrics) and principles of generation three, but also focus on knowledge indicators, networks and conditions for innovation (e.g. policy, infrastructure, cultural factors, etc.) (Bund et al., 2013; Milbergs and Vonortas, 2005; Muller et al., 2005; Scott et al., 2008). Given that innovation processes are increasingly non-linear, complex, innovation management is highly context specific, and the importance of collaborative innovation in the bioeconomy context, these more inclusive metrics that move beyond simple input and output are required to truly understand the innovation behavior of firms in this context. The data from CIS 2012 used in chapter 1 illustrates this, as the survey focusses strongly on output metrics, resulting in only limited insights into the innovation management strategies of surveyed firms. It might be worth considering updating the CIS survey design to the latest generations of innovation metrics for it to be more useful as a data source for in depth analysis of innovation management behaviour on large samples. Indeed, many of the scholars that have used the CIS data in their research, had to derive their studied constructs (e.g. absorptive capacity) from a number of questions only remotely related to the construct.

## 6.4 Conclusion

This chapter set out to reflect and discuss on four important issues that are currently hindering the development of innovations towards a bio-based economy. The first issue we elaborated on is the ambiguous definition of the bioeconomy and the related concepts of biorefinery and biomass cascade. The second issue that was discussed is the current lack of standardized tools to measure key bioeconomy aspects such as the size of the bioeconomy, the available biomass and the environmental sustainability of bioeconomy value chains. The lack of knowledge on how innovation management should be approached in the bioeconomy context is the third major issue. We reflect on five important contextual elements; the need for radical innovation, the broad and complex knowledge base these innovations will be based on, the need for collaboration to develop these innovations and set up new supply chains, the complex and often incoherent legislation and policy regarding bioeconomy topics, and the difficulties in commercializing bio-based products. The fourth major issue discussed in this conclusive chapter is the lack of knowledge on how innovation management strategies should be shaped at the organizational level in the bioeconomy. We discuss the importance of opening up the organization using a layered collaboration scheme, four organizational traits conducive to (open) innovation, and the innovation process configuration.

Based on these findings, we formulated six recommendations for policy makers that can help stimulate innovation towards the bioeconomy, ten good practices for innovation management in the bioeconomy context that can aid industry in configuring high-performance innovation management strategies, and three general recommendations for researchers on the bioeconomy and innovation, divided into a number of specific research recommendations and suggestions for future research.

# Chapter 7
# Conclusions

**Abstract**

In this final chapter of this dissertation, we provide an extended overview of our main findings, lessons learned, conclusions, and recommendations for innovation management at the organizational level, relevant for the bioeconomy context. Our research indicates that collaborative innovation efforts with a variety of different stakeholders will be required in order to develop the necessary new technologies and products to make the transition towards a more bio-based economy. Firms are concerned with sustainability issues, but the bioeconomy appears to not be a main driver in their innovation endeavours. To make the bioeconomy a truly interesting prospect for industry, policy makers will need to address a number of currently hindering obstacles and more research on many bioeconomy related topics is required.

## Chapter 7 - Conclusions

The overall aim of the research presented in this dissertation is to to better understand the innovation management strategies at the organizational level applicable in the transition towards a more bio-based economy. To achieve this, we have used a combination of theoretical and empirical case study research in the Flanders region (Belgium), a good example of a small European economy relying heavily on imported fossil inputs, with a keen interest in developing a bio-based economy. In Flanders, data for 2014 from Statistics Belgium show that the sectors that are supposed to drive the bioeconomy transition (excluding biomass production) represents roughly 3% of the total active firms in Flanders and 20% of total Flemish firms' turnover. The traditional bio-based sectors (e.g. food and beverage and paper sector) represent two-thirds of firms in the bioeconomy sectors, but generates only 26,6% of the turnover, while the new bio-based sectors (e.g. chemistry and pharmaceutical sectors) and the waste management sector are responsible for three-fourths of the turnover. Data from the Community Innovation Survey (CIS) for 2012, show that over half the responding firms in the relevant sectors can be considered innovators. The most innovative sectors are the chemistry and pharmaceutical sector. To develop their innovations, the firms use a combination of closed processes and processes open to external knowledge and partners. The suppliers and customers are the external actors that were rated the most important knowledge providers. However, as Statistics Belgium and CIS both use NACE-nomenclature, it is not possible to delineate the bioeconomy firms from the non-bioeconomy firms in the new bio-based sectors. Hence, these figures can only be viewed as exploratory insights providing a first idea of the current bioeconomy context. Indeed, the Flemish bioeconomy almost certainly, smaller than the afore mentioned 20% of total turnover by Flemish firms due to issues with the sample, as indicated by previous analyses that estimate that the bioeconomy is Flanders (excluding biomass production) accounts for 1.5 to 1.8% of Firm's gross margin in Flanders and 0.4-1% of total Flemish employment (Flemish government, 2014; Vandermeulen et al. 2011).

The general aim of this dissertation is operationalized into the two main research objectives: (i) developing a conceptual model for and framework for analysis of innovation management strategies applicable in a bioeconomy context, and (ii) empirically exploring innovation management strategies both at a relevant academic and industrial setting. This translates into four main research questions. An overview of this dissertation and the broad contributions can be found in figure 13.

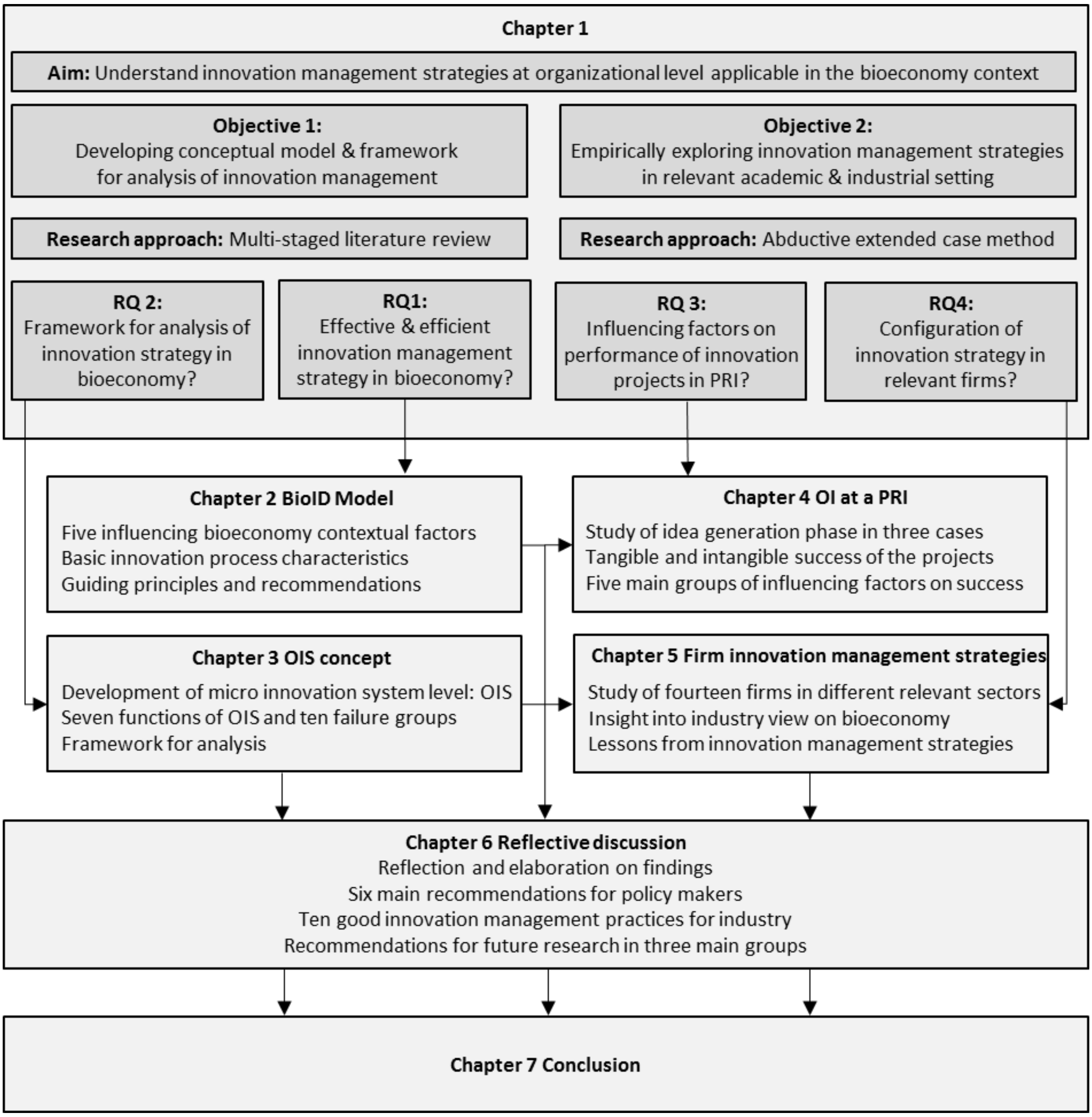


**Figure 13** Overview of dissertation structure and broad contributions

We tackled research question one: what is an effective and efficient configuration of an innovation management strategy in the bioeconomy context, in chapter 2 of the research. In this chapter, we first identify five contextual factors that influence the configuration of the innovation management strategy in the bioeconomy contexts. These five factors are: (i) the need for radically new and disruptive innovations; (ii) the complex knowledge base these innovations will be built on; (iii) the necessity of cooperation between different actors in order to exchange knowledge and create the required new supply chains; (iv) the expected issues with commercialization of a large amount of the new bio-based concepts; and (v) the complex and fragmented policies and legislation which regulates the bioeconomy.

Then, we explore the rich valuable insights of previous innovation management studies for the most relevant aspects of innovation management in relation to the development of new concepts (i.e. products, processes, or technologies) in the emerging bioeconomy. Based on the afore mentioned contextual factors, we postulate innovation processes in the bioeconomy context should be transdisciplinary in nature, have open boundaries to include a network of diverse stakeholders, and be organized in a non-linear, flexible way to allow iteration and feedback between the different process phases; the idea generation phase, invention phase, and commercialization phase. We also elaborate on the potential contributions of seven relevant stakeholder groups: policy makers, competitors, universities and research institutes, suppliers, actors within the value chains and organizations from previously unrelated industries, users and customers, and consultants. To meaningfully interact with these relevant stakeholder groups, we propose a layered network management strategy, which divides stakeholders into a core group of important stakeholders and a periphery group containing less crucial actors. In this strategy, the innovating firm dynamically determines which stakeholder groups belong to which group, depending on e.g. project characteristics, the novelty of the innovation and the innovation process phase.

In order to be able to develop such an open innovation approach, a number of organizational characteristics are required. We identified and elaborated five groups of prerequisites: (i) innovation culture; (ii) leadership support; (iii) good project team configuration; (iv) a clear appropriation strategy; and (iv) adequate resources and capabilities. The formulated recommendations and guidelines are integrated into the Bioeconomy Innovation Development (BioID) model. With the BioID model, we provide practitioners with a guiding model in the bioeconomy context and other similar contexts, while also offering a contribution from an innovation management perspective to the bioeconomy transition, which is currently underdeveloped.

In chapter 3 of the dissertation, we developed the Organizational Innovation System (OIS) as a response to research question two: what conceptual framework for analysis can be used to examine the innovation management strategy of organizations developing innovations relevant to the bioeconomy? This theoretical-conceptual framework adds a micro level to the innovation systems theory based on the Open Innovation and related literature. The OIS is defined as an innovation network of diverse actors, collaborating with a focal innovating organization in an innovation process, to generate, develop and commercialize a new concept, shaped by institutions. It has four main structural components: (i) the innovation process; (ii) the actors; (iii) the innovation network; and (iv) the institutions. Besides elaborating on these main components; we develop seven functions that an OIS can provide to the innovating organization: (i) provide opportunities, trends and ideas; (ii) reduce uncertainty about the innovative idea; (iii) provide complementary human and financial resources; (iv) act as a reference group during the innovation process; (v) create awareness, legitimacy and support for the innovation; (vi) facilitate market formation; and (vii) aid in supply chain formation. Additionally, based on the structural components and functions, ten groups of system failures are listed, i.e. aspects that can hinder the organizational innovation system to work optimally, leading to subpar innovation performance. The main components, functions and system failure groups combine into a guiding framework for the design of radical innovation projects and allows the analysis of innovation management strategies in different contexts, including the bioeconomy.

In chapter 4, we used a combination of the OIS framework and BioID model to analyse the idea generation phase of three innovation processes originating from a public research institute (PRI) to provide meaningful insights into research question 3**:** what factors influence the performance of innovation projects towards a more bio-based economy initiated by a public research institute? We find that the open innovation approach, which was relatively new to the public research institute, produced a good number of positive outcomes including access to more and complementary resources, more and better ideas for innovation, increased legitimacy for the research, and increased reputation for the involved researchers and PRI. However, the implementation of the open innovation approach was accompanied with a number of challenges. Our research reveals up to twenty-four influencing factors that contributed to these experienced challenges, which can be grouped into five main groups: (i) factors related to the environmental context surrounding the PRI; (ii) factors connected to the configuration of the networks that were built by the case researchers; (iii) factors concerning the availability of internal resources; (iv) and internal capabilities; and (v) issues with the organizational structure, culture, and leadership. Based on these insights, we formulated three general recommendations which can help alleviate potential sources for struggles when implementing open innovation activities in a PRI context. The first recommendation is to carefully consider the goal of the project, i.e. either specifically choose to pursue either a scientific goal or an innovation goal, or clearly prioritize one of the two. Additionally, the goals of the external partners also need to be taken into account in order to avoid goal divergence. Second, we recommend building a well-balanced, complementary project team. This involves including people with adequate background knowledge on the researched topic and a number of T-shaped researchers. The third, and perhaps most important recommendation, as many of the challenges can be traced back either directly or indirectly to the institute's culture, is creating an organizational culture, structure and leadership style conducive towards innovation. This includes academia moving beyond the role of intellectual centre to an active contributor to innovation, stimulating internal and external collaboration and developing clear strategies on IP-related topics.

Research question four: how do firms configure their innovation management strategy in sectors anticipated to realize the bioeconomy transition, is tackled in chapter 5 of the dissertation. In this chapter 5, we analysed the innovation management strategies of fourteen firms in several sectors relevant to the bioeconomy. We also took a closer look at the view of the industry on the bioeconomy concept. The results indicate that, not unlike among policy makers and researchers, the definition of the bioeconomy varies strongly between firms. Some firms give a very narrow definition of the bioeconomy, while others give a very inclusive definition, sometimes even including sustainability efforts that cannot fully be considered bio-based. Although increasing the ecological sustainability is an explicit goal for a considerable number of the interviewed firms, becoming more bio-based is not. Most firms even find the *bioeconomy* to be a vague concept that has limited practical use.

With regards to the innovation management strategies of the firms in the sectors relevant to the bioeconomy, a large amount of communalities could be observed despite a difference in the way innovation is defined and the age of the innovation strategy in some firms. The majority of firms have formalized strategies with a holistic view on a large number of relevant innovation management aspects, in which coherence between the different aspects is important. The backbone of these formalized strategies is often a culture and leadership style conducive to innovation. Formal innovation processes are described in the strategies, combining technology push and market pull approaches, with a focus on the management of the early phases of the process, i.e. phases belonging to the idea development phase. The strategies have a strong focus on collaboration with external stakeholders, mainly to bring outside knowledge into the firm from predominantly universities and customers. To streamline this exchange of knowledge and other beneficial resources between the firms and outside partners, the strategies often develop strong appropriation strategies, with an emphasis on intellectual property protection.

In chapter 6, we reflect on the results and lessons learned from the studies in this dissertations. We discuss a number of issues concerning the bioeconomy concept and innovation management at the organizational level in the bioeconomy context. Based on our findings, we formulate a number of recommendations for three of the most important actor groups in the bioeconomy transition. We posit six recommendations for policy makers that can help stimulate innovation towards the bioeconomy.

One, we recommend to facilitate and support processes aimed at setting an unambiguous definition for the bioeconomy and related concepts. These processes should involve all relevant actors relevant to the transition: policy makers, scholars, the various relevant industries, and representatives of consumers and civil society. Moreover, the biomass cascade and biorefinery concept also need a clear definition. Agreement on the ranking of different biomass applications in the cascade and a holistic approach to the implementation of biorefineries can facilitate the development of new greener value chains. For the development of such a holistic approach, we advocate three essential foundations: the food-first rule, the zero-waste solution, and the current local optimum.

Two, we recommend the development and/or support of efforts facilitating the measurement of certain key bioeconomy aspects, specifically the size of the bioeconomy, the availability of biomass, and the sustainability of single technologies or multiple technologies coupled in biorefineries. The goal should be to developed reliable, standardized and repeatable methods for data collection and analysis on these topics. Such standardized methods allow policy makers to better evaluate the viability of a bioeconomy, monitor the growth evolution of the bioeconomy, assess the sustainability of certain technologies and refinery options, gain a better indication whether or not their policy measures are working, and improve their understanding of what kind of policy measures need to be implemented to foster the growth of the bioeconomy.

Three, we recommend continued investment in research and development aimed at bioeconomy advancements. Three specific areas that can benefit from further support are: (i) the development of bioeconomy products, technologies, and integrated biorefineries; (ii) the development of tools to enhance learning and collaboration between different bioeconomy actors (i.e., policy makers, industry, scholars, and the general public); and (iii) the development of our understanding of how innovation management should be approached and how the different relevant actors can work together and collaborate to foster the bioeconomy transition.

Four, we recommend adjustments to the policy and legislation concerned with bioeconomy topics in two main areas. First, the legislative framework should be adjusted to be more conducive towards developing all bio-based applications, resulting in a level-playing-field. Second, efforts should be made to alleviate existing regulatory barriers, reducing the fragmented nature of the regulation, legislation and policy across different schemes (e.g. food security, climate change mitigation, waste treatment) and political levels (national, regional, municipal).

Five, we believe policy makers should support processes educating the consumer and general public on what the bioeconomy entails and the beneficial aspects of the development of this greener economy. Besides efforts to raise awareness and thus help create legitimacy, we also recommend aiding in the development of markets for the bio-based concepts through, for instance, green public procurement, standard setting and labelling, the development of commodity markets, or setting progressive short and medium term targets for bio-based applications.

Six, we recommend that policy makers re-evaluate the business models of public research organizations, specifically public research institutes. Public research organizations are currently often not geared to play the crucial role they have in the innovation system, especially in the bioeconomy transition laced with radical innovation. We believe public research organizations should be reconfigured to allow for the optimal development of both fundamental, disruptive knowledge, (scientific research) and for research aimed at knowledge more readily commercially applicable (innovation research).

Besides these six groups of recommendations to policy makers, we also introduce ten good practices for innovation management in the bioeconomy context: (i) formalize the innovation management strategy into a holistic and inclusive whole of all strategy elements; (ii) couple KPIs to the formalized strategy, taking into account short and long term profits; (iii) include a formalized innovation process for all types of innovation pursuit including different phases and ways to measure success; (iv) open up the firm to external partners, but view open innovation as a means to an end, not as an end goal; (v) develop a strategy, e.g. a layered network management scheme, to manage the open innovation activities; (vi) include a clear appropriation strategy with a large variety of formal and informal institutional arrangement to allow for tailor-made interaction with each specific type of stakeholders; (vii) invest in a culture that supports innovation and external collaboration through management and leadership support, employee selection and development, conducive reward systems, and high employee involvement in the innovation processes; (viii) ensure adequate levels of absorptive and desorptive capacity, as well as relational capabilities to maximize the opportunities open innovation presents; (ix) do not fully outsource innovation activities, as in-house research contributes to the development of core capabilities leading to competitive advantage and to important capacities for open innovation; (x) carefully configure the organizational structure to facilitate innovation.

We further suggest three recommendations for technology and innovation management researchers on the bioeconomy. First, we want call for a clear conceptualization of the concepts *innovation* and *open innovation* which are currently not used in the same way between different actor groups and within actor groups. This contributes to confusion and inaccurate research results on the topics. Second, we recommend further research towards innovation management and the bioeconomy using multi- and even transdisciplinary approaches on the higher innovation system levels, where we believe the regional innovation system approach can yield the most relevant insights. Third, we recommend more research on the micro innovation system level. Specifically more empirical research is required, for instance through comparative case study analyses between bioeconomy projects and fossil economy project to gain further more insights asto whether the bioeconomy context merits different bioeconomy innovation strategies. We further recommend researchers to currently focus on the project level in bioeconomy innovation research until definitions and tools are established to allow the study of the firm level without significant biases. More empirical research on the OIS and BioID concept is recommended in the context of the bioeconomy as well as in other innovation contexts, to further increase validity, inclusivity and comprehensiveness of the concepts. Besides new empirical studies, we suggest additional extensive literature reviews on related research strands, especially on the innovation ecosystem perspective in order to further strengthen the BioID and OIS concepts with the findings from this literature. Also, future empirical research has to be conducted to better understand which innovation management configurations are successful in different specific innovation endeavours within the bioeconomy context. Finally, we recommend the use of fourth generation innovation metrics in quantitative research on innovation management issues in order to truly grasp the increasingly complex and context specific innovation management strategies.

The studies presented in this dissertation offer a considerable number of insights. They provide an insight into the view on the bioeconomy of firms from the sectors that are supposed to drive the transition towards this more bio-based economy, something that has only been limitedly addressed. The studies reaffirms that many different views and conceptualizations exist both in the different stakeholder groups and between the groups. Additionally, the empirical studies further shows that steps need to be taken with regards to data collection and measurement methods to effectively conduct research on bioeconomy topics.

We further contribute to the knowledge on the bioeconomy by identifying five contextual factors that will influence the way innovation management is approached in organizations operating in the bioeconomy context. We have built the BioID model, which is one of the first models bundling guidelines and recommendations for organizations that want to venture into the creation of innovative bio-based concepts. The OIS concepts contributes to the innovation management theory and practice by offering an inclusive guiding model for the development of an innovation strategy and by adding a currently largely overlooked and lacking micro level in the innovation systems perspective. In addition, it offers a framework for analysis which provides a stepping stone for scholars and innovation managers alike who want to analyse open, collective innovation processes and/or strategies in different contexts, including the bioeconomy. The empirical studies in this research offer a first clue that both the BioID and

OIS concepts are indeed very inclusive and holistic, as the very large majority of the surfaced important innovation management aspect and challenges were included in the two concepts.

With the empirical studies, we also contribute to our understanding on innovation management in the bioeconomy in two specific context: (i) in the context of a public research organization; and (ii) in the context of industrial firms in the relevant sectors. These results give us the first insights in, on the one hand, how public research organizations can further improve their business model configuration to maximise their role as a crucial actor in the innovation system and, on the other hand, how firms can tune their innovation management strategies to increase the chance of bioeconomy innovation success.

This work offers only first insights into the afore mentioned topics. Given the limited scientific work on a great number of these topics, more research is required to confirm the findings in these studies, elaborate and refine the concepts, and further increase our understanding and knowledge.

The bioeconomy offers tremendous opportunities for society. If (i) policy makers can set the right boundary conditions to ensure a sustainable bio-based economy; (ii) consumers are made aware of the benefits; (iii) public research organizations organize for knowledge dissemination; (iv) and firms can develop consistent innovation management strategies that enable them to find the delicate equilibrium in the balancing act that is open innovation, we follow Hardy (2001) in stating that the bioeconomy can be to the 21$^{st}$ century what the fossil-based economy was to the 20$^{th}$ century.

# References

Adner, R. (2017). *Ecosystem as structure, an actionable construct for strategy*. Journal of Management, 43, 39-58.

Adner, R., Kapoor, R. (2010). *Value creation in innovation ecosystems: how the structure of technological interdependence affects firm performance in new technology generations*. Strategic Management journal, 31, 306-333.

Aguilar, A., Magnien, E., Thomas, D. (2013) *Thirty years of European biotechnology programmes: from biomolecular engineering to the bioeconomy*. New Biotechnology, 30, 410-425.

Ahn, M.J., Hajela, A., Akbar, M. (2012). *High technology in emerging markets: Building biotechnology clusters, capabilities and competitiveness in India*. Asia-Pacific Journal of Business Administration, 4, 23–41.

Almirall, E. and Casadesus-Masanell, R. (2010). *Open versus closed innovation: a model of discovery and divergence*. Academy of Management Review, 35, 27–47.

Almirall, E., Lee, M., Majchrzak, A. (2014). *Open innovation requires integrated competition-community ecosystepattoms: Lessons learned from civic open innovation*. Business Horizons, 57, 391–400.

Andersson, G. (2013). *Rethinking Regional Innovation*. Systemic Practice and Action Research, 26, 99-110.

Arcese, G., Flammini, S., Caludia, M., Lucchetti, C., Martucci, O. (2015). *Evidence and experience of open sustainability innovation practices in the food sector.* Sustainability, 7, 8067-8090.

Arnold, M. and Barth, V. (2012). *Open innovation in urban energy systems*. Energy Efficiency, 5, 351-364.

Arts, J. W. C., Frambach, R. T., Bijmolt, T. H. A. (2011). *Generalizations on consumer innovation adoption: A meta-analysis on drivers of intention and behavior*. International Journal of Research in Marking, 28, 134-144.

Asheim, B.T., Smith, H.L., Oughton, C. (2011). *Regional innovation systems: Theory, empirics and policy*. Regional Studies, 45, 875-891.

Alänge, A. (2013). *A corporate system for continuous innovation: the case of Google Inc.*. European Journal of Innovation Management, 16, 243 – 264

Bahemia, H. and Squire, B. (2010). *A contingent perspective of open innovation in new product development projects*. International Journal of Innovation Management, 14, 603-627.

Balzat, M. and Hanusch, H. (2004). *Recent trends in the research on national innovation systems*. Journal of Evolutionary Economics, 14, 197-210.

Belderbos, R., Cassiman, B., Faems, D., Leten, B. Van Looy, B. (2013). *Co-ownership of intellectual property: exploring the value-appropriation and value-creation implications of co-patenting with different partners.* Research Policy, 43, 841-852.

Bellantuono, N., Pontrandolfo, P., Scozzi, B. (2013). *Different practices for open innovation: a context-based approach.* Journal of Knowledge Management, 17 558-568.

BELSPO http://www.stis.belspo.be /nl/statisticsCIS.asp (accessed on 22.12.2016).

Berchicci, L. (2013). *Towards an open R&D system: Internal R&D investment, external knowledge acquisition and innovative performance*. Research Policy, 42, 117-127.

Berkhout, G., Hartmann, D., Trott, P. (2010). *Connecting technological capabilities with market needs using a cyclic innovation model*. R&D Management, 40, 474-490.

Berggren, C., Magnusson, T., Sushandoyo, D. (2015). *Transition pathways revisited: established firms as multi-level actors in the heavy vehicle industry*. Research Policy, 44, 1017-1028.

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., Rickne, A. (2008). *Analyzing the functional dynamics of technological innovation system: A scheme of analysis*. Research Policy 37, 407-429.

Bianchi, M., Croce, A., Dell'Era, C., Di Benedetto, A., Frattini, F. (2016). *Organizing for inbound open innovation, how external consultants and a dedicated R&D unit influence product innovation performance.* Journal of Product Innovation Management, 33, 492-510.

Bigliardi, B., Dormio, A., Galati, F. (2012). *The adoption of open innovation within the telecommunication industry.* European Journal of Innovation Management, 15, 27-54.

Bigliardi, B., Galati, F. (2013). *Models of adoption of open innovation within the food industry*. Trends Food Science and Technology, 30, 16–26.

Biotec Canada. (2008). *The Canadian Blueprint beyond Moose and Mountains: How We Can Build the World's Leading Bio-based Economy*. Biotec Canada, Ottawa, Canada.

Birch, K., Tyfield, D. (2012). *Theorizing the Bioeconomy: Biovalue, Biocapital, Bioeconomics or What?* Science, Technology and Human Values, 38, 299–327.

Blackstock, K.L., Kelly, G.J., Horsey, B.L. (2007). *Developing and applying a framework to evaluate participatory research for sustainability.* Ecological Economics, 60, 726–742.

Boardman, P.C., Corley, E.A. (2008). *University research centers and the composition of research collaborations.* Research Policy, 37, 900–913.

Bocken, N.M.P., Farracho, M., Bosworth, R., Kemp, R. (2014). *The front-end of eco-innovation for eco-innovative small and medium sized firms.* Journal of Engineering and Technology Management, 31, 43–57.

Bocken, N.M.P., Short, S.W., Rana, S., Evans, S. (2014). *A literature and practice review to develop sustainable business model archetypes.* Journal of Cleaner Production, 65, 42-56.

Boehlje, M., S. Bröring, S. (2011). *The increasing multifunctionality of agricultural raw materials: three dilemmas for innovation and adoption*. International Food Agribusiness Management Review, 14, 1-16.

Bogers, M. (2011). *The open innovation paradox: Knowledge sharing and protection in R&D collaboration.* European Journal of Innovation Management, 14, 93-117.

Bogers, M., West, J. (2012). *Managing distributed innovation: strategic utilization of open and user innovation.* Creativity and Innovation Management, 21, 61-75.

Boons, F., Montalvo, C., Quist, J., Wagner, M. (2013). *Sustainable innovation, business models and economic performance: an overview.* Journal of Cleaner Production, 45, 1-8.

Börjesson, S., Dahlsten, Fl., Williander, M. (2006). *Innovative scanning experiences from an idea generation project at Volvo Cars.* Technovation, 26, 775-783.

Brem, A., Voigt, K-I. (2009). *Integration of market pull and technology push in the corporate front end and innovation management – Insights from the German software industry*. Technovation, 29, 351-367.

Brettel, M. and Cleven, N.J. (2011). *Innovation culture, collaboration with external partners and the NPD performance.* Creativity and Innovation Management, 20, 253-272.

Broström, A. (2010). *Working with distant researchers—Distance and content in university–industry interaction*. Research Policy, 39, 1311–1320.

Bruns, M., Trienekens, J.H., Omta, S.W.F., Hamer, M., Petersen, B. (2010). *Demand of the meat industry for management support in R&D cooperation projects.* In: Proceedings of the 9th Wageningen International Conference on Chain and Network Management (WICaNeM), Wageningen, The Netherlands, 26-28 May 2010.

Budde, B., Alkemade., F. Weber, M. (2012). *Expectations as a key to understanding actor strategies in the field of fuel cell land hydrogen vehicles.* Technological Forecasting & Social Change, 79, 1072-1083.

Bugge, M., Hansen, T., Klitkou, A. (2016). *What is the bioeconomy? A review of the literature*. Sustainability, 8, 691.

Bughin, J.R., Chui M., Johnson, B. (2008). *The next step in open innovation*. McKinsey Quarterly, 113–122.

Bund, E., Hubrich, D-K., Schmitz, B., Mildenberger, G., Krlev, G. (2013). *Blueprint of social innovation metrics – contributions to an understanding of opportunities and challenges of social innovation measurement. A deliverable of the project: "The theoretical, empirical and policy foundations for building social innovation in Europe"* (TEPSIE), European Commission – 7th Framework Programme, Brussels: European Commission, DG Research

Bünger M., *Biofuels: Putting Pressure on Petrol*. Available online: http://www.renewableenergyworld.com/rea/news/article/2010/06/biofuelsputting-pressure-on-petrol (accessed on 13 05.13.).

Burcharth, A., Knudsen, A., Søndergaard, H. (2014). *Neither invented nor shared here: the impact and management of attitudes for the adoption of open innovation practices*. Technovation, 34,149-161.

Burawoy, M. (1991). *Ethnography unbound: Power and resistance in the modern metropolis*. University of California Press, USA.

Caetano, M. and Amaral, D. (2011). *Roadmapping for technology push and partnership: A contribution for open innovation environments*. Technovation, 31, 320-335.

Calia, R., Guerrini, F., Moura, G. (2007). *Innovation networks: from technological development to business model reconfiguration*. Technovation 27, 426-432.

Carlsson, B. (1997). *On and off the beaten path: the evolution of four technological systems in Sweden*. International Journal of Industrial Organization, 15, 775-799.

Carlsson, B., Jacobsson, S. (1997). *Technological system and economic policy: the diffusion of factory automation in Sweden*. Research Policy, 23, 235-248.

Carlsson, B., Jacobsson, S., Holmen, M., Rickne, A. (2002). *Innovation systems: analytical and methodological issues. Research Policy*, 31, 233-245.

Canhoto, A.I., Quinton, S., Jackson, P., Dibb, S. (2014). *The co-production of value in digital, university-industry R&D collaborative projects*. Industrial Marketing Management, 56, 86–96.

Carrez, D., Soetaert, W. (2002). *Industrial or White Biotechnology - A Driver of Sustainable Growth in Europe.* Brussels, Ghent, Belgium.

Carus, M., Dammer, L. (2011). *Food or Non-Food: Which Agricultural Feedstocks are Best for Industrial Uses?* Available online: http://bio-based.eu/download/?did=882&file=0 (accessed on 01.03. 2017).

Chai, S., Shih, W. (2016). *Bridging science and technology through academic-industry partnerships*. Research Policy 45, 148–158.

Cheng C., Chen, J. (2013). *Breakthrough innovation: the roles of dynamic innovation capabilities and open innovation activities*. Journal of Business & Industrial Marketing, 28, 444-454.

Cheng, C., Huizingh, E. (2014). *When is open innovation beneficial? The role of strategic orientation.* Journal of Product and Innovation Management, 31, 1235-1253.

Chen, Y., Vanhaverbeke, W., Du, J. (2016). *The interaction between internal R&D and different types of external knowledge sourcing: an empirical study of Chinese innovative firms*. R&D Management, 46, 1006-1023.

Cherubini, F., Stromman, A.H. (2011) *Life cycle assessment of bioenergy systems: state of the art and future challenges.* Bioresources and Technology, 102, 437-451.

Chesbrough, H. (2003). *The Era of Open Innovation*. MIT Sloan Management Review, 45, 35–42.

Chesbrough, H. (2012). *Open innovation: Where we've been and where we're going*. Research Technology Management, 55, 20-27.

Chesbrough, H., Brunswicker, S. (2014). *A fad or a Phenomenon? The adoption of open innovation practices in large firms*. Research and Technology Management.

Chesbrough, H., Crowther, A.K. (2006). *Beyond high technology: early adopters of open innovation in other industries*. R&D Management, 36, 229–236.

Chesbrough, H. and Schwartz, K. (2007). *Innovation business models with co-development partnerships.* Research Technology Management, January-February, 55-59.

Chung, S. (2002). *Building a national innovation system through regional innovation systems*. Technovation, 22, 485-491.

Chiaroni, D., Chiesa, Vittorio, F.F. (2010). *Unravelling the process from Closed to Open Innovation: evidence from mature, asset-intensive industries*. R&D Management,40, 222-245.

Clever Consult. (2010). *The Knowledge Based Bio-Economy in Europe: Achievements and Challenges.* Clever Consult: Brussels, Belgium.

Coase R.H. (1937). *The Nature of the Firm*. Economica, 4: 386-405.

Coenen, L., Diaz Lopez, F. (2010). *Comparing systems approaches to innovation and technological change for sustainable and competitive economies: An explorative study into concepts commonalities, differences and complementarities.* Journal of Cleaner Production, 18, 1149-1160.

Cohen, W.M., Levinthal, D.A. (1990). *Absorptive capacity: a new perspective on learning and innovation.* Administrative Sciences Quaterly, 35, 128-152.

Collins, P. and Pontikakis, D. (2006). *Innovation systems in the European periphery: The policy approaches of Ireland and Greece.* Science and Public Policy, 33, 757-769.

Cologne paper, German Presidency (2007). *En Route to the Knowledge-Based Bio-Economy*, German Presidency of the Council of the European Union. Cologne, Germany.

Cooke, P., Uranga, M.G., Extxebarria, G. (1997). *Regional innovation systems: Institutional and organizational dimensions*. Research Policy, 26, 475-491.

Cooper, R., Kleinschmidt, E. (1995). *Benchmarking the firm's critical success factors in new product development.* Journal of Product Innovation Management, 12, 374-391.

Correll, D., Suzuki, Y. Martens, B. (2014). *Logistical supply chain design for bioeconomy applications*. Biomass and Bioenergy, 66, 60-69.

Cricelli, L.,, Greco, M., Grimaldi, M. (2016). *Assessing the open innovation trends by means of the Eurostat community innovation survey.* International Journal of Innovation Management, 20(3).

Cristobal, J., Matos, C., Aurambout, J.P., Manfredi, S., Kavalov, B. (2016). *Environmental sustainability assessment of bioeconomy value chains.* Biomass and Bioenergy, 89, 159-171.

Cruz-González, J., López-Sáez, P., Navas-López, J.E. (2015). *Absorbing knowledge from supply-chain, industry and science: The distinct moderating role of formal liaison devices on new product development and novelty.* Industrial Marketing Management, 47, 75–85.

Dahlander, L., Gann, D. (2010). *How open is innovation?* Research Policy, 39, 699-709.

Danneels, E. (2002). The Dynamics of Product Innovation and Firm Competences. *Strategic Management Journal*, 23, 1095-1121.

Danneels, E. (2003). *Tight-Loose Coupling with Customers: The Enactment of Customer Orientation.* Strategic Management Journal, 24, 559-576

D'Este, P., Perkmann, M. (2011). *Why do academics engage with industry? The entrepreneurial university and individual motivations*. The Journal of Technology Transfer, 36, 316–339.

De Besi, M., McCormick, K. (2015). *Towards a bioeconomy in Europe: national, regional and industrial strategies*, Sustainability, 7, 10461-10478.

De Meester, S., Callewaert, C., de Mol, E., van Langenhove, H., Dewulf, J. (2011). *The resource footprint of biobased products: A key issue in the sustainable development of biorefineries.* Biofuels Bioproducts and Biorefinieries, 5, 570–580.

Debackere, K., Veugelers, R. (2005). *The role of academic technology transfer organizations in improving industry science links.* Research Policy, 34 (3), 321–342.

Denicolai, S., Ramirez, M., Tidd, J. (2016). *Overcoming the false dichotomy between internal R&D and external knowledge acquisition: absorptive capacity dynamics over time.* Technological Forecasting & Social Change, 104, 57-65.

Devaney, L., Henchion, M., Regan, A. (2017). Good Governance in the Bioeconomy. EuroChoices, 0, 1-6.

Dodgson, M., Gann, D., Salter, A. (2006). *The role of technology in the shift towards open innovation : the case of Procter & Gamble*. R&D Management, 36, 333–346.

Dodourova, M., Bevis, K. (2014). *Networking innovation in the European car industry: does the open innovation model fit?* Transportation Research Part A, 69, 252-271.

Drechsler, W. and Natter, M. (2012). *Understanding a firm's openness decisions in innovation*. Journal of Business Research, 65, 438-445.

Du, J., Leten, B., Vanhaverbeke, W. (2014). *Managing open innovation projects with science-based and market-based partners*. Research Policy, 43, 828–840.

Dunham, L., Ahn, M., & York, A.S. (2012). *Building a bioeconomy in the heartland: Bridging the gap between resources and perceptions*. Journal of Enterprising Communities, 6, 84–100.

Dyer, J., Nobeoka, K. (2000). *Creating and Managing a High-Performance Knowledge-Sharing Network: The Toyota Case.* Strategic Management Journal, 21, 345-367.

Edquist, C., Hommen, L., Johnson, B., Lemola, T., Malerba, F., Reiss, T., Smith, K. (1998). *The ISE Policy Statement—the Innovation Policy Implications of the 'Innovations Systems and European Integration'*. Research project funded by the TSER programme (DG XII). Linköping University, Linköping.

Efken, J., Dirksmeyer, W., Kreins, P., Knecht, M. (2016). *Measuring the importance of the bioeconomy in Germany: concept and illustration.* Wageningen Journal of Life Sciences, 77, 9-17.

Ekman, A., Campos, M., Lindahl, S., Co,M., Börjesson, P., Karlsson, E.N., Turner, C. (2013). *Bioresource utilisation by sustainable technologies in new value-added biorefinery concepts—Two case studies from food and forest industry.* Journal of Cleaner Production, 57, 46–58.

Enkel, E., Bell, J., Hogenkamp, H. (2011). *Open Innovation Maturity Framework. International Journal for Innovation Management*, 15, 1161–1189.

Enkel, E., Gassmann, O., Chesbrough, H. (2009). *Open R & D and open innovation : exploring the phenomenon*. R&D Management 39, 311–316.

Enkel, E., Heil, S. (2014). *Preparing for distant collaboration: antecedents to potential absorptive capacity in cross-industry innovation*. Technovation, 34.

Ellen MacArthur Foundation (EMF), (2013). *Towards the Circular Economy, vol. 1* (Isle of Wight).

EPSO. (2011). *The European Bioeconomy in 2030: Delivering Sustainable Growth by Addressing the Grand Societal Challenges*.

Etzkowitz, H., Webster, A., Gebhardt, C., Terra, B.R.C. (2000). *The future of the university and the university of the future: evolution of ivory tower to entrepreneurial paradigm*. Research Policy, 29 (2), 313–330.

Etzkowitz, H., 2003. *Innovation in innovation: the Triple Helix of university—industry–government relations.* Social Science Information, 42 (3), 293–337.

EU SCAR. (2012). *Agricultural Knowledge and Innovation Systems in Transition: a Reflection Paper.* Brussels, Belgium.

Eucher, J. (2013). *The uses and risks of open innovation.* Research and Technology Management, 49-54.

European Bioeconomy Panel (EBP). (2014). *13 Case studies of market-making in the bioeconomy*.

European Bioeconomy Panel (EBP) and SCAR. (2014). *Where next for the European bioeconomy*. Brussels, Belgium.

European Commission. (2005). *New Perspectives on the Knowledge-Based Bio-Economy.* European Commission: Brussels, Belgium.

European Commission. (2012). Communication from the Commission to the European Parliament, the Councel, the European Economic and Social Committee and the Commitee of the Regions, *Innovating for Sustainable Growth: a Bioeconomy for Europe, European Commission.* Brussels, Belgium.

European Commission. (2015). Communication from the Commission to the European parliament, the council, the European economic and social committee and the committee of the regions, *Closing the loop – An EU action plan for the circular economy*.

European Commission. (2017). http://ec.europa.eu/ research/bioeconomy/ (accessed on 04.02.2017)

Evangelista, R., Iammarino, S., Mastrostefano, V., Silvani, A. (2001). *Measuring the regional dimension of innovation. Lessons from the Italian innovation survey.* Technovation, 21, 733-745.

Faber, J., Hesen, B. (2004). *Innovation capabilities of European nations cross-national analyses of patents and sales of product innovations*. Research Policy, 33, 193-207.

Faber, A., Hoppe, T. (2013). *Co-constructing a sustainable built environment in the Netherlands – Dynamics and opportunities in an environmental sectoral innovation system*. Energy Policy, 53, 628-638.

Faems, D., de Visser, M., Andries, P., Van Looy, B. (2010). *Technology alliance portfolios and financial performance: value-enhancing and cost-increasing effects of open innovation*. Journal of product innovation management, 27, 785-769.

Farla, J., Alkemade, F., Suurs, R. (2010). *Analysis of barriers in the transition toward sustainable mobility in the Netherlands.* Technological Forecasting & Social Change, 77, 1260–1269.

Federal Ministry of Education and Research (FMER). (2011). *National Research Strategy Bio Economy 2030 Our Route towards a Biobased Economy*.

Fetterhoff, TJ. And Voelkel, D. (2006). *Managing open innovation in biotechnology*. Research Technology Management, 49, 14-18.

Flemish Government. (2014). *Bioeconomy in Flanders, the vision and strategy of the government of Flanders for a sustainable and competitive bioeconomy in 2030*. 24 p.

FPS Belgium, http://economie.fgov.be/en/modules/publications/ (accessed on 27.02.2017)

Franco, M., Haase, H. (2015). *University–industry cooperation: Researchers' motivations and interaction channels.* Journal of Engineering and Technology Management, 36, 41–51.

Frambach, R. T. and Schilewaert, N. (2002). *Organizational innovation adoption a multi-level framework of determinants and opportunities for future research*. Journal of Business Research, 55, 163-176.

Frambach, R. T., Barkema, H. G., Nooteboom, B., Wedel, M. (1998). *Adoption of a service innovation in the business market: An empirical test of supply-side variables*. Journal of Business Research, 41, 161-174.

Freeman, R. E. (1984.) *Strategic management: A stakeholder approach*. Boston: Pitman.

Freeman, C. (1995). *The 'national system of innovation' in historical perspective*. Cambridge Journal of Economics, 19, 5-24.

Freeman, C. (2002). *Continental, national and sub-national innovation systems – Complementarity and economic growth*. Research Policy, 31, 1391-221.

Frewer, L.J., Howard, C., Hedderley, D., Shepherd, R. (1997). *Consumer attitudes towards different food-processing technologies used in cheese production: the influence of consumer benefit.* Food Quality and Preferences, 8, 271-280.

Friesike, S., Widenmayer, B., Gassmann, O., Schildhauer, T. (2015). *Opening science: towards an agenda of open science in academia and industry*. Journal of Technology Transfer, 40, 581–601.

Frishammar, J., Ericsson, K., Patel, P. (2015). *The dark side of knowledge transfer: exploring knowledge leakage in joint R&D projects.* Technovation, 41-42, 75-88.

Fritsche, U., Iriarte, L. (2014). *Sustainability Criteria and indicators for the bio-based economy in Europe: state of discussion and way forward*. Energies, 7, 6825-6836.

Fromhold-Eisebith, M. (2007). *Bridging scales in innovation policies: How to link regional, national and international innovation systems*. European Planning Studies, 15, 217-233.

Galanakis, K. (2006). *Innovation process. Make sense using systems thinking*. Technovation, 26, 1222-1232.

Gallagher, K.S., Grübler, A., Kuhl, L., Nemet, G., Wilson, C. (2012). *The Energy Technology Innovation System.* Annual Review of Environment and Resources, 37, 137-162.

Gassmann, O., Enkel, E., Chesbrough, H., (2010). *The future of open innovation*. R&D Management, 40, 213–221.

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

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

Geels, F.W. (2006). *Co-evolutionary and multi-level dynamics in transitions: The transformation of aviation systems and the shift from propeller to turbojet (1930–1970)*. Technovation, 26: 999-1016.

Geels, F., Schot, J. (2007). *Typology of sociotechnical transition pathways.* Research Policy, 36, 399-417.

Geissdoerfer, M., Savaget, P., Bocken, N., Hultink, EJ. (2017). *The Circular Economy - A new sustainability paradigm?* Journal of Cleaner Production, 143, 757-768

Gesing, J., Antons, D., Piening, E., Rese, M., Salge, T. (2015). *Joining forces or going it alone? On the interplay among external collaboration partner types, interfirm governance modes and internal R&D.* Journal of Product and Innovation Management, 32, 424-440.

Ghisetti, C., Marzucchi, A., Montresor, S. (2015). *The open eco-innovation mode. An empirical investigation of eleven European countries.* Research Policy, 44, 1080-1093.

Giannopoulou, E., Ystroumlm, A., Ollila, S. (2011). *Turning open innovation into practice: Open innovation research through the lens of managers.* International journal of innovation management, 15, 505-524.

Goduscheit, R.C., Knudsen, M.P. (2015). *How Barriers to Collaboration Prevent Progress in Demand for Knowledge : A Dyadic Study of Research and Technology Organizations and Universities*. Creativity and Innovation management, 24, 29–54.

Golembiewski, B., Sick, N., Bröring, S. (2015). *The emerging research landscape on bioeconomy: what has been done so far and what is essential from a technology and innovation management perspective?* Innovative Food Science and Emerging Technologies, 29, 308-317.

Gould, R. (2012). *Open innovation and stakeholder engagement*. Journal of Technology Management and Innovation, 7, 1-11.

Greco, M., Grimaldi, M., Cricelli, L. (206). *An analysis of the open innovation effect on firm performance.* European Management Journal, 34, 501-516.

Groenewegen, J. and van der Steen, M. (2006). *The evolution of national innovation systems*. Journal of Economic Issues, 40, 277-285.

Grote, M., Herstatt, C., Gemünden, H.G. (2012). *Cross-Divisional Innovation in the Large Corporation: Thoughts and Evidence on Its Value and the Role of the Early Stages of Innovation.* Creativity and Innovation management, 21, 361–375.

Grönlund, j. Rönnberg, D., Frishammar, J. (2010). *Open innovation and the stage-gate model: a revised model for new product development.* California Management Review, 52, 106-131.

Gruner, K., Homburg, C. (2000). *Does customer interaction enhance new product success*? Journal of Business Research, 49, 1-14.

Guan, J. and Chen, K. (2012). *Modeling the relative efficiency of national innovation systems*. Research Policy, 41, 102-115.

Guertler, M., Michailidou, I., Lindemann, U. (2016). How to assess a company's open innovation situation. Design Science, 2.

Guiltinan, J.P. (1999). *Launch strategy, launch tactics, and demand outcomes*. Journal of Product Innovation Management, 16, 509-529.

Gulati, R., Puranam P., Tushman, M,. (2012). *Meta-Organizational Design: Rethinking Design in Inter-Organizational and Community Contexts.* Strategic Management Journal, 33, 571–586.

Hadorn, G. H., Bradley, D., Pohl, C., Rist, S., Wiesmann, U. (2006). *Implications of transdisciplinarity for sustainability research.* Ecological Economics, 60, 119-128.

Han, K., Wonseok, O., Im, K. S., Chang, R., Oh, H., Pinsonneault, A. (2012). *Value cocreation and wealth spillover in open innovation alliances*. MIS Quarterly, 36, 291-315.

Hansen, M.T., Birkinshaw, J. (2007). *The Innovation value chain.* Harvard Business Review,85, 121-130.

Hansen M.T., von Oetinger B. (2001). *Introducing T-shaped managers: knowledge management's next generation*. Harvard Business Review, 79, 106-116.

Hameed, M.A., Counsell, S., Swift, S. (2012). *A conceptual model for the process of IT innovation adoption in organizations*. Journal of Energy and Technology Management, 29, 358-390.

Hardy, R.W.F. (2002). *The bio-based economy*. In J. Janick, & A.Whipkey (Eds.), Trends in new crops and new uses (pp. 11–16). Alexandria, USA: ASHS Press.

Hegger, D., Van Zeijl-Rozema, A., Dieperink, C. (2014). *Toward design principles for joint knowledge production projects: lessons from the deepest polder of The Netherlands*. Regional and Environmental Change, 14, 1049–1062.

Hekkert, M.P., Suurs, R.A.A., Negro, S.O., Kuhlmann, S., Smits, R.E.H.M. (2007). *Functions of innovation systems: A new approach for analyzing technological change*. Technological Forecasting & Social Change, 74, 413-432.

Hellsmark, H. Mossberg, J., Söderholm, P., Frishammar, J. (2016). *Innovation system strengths and weaknesses in progressing sustainable technology: the case of Swedish biorefinery.* Journal of Cleaner Production, 131, 702-715.

Henchion, M., McCarthy, M., Greehy, G., McCarthy, S., Dillon, S., Kavanagh, G. Williams, G. (2013). *Irish Consumer and Industry Acceptance of Novel Food Technologies: Research Highlights, Implications & Recommendations*. Teagasc Food Research Centre, Ashtown (Dublin), Ireland.

Hennig, C., Browsowski, A., Majer S. (2016). *Sustainable feedstock potential - a limitation for the bio-based economy?* Journal of Cleaner Production, 123, 200-202.

Hermans, F. (2011). *Social Learning in Innovation Networks: How multisectoral collaborations shape discourses of sustainable agriculture*. PhD-thesis, Wageningen University, The Netherlands.

Hermans, F., Stuiver, M., Beers, P.J., Kok, K. (2013). *The distribution of roles and functions for upscaling and outscaling innovations in agricultural innovation systems*. Agricultural Systems, 115, 117-128.

Hermans, F., van Apeldoorn, D., Stuiver, M., Kok, K. (2013). *Niches and networks: Explaining network evolution through niche formation processes*. Research Policy, 42: 613-623.

Herskovits, R., Grijalbo, M., Tafur, J. (2013). *Understanding the main drivers of value creation in an open innovation program.* International Entrepreneurial Management Journal, 9, 631–640.

Henttonen, K., Hurmelinna-Laukkanen, P., Ritala, P. (2016). *Managing the appropriability of R&D collaboration.* R&D Management, 46, 145–158.

Hodgson, E., Ruiz-Molina, M., Marazza, D., Pogrebnayokova, E., Burns, C., et al. (2016). *Horizon scanning the European bio-based economy: a novel approach to the identification of barriers and key policy interventions from stakeholders in multiple sectors and regions.* Biofuels, Bioproducts and Biorefineries, 10, 508-522.

Holl, A. and Rama, R. (2012). *Technology sourcing: Are biotechnology firms different? An exploratory study of the Spanish case.* Science and Public Policy, 39: 304-317.

Huang, M.H., Chen, D.Z. (2015). *How can academic innovation performance in university-industry collaboration be improved?* Technology Forecasting and Social Change, 94, 1077-1098.

Huang, F., Rice, J., Galvin, P., Martin, N. (2014). *Openness and Appropriation: Empirical Evidence From Australian Businesses.* IEEE Transactions on Engineering Management, 61, 488-498.

Huizingh, E. (2011). *Open innovation: State of the art and future perspectives*. Technovation, 31, 2-9.

Huston, L., Sakkab, N. (2004) *Connect and develop: inside Procter & Gamble's new model for innovation.* Harvard Business Review, 84, 58-66.

Itturioz, C., Aragon, C., Narvaiza, L. (2015). *How to foster shared innovation within SMEs' networks: social capital and the role of intermediaries*. European Management Journal, 33, 104-115.

Janeiro, P., Proença, I., Gonçalves, V.D.C. (2013). *Open innovation: factors explaining universities as service firm innovation sources*. Journal of Business Research, 66, 2017-2023.

Jarvenpaa, S.L., Wernick, A. (2011). *Paradoxical tensions in open innovation networks*. European Journal of Innovation Management, 14, 521–548.

Jensen, J.R., Halvorsen, K.E., Shonnard, D.R. (2011). *Ethanol from lignocellulosics, US federal energy and agricultural policy, and the diffusion of innovation.* Biomass and Bioenergy, 35, 1440–1453

Johnson, T.G., & Altman, I. (2014). *Rural development opportunities in the bioeconomy*. Biomass and Bioenergy, 63, 341–344.

Joint Research Centre European Commission. (2014). *National Bioeconomy Profile Belgium*. https://biobs.jrc.ec.europa.eu/sites/default/files/generated/files/country/National%20Bioeconomy%20Profile%202014%20Belgium_0.pdf

Jones, J., Cope, J., Kintz, A. (2016). *Peering in to the future of innovation management.* Research & Technology management, 49-58.

Kaiser, R. and Prange, H. (2004). *The reconfiguration of national innovation system – the example of German biotechnology*. Research Policy, 33, 395-408.

Kamm B., Kamm, M. (2004). *Principles of biorefineries.* Applied Microbiology and Biotechnology, 64, 137-145.

Keegan, D., Kretschmer, B., Elbersen, B., Panoutsou, C. (2014). *Cascading Use: a Systematic Approach to Biomass Beyond the Energy Sector.* Biofuels and Bioproducts and Biorefining, 7, 193-206.

Keupp, M. and Gassman, O. (2009). *Determinants and archetype users of open innovation*. R&D management, 39, 331-341.

Khan, R., Grigor, J., Winger, R., Win, A. (2013). *Functional food product development e opportunities and challenges for food manufacturers.* Trends in Food Science and Technology, 30, 27-37.

Kim, B., Kim, O., Foss, N. (2016). Balancing absorptive capacity and inbound open innovation for sustained innovative performance: an attention-based view. European Management Journal, 34, 80-90.

Kirchen, M. (2012). *The transition to a bio-economy: National perspectives*. Biofuels, Bioproduction and biorefinery, 6, 240-245.

Kircher, M. (2015). Sustainability of biofuels and renewable chemicals production from biomass. Current Opinion in Chemical Biology, 29, 26-31.

Kirschbaum, R. (2005). *Open innovation in Practice.* Research and Technology Management.

Klerkx, L., Aarts, N., Leeuwis, C. (2010). *Adaptive management in agricultural innovation systems: The interactions between innovation networks and their environment*. Agricultural Systems, 103, 390–400.

Klerkx, L., Leeuwis, C. (2009). *Establishment and embedding of innovation brokers at different innovation system levels: Insights from the Dutch agricultural sector*. Technological forecasting and social change, 76, 849- 860.

Kleinschmit, D., Lindstad, B.H., Thorsen, B.J., Toppinen, A., Roos, A., Baardsen, S. (2014). *Shades of green: a social scientific view on bioeconomy in the forest sector.* Scandinavian Journal of Forest Research, 1-31.

Knoben, J., & Oerlemans, L.A.G. (2006). *Proximity and inter-organizational collaboration: A literature review.* International Journal of Management Reviews, 8, 71–89.

Knoskova, L. *Innovation processes and entrepreneurial culture for radical innovation*. Amfiteatru Economic, 17, 342-357.

Koen, P. A., Ajamian, G, M., Boyce, S., Clamen, A., Fisher, E., Fountoulakis, S., Johnson, A., Pushpinder, P., Seibert, R. (2001). *Fuzzy front end: Effective methods, tools, and techniques*. The PDMA ToolBook for New Product Development.

Kogut, B. and Zander, U. (1996). *What Firms Do? Coordination, Identity, and Learning*. Organization Science, 7, 502-518.

Kotler, P. (2002), *Marketing Management. Analysis, Planning, Implementation, and Control.* 11th ed., Prentice-Hall, Englewood Cliffs, NJ.

Kroon, M.C., Hartmann, D. & Berkhout, A.J. (2008). *Toward a sustainable chemical industry: cyclic innovation applied to ionic liquid-based technology*. Industrial and Engineering Chemistry Research, 47, 8517-8525.

Kutvonen, A. (2011). *Strategic application of outbound open innovation*. European Journal of Innovation Management, 14, 460-474.

Laursen, K. (2011*). User-producer interaction as a driver of innovation: cost and advantages in an open innovation model*. Science and Public Policy, 38, 713-723.

Laursen, K., Salter, A. (2006). *Open for innovation: The role of openness in explaining innovation performance among UK manufacturing firms*. Strategic Management Journal, 27, 131-150.

Lawrence, R., Despres, C. (2004). *Futures of transdisciplinarity*. Futures 36, 397-405.

Lawrence, P.R. and Lorsch, J. (1967). *Organization and Environment*. Harvard University Press, Boston, MA.

Lazzarotti, V. and Manzini, R. (2009). *Different Modes Of Open Innovation: A Theoretical Framework And An Empirical Study.* International Journal of Innovation Management, 13, 615-636.

Leten, B., Vanhaverbeke, W., Roijakkers N., Clerix A., Van Helleputte, J. (2013). *IP Models to Orchestrate Innovation Ecosystems: IMEC, a public research institute in nano-electronics*. California Management Review, 55, 51-64

Li, Q., Zhao, Q., Hu, Y., Wang H. (2006). *Biotechnology and bioeconomy in China*. Biotechnology journal, 1, 1205-1214.

Lichtenthaler, U. (2011). *Open innovation: Past research, current debates and future directions.* Academy of Management Perspectives, 25: 75-93.

Lichtenthaler, U. (2013). *The Collaboration of Innovation Intermediaries and Manufacturing Firms in the Markets for Technology*. Journal of Product Innovation Management, 30: 142-158.

Lieder, M., Rashid, A. (2016). *Towards circular economy implementation: a comprehensive review in context of manufacturing industry*. Journal of Cleaner Production. 115, 36-51.

Lopolito, A., Morone, P., Sisto, R. (2011). *Innovation niches and socio-technical transition: a case study of bio-refinery production*. Futures, 43: 27-39.

Maine, E., Thomas, V. J., Utterback, J. (2014). *Radical innovation from the confluence of technologies: Innovation management strategies for the emerging nanobiotechnology industry.* Journal of Engineering and Technology Management, 32, 1-25.

Malerba, F. (2002). *Sectoral systems of innovation and production*. Research Policy, 31, 247-264.

Martin-de Castro, G. (2015). *Knowledge management and innovation in knowledge-based and high-tech industrial markets: the role of openness and absorptive capacity.* Industrial Marketing Management 47, 143-146.

Martin, R. and Moodysson, J. (2013). *Comparing knowledge bases: On the geography and organization of knowledge sourcing in the regional innovation system of Scania, Sweden*. European Urban and Regional Studies, 20, 170-187.

Martinez-Senra, A., Quintas, M., Sartal, A., Vazquez, X. (2015). *How can firms' basic research turn into product innovation? The role of absorptive capacity and industry appropriability.* IEEE Transactions on Engineering Management, 62 205-2017.

Matharu, A., de Melo, E., Houghton, J. (2016). *Opportunity for high value-added chemical from food supply chain wastes.* Bioresource Technology, 215, 123-130.

McCormick, K., Kautto, N. (2013). *The bioeconomy in Europe: an overview*. Sustainability, 5, 2589-2608.

Melese, T., Lin, S. M., Chang, J. L., Cohen, N. H. (2009). *Open innovation networks between academia and industry: an imperative for breakthrough therapies.* Nature Medicine, 15, 502-507.

Michelfelder, I., Kratzer, J. (2013). *Why and how combining strong and weak ties within a single interorganizational R&D collaboration outperforms other collaboration structures.* Journal of Product Innovation Management. 30, 1159-1177.

Michelino, F., Lamberti, E., Cammarano, A., Caputo, M. (2015). *Measuring open innovation in the bio-pharmaceutical industry.* Creativity and Innovation Management, 24, 4-28.

Mina, A., Bascavusoglu-Moreau, E., Hughes, A. (2013). *Open service innovation and the firm's search for external knowledge.* Research Policy, 43, 853-866.

Milbergs E, Vonortas N. (2005). *Innovation Metrics: Measurement to Insight. White Paper of National Innovation Initiative*, 21st Century Innovation Working Group. IBM Corporation.

Miller, D.J., Fern, M.J., Cardinal, L. (2007). *The use of knowledge for technological innovation within diversified firms*. Academic Management Journal, 50, 308-326.

Miller, K., McAdam, R., Moffett, S., Alexander, A., Puthusserry, P. (2016). *Knowledge transfer in university quadruple helix ecosystems: an absorptive capacity perspective*. R&D Management, 46, 383-399.

Mohan, S. (2016). *Strategy and design of innovation policy road mapping for a waste biorefinery*. Bioresource Technology, 2015, 76-83.

Moore, G. A. (1991). *Crossing the Chasm: Marketing and Selling Technology Products to Mainstream Customers*. New York, Harper Business.

Mu, J. (2014). *Networking Capability, Network Structure, and New Product Development Performance.* IEEE Transactions on Engineering Management, 61, 599-609.

Muller, A., Välikangas, L., Merlyn, P. (2005). *Metrics for innovation: guidelines for developing a customized suite of innovation metrics.* Strategy & Leadership, 33, 37 – 45.

Nair, S., Paulose, H. (2014). *Emergence of green business models: the case of algae biofuel for aviation.* Energy Policy 65, 175-184.

Nakagaki, P., Aber, J., Fetterhoff, T. (2012). *The Challenges in Implementing Open Innovation in a Global Innovation-Driven Corporation.* Research Management 55, 32–38.

Nambisan, S., (2013). Information Technology and Product/Service Innovation: A Brief Assessment and Some Suggestions for Future Research. Journal of the Association for Information Systems, 14, 215-226.

Nambisan, S., Baron, R. (2013). *Entrepreneurship in Innovation Ecosystems: Entrepreneurs' Self-Regulatory Processes and Their Implications for New Venture Success*. Entrepreneurship Theory and Practice, 37, 1071-1097.

Naqshbandi, M.M., Kaur, S., Ma, P. (2015). *What organizational culture types enable and retard open innovation?* Qual. Quant. 49, 2123–2144.

Nita, V., Benini, L., Ciupagea, C., Kavalov, B., & Pelletier,N. (2013). *Bioeconomy and sustainability: A potential contribution to the Bioeconomy Observatory*. Luxembourg: European Commission — Joint Research Centre — Institute for Environment and Sustainability.

Nobelius, D. (2004). *Towards the sixth generation of R&D management. International Journal of Project Management*, 22, 369-375.

Noh, Y. (2015). *Financial effects of open innovation in the manufacturing industry.* Management Decision, 53, 1527-1544.

Nooteboom, B. (1989). *Diffusion, uncertainty and firm size.* International Journal of Research in Marketing, 6, 109-128.

Nowicki, P., Banse, M., Bolck, C., Bos, H., Scott, E. (2008). *Biobased economy, state-of-the-art assessment*. LEI, The Hague, 66p.

Nowotny, H., Scott, P., Gibbons, M. (2003). '*Mode 2' revisited: The New Production of Knowledge.* Minerva 41, 179-194.

OECD. (2009). The Bioeconomy to 2030 - *Designing a Policy Agenda*. Paris, France.

Odegard, I., Croezen, H., Bergsma, G. (2012). *Cascading of Biomass, 13 solutions for a sustainable bio-based economy.* Report, Delft.

Ollikainen M. (2014). *Forestry in bioeconomy e smart green growth for the humankind*. Scandinavian Journal of Forest Research, 37-41.

Ollila, S., Elmquist, M. (2011). *Managing open innovation: exploring challenges at the interfaces of an open innovation arena.* Creativity and Innovation Management, 20, 273-283.

Ortt, J. (1998). *Videotelephony in the consumer market*. doctoral dissertation, Delft University of Technology, Delft.

Ortt, J., van der Duin, P. (2008). *The evolution of innovation management towards contextual innovation*. European Journal of Innovation Management, 11, 522-538.

Osterwalder, A., Pigneur, Y., 2005. *Clarifying Business Models: Origins, Present, and Future of the Concept.* Commun. AIS 15.

Palgan Y., McCormick, K. (2016). *Biorefineries in Sweden: perspectives on the opportunities, challenges and future.* Biofuels, Bioproducts and Biorefining, 10, 523-533.

Paredis, E. (2013). *A winding road, transition management, policy change and the search for sustainable development*. PhD-thesis, Ghent University, Ghent, Belgium.

Park, S.-C. and Lee, S.-K. (2005). *The innovation system and regional growth strategy in Denmark.* AI & Society, 19, 292-308.

Patterson, W. and Ambrosini, V. (2015). *Configuring absorptive capacity as a key process for research intensive firms.* Technovation, 36-37, 77-89.

Patton, M.Q. (1997). *Toward distinguishing empowerment evaluation and placing it in a larger context.* Evaluation Practice 18, 147–163.

Patton, M. (2002). *Qualitative research and evaluation methods*. Sage Publications, Thousand Oaks, California, USA.

Paula, L., & Birrer, F. (2006). *Including public perspectives in industrial biotechnology and the biobased economy.* Journal of Agricultural and Environmental Ethics, 19(3), 253–267.

Payne, A.F., Storbacka, K., Frow, P. (2008). *Managing the co-creation of value*. Journal of Academic Marketing Science. 36, 83-96.

Peerlings, J., Ge, L., van Galen, M. (2012). *Regional innovation system: institutional and organisational dimensions.* Research Policy, 30.

Permann, M., Schildt, H. (2015). Open data partnerships between firms and universities: the role of boundary organizations. Research Policy, 44, 1133-1143.

Perkmann, M., Walsh, K. (2007). *University–industry relationships and open innovation: towards a research agenda.* International Journal of Management Reviews, 9, 259–280.

Perkmann, M., Tartari, V., McKelvey, M., Autio, E., Broström, A., D'Este, P., Fini, R., Geuna, A., Grimaldi, R., Hughes, A., Krabel, S., Kitson, M., Llerena, P., Lissoni, F., Salter, A., Sobrero, M. (2013). *Academic engagement and commercialisation: A review of the literature on university–industry relations.* Research Policy 42, 423–442.

Pfau, S.F., Hagens, J.E., Dankbaar, B., Smits, A.J.M. (2014). *Visions of sustainability in bioeconomy research.* Sustainability, 6, 1222-1249.

Philippidis, G., M'barek, R., Ferrari, E. (2015). *Drivers of the European Bioeconomy in Transition (BioEconomy2030) - an exploratory, model-based assessment*. EUR 27563

Philp, J.C., Ritchie, R.J., Guy K. (2013) *Biobased plastics in a bioeconomy*. Trends in Biotechnology, 31, 65-67.

Pitkanen, K., Antikainen, R., Droste, N., Loiseau, E., et al. (2016). *What can be learned from practial cases of green economy? Studies form five European countries.* Journal of Cleaner Production, 139, 666-676.

Plewa, C, Korff, N., Johnson, C., Mcpherson, G., Baaken, T., Rampersad, G. (2013). *The evolution of university-industry linkages – a framework.* Journal of Engineering and Technology Management, 30, 21-44.

Pohl, C. (2005). *Transdisciplinary collaboration in environmental research*. Futures, 37, 1159-1178.

Pohl, C. (2008). *From science to policy through transdisciplinary research*. Environmental Science Policy, 11, 46-53.

Pohl, C. (2011). *What is progress in transdisciplinary research?* Futures, 43, 618-626.

Prahalad, C.K., Ramaswamy, V. (2004). *Co-creation experiences: the next practice in value creation.* Journal of Academic Marketing Science 18.

Pülzl, H., Kleinschmit, D., Arts, B. (2014). *Bioeconomy e an emerging meta-discourse affecting forest discourses?* Scandinavian Journal of Forest Research, 37-41.

Pullen, A., de Weerd-Nederhof P., Groen, A., Fisscher, O. (2012). *Open Innovation in Practice: Goal Complementarity and Closed NPD Networks to Explain Differences in Innovation Performance for SMEs in the Medical Devices Sector.* Journal of Product Innovation Management, 29, 917-934.

Rampersad, G., Quester, P., Troshani, I. (2010). *Managing innovation networks: Exploratory evidence from ICT, biotechnology and nanotechnology networks*. International Marketing Management, 39, 793-805.

Reinders, M. J., Frambach, R. T., Schoormans, J. P. L. (2010). *Using product bundling to facilitate the adoption process of radical innovation.* Journal of Product Innovation Management, 27, 1127-1140.

Ritter, T. and Gemünden, H. G. (2004). *The impact of a company's business strategy on its technological competence, network competence and innovation success.* Journal of Business Research, 57, 548-556.

Robin, S., Schubert, T. (2013). *Cooperation with public research institutions and success in innovation: Evidence from France and Germany*. Research Policy, 42, 149–166.

Rogers, E. M. (1995)*. Diffusion of Innovations*, 3rd. ed., The Free Press, New York. 1983.

Rönnlund, I., Pursula, T., Bröckl, M., Hakala, L., Luoma, P., Aho, G. et al. (2014). *Creating Value from Bioresources Innovation in Nordic Bioeconomy*.

Ronzon, T., Santini, F. and M'Barek, R. (2015). *The Bioeconomy in the European Union in numbers. Facts and figures on biomass, turnover and employment*. European Commission, Joint Research Centre, Institute for Prospective Technological Studies, Spain, 4p.

Rohrbeck, R., Hölzle, K., Gemünden, H.G. (2009) *Opening up for competitive advantage - How Deutsche Telekom creates an open innovation ecosystem.* R&D Management, 39.

Rothwell, R. (1994). *Towards the fifth-generation innovation process*. International Marketing Review, 11, 7-31.

Rothwell R and Zegveld (1985). *Reindustrialisation and Technology.* London: Longman.

Saebi, T., Foss, N.J. (2015). *Business models for open innovation: Matching heterogeneous open innovation strategies with business model dimensions*. European Management Journal, 33, 201–213.

Saguy, I.S., Sirotinskaya, V. (2014). *Challenges in exploiting open innovation's full potential in the food industry with a focus on small and medium enterprises (SMEs).* Trends Food Science Technology, 38, 136–148.

Salter, A., Criscuolo, P., Ter Wal, A. (2014). *Coping with open innovation: responding to the challenges of external engagement in R&D.* California Management Review, 56, 77-95.

Salter, A., Ter Wal, A., Criscuolo, P., Alexy, O. (2015). *Open for Ideation: Individual-Level Openness and Idea Generation in R&D.* Journal of Product Innovation Management, 32, 488-504.

Sanders, J., van der Hoeven, D. (2008). *Opportunities for a bio-based economy in the Netherlands.* Energies, 1, 105-119.

Sandulli, F. D., Fernandez-Menendez, J., Rodriguez-Duarte, A., Lopez-Sanchez, J. I. (2012). *Testing the Schumpeterian hypotheses on an open innovation framework*. Management Decision, 50, 1222-1232.

Sandmeier, P., Jamali, N., Kobe, C., Enkel, E., Gassmann, O., Meier, M. (2012). *Towards a structured and integrative front-end of product innovation*. Conference Paper of R&D Management Conference, Lisbon, Portugal, 2004.

Sarkar, S., Costa, A. (2008). *Dynamics of open innovation in the food industry*. Trends in Food Science & Technology, 19, 274-580.

Schiele, H. (2010). *Early supplier integration: The dual role of purchasing in new product development.* R&D Management, 40, 138–153.

Schmid, J.C., Knierim, A., Knuth, U. (2016). *Policy-induced innovations networks on climate change adaptation - An ex-post analysis of collaboration success and its influencing factors*. Environmental Science and Policy, 56, 67–79.

Schmid, O., Padel, S., Levidow, L. (2012). *The bio-economy concept and knowledge base in a public goods and farmer perspective*. Bio Based and Applied Economics, 1, 47-63.

Schaltegger, S., Beckmann, M., Hansen, E. (2013). *Transdisciplinarity in corporate sustainability: mapping the field.* Business and Strategy Environment, 22, 219-229.

Schuhmacher, A., Germann, P-G., Trill, H., Gassmann, O. (2013). *Models for open innovation in the pharmaceutical industry.* Drug Discovery Today, 18, 1133-1137.

Scott, A., Johnson, M., Sinfield, J., Altman, E. (2008). *Innovation Metrics*, Chapter 10 of Innovator's guide to growth: putting disruptive innovation to work. Harvard Business School Publishing.

Schot, J. and Geels, F. (2007). *Niches in evolutionary theories of technical change*. Journal of Evolutionary Economics, 17, 605-622.

Shortall, O.K, Raman, S., Millar, K. (2015). *Are plants the new oil? Responsible innovation, biorefining and multipurpose agriculture.* Energy Policy, 86, 360-368.

Siegrist, M. (2008). *Factors influencing public acceptance of innovative food technologies and products.* Trends in Food Science & Technology, 19, 603–608.

Sisodiya, S. R., Johnson, J. L., Grégoire, Y. (2013). *Inbound open innovation for enhanced performance: Enablers and opportunities.* Industrial Marketing management, 42, 836-849.

Spencer, J. W. (2003). *Firms' knowledge-sharing strategies in the global innovation system: empirical evidence from the flat panel display industry*. Strategic Management Journal, 24, 217-233.

Spencer, R. (2013). *Open innovation in the eighteenth century, the longitude problem*. Research and Technology Management, 39-44.

Spitsberg, I, Brahmandam, S., Verti, M, Coulston, G. (2013). *Technology landscape mapping: at the heart of open innovation.* Research Management, 56, 27-35.

Smith, A., Voß, J. Grin, J. (2010). *Innovation studies and sustainability transitions: the allure of the multi-level perspective and its challenges*. Research Policy 39,, 435-448.

Smith, A. Stirling, A., Berkhout, F. (2005). *The governance of sustainable sociotechnical transitions*. Research Policy 34, 1491-1510.

Spithoven, A., Clarysse, B., Knockaert, M. (2010). *Building absorptive capacity to organise inbound open innovation in traditional industries.* Technovation, 30, 130-141.

Spithoven, A., Teirlinck, P. (2015). *Internal capabilities, network resources and appropriation mechanisms as determinants of R&D outsourcing*. Research Policy, 44, 711–725.

Staffas, L, Gustavsson, M, McCormick, K. (2013). *Strategies and policies for the bioeconomy and bio-based economy: an analysis of official national approaches.* Sustainability, 5, 2751-2769.

Steinmo, M., Rasmussen, E. (2016). *How firms collaborate with public research organizations: The evolution of proximity dimensions in successful innovation projects*. Journal of Business Research, 69, 1250–1259.

Stevens, E., 2014. *Fuzzy front-end learning strategies: Exploration of a high-tech company*. Technovation 34, 431–440.

Stevens, H., Van Overwalle, G., Van Looy, B., Huys, I. (2013). *Perspectives and Opportunities for Precompetitive Public–Private Partnerships in the Biomedical Sector*. Biotechnology Law Report, 32, 131–139.

Strauss, A., J. Corbin. (1998). *Basics of qualitative research: grounded theory procedures and techniques.* Sage Publications, Thousand Oaks, California, USA.

Szogs, A., & Wilson, L. (2008). *A system of innovation?. Biomass digestion technology in Tanzania*. Technology in Society, 30, 94–103.

Tanguy, S. (2016). *Cooperation in the food industry: contributions and limitations of the open innovation model.* Journal of Innovation Economics and Management, 19, 61-86.

Thanasopon, B., Papadopoulos, T., Vidgen, R. (2016). *The role of openness in the fuzzy front-end of service innovation.* Technovation, 32-46.

Tesla. (2017). *All our patent are belong to you*. https://www.tesla.com/blog/all-our-patent-are-belong-you (accessed on 05.02.2017).

Tether, B., Tajar, A. (2008). *Beyond industry-university links: sourcing knowledge for innovation from consultants, private research organizations and the public science-base*. Research Policy, 37, 1079-1095.

Thong, R. and Lotta, T. (2015). *Creating a Culture of Productivity and Collaborative Innovation.* Research-Technology Management, 41-50.

Timmermans, S., Tavory, I. (2012). *Theory construction in qualitative research: from grounded theory to abductive analysis.* Sociological Theory, 30, 167-186.

Traitler, H., Watzke, H., Saguy, S. (2011). *Reinventing R&D in an open innovation ecosystem*. Journal of Food Science, 76, 62-69.

Triste, L., Marchand, F., Debruyne, L., Meul, M., Lauwers, L. (2014). *Reflection on the development process of a sustainability assessment tool : learning from a Flemish case The MOTIFS case.* Ecology and Society, 19, 47.

Trott, P., Hartmann, D. (2009). *Why "open innovation" is old wine in new bottles.* International Journal of Innovation Management, 13, 715-736.

Tödtling, F. en Trippl, M. (2005.) *One size fits all?: Towards a differentiated regional innovation policy approach.* Research Policy, 34, 1203-1219.

U.S. Administration. (2012). *National Bioeconomy Blueprint*. The White House Office of Science and Technology Policy, Washington, USA.

Ulrich, L. (2011). *Open Innovation: Past Research, Current Debates and Future Directions*, p. 607.

Van Buggenhout E., Vuylsteke A., Van Gijseghem D. (2016). *Back to basics? Circulaire economie en landbouw.* Departement Landbouw en Visserij, afdeling Monitoring en Studie, Brussel.

Van den Ende, J., Frederiksen, L., Prencipe, A. (2015). *The Front End of Innovation: Organizing Search for Ideas.* Journal of Product Innovation Management 32, 482–487.

Van der Duin, P., Ortt, R., Kok, M. (2007). *The cyclic innovation model: A new challenge for a regional approach to innovation systems?* European Planning Studies, 15, 195-215.

Van der Panne, G. Beers, C., Kleinknecht, A. (2003). *Success and failure of innovation: a literature review.* Journal of Innovation Management, 7, 1-29.

Van Hemert, P., Nijkamp, P., Masurel, E. (2013). *From innovation to commercialization through networks and agglomerations: analysis of sources of innovation, innovation capabilities and performance of Dutch SMEs.* Ann. Reg. Sci., 50, 425-452.

Van Humbeeck, P. (2003). *Naar een industrieel beleid voor het milieu*. Technologie en innovatie als sleutel voor een duurzame welvaart, SERV, Brussel.

van Kleef, J., Roome, N. (2007). *Developing capabilities and competence for sustainable business management as innovation: a research agenda.* Journal of Cleaner Production, 15, 38-51.

Van Lancker, J., Wauters, E., Van Huylenbroeck, G. (2016a*). Managing innovation in the bioeconomy: An open innovation perspective.* Biomass and Bioenergy 90, 60–69.

Van Lancker, J., Mondelaers, K., Wauters, E., Van Huylenbroeck, G. (2016b). *The Organizational Innovation System: A systemic framework for radical innovation at the organizational level.* Technovation 52-53, 40–50.

von Hippel, E. (2005). *Democratizing Innovation.* Cambridge, MA: MIT Press.

Vandermeulen, V., Nolte, S., Van Huylenbroeck, G. (2010). *Hoe biobased is de Vlaamse economie?,* Departement Landbouw en Visserij, Afdeling Monitoring en Studie, UGent, Brussel, 132 p.

Vanhaverbeke, W. and Cloodt, M. (2006). *Open innovation in value networks*. In Open innovation: researching a new paradigm, Oxford University Press.

Vaquero, M., Reinhardt, R., Gurther, S. (2016). *Stakeholder integration in new product development: a systematic analysis of drivers and firm capabilities.* R&D Management, 46, 1095-1103.

Vandermeulen, V., Prins, W., Nolte, S., Van Huylenbroeck, G. (2011). *How to measure the size of a bio-based economy: evidence from Flanders.* Biomass and Bioenergy 35, 4368-4375.

Vandermeulen, V., Van der Steen, M., Stevens, C., Van Huylenbroeck, G. (2012). *Industry expectations regarding the transition toward a biobased economy.* Biofuels Bioproducts and Biorefining 6, 453-464.

Verbeke, W. (2007). *Consumer attitudes toward genetic modification and sustainability: Implications for the future of biorenewables*. Biofuels, Bioproducts and Biorefining, 1, 215–225.

Veldkamp, A., Van Altvorst, A. C., Eweg, R., Jacobsen, E., Van Kleef, A., Van Latesteijn, H., Mager, S. (2009). *Triggering transitions towards sustainable development of the Dutch agricultural sector: TransForum's approach*. Agronomy for Sustainable Development, 29, 87-96.

Veer, T., Lorenz, A., Blind, K. (2016). *How open is too open? The mitigating role of appropriation mechanisms in R&D cooperation settings*. R&D Management, 46, 1113-1129.

Viaene, J., Van Lancker, J., Vandecasteele, B., Willekens, K., Bijttebier, J., Ruysschaert, G., De Neve, S., Reubens, B. (2016). *Opportunities and barriers to on-farm composting and compost application: A case study from northwestern Europe*. Waste Management ,48, 181–192.

Viaggi, D. (2015). *Research and innovation in agriculture, beyond productivity*. Bio-based and Applied Economics, 4, 279-300.

Villarreal, O., Calvo, N. (2015). From the Triple Helix model to the Global Open Innovation model: A case study based on international cooperation for innovation in Dominican Republic. Journal of Engineering and Technology Management, 35, 71–92.

Walshok, M., Shapiro, J., Owens, N. (2014). *Transnational innovation networks arent' all created equal: towards a classification system*. Journal of Technology Transfer, 39, 345-357.

Walter, S., Ulli-Beer, S., Wokaun, A. (2012). *Assessing customer preferences for hydrogen-powered street sweepers: A choice experiment.* International journal of hydrogen energy, 37, 1203-12014.

Walter, A.I., Helgenberger, S., Wiek, A., Scholz, R.W., 2007. *Measuring societal effects of transdisciplinary research projects: design and application of an evaluation method*. Evaluation and Program Planning, 30, 325–338.

Wang, Y., Vanhaverbeke, W., Roijakkers, N. (2012). *Exploring the impact of open innovation on national systems of innovation – A Theoretical analysis.* Technological Forecasting & Social Change, 79, 419-428.

Weckowska, D. (2015). *Learning in university technology transfer offices: transaction-focused and relation-focused approaches to commercialization of academic research*. Technovation, 41-42, 62-74.

West, J. and Gallagher, S. (2006). *Challenges of open innovation: the paradox of firm investment in open-source software.* R&D Management, 36, 319-331.

West, J. and Bogers, M. (2014). *Leveraging External Sources of Innovation: A Review of Research on Open Innovation.* Journal of Product Innovation Management, 31, 814-831.

Westergren, U.H. and Holmström, J. (2012). *Exploring preconditions for open innovation: Value networks in industrial firms.* Information and Organization, 22, 209-226.

Wikhamn, B. (2013). *Two different perspectives on open innovation – libre versus control.* Creativity and Innovation Management, 22, 375-390.

Wield, D. (2013). *Bioeconomy and the global economy: Industrial policies and bioinnovation*. Technology Analysis & Strategic Management, 25, 1209–1221.

Woolthuis, R. K., Lankuizen, M., Gilsing, V. (2005). *A system failure framework for innovation policy design.* Technovation, 25, 609-619.

Zott, C., Amit, R, (2010). *Business model design: an activity system perspective.* Long Range Planning, 43, 216-226.

Zwier, J., Blok, V., Lemmens, P., Geerts, R.-J. (2015). *The ideal of a zero-waste humanity: philosophical reflections on the demand for a bio-based economy*. Journal of Agricultural and Environmental Ethics, 353-374.

# Annex 1: Extended explanation of method used for section 1.5

In order to gain insight into the size of the Flemish bioeconomy and gain insight into the innovation landscape of the different relevant sectors identified in chapter 1, quantitative data form the Community Innovation Survey (CIS) and Statistics Belgium are used.

First, based on the analysis of the definitions and elaborations on these definitions in terms of sectors, technologies and end products in the included texts, a list of sectors and subsectors relevant to the bioeconomy was developed. To further operationalize the list, these sectors were translated to 18 level 2 NACE-codes: codes that are used to group organizations according to their economic activities (FPS Economy Belgium, 2017). NACE-codes 01, 02 and 03 relate to the production of biomass, aggregating all organizations with activities in Agriculture, Forestry and Fisheries and Aquaculture respectively. The sectors that traditionally have a strong reliance on biomass as a feedstock, are represented by six codes; 10 and 11 for Food and Beverage producers, 13 for the Textile industry, code 16 which holds the Wood Processing industry, 31 for the Furniture builders, and code 17 which aggregates the Paper and Pulp industry. These six codes can be considered the Traditional Bio-based Economy. Five other included codes embody those sectors that could be part of the bioeconomy, i.e. the New Bio-based Economy. These are code 20 which include the Bio-based Chemistry, the organizations involved in Biopharmaceuticals which are registered under code 21, other producers of Bio-based Products such as construction materials are part of codes 22 and 23 (hereafter called bio-based materials group), and the Bioenergy sector resides in the energy production group (code 35). A last group of codes we have included are codes 36 to 39, which represent the organizations concerned with waste management, which can play an important role in the maximum valorisation of waste and side streams. A schematic representation of the included NACE-code groups can be found in figure 2.

Further refining the bioeconomy using the NACE-nomenclature proved challenging, because the codes only make distinctions between sectors based on their activities, and not between fossil-based and bio-based production (Ronzon et al., 2015). As a result, it is very difficult to further split the (sub)sectors of especially the new bio-based economy into those organizations with bioeconomy activities and those with traditional fossil-based activities, as illustrated in several tables in the National Bioeconomy Profile document of Belgium (JRC, 2014) that report the bio-based fraction of different sectors and subsectors currently only partly bio-based as *not available*. Consequently, the attempts to determine the size of the bioeconomy in various countries are often only rough estimates based on approximations made by industry organizations or captains of industry. The insights gained can therefore only be considered indications of the current state of the Flemish bioeconomy.

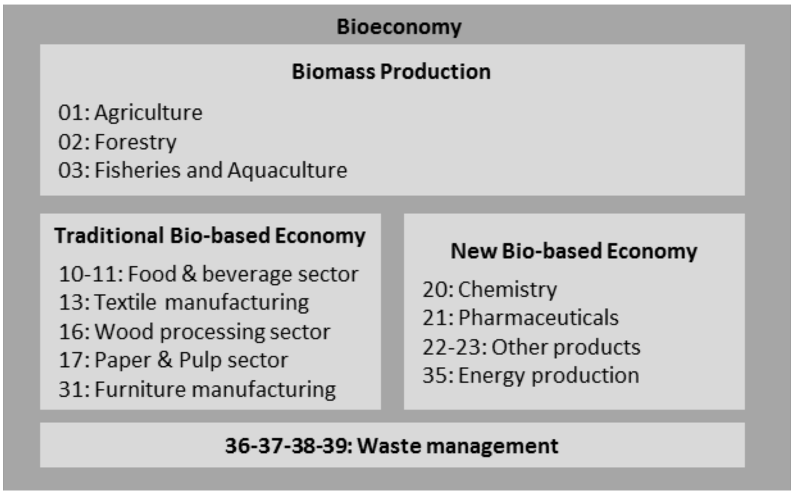


**Figure 14** Schematic representation of sectors included, with corresponding NACE-codes

In congruence with other studies on the size of the bioeconomy (e.g. Vandermeulen et al. (2011) and Nowicki et al. (2008)), we excluded the biomass production, i.e. agriculture, forestry, and fisheries and aquaculture for this overview. The food and beverage sector, which is also sometimes excluded in previous studies, was not excluded from this study, because it is an important traditional bio-based sector and an important potential market for many novel bio-based products such as food additives derived from biomass waste streams. Because some of the sectors in Flanders are too small in term of active organizations to guaranty confidentiality, several NACE-codes had to be aggregated into clusters. All wood-based industries (codes 16, 17 and 31) are clustered into one group, the Chemistry and Pharmaceuticals are one cluster, and the firms with activities in electricity and waste management are also bundled together.

Second, the data from the firms belonging to these sectors are derived from the CIS data and Statistics Belgium. The data from Statistics Belgium, the national institute responsible for collecting official national statistics and for the production of European statistics (http://statbel.fgov.be/), were used to gain insights into the size of the Flemish bioeconomy (table 1). For the insights into the innovation behaviour and strategies, the data from CIS 2012 for Flanders was used. The Community Innovation Survey is an effort of Eurostat to gain more insight into the innovation activities across industrial sectors and countries in the EU member states, through the development of a harmonized questionnaire (Evangelista et al., 2001). Data gathered through these questionnaires, which are send out in three year intervals, have been used in a large number of scientific studies (e.g. Faber and Hesen, 2004; Faems et al., 2010; Janeiro et al., 2013; Laursen, 2011; Laursen and Salter, 2006). For Flanders, a combination of survey and census was used, depending on the population in the various strata, to ensure Eurostat's quality standards. Organizations with less than 10 employees were excluded. The survey, 16 pages in 2012, was send out by both electronic and regular mail. Several reminders were send to non-responding firms, resulting in a total response rate for the three surveys of approximately 45% for the sectors of interest for this study. More detailed information on the methodology of the study can be found on the website of the institute responsible for the CIS survey in Belgium (BELSPO, 2016). From the sectors considered in this study, 794 firms returned the Community Innovation Survey.

## Scientific Curriculum Vitae

Jonas Van Lancker was born in Oudenaarde on January 6th, 1988. He obtained a secondary school degree in Modern Languages and Economics at GO! Atheneum in Oudenaarde in 2007. In 2010, he gained a Bachelor degree in Business Management, option SME-Management and in 2012, he graduated as a Master in Business Administration, specializing in Strategic Management. Since 2012, he works at the Social Sciences Unit of the Research Institute for Agriculture, Fisheries and Food Research (ILVO Landbouw en Maatschappij), where he started on the GeNeSys project. This transdisciplinary project aimed to develop new technological options for the valorisation of waste products from the agricultural and fisheries sectors. In this project, he was responsible for the development of new insights and knowledge on how innovation projects aimed at developing novel bio-based applications should be approached.

**Peer reviewed articles**

Van Lancker, J., Mondelaers, K., Wauters, E., Van Huylenbroeck, G. (2016). The Organizational Innovation System: A systemic framework for radical innovation at the organizational level. *Technovation* 52-53, 40-50.

Van Lancker, J., Wauters, E., Van Huylenbroeck, G. (2016). Managing innovation in the bioeconomy: An open innovation perspective. *Biomass & Bioenergy* 90, 60-69.

Viaene, J., Van Lancker, J., Vandecasteele, B., Willekens, K., Bijttebier, J., Ruysschaert, G., De Neve, S., Reubens, B. (2016). Opportunities and barriers to on-farm composting and compost application: A case study from northwestern Europe. *Waste Management* 48, 181–192.

**Conference papers**

Van Lancker, J., Wauters, E., Van Huylenbroeck, G. (2015). The Challenges of Implementing Open Innovation in a Public Research Institute. 26th ISPIM conference 2015.

Van Lancker, J., Mondelaers, K., Van Huylenbroeck, G. (2014). The Organizational Innovation System: Innovation rationale and framework for analysis. 25th ISPIM conference 2014.

Van Lancker, J., Hanseeuw, E., Kips, L., Viaene, J., Mondelaers, K. (2013). A conceptual model for innovation research in the bio-economy. 17th ICABR Conference 2013.

**Presentations at international conferences**

Van Lancker, J., Wauters, E., Van Huylenbroeck, G. (2015). The Challenges of Implementing Open Innovation in a Public Research Institute. Paper presentation at the 146th EAAE seminar: Technology transfer as a driver of innovative entrepreneurship in agriculture and the agri-food industry. July 15-16 2015 Chania, Crete.

Van Lancker, J., Wauters, E., Van Huylenbroeck, G. (2015). The Challenges of Implementing Open Innovation in a Public Research Institute. Paper presentation at the 26th ISPIM conference: Shaping the frontiers of innovation management, June 14-17 2015, Budapest, Hungary.

Van Lancker, J., Mondelaers, K., Viaene, J., Kips, L., Hanseeuw, E., Van Huylenbroeck, G. (2014). Supporting system innovation in the bio-economy: illustration of an innovation feasibility evaluation instrument. Poster presented at the biannual ISEE Conference: Wellbeing and equity within planetary boundaries. August 12-15 2014, Reykjavik, Iceland.

Van Lancker, J., Mondelaers, K., Van Huylenbroeck, G. (2014). The Organizational Innovation System: Innovation rationale and framework for analysis. Paper presented at the 25th ISPIM conference: Innovation for sustainable economy & Society. June 8-14 2014, Dublin, Ireland.

Van Lancker, J., Hanseeuw, E., Kips, L., Viaene, J., Mondelaers, K. (2013). A conceptual model for innovation research in the bio-economy. Paper presented at the 17th ICABR Conference: Innovation and policy for the bio-economy. June 18-21 2013, Ravello, Italy.

Van Lancker, J., Mondelaers, K. (2013). A conceptual model for innovation research in the bio-economy. Poster presentation at 9th International Conference on Renewable Resources & Biorefineries. June 5-7 (2013, Antwerp Belgium.

**Scientific reports**

Gellynck, X., Lambrecht, E., Lauwers, L., Bijttebier, J., Debruyne, L., Taragola, N., Van Lancker, J. (2016). Slim innoveren in de landbouw: Ontwikkel en realiseer je innovatief idee via samenwerking. 16p.

Van Lancker J., Mondelaers K. (2014) Innoveren in de bio-economie: innovatieproces en netwerken doorgelicht. ILVO-mededeling nr. 164. 50p.

### Supervision of Master students

Jeroen Van de Walle. (2015). Valorisatie, karakterisatie en economische doorrekening van de overproductie van tomaat. Master of Science in Industrial sciences, option Food Industry. Ghent University. Supervisor: Prof. dr. Marc De Loose.

### Peer reviewing

Peer reviewer for Technovation (2)

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### Specialist courses and summer schools (Ghent University)

2016: Summer School: Plunge into your own business plan, September 12-15 2016.

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2013: Advanced academic English: Conference skills