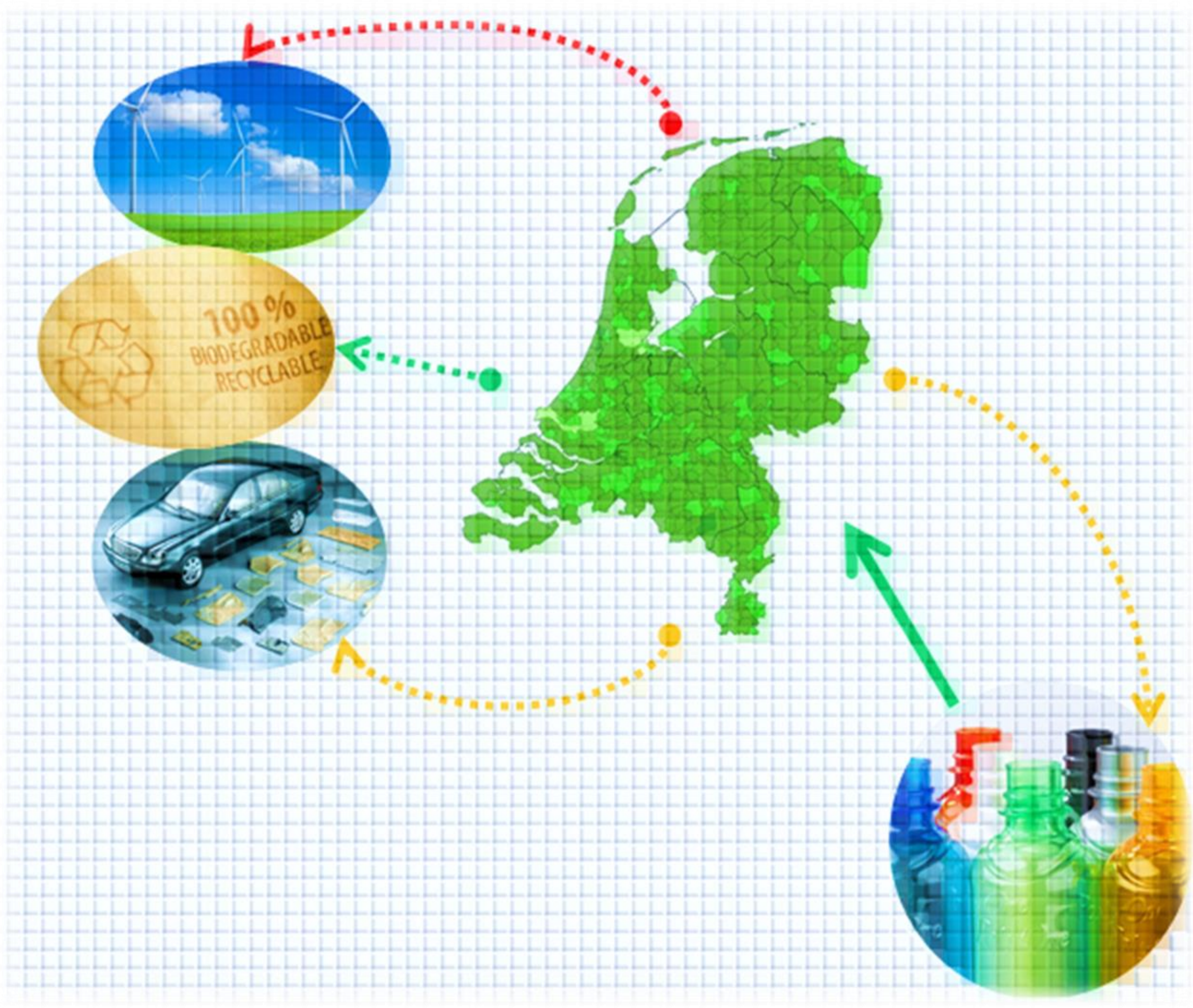
Ministry of Economic Affairs of the Netherlands

Biobased Sectoral Development in the Netherlands:

A Multi-case Analysis using Strategic Niche Management and Business Model Concepts

Raymon van den Heuvel, May 2016



Biobased Sectoral Development in the Netherlands:
A Multi-case Analysis using Strategic Niche Management and Business Model Concepts

Student:	Raymon van den Heuvel
Student number:	891204-334-020
Contact details:	+31 (0)6 24 28 22 02; raymonvandenheuvel@gmail.com
Study program:	MSc Management Economics and Consumer studies
Course:	MST-80433
Supervisor:	Dr. E.F.M. Wubben
Co-reader:	Prof.dr. S.W.F. Omta
Commissioner:	Ir. P.A.M. Besseling, Ministry of Economic Affairs of the Netherlands

May 2016

PREFACE

This thesis is the crown of my Master's degree programme, Management, Economics and Consumer studies at Wageningen University. Writing the thesis was not a simple act. Most of the times, writing this thesis required much work and dedication. Sometimes, I felt proud, seeing different chapters of the report emerging from scratch. Overall the process required more time than anticipated, but I have always prioritized the quality of my research. In particular writing the cases studies from a huge pile of data (including interview recordings of over two hours) was challenging. I could not have done it without the help of many people.

First of all, I thank Emiel Wubben for his support throughout writing this thesis. As the direct supervisor of my research project he provided me his scientific guidance and made me feel welcome for questions any time. I enjoyed our discussions and you were always able to provide me with creative, new insights. During the early months, I also thoroughly enjoyed setting up the new course Biobased Business/Transition with you. The second person who has been committed since the beginning is Peter Besseling. Peter, I experienced as a delightful, humorous person with a great deal of knowledge. In the beginning we had several discussions in order to get the project on the right track (many of my proposals ended up in the waste bin). In the end, I feel lucky with this memorable project, and I am grateful for the opportunity to have conducted my research in cooperation with the driven people from the Ministry of Economic Affairs of the Netherlands. Last but not least, I thank my friends and family for their help and encouragement in many ways.

I hope you enjoy your reading.

Wageningen, The Netherlands | May 2016
Raymon van den Heuvel

EXECUTIVE SUMMARY

Expectations are positive that the fossil based economy may partially be substituted by the biobased economy. The biobased economy is an economy in which plants, crops, and waste streams from agriculture and the food industry, the so-called green feedstock or biomass, are utilized for non-food applications like pharma, materials, chemicals, fuels, and energy (Harmsen & Hackmann, 2012). Starting point for this research project was that the Netherlands does not seem to deliver upon expectations of creating flourishing biobased sectors. By means of back casting, this study aims to signal key factors in/or patterns that explain and can systematically help forward biobased sectoral development in the Netherlands. The research objective is formulated as follows: *''To compare and derive factors influencing the development of a biobased sector in the Netherlands by learning from comparable Dutch trajectories''*. To achieve the research objective a general research question is formulated: *''What can be learned regarding the development of a biobased sector in the Netherlands from comparable Dutch trajectories?''* Limited research on biobased sectoral development and scarce attention for the role of business model concepts herein leave space for further research on this topic. For answering the general research question, the following sub research questions are formulated:

1. *What are the literature-based factors influencing the development of a biobased sector that together constitute the theoretical framework?*
2. *Which factors influenced the development of the three cases (results), and what can be derived from comparing these factors? (analysis)*
3. *Which factors are influencing the development of the PLA case (results), and what can be learned from comparing these factors with the findings from empirical part 1? (analysis)*
4. *How is the theoretical framework represented in practice and what are recommendations for policymakers?*

Based on an extensive literature review, the researcher constituted a theoretical framework for approaching the complexity of innovation trajectories towards biobased sectoral development. For constituting this framework, business model concepts were integrated in the conceptual bases of Strategic Niche Management (SNM) and the Multi-Level Perspective (MLP). Drawing on SNM, innovation trajectories are approached as evolving via a three-stage process of *niche development* (Schot & Geels, 2008). In this conception, innovations move from R&D niches, via experimentation in technological niches, towards market niches. It is posited that niche development (micro-level) depends on an increasing alignment of the market and a particular technology (Van der Laak *et al.*, 2007), while interacting with a broader environment, i.e. regimes (meso-level) and the landscape (macro-level). We arrived at the following factors proposed to being related to biobased sectoral development:

- *Regime stability*, accounting for the existing production systems which tend to resist changes that primarily are to the advantage of (innovations in) niches. Conceptually, regime stability decreases when actors embark on a search for other technologies (or products), referred to as (the creation of) *cracks* in regimes.
- *Landscape pressure*, resembling the set of macro-level factors that can activate actors to break away from the (predominant) regimes and (potentially) start supporting (challenging) alternatives (in niches).
- *Momentum*, the conceptual force that decides whether a niche breaks through or keeps struggling to diffuse at the regime level. It is posited that momentum is a function of niche development and regime stability. When momentum is gathered by a niche, the embedded innovation should be able to diffuse.
- *Innovation diffusion* (endogenous variable), the spreading of an innovation among users (Rogers, 1983) such that the innovation changes an existing sector or constitutes a new one.
- Built on SNM and business model literature, furthermore three factors influencing niche development are selected: (i) *visioning*, (ii) *value proposition*, and (iii) *finances*.

Assumed is that if adjustments of factors in the framework work out positively for the research objects, similar adjustments can also be helpful in steering the research objects in real-life. Herewith, this research strives to act as a stepping stone towards adequate governmental policy.

Given the complexity of real-life trajectories, and the need to trace factors over time, this study relies on the case study design. *Four cases* are selected as research objects: one different but yet comparable case, namely *wind turbines* (1970-2015), and three biobased cases, knowing *industrial hemp (1990-2015), starch plastics (1990-2015)*, and *poly lactic acid (PLA, 2000-2015).* Whereas the PLA case can be seen as the 'ongoing case' with high potential still, the three other cases were at similar starting points, but ended up being different by 2015. Explaining this difference, by means of the theoretical framework, and subsequently verifying the learnings in

the PLA case is how this research project is set up. Data comes from two sources: documents, and interviews. A total of 19 interviews were conducted. By corroborating information from documents with that from interviews, and vice versa, this study aimed to triangulate the obtained insights with information that is supportive.

Based on a gathering of findings from the three case studies in empirical part 1, several findings were found which were consistent with the factors from the theoretical framework. Hence is concluded that the *framework systematically extracts factors from real-life regarding the development of innovations towards evolving into a sector*. Generally, it can be stated that entrepreneurs seek to develop their (market) niches while looking to benefit from cracks in regimes, hopefully promoting a rapid development of their niches by gaining momentum. More specifically, by early-2016, only 3 out of 19 niches identified in empirical part 1 were able to gather momentum so that they are now diffusing at the regime level, i.e. change existing sectors or constitute new ones. These focal niches were able to attain the required stability for gathering momentum because the respective entrepreneurs deliver true added value to users, based on functional advantages, inherent to the resource. With 16 less promising out of 19 niches, it must be concluded that the factual presence of the factor Innovation diffusion remained modest, not foregoing that this is something that could be expected as problems in biobased sectoral development were the main reason for starting this research.

The PLA case verified several findings from the three case studies in empirical part 1, confirming the practical relevance of these findings for biobased settings:

- Insufficient alignment of demand and supply for stabilizing the niches;
- Niches typically embed innovations which strive to comply with the market requirements, i.e. licenses, guarantees, and standards of regimes;
- Achieving high technological readiness levels is not enough to create demand, as appealing value propositions are required;
- Relatively high expectations (of positive returns and growth) provided legitimacy to more entrepreneurs and other kinds of actors to invest in the innovations, e.g. in time, money, strengthening the hype-status;
- A viable business case for entrepreneurs promotes niche stabilization;
- Niche protection by the government was limited, slowing down niche development;
- The relative value of environmental benefits in cost-benefit assessments is rising, but users cannot be activated solely based on environmental claims;
- Regimes have an internal resistance to change due to embeddedness, vested interests, and risk-aversion;
- The high standards of regimes become the benchmark for innovations in particular markets;
- In the absence of momentum, niche development stagnates.

Reflecting on both empirical parts, in total 24 niches and associated regimes were identified in this study. By early 2016, 8 niches were able to evolve into market niches. The development of the remaining 16 niches (two third) typically stagnated in the phase of technological niche, having to cope with regimes. Analysis shows that the entrepreneurs tend to lack a viable business case, often related to user preference for their innovations being absent. In order to be considered by users, innovations namely need to need to follow and outperform the (high) standards set by regimes, but often fail to do so. It appears that many biobased innovations have cost disadvantages as compared to regimes (e.g. in construction, energy, plastics), partly due to relatively high feedstock costs. We derived from the cases that entrepreneurs with biobased innovations best seek true added value applications such that price gaps can be compensated for by the added value it brings. Innovations are furthermore locked out by users via benchmarking, risk-aversion and vested interest. From the analyses, we derived that these problems are pivotal for the studied biobased innovations, slowing down their uptake towards sectoral development. Interestingly, the landscape does activate actors which increasingly value the standards of innovations and create cracks in regime stability, especially from a carbon footprint point of view.

Looking back at over 25 years of biobased innovations, we conclude that the transition to biobased products is complex, with different factors, simultaneously influencing biobased sectoral development. Overall, the developments at the regime level and the level of niches have increased considerably in the last decade. Although momentum was only scarcely gathered by the focal niches, multiple breakthroughs are expected in the upcoming years. Meanwhile, the government's stimulating measures seem to have focused on the creation and development of R&D and technological niches, while market niches need supporting as well, if they were to gather momentum. Built on the case studies, this research delivered a *condensed listing of factors influencing biobased sectoral development in the Netherlands, in fact, guidelines that are important to consider when developing policy for the biobased economy.*

TABLE OF CONTENTS

List of figures

List of tables

List of appendices

1. INTRODUCTION

In this introductory chapter, first the research background and problem statement are discussed. From the problem statement, a research objective is derived in section 1.2. In section 1.3, the research framework is presented, followed by the research questions in section 1.4. Finally, the report structure is given in section 1.5.

1.1 Research background and problem statement

Expectations are positive that the fossil based economy may partially be substituted by the biobased economy, with biomass already providing the majority of sustainable energy in the Netherlands. The *biobased economy* is an economy in which plants, crops, and waste streams from agriculture and the food industry, the so-called green feedstock or biomass, are utilized for non-food applications like pharma, materials, chemicals, fuels, and energy (Harmsen & Hackmann, 2012). Already in the late-1980s, several (typically European) countries started developing biobased products, at that time referred to as *agrification*. It has been concluded that the Netherlands holds a promising position to create and utilize opportunities in the transition to biobased products (Nova institute, 2014; Deloitte, 2014; Bruggink *et al.*, 2014; WTC, 2014). The Netherlands has strong industries in both chemistry and agro & food, as well as in horticulture, water and transport. These large, mature industries fit the envisioned biobased economy and benefit productively from the Dutch willingness to cooperate, high quality educational systems and its solid knowledge base (Panteia, 2014).

One suited sectoral development is the development of a Dutch bioplastics industry. Volumes in bioplastics, in particular the biobased polymer *poly lactic acid (PLA)*, are expected to rise substantially (Bos & Sanders, 2013). At least 7 new large PLA-plants need to be built globally in the upcoming years (Nova Institute, 2013), and the Netherlands has been pointed out as a foremost suitable location for this fermentation-based chemical industry (Deloitte, 2014).

However, the Netherlands does not seem to deliver upon expectations, jeopardizing prospects for flourishing biobased sectors, profitable companies, and new jobs. The biobased investment climate in the Netherlands seems less positive when it comes to *(semi-)commercial activities* (TNO, 2015). Illustratively, several high-profile Dutch bioplastics companies, notably Corbion and Avantium, have recently decided to apply their technologies, funded and developed in the Netherlands, in production locations outside the Netherlands. Other firms, however, do invest in the Netherlands. Reflection on realizing new sectors and industries may be instrumental to policymaking on the biobased economy.

To be able to develop and benefit from competitive advantages with regard to the biobased economy, lessons may be drawn from earlier trajectories of sectoral development that are *comparable*. Because the Netherlands has been both successful and unsuccessful in innovation trajectories in the past, the following question aroused: what can be learned regarding the development of a biobased sector in the Netherlands from comparable Dutch sectoral developments?

Studies have been carried out for explaining biobased developments, relying on diverse theoretical foundations, like Industrial Architecture (Jacobides, Knudsen, & Augier, 2006), Innovation Management (e.g. the Dutch Top Sector policy), and Strategic Niche Management (SNM) (Bos *et al.*, 2008; Geels, 2004). For example, the SNM approach emerged in reaction to the observation that many firms with sustainable technologies fail to pass the so-called Valley of Death, to commercialize their products (Raven, 2005; Van der Laak *et al.*, 2007).

Different authors point out that firms with sustainable technologies often lack a competitive advantage at the start (Van der Laak *et al.*, 2007), are locked out by the established system (Unruh, 2000), and/or face constraints related to path-dependency (Coombs & Hull, 1998). These problems appear ''pivotal for many new technologies, particularly for technologies with sustainability promises'' (Schot & Geels, 2008), potentially also hindering biobased developments in the Netherlands. Limited research on biobased sectoral development and scarce attention for the role of business model concepts herein leave space for further research on this topic.

Built on Strategic Niche Management (SNM), the Multi-Level Perspective (MLP), and Business Model literature, this study is able to review innovation trajectories from an interrelated multi-level perspective over time. At present, this approach has not been applied before in a comparative case study design. By means of back casting, this study aims to signal key factors in/or patterns that explain and can systematically help forward biobased sectoral development in the Netherlands. Herewith, as later also explained, this study strives to act as a *stepping stone* towards adequate governmental policy.

1.2 Research objective

Inferred from the previous section, the research objective is formulated as follows:

To compare and derive factors influencing the development of a biobased sector in the Netherlands by learning from comparable Dutch trajectories

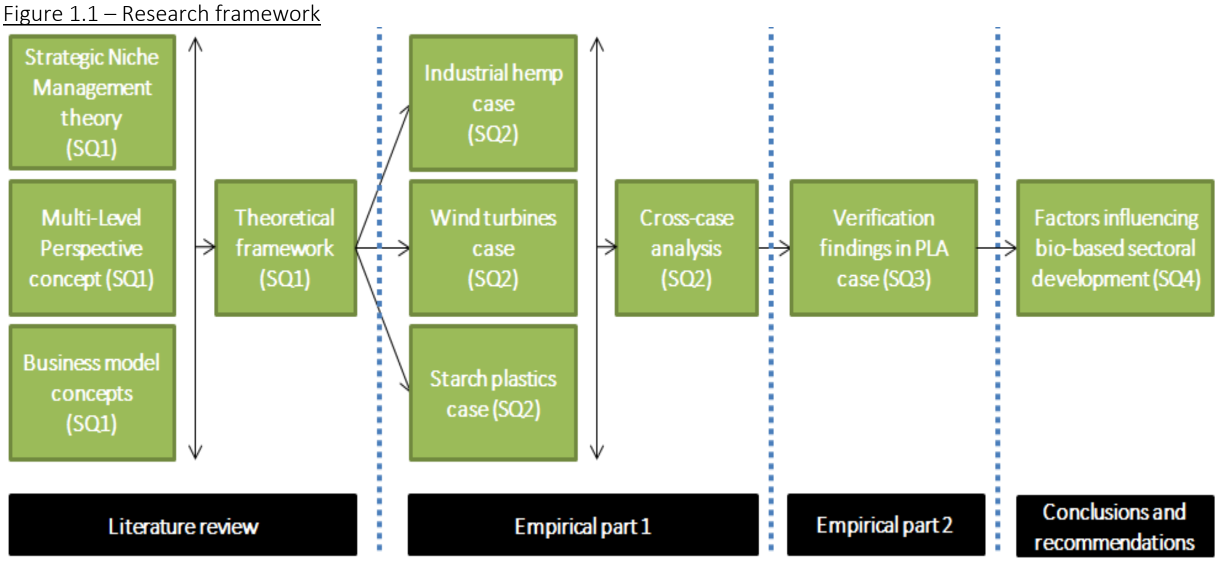
For achieving this research objective, this study conducted multiple case studies in Dutch innovative industries (phenomena of research). In the case selection, attention was paid to selecting both successful and unsuccessful cases in order to promote a (more) equal representation in the cases' rate of success. The Netherlands is explicitly chosen as area of research given its widely claimed potential for developing a biobased economy (Nova institute, 2014; Deloitte, 2014; Bruggink, Hoeven & Reinshagen, 2014; WTC, 2014). Being a relatively small country with a diversity of strengths and relatively strong sectors, the Netherlands proves itself an interesting country for learning. An explanation of prominent terms in the research objective is provided in the appendices. More details regarding the research design can be found in chapter 3, research methodology.

1.3 Research framework

The research framework describes the steps that are taken for realizing the research objective. In this study, the framework comprises of four main steps including a literature review, empirical part 1, empirical part 2, and a conclusions and recommendations part.

In the literature part, a review of the state-of-the-art literature resulted in the constitution of a theoretical framework. This framework consists of several factors which were selected for approaching the complexity of real-life innovation trajectories. Based on this framework, the three different but yet comparable cases were examined in empirical part 1. Here, the results from the individual case studies were systematically analyzed per case, and then compared, among others, for assessing the relevance of the framework in explaining biobased sectoral development. Subsequently, in empirical part 2, the representative and/or high impact findings from the cross-case analysis were verified in the PLA case. The research project finalizes by concluding on and discussing the key factors in/or patterns that can systematically help forward biobased sectoral development, and putting forward recommendations. Figure 1.1 presents the research framework to further clarify the research process. The research objective can be found in the utmost right box of the framework.

Figure 1.1 – Research framework



This study is characterized as *practice-oriented theory-driven research*. Practice-oriented research in the context of case studies means that we investigate particular examples in their natural contexts. The theory-driven aspect relates to the empirical design of this research as we try to analyze theory in practice. Phrased differently, this study will accumulate knowledge from innovation trajectories in order to formulate and implement a theoretical framework for biobased sectoral development. Hence, this research serves both theoretical and practical goals and is assumed to have both theoretical and practical relevance. It can be derived that this study incorporates elements of *problem analysis* and *diagnosis*, as elaborated upon by Verschuren & Doorewaard (2010).

1.4 Research questions

To achieve the research objective a general research question is formulated:

What can be learned regarding the development of a biobased sector in the Netherlands from comparable Dutch trajectories?

For answering the general research question, the following sub-questions (SQ) are formulated:

Literature review

SQ1 *What are the literature-based factors influencing the development of a biobased sector that together constitute the theoretical framework?*

Empirical part 1

SQ2 *Which factors influenced the development of the three cases (results), and what can be derived from comparing these factors? (analysis)*

Empirical part 2

SQ3 *Which factors are influencing the development of the PLA case (results), and what can be learned from comparing these factors with the findings from empirical part 1? (analysis)*

Conclusions and recommendations

SQ4 *How is the theoretical framework represented in practice and what are recommendations for policymakers*?

1.5 Report structure

The report is structured as follows: chapter 2 presents the literature review. Subsequently, chapter 3 presents the research methodology. Chapters 4, 5 and 6 describe the individual case studies. These case studies are cross-analyzed in chapter 7, to see to what extent the theoretical framework is valid and/or constitutes new knowledge regarding biobased sectoral development. In chapter 8 the findings are then verified in the PLA case. Lastly, in chapter 9, conclusions are drawn, findings discussed, and recommendations formulated.

Readers that are specifically interested in the case studies could decide to only read chapters 4 to 8.

2. LITERATURE REVIEW

This chapter aims to disclose literature-based factors influencing innovation trajectories towards biobased sectoral development. It seeks to answer the research question: *What are the literature-based factors influencing the development of a biobased sector that together constitute the theoretical framework?* This study draws factors from three conceptual bases: Strategic Niche Management (SNM), the Multi-Level Perspective (MLP), and the Business Model Perspective (BMP). Firstly, SNM theory is discussed. Secondly, MLP is covered as an extension of SNM concepts. Thirdly, BMP is discussed in relation to (assumed shortcomings in) SNM and MLP concepts. Lastly, the theoretical framework is presented.

2.1 Strategic Niche Management

This section covers Strategic Niche Management (SNM) theory. As described in the introductory chapter, the SNM approach emerged as a reaction on the observation that many firms with sustainable technologies never reach to develop and diffuse in spite of potentially improved (environmental) performance of their inventions (Raven, 2005; Van der Laak *et al.*, 2007). In paragraph 2.1.1, SNM is defined and discussed in relation to this study. In paragraph 2.1.2, the niche internal processes are covered. In paragraph 2.1.3, SNM as a research tool is explained. This section finalizes with a conclusion.

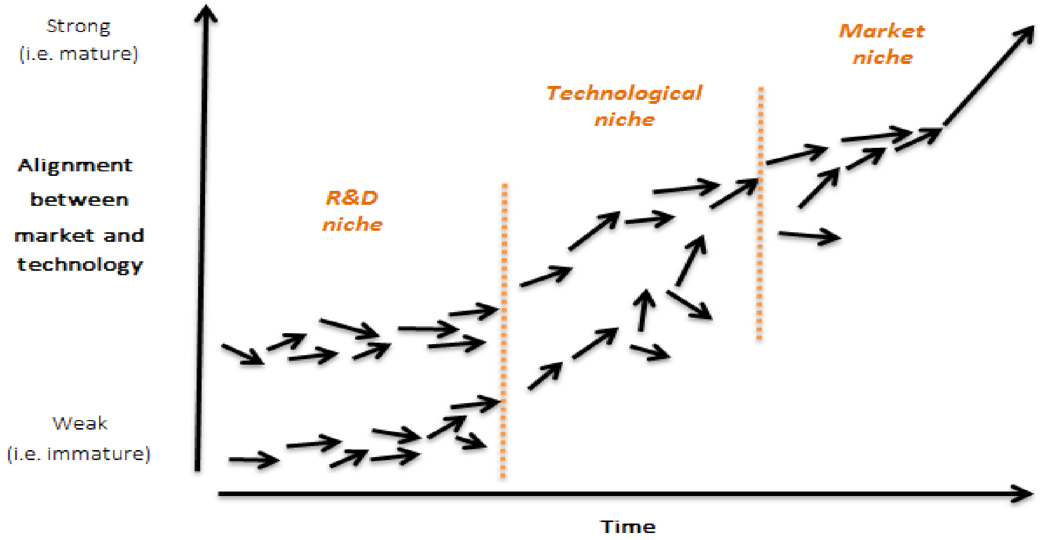
2.1.1 Defining Strategic Niche Management

SNM is defined as ‘’a tool to understand and manage radical socio-technical innovations and facilitate their diffusion’’ (Witkamp, Raven, & Royakkers, 2011). Innovation diffusion is defined as the spreading of an innovation among users (Rogers, 1983). Radical innovation refers to innovation that is not a minor deviation from the prevailing set of technologies, but is radically different (Schot & Geels, 2008). In contrast to incremental innovations, radical innovations are ‘’not based on previous designs and also incorporate changes in, for example, cognitive frameworks and infrastructure’’ (Witkamp, Raven, & Royakkers, 2011). Many sustainable innovations, including biobased innovations, tend to be radical.

Radical innovations are often incapable of immediately competing on existing markets (Loorbach & Raak, 2006), i.e. they are ‘immature’, and need to be developed in a *process of co-evolution of market and technology* (Van der Laak *et al.*, 2007). In this view, the market (i.e. demand) needs to develop in congruence with a specific technology because then the two can conceptually meet. We then refer to an *alignment of market and technology* and both may be considered ‘mature’. Conceptually, *alignment increases when the stability of a variation increases*. In figure 2.1, it is visualized by arrows, each representing a variation, a new business model or initiative, with or without a new technology. Some variations may provide better alignment of market and technology, others are more enduring. Variations may co-exist, but when for example different entrepreneurs/inventors align on technology design, this lowers the variations, making the remaining one more stable, i.e. ‘stronger’ aligned. We posit that ‘alignment’ and ‘stability’ are roughly similar and can be regarded identical. The process of co-evolution of market and technology is critical given the assumption in SNM that *user needs and wants are not fixed;* users have choice and create competition among products (Schot & Geels, 2008). As demand is often not readily available for innovations, SNM herewith highlights the need of protecting innovations (in niches) for achieving innovation diffusion.

In SNM, the concept of niches is used to explain innovation trajectories. Niches may be considered ‘protected spaces’ where inventors can test, nurture and develop their radical inventions. Three kinds of niches are distinguished: R&D niches, technological niches, and market niches. An *R&D niche* is defined as ‘’a protected space in R&D activities’’ (Geels, 2011) that is created on the basis of expectations and has no contemporary market value (Raven, 2005). Typically, both the market and technology in R&D niches show weak alignment, i.e. are immature. *Technological niches* are ‘’special application domains’’ (Raven, 2005) which allow actors (like governments and firms) to develop radical inventions which do not (yet) fit in the existing markets (Schot & Geels, 2008). SNM proposes real-life experiments (i.e. pilot, demonstration) for creating technological niches. Literature claims that experiments stimulate the process of co-evolution and, doing so, work towards societal embedding and adoption of radical inventions (Hoogma *et al.*, 2002; Schot & Geels, 2008). Hence technological niches enable actors to test their technological designs, articulate and align demand and/or technologies towards *stabilizing* the niche (Raven, 2005). A stabilized technological niche may eventually result in market niche creation. A *market niche* is a ‘’specific application domain, where specific, local conditions result in a *user preference* for a new technology over the established technology’’ (Levinthal, 1998). Since there is user preference for the new technology (or invention), generally no extra protection is needed, and market and technology can be considered strongly aligned, i.e. mature (Schot & Geels, 2008). A market niche thus represents the initial strong alignment of market and technology, and thereby a viable business case for inventors. Figure 2.1 presents the *three-stage process of niche development.* The arrows represent different variations which, collectively, help to achieve niche maturity. The alignment of market and technology is presented as the main driver in this process at the Y-axis.

Figure 2.1 - Three-stage process of niche development



In sum, through the three niches, the innovation trajectories of radical inventions can be conceptualized. Deemed to be evident in innovation trajectories is the *alignment of market and technology* given that users have choice. Hence that actors need to work on developing the market in accordance with a specific technology for developing radical inventions from a R&D invention (in a R&D niche) to an experiment (in a technological niche), and towards market introduction (in a market niche). It is posited that *stabilized niches require a strong alignment of market and technology*. Drawing from SNM, this study adopts the three-stage process of niche development as a way to approach real-life regarding innovation trajectories, and operationalizes niche development by means of (the alignment of) the two factors market and technology.

2.1.2 Niche internal processes

The process of niche development is deemed to be managed via three niche internal processes: visioning, networking and learning (Hoogma *et al.*, 2002). *Visioning* includes articulating visions and expectations as these provide ''legitimacy for actors to invest time and effort into a new technology that does not yet have any market value'' (Raven, 2005). In addition, visioning provides direction for learning and legitimates protection (Schot & Geels, 2008). *Networking* refers to processes regarding social networks as these can carry expectations, nurture and develop novelties, for instance via the articulation of new requirements such as legislative adaptations (Grin, Rotmans, & Schot, 2010; Raven, 2005). *Learning* refers to processes for retrieving knowledge in favor of the technology and/or societal embedding in order to facilitate diffusion (Van der Laak *et al.*, 2007).

Multiple studies containing empirical (case) studies (for instance Hoogma *et al.*, 2002; Van der Laak *et al.*, 2007; Bos *et al.*, 2008; Raven, 2005) have discussed niche internal processes in relation to outcomes of niche development. A review of these studies by Schot & Geels (2008) showed that many cases were organized in an overly contained way, meaning that networks tend to be narrow and learning tends to focus on broadening dimensions of innovations (e.g. technical) within the given set of rules and norms, i.e. first-order learning, instead of also questioning the underlying norms, i.e. second-order learning (Hoogma *et al.*, 2002; Grin, Rotmans, & Schot, 2010). Schot & Geels (2008) explicitly point to the role of visions as a *promising research issue* in the process of niche development. Whereas visions and expectations are considered to be 'support mechanisms for triggering further actions', for instance the branching of niches (Raven, 2005), and can overcome barriers and limitations in existing systems (Schot & Geels, 2008), the involvement of outsiders (important actors within networks for example for providing alternative views), and second-order learning appear to do not happen easily (Schot & Geels, 2008; Grin, Rotmans, & Schot, 2010). Hence this study emphasizes on analyzing processes regarding visioning as this appears to be most interesting with regard to usefulness (e.g. expectations can provide legitimacy to actors to invest time when a technology does not yet have market value) and distinctiveness (e.g. finding new knowledge). In a critical interpretation, there is fewer added value expected to gain from analyzing processes regarding networking and learning as these have been widely discussed before and resulted in similar outcomes (Schot & Geels, 2008).

2.1.3 Strategic Niche Management as a research tool

SNM is presented as both a research tool and a policy tool in literature (Schot & Geels, 2008; Bos *et al.*, 2008; Van der Laak *et al.*, 2007; Raven, 2005). *SNM as a research tool* refers to the fitness of SNM as a framework for analyzing specific contexts. SNM is particularly useful for research questions related to *why* a certain innovation trajectory became a success or failure (according to the framework) (Raven, 2005). However, SNM theory needs to be considered a way of *approaching real-life* as it provides a foundation for understanding its complexity and proposes factors which try to grasp this complexity. Hence SNM gives an *estimate of the context* of a research object based on the factors included in the framework. *SNM as a policy tool* refers to the ability of providing *guidelines for influencing* the diffusion of technologies by means of the framework (Schot & Geels, 2008; Raven, 2005). The assumption is that if adjustments of factors in the framework work out positively for the research object, similar adjustments can also be helpful in steering the research object in real-life.

This study uses SNM as a tool for analysis (i.e. research) rather than as a basis for policy. The aim of this study is to learn from the development of earlier Dutch sectoral developments in order to help using current and emerging competitive advantages. Prime focus lies on comprehending a full understanding of the innovation trajectories of the cases with regard to factors influencing innovation diffusion. This way, this study aims to provide levers for policy makers. Although governmental policy is important in analyzing the research objects (see section 2.2.3), this research thus does not aim to propose guidelines for policy as such. In this sense, the research strives to act as a stepping stone towards adequate governmental policy.

2.1.4 Conclusion

This study seeks to grasp the complexity of innovation trajectories towards biobased sectoral development by using, among others, SNM as a framework for approaching and understanding innovation diffusion in real-life (SNM as a research tool). Built on the notion of niches, this study defines innovation trajectories as a process of *niche development* that evolves according to a *three-stage process*: (1) radical inventions move from a R&D invention (in a R&D niche) to (2) experiments (in technological niches), and towards (3) market introduction (in market niches). Here, an increasing alignment of *market* and *technology* is evident as often no markets exist for new (sustainable) technologies (or products) due to their frequently radical character. SNM assumes that inventors require an *alignment of market and technology* for making a viable business case. Literature, however, shows that inventors have a hard time bridging the 'valley of death' between R&D and market introduction. Following the three-stage process of niche development, this imposes that inventors experience *difficulties moving past the phase of technological niches.* Simultaneously, SNM scholars argue that experimentation (i.e. pilot, demonstration) in technological niches is critical for reaching niche maturity. Therefore, in empirical part 1, the research objects are explicitly investigated in moving from R&D to market introduction as apparently many innovation trajectories seem to stagnate there. All in all, this study integrates the factors *market* and *technology* as means to operationalize niche development, and focuses on the *process of visioning*, i.e. the articulation of visions and expectations, as an influencing factor of niche development. Do note that niches and the related factors and/or processes which are described are not the sole forces in innovation diffusion. The next section expands SNM into a three-level model for increasing the understanding of innovation trajectories.

2.2 Multi-Level Perspective

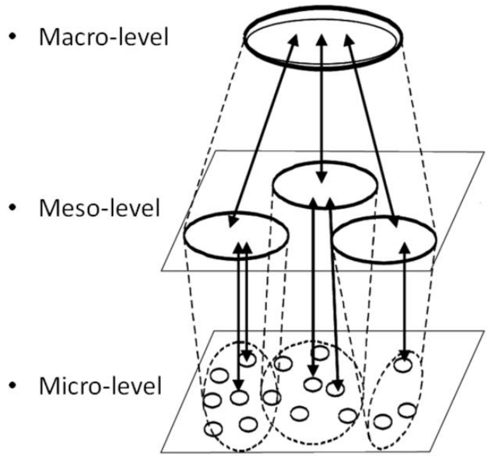
This section covers the concept of the Multi-Level Perspective (MLP) in Strategic Niche Management (SNM). Since the emergence of SNM in the 1990s, SNM focused on the *single level of niches* for understanding innovation diffusion (Kemp, Schot *et al.* 1998; Weber 1999). The assumption was that if niches were properly constructed, new (sustainable) technologies could be nurtured and developed (in niches) by actors until they eventually replace the existing (polluting) technology. Later (since the turn of the century), different authors (H. Bos *et al.*, 2008; Verbong & Geels, 2007; Raven, 2005) applied SNM in a *multi-level conceptualization* consisting of three interacting levels. In paragraph 2.2.1, the three-level model is defined and discussed in relation to this study. In paragraph 2.2.2, the role of interactions between levels is presented. In paragraph 2.2.3, regime stability is discussed. In paragraph 2.2.4, landscape pressure is covered. This section finalizes with a conclusion.

2.2.1 Three-level model

In MLP, innovation diffusion is conceptualized as being dependent on three levels: the level of niches, regimes, and the landscape. The three levels resemble the classic distinction between micro-, meso- and macro-level processes (Jørgensen, 2012) (see figure 2.2). The *level of niches* in MLP is conceptualized at the bottom level of the model and is coherent with the concept of niches as described in SNM (paragraph 2.1.1), and thus our conceptualization according to the three-stage process. Note that in figure 2.2, the 'dots' at the micro-level represent different niches, whereas the arrows in figure 2.1 visualize different variations which, collectively, help to develop a *single* niche. Literature shows that at the level of niches clear overlap exists between SNM and MLP; both concepts, for example, learn that innovation trajectories can be facilitated by creating technological niches.

The added value of MLP in conceptualizing biobased sectoral development is presented via *the involvement of the broader environment*, i.e. regimes and the landscape. Niches are embedded in the *level of regimes* (middle layer of the model). Regimes compose of (groups of) actors which share routines, perceptions and incorporate rules that are specific for a particular regime (Raven, 2005). Examples are the energy- or transport regime. The concept of *rules* is central to regimes and refers to a *shared structure* (e.g. routines, norms, systems etc.) that guides actor behavior (e.g. in innovation) (Raven, 2005). *Actors* are restricted to follow and reproduce the rules in a regime (Jørgensen, 2012), thereby giving stability to the regime via its 'rule-set'. In line with our earlier conceptualization of stability, we posit that *stability refers to the alignment of rules between the actors, in regimes or niches, regarding the factors market and technology*. For regimes, rules are well-articulated and stable, market structures and exchange relationships have stabilized, as well as (cognitive rules such as) technology designs (Grin, Rotmans, & Schot, 2010). The *landscape level* (top layer of the model) represents the relatively hard material and immaterial wider context in which niches and regimes are embedded (Raven, 2005). Parts of this context are for example environmental problems, political coalitions, and lifestyles and cultural beliefs. The relative *harshness* of these factors implicates that actors cannot shape the factors in the short run (Raven, 2005). The three levels need to be interpreted as a *nested hierarchy*.

Figure 2.2 – Linkages in the three-level model (Geels, 2004)

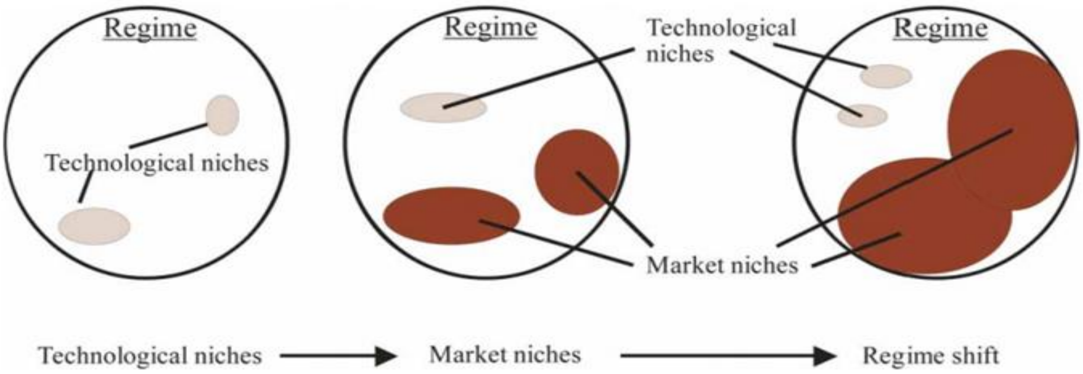


2.2.2 Interactions between levels

MLP explicitly states that innovation diffusion is not the outcome of dynamics at any specific level, but occurs as a result of *interactions between levels* (Raven, 2005) (see arrows in figure 2.2). This indicates an extension of our current conceptualization of innovation trajectories as (the requirement of) interaction of niches with the level of regimes and/or landscape is not yet included. Key notion is that interactions between levels create *windows of opportunity* for niche development. Conceptually, windows of opportunity represent possibilities for niches to diffuse by gaining *momentum*. This study defines momentum as the conceptual force that decides whether a technology breaks through or keeps struggling to diffuse at the level of regimes. Until momentum is gathered by a niche, niche development is expected to evolve slowly. As a consequence, the innovation that is embedded in the niche also diffuses slowly, challenging the perseverance of actors as for instance extra funding and protection are likely to be needed in the innovation process.

However, innovations can reach a decisive point, in innovation management literature denoted as a 'tipping point' (Philips, 2007), where demand suddenly takes off. Momentum may be considered the *impetus* for this process of rapid development, or 'spreading'. A niche gathers momentum when the stability of a regime decreases - referred to as the emergence of *cracks* - while the niche itself stabilized (Grin, Rotmans, & Schot, 2010). This study defines a crack as a source of instability for regimes, a feature or standard other than those in which regimes rule, pressurizing regimes to change. In this conception, due to cracks, regime-actors also begin to engage seriously with the alternatives (in niches). Ultimately, when momentum is gathered by a niche, the (market) niche grows and (potentially) results in the transformation of an existing regime, or emerges as a viable alternative to one (Witkamp, Raven, & Royakkers, 2011). In figure 2.3, the process of spreading presented, visualizing how niches 'spread' at the level of regimes, or in other words, are breaking through at the level of regimes. As described, sectoral development is equivalent to innovation diffusion, defined as the spreading of innovations. Since momentum allows for the 'spreading' of innovations, and innovation diffusion refers them actually becoming widespread (Rogers, 1983), this study posits that momentum is *positively related* to innovation diffusion. *When momentum is gathered by niches, the embedded inventions should thus be able to diffuse such that they constitute new sectors or change existing ones*. Supporting this conceptualization, Geels (2004) argues that when a technology fulfills societal functions (e.g. energy, materials supply), a system may develop at the sectoral level as a result of innovation diffusion. Systems are groups of firms ''active in developing and making a sector's products and in generating and utilizing a sector's technologies'' (Geels, 2004).

Figure 2.3 – Niche development at the level of regimes ('spreading') (Weber *et al.*, 1999)



We argue that momentum (*M*) is a function of niche development (*ND*) and regime stability (*RS*), so $M = f(ND, RS)$. In accordance with MLP literature that states that niche development requires interaction between levels, in particular *niche-regime interaction*, momentum is included as a factor in the theoretical framework. Here, momentum is presented as a precondition for innovation diffusion: the breakthrough of innovation at the sectoral level, such that new sectors are being formed or existing ones adapted.

2.2.3 Regime stability

Regime stability may be considered the 'entrenchment' of actors *and* infrastructures (e.g. production systems) due to an alignment of rules between actors (Unruh, 2000; Raven, 2005). If there is (strong) alignment of rules between the actors in a regime, this namely gives the regime stability and strength to coordinate activities (Geels, 2004). An example of aligning rules is the establishment of codes of conduct as they provide stability to a regime with regard to 'how we do things here'. When a code of conduct emerges and is agreed upon by actors, it is hard to deviate from it and, as a consequence, rules start coordinating actor behavior. In the example of the fossil-based production system, Unruh (2000) refers to this situation as the 'carbon lock-in'.

Interestingly, rules do *not determine* the direction of actor behavior because rules only provide stability to a regime as long as they are carried and (re)produced by actors such as scientists and NGOs (Raven, 2005). Actors thus provide stability to a regime by *sharing* its rule-set. This view also indicates that actors have the ability to break away from the rule-set that frames actor behavior (Raven, 2005; Geels, 2004), particularly the government. Several authors (Bos *et al.*, 2008; Negro, Hekkert & Smits, 2007) claim that the government has a specific role in innovation trajectories as they can disrupt regimes while stimulating niches, for instance by granting legitimacy to stakeholders to develop sustainable technologies (e.g. via target setting in policy) (Raven, 2005; Negro, Hekkert & Smits, 2007), mobilizing resources for innovators (Negro, Hekkert & Smits, 2007) and/or by creating an enabling environment for specific niches (e.g. via taxes, subsidies) (Bos *et al.*, 2008).

Hence that the way actors are entangled in the (re)production of rules may be considered central to regime stability. Actors can be involved in two ways (Jørgensen, 2012): either as game players, or as rule followers. In contrast to *rule followers*, *game players* are actors which attempt to break away from the existing rule-set (related to the predominant product/technology) and/or start sharing new rules (related to an invention) (Jørgensen, 2012). This indicates that when the regime is stable, sufficient rule followers carry the rule-set of the regime. Following this conception, a decreasing regime stability indicates that game players are inducing change in the rule-set of a regime, thereby creating cracks in (the alignment of rules of) the regime. When cracks emerge, one condition regarding the gathering of momentum – namely a decrease in regime stability - is fulfilled. Given that rules, which are being (re)produced by actors, account for niche development on the one hand, and stability and lock-in of existing large-scale systems on the other hand (Schot & Geels, 2008; Geels, 2011; Grin, Rotmans, & Schot, 2010), difficulties in innovation diffusion can refer to problems in actor involvement. This study includes *actor involvement* in the theoretical framework for operationalizing regime stability. Next, landscape pressure is discussed in relation to niche development and regime stability.

2.2.4 Landscape pressure

The landscape represents the *set of macro-level factors* that influences innovation trajectories (Witkamp, Raven, & Royakkers, 2011; Loorbach & Raak, 2006). Parts of this set are for example environmental problems, infrastructures (e.g. electricity, city planning), natural resources, political coalitions, and macro-economic aspects (e.g. oil prices, recessions). When a macro-level factor affects an innovation trajectory, we refer to *landscape pressure*, of which two types are distinguished (Grin, Rotmans, & Schot, 2010), knowing: stabilizing pressures and destabilizing pressures. Particularly destabilizing pressures are deemed to be important for innovation diffusion as they can activate actors (Grin, Rotmans, & Schot, 2010), necessary for stimulating niche development and disrupting regimes. For example environmental problems (e.g. ozone depletion) can activate actors to become game players, and result in cracks in the existing system (e.g. via restrictions on ozone-depleting substances), thereby creating windows of opportunity for niches to develop (Schot & Geels, 2008; Raven, 2005). This study integrates *landscape pressure* as an influencing factor of regime stability and niche development. Given that macro-level factors, in contrast to micro- and meso-level factors, are beyond the direct influence of actors and cannot be changed in a relatively short time period, this study focuses on niche-regime interactions. Emphasis on the slowly changing landscape would divert attention from this study's aim to provide levers for policymakers.

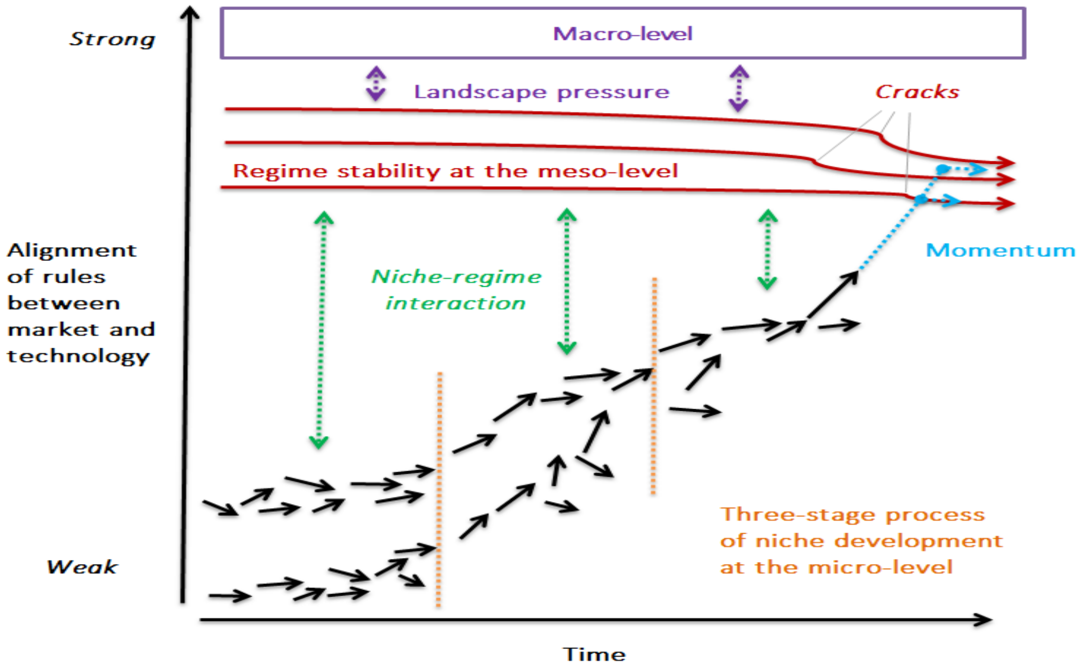
2.2.5 Conclusion

Drawing from MLP literature, the involvement of the broader environment is introduced in relation to niche development. It is argued that innovation diffusion cannot be understood as the result of dynamics on the single level of niches (our current conceptualization based on SNM). Therefore, built on SNM and MLP insights, this study approaches innovation diffusion as the outcome of interplay between niches, regimes, and the landscape.

Whether a (market) niche can diffuse in order to replace an existing regime, in which it is embedded, or become a viable alternative to one (see blue dashed arrows in figure 2.4) is posited to depend on *momentum*. This study defines momentum as the conceptual force that decides whether a technology breaks through or keeps struggling to diffuse at the sectoral level. When momentum is gathered by niches, the embedded inventions should thus be able to diffuse such that they constitute new sectors or change existing ones. This study considers the gathering of *momentum* by niches as a *precondition for innovation diffusion*. A niche gathers momentum when the stability of a regime decreases, i.e. when *cracks* emerge, while the niche itself stabilized (Grin, Rotmans, & Schot, 2010). Hence this study proposes momentum (*M*) to be a function of niche development (*ND*) and regime stability (*RS*), so $M = f(ND, RS)$.

As described in section 2.1, *niche development* is facilitated by an increasing alignment of rules relating to market and technology. *Regime stability*, accounting for the stability of an existing production system, however, hampers niche development via its already strongly aligned rule-set, resisting changes which are primarily to the advantage of niches. Regarding regime stability, actor involvement is found to be central, as rules only provide stability to a regime as long as they are carried by actors, referred to as *rule followers* (Jørgensen, 2012). Interestingly, regime stability decreases when actors adopt the role of *game players* and break away from the rule set of a particular regime, imposing a decreasing alignment of rules between actors, and the emergence of (larger) cracks. This study includes actor involvement in the theoretical framework for operationalizing regime stability. *Landscape pressure* is deemed to influence niche-regime interactions via actor involvement as it can activate game players. In sum, three factors are included in the theoretical framework based on MLP literature, knowing: momentum, regime stability, and landscape pressure. Figure 2.4 presents our conceptualization of innovation trajectories using SNM and MLP. The next section discusses the Business Model Perspective (BMP).

Figure 2.4 – Conceptualization based on SNM and MLP



2.3 Business Model Perspective

This section covers the Business Model Perspective (BMP). Insights from BMP are integrated in the conceptual bases of SNM and MLP for increasing the understanding of innovation trajectories. In addition, empirical appliances of SNM/MLP have revealed shortcomings (Geels, 2011; Raven, 2005). Currently, nor SNM nor MLP allow for the assessment of for instance financial dimensions while these appeared critical in realizing niche development in practice (Jansma, Israël-Hoevelaken, & Wubben, 2014). In paragraph 2.3.1, BMP is defined and discussed in relation to SNM and MLP. In paragraph 2.3.2, the business model design is presented. In paragraph 2.3.3, the relevancy of business model components is covered. This section finalizes with a conclusion.

2.3.1 Defining business models

The business model concept is a relatively new concept and has no theoretical grounding in scientific fields as it was developed in the industry (Teece, 2010). Although relatively few articles address the concept of business models, literature shows an evolvement on business models that is twofold: (1) from static procedures towards dynamic processes, and (2) from closed business models to (more) open business models (see figure 2.5).

Figure 2.5 - Evolvement on business model literature

In the static perspective on business models, the prevalence of deliberate planning characterized the conceptualization of business models. The business model design was controlled by firms in a step-wise procedure that did not take into consideration changes (e.g. in the market and/or business). In 2002, Osterwalder & Pigneur proposed the Business Model Framework to illustrate the set of interrelated elements that make up firms. Built on four pillars that basically outline *what* a firm has to offer, *who* is targeted with this, *how* this can be realized and *how much* can be earned (Osterwalder & Pigneur, 2002), they gave rise to a framework to seize the 'logic of firms' and that may be considered a static perspective. In 2003, the paradigm of open innovation was coined by Chesbrough, what referred to (new) principles in doing business and more 'openness'. For instance outside-in rather than inside-out was promoted with regard to business models, as well as incorporation of the belief that business models cannot be fully anticipated in advance, i.e. require iteration (McWrath, 2010). The latter, and more broadly the emergence of openness, imposed that business model design is currently deemed to be a *dynamic process* rather than a *static procedure*. Additionally, following the open innovation paradigm, business model design was increasingly viewed as transcending beyond the own firm. For example making use of both internal and external ideas is advised in 'open business models, i.e.

business models based on open innovation, whereas 'closed business models' emphasize on creating and developing the best products individually (Chesbrough, 2006).

Recently, the business model concept was updated according to the open innovation paradigm in combination with a dynamic approach to business model design (McWrath, 2010; Teece, 2010; Osterwalder & Pigneur, 2010). Built on the new principles, Osterwalder & Pigneur (2010) proposed a concept named Business Model Canvas (BMC). In contrast to the static predecessor, the BMC may be considered a dynamic and open model that is innovation-centred and interaction-based. In line with SNM and MLP, it is argued that inventors need to experiment with their technology and business model in the early phases of development. Overall, many different definitions and business model components can be found as there is a lack of unified terms.

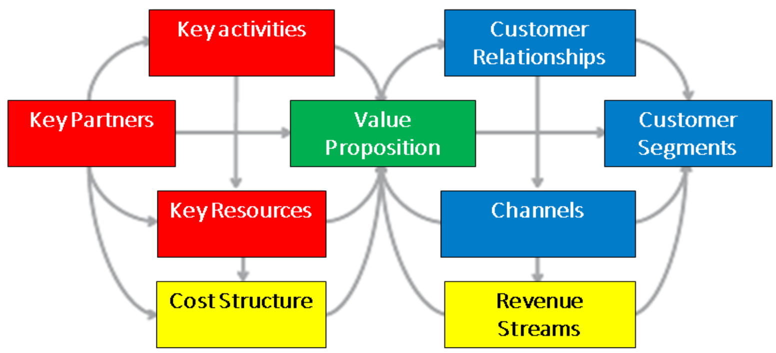
Regardless of disagreements on terms in literature, there is agreement that all firms incorporate business models. Business models (are conceptual tools that) define how a firm ''creates and delivers value to customers, and then converts payments received to profits'' (Teece, 2010). Thus, business models should provide value to the customer and appropriate value to the implementer, i.e. the inventor (Chesbrough, 2010). The assumption is that inventions do not create value *naturally* and simply capture value by making it available for customers, who will always pay for it, in pre-existing markets (Chesbrough, 2010; Teece, 2010). To the contrary, and in line with SNM and MLP, the Business Model Perspective is built on the notion that *user wants and needs are not fixed*. Instead, BMP literature claims that *markets may not even exist* for new technologies so demand first needs to be created *via* business models of inventors (Chesbrough, 2010). Hence business models are considered to be 'market devices' which allow (or hinder) inventors to unfold their invention's assumed potential (Boons, Montalvo, Quist, & Wagner, 2013). Phrased differently, business models can translate technology inputs (e.g. radical inventions) into economic outputs (e.g. commercially available products, profit) (Chesbrough, 2010).

Because business models translate technical success into commercial success (Chesbrough, 2010; Teece, 2010), *difficulties in niche development can refer to struggles in creating viable business models*. Business model design is a key decision for inventors who create a new firm, and managers who are ''charged with rethinking their old model to make their firm fit for the future'' (Zot & Amit, 2010). This study analyses the cases against the background of BMP at the micro-level as business models can be regarded firm-specific. This study, however, applies BMP by conceptualizing that not one firm attempts to develop activities, but a *group of particular firms*, or a *cluster of firms*, and which experience similar pressures in their innovation trajectories concerning the components that constitute a business model. Next, the business model design is discussed.

2.3.2 Business model design

The business model concepts in literature can be characterized by a lack of unified terms and, consequently, a variety of concepts exists. This study selects the concepts of Osterwalder & Pigneur (2010; 2003; 2002) for describing the business model design for two reasons: their models (1) are based on *similarities of a wide range* of business model conceptualizations, and (2) clearly capture the *generic* elements of a business model. According to Osterwalder & Pigneur (2003; 2002) a business model design is built on *four pillars*: the Infrastructure, Offering, Customers, and Finances. Each pillar composes of *one or more components* of a business model. Figure 2.6 integrates the components of the most recent framework (2010) in a canvas design that demonstrates the connectivity of components. The colored boxes in the figure display what pillar includes which components (Infrastructure: red; Offering: green; Customers: blue; Finances: yellow).

Figure 2.6 - Business Model Canvas (adapted from Osterwalder & Pigneur, 2010)



The different pillars and components from figure 2.6 are described next.

Infrastructure

Infrastructure refers to the ''configuration of activities and resources between the firm and its partners in order to create value and reach the customer'' (Osterwalder & Pigneur, 2003; 2002). Derived from the canvas, Infrastructure influences the components Cost Structure and Value Proposition.

Three components make up the pillar Infrastructure: Key Partners, Key Activities, and Key Resources (Osterwalder & Pigneur, 2010). *Key Partners* refer to the collaborating parties of a firm, which help leverage the firm's business model as some activities may require to be performed externally. *Key Activities* include all the processes that a firms needs to perform well because they are vital for the functioning of the business model. *Key Resources* include the indispensable assets and capabilities in a firm's business model.

Offering

Offering refers to the bundles of products and services which the firm offers to its customers, and how it differentiates itself from competitors (Osterwalder & Pigneur, 2002). The offering composes of the *Value Proposition* what is defined as ''the value created for users by an offering based on technology'' (Chesbrough, 2010). Thence the offering can be regarded as the value creating 'promise' on which the firm operates. According to Osterwalder & Pigneur (2010), value propositions should seek to *solve customer problems* and *satisfy customer needs*. Conceptually, Value Proposition is pictured at the centre of the canvas as it is deemed to be essential in linking the left side of the canvas (e.g. Cost Structure) with the right side (e.g. Revenue Streams). Without an *effective* value proposition, potential users will not be interested in firms with new technologies and, as a consequence, their innovation processes will likely stagnate.

Customers

Customers covers all customer related aspects. As derived from the canvas, the components of the pillar Customer account for the Revenue Streams. Three components make up the pillar Customers: Customer Relationships, Channels, and Customer Segments (Osterwalder & Pigneur, 2010).

Customer Relationships outline the type of relationships each Customer Segment expects firms to establish and maintain with them, the relationships that are already established by firms, and how they are integrated with the rest of the business model (Osterwalder & Pigneur, 2010). Examples of customer relationships are communities or co-creation. *Channels*, also described as 'touch points', include all the ways through which firms interact with *all* their customers and deliver value (e.g. via communication, distribution and sales channels) (Osterwalder & Pigneur, 2010). *Customer Segments* include all the customers and organisations for whom firms are creating value. A firm serves one or several customer segments (e.g. mass market, niche market), i.e. users to whom a technology is useful (Chesbrough, 2010).

Finances

Finances refer to the *financial aspects* of a business model. Here, the focus is to have balance in finances in order to ensure long-term (financial) success of firms (Osterwalder & Pigneur, 2002). Two components make up the pillar Finances: Cost Structure, and Revenue Streams (Osterwalder & Pigneur, 2010).

Cost Structure includes ''all the costs the firm has to incur to create, market and deliver the value proposition'' (Osterwalder & Pigneur, 2002). The costs a firm has to incur depend on the focus of the business model. If for example a business model is cost-driven, focus lies on minimizing costs while when it is value-driven, costs matter less and focus primarily lies on creating value. Here, it is thus important to estimate the *size of opportunities/markets* with regard to costs. *Revenue Streams* result from value propositions successfully offered to customers and include the ways firms make income (Chesbrough, 2010). Several ways exist to generate revenue streams. Key is the pricing model (Osterwalder & Pigneur, 2003; 2002). As can be derived from figure 2.6, the Cost Structure flows from the set-up of the Infrastructure, and Revenue Streams flow from Customers.

2.4.3 Relevancy of business model components

Built on the business model design (Osterwalder & Pigneur, 2010; 2002), three components are viewed to be relevant for this research: Value Proposition, Cost Structure, and Revenue Streams. The component *Value Proposition* is at the center of the canvas and conceptually links the cost side with the revenue side of a business model. When a value proposition is not appealing, it is unlikely that users will be attracted by the offer of an inventor and its innovation process will likely stagnate due to a lack of interest. The factor *Finances*, consisting of the components *Cost Structure* and *Revenue Streams*, may be considered relevant for this research as financial aspects appeared critical in organizing and realizing niche development in practice (Jansma, Israël-Hoevelaken, &

Wubben, 2014), and SNM and MLP currently lack such dimensions for analyzing the success or failure of innovation pathways. Revenue streams are regarded as the translation of value propositions into ways of generating value with the aim to exceed the cost structure. Underlining the importance of the components described, Teece (2010) argues that ''a good business model yields value propositions that are compelling to customers, achieves advantageous cost and risk structures, and enables significant value capture by the business that generates and delivers products and services''. All in all, two separate factors are thus included in the theoretical framework as influencing factors of niche development: Value Proposition, and Finances.

Six other components are excluded from the theoretical framework. The component *Customer Segments* is excluded because it is roughly similar to the factor Market (that is already included), and can be regarded identical (Osterwalder & Blank, 2015). The same goes for the component *Key Partners* that is excluded from the theoretical framework as it shows overlap with the factor Actor involvement. It should be noted that Key Partners mostly refer to commercial partners while actors also include noncommercial actors. Nevertheless, the added value of Key Partners as a separate factor would most come to light when this study emphasized on (value) networks, but this is not the case. The components *Key Activities, Key Resources* and *Channels* appear to lack relevance in relation to this study because they mainly refer to matters which inventors should be able to arrange internally and should not necessarily be problematic for innovation trajectories from the perspective of a group of particular firms. The component Key Resources is (partly) addressed via the factors Finances and Technology given the four types of key resources (Osterwalder & Pigneur, 2010): physical, intellectual, human, and financial. This study explicitly excludes human resources (e.g. qualified employees) as inventors should also be able to arrange component of a business model internally. Finally, the component Customer Relationships is excluded as the type of relationships (established) is expected to have little added value for this study.

2.4.4 Conclusion

Drawing from BMP literature, demand first needs to be developed *via* business models created by inventors. As business models can translate technical success into commercial success (Chesbrough, 2010; Teece, 2010), this study posits that difficulties in niche development can refer to struggles in creating viable business models. Three out of nine components of the business model design as proposed by Osterwalder & Pigneur (2010) are expected to be relevant for this research, and resulted in two extra factors for the theoretical framework: Value Proposition, and Finances (consisting of the components Cost Structure and Revenue Streams). This study posits that the value proposition is critical in innovation trajectories as it should create a fit between the market and a particular technology, also referred to as the 'Product/Market fit' (Blank, 2014; Osterwalder & Pigneur, 2010), considered to be a requirement for generating revenue. In addition, value propositions should differentiate the firm from competitors when seeking to solve customer problems and satisfy customer needs (Osterwalder & Pigneur, 2010). If the offer of an inventor is less compelling than what (existing) competitors offer, the innovation process of the inventor will likely stagnate. Furthermore should the cost structure and revenue streams be balanced for ensuring the long-term success of inventors. In the empirical appliance of insights from BMP it is conceptualized that, instead of one firm, a *group of particular firms* (or a cluster) attempts to reach innovation diffusion and experiences similar pressures in their innovation trajectories regarding the components of their business models. The next section presents the theoretical framework.

2.4 Theoretical framework

This section covers the theoretical framework. The theoretical framework is presented in figure 2.7, presenting the set of exogenous variables which are proposed being related to the endogenous variable. First, innovation diffusion is discussed. Second, momentum is covered as a precondition for innovation diffusion. Third, niche development and the influencing factors are presented, followed by regime stability, and landscape pressure.

First, *innovation diffusion*, presented as the endogenous variable in this study, is defined as the *spreading* of innovations among users (Rogers, 1983), such that the innovations change existing sectors or constitute new ones (locus of research). Phrased differently, built on SNM and MLP concepts, innovation diffusion conceptualizes the breakthrough of an innovation towards replacing an existing regime, in which it is embedded (in fact the niche), or becoming an alternative to one.

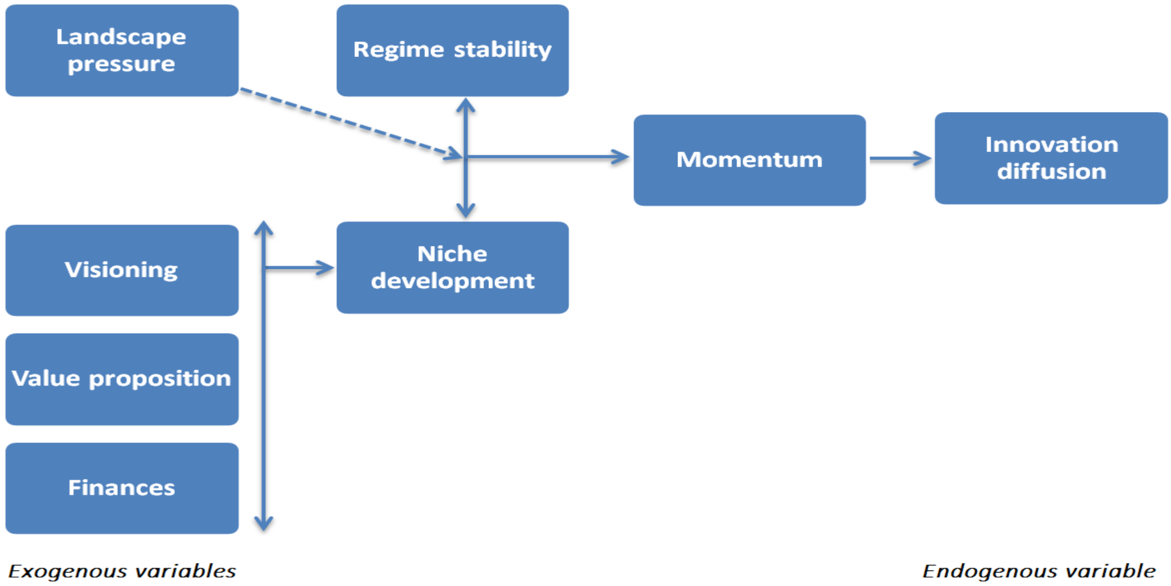
Second, inventors aiming at developing and diffusing their innovations should operate in niches (Loorbach & Raak, 2007; Unruh, 2000). However, whether an innovation in a niche is able to diffuse depends on *momentum* (Grin, Rotmans, & Schot, 2010). This study considers momentum to be the *impetus* for the process of (rapid) diffusion of an innovation, or spreading. Hence momentum is presented as the conceptual force that decides whether an innovation breaks through *or* keeps struggling to diffuse at the sectoral level. Momentum can be gathered by a niche when the regime stability decreases, i.e. cracks emerge, while the niche itself stabilized (Grin, Rotmans, & Schot, 2010). Hence momentum (*M*) is presented in the theoretical framework as a function of niche development (*ND*) and regime stability (*RS*), so $M = f(ND, RS)$. This study posits that momentum is a precondition for innovation diffusion that is positively related to the latter such that when momentum is gathered by a niche, the embedded innovation should be able to diffuse.

Third, built on the notion of niches, innovation trajectories are approached as evolving via a three-stage process of *niche development* (Schot & Geels, 2008). In this conception, inventions move from R&D niches, via experimentation in technological niches, towards market niches. Drawing from MLP, it is posited that niche development is facilitated by an *increasing alignment of rules relating to market and technology* (Raven, 2005; Van der Laak *et al.*, 2007). This study included *market* and *technology* in the theoretical framework as factors for operationalizing niche development. It is furthermore posited that the two factors should be (strongly) aligned for creating a viable business case for inventors, and stabilizing the niche. The latter is, besides a decrease in regime stability, one of the two conditions for niches in gaining momentum. Built on SNM and BMP literature, three factors are selected for influencing niche development: (1) the process of *visioning*, i.e. the articulation of visions and expectations, (2) *value proposition*, and (3) *finances*.

Fourth, whereas niche development is facilitated by an increasing alignment of rules related to market and technology, the already strongly aligned rule-sets of regimes account for the stability of existing production systems. SNM literature states that regimes herewith resist changes of rules that primarily are to the advantage of niches. Regarding *regime stability*, actor involvement is found to be central, as rules only provide stability to a regime as long as they are carried by actors (Raven, 2005). Hence regime stability indicates that actors carry the rule-set, referred to as the *rule followers* (Jørgensen, 2012). Interestingly, regime stability decreases when actors adopt the role of *game players* and break away from the rule-set, thereby creating *cracks* in the regime. When cracks emerge, one condition regarding the gathering of momentum – a decrease in regime stability - is fulfilled. Hence this study posits that difficulties in innovation diffusion can refer to problems in actor involvement. This study includes *actor involvement* as a factor in the theoretical framework for operationalizing regime stability.

Fifth, drawing from literature on MLP, *landscape pressure* can activate actors in adopting the role of game players (e.g. via environmental concerns), making them break away from the (predominant) regimes and (potentially) starting to support (challenging) alternatives (in niches). In figure 2.7, we present landscape pressure as an influencing factor of niche-regime interaction. We acknowledge that cases may be found wherein the landscape merely affects a single regime instead of also associated niches, if any. However, since this study specifically relies on cases wherein innovations aim to replace existing products, the current representation of landscape pressure (see dashed blue arrows in figure 2.7) was regarded the best choice for this research project. The arrows represent causal relationships. The theoretical framework is applied in the first empirical part, after operationalizing each factor in the following chapter.

Figure 2.7 - Theoretical framework for trajectories of sectoral development



3. RESEARCH METHODOLOGY

This chapter elaborates on the empirical research design and outlines which steps are taken in order to conduct empirical parts 1 and 2. Firstly, the field procedures are discussed. Secondly, the operationalization process is presented. Lastly, the empirical data analysis is described.

3.1 Field procedures

This section covers the field procedures. This study aims to learn from the development of recent Dutch innovation trajectories in order to signal key factors in/or patterns that can systematically help forward biobased sectoral development. Given the complexity of real-life trajectories, and the need to trace factors over time instead of analyzing mere frequencies, this study relies on the *case study design*. Three cases were selected for empirical part 1, and one case for empirical part 2. Data comes from two sources: documents, and interviews. A total of 19 interviews were conducted (see expert selection criteria in 3.1.3 and appendices). By corroborating information from documents with that from interviews, and vice versa, this study triangulated the obtained insights with information that is supportive. This study explicitly integrated *triangulation of evidence* since the case study design is the sole methodology (also see paragraph 3.3.3). *Note that the development during the interviews, with regard to aspects brought in by the researcher and the refinement of these aspects, did not outweigh the preliminary work that was performed and came forward in each interview*. Overall, the research strategy includes qualitative research methods given that depth was preferred over breadth. In paragraph 3.1.1, the case study is discussed. In paragraph 3.1.2, the case selection is covered. In paragraph 3.1.3, the data sources are presented, followed by the case study interview in paragraph 3.1.4, and protocol in paragraph 3.1.5.

3.1.1 Case study

This research project relies on case study research as the main research strategy for collecting and analyzing empirical data. Case studies offer ''detailed insights into mechanisms, motives of actors, and constraints they face at particular moments'' (Hancké, 2010). A case can be ''anything, as long as it is, as an object of research, *limited in time and space*, and allows you to say something meaningful *beyond* the case in question'' (Hancké, 2010). The latter refers to the wider phenomenon that a study is trying to get sense of. In the current research, this entails biobased sectoral development.

Several scholars explored advantages and disadvantages of case study research (Hancké, 2010; Bryman, 2008; Yin, 2003). In relation to this study, we consider the advantage*s* to be threefold: (1) case studies can be employed in an embedded design, i.e. multiple levels of analysis can be applied (Eisenhardt, 1989), while (2) retrieving in-depth insights into the research objects (Verschuren & Doorewaard, 2010; Yin, 2003). In addition, (3) results are more easily accepted by stakeholders because the holistic and meaningful characteristics of real-life contexts are retained in case studies (Verschuren & Doorewaard, 2010; Yin, 2003). One disadvantage of case study research is the potential lack of rigor. For example, researchers can let biased views influence the results, or do not follow a systemic approach in conducting the case studies (Yin, 2003; Eisenhardt, 1989). As an answer to these concerns, this study focuses on *data triangulation*, a way of cross verifying data by using at least two methods (Bryman, 2008). This study furthermore formulated an interview protocol including general rules to be followed in the empirical parts. Another claimed disadvantage is that case studies provide little basis for generalization (Hancké, 2010; Bryman, 2008). This is the result of questionable external validity since the number of research objects is typically small in case studies and the selected cases frequently similar to each other (Verschuren & Doorewaard, 2010). In response, this study selected *multiple, different but yet comparable cases* in order to obtain a better position in establishing the circumstances in which the theoretical framework will or will not hold. In paragraph 3.3.3, more readings with regard to the quality of research are provided.

3.1.2 Case selection

Case selection is strategically performed such that the selected cases serve a specific purpose within the overall scope of the inquiry. Given the relative newness of the biobased economy, most sectors are still limited to a relatively small number of firms. Therefore, in order to investigate biobased sectoral development, this study reasons that lessons should be learned from earlier trajectories of sectoral development which are *comparable* to biobased settings. The following case selection criteria are applied:

1. Involvement of multiple commercial firms, located in the Netherlands
2. Illustrating a trajectory of sectoral development (figure 2.7), preferably recent

3. Instructive for the transition to biobased products, i.e. can be linked to biobased sectoral development
4. Engagement in (sustainable) innovative practices
5. As a whole, the cases demonstrate a mixture in the success of sectoral development

Whereas the first four criteria account for a degree of uniformity in the cases, the fifth criterion underlines the importance of distinctiveness in order to gain a varied picture of sectoral developments. Regarding the first criterion, the Dutch situation is explicitly chosen as area of research due to its widely claimed potential for developing a biobased economy (Nova institute, 2014; Deloitte, 2014; Bruggink, Hoeven & Reinshagen, 2014; WTC, 2014). Regarding the second criterion, a trajectory of sectoral development refers to the trajectory as displayed by the theoretical framework. Regarding the third criterion, both the expected relevancy of factors from the theoretical framework and the definition of biobased economy as put forward by Hackmann & Harmsen (2012) were leading in assessing the cases' suitability.

Four cases are selected as research objects: one different but yet comparable case, namely *wind turbines*, and three biobased cases, knowing *industrial hemp, potato starch plastics*, and *poly lactic acid (PLA).* Whereas the PLA case can be seen as the 'ongoing case' with high potential still, the three other cases were at similar starting points, but ended up being different by 2015. Explaining this difference, by means of the theoretical framework, and subsequently verifying the learnings in the PLA case is how this research project is set up. As also described in the introductory chapter, thence two empirical parts are identified. Next, the cases are introduced, after which table 3.1 presents the selection criteria and characteristics per case.

Wind turbines
After the 1973-oil supply squeeze, alternative renewable resources such as wind energy were extensively discussed in the Netherlands. Referring to the Dutch windmills-tradition, the Netherlands had to become an international frontrunner in wind turbine production. Despite relatively high enthusiasm of stakeholders at different timings, the Dutch wind sector could not live up to the high expectations. Interestingly, wind turbines seemed to trigger actor involvement, similar to the biobased economy, but failed to develop accordingly. At present, the Dutch wind sector may be considered a mature, stable sector, but the share of renewable energy in primary energy consumption when comparing the Netherlands with other European Union countries is still relatively low (Kaldellis & Zafirakis, 2011). This study included this case as a benchmark for the biobased cases.

Industrial hemp
Industrial hemp refers to the high growing variety of the plant *Cannabis Sativa*, and has been extensively cultivated throughout history for its multipurpose plant components. Until the year 1910, industrial hemp was also produced in the Southwest Netherlands, mainly for its strong fibers from the plant's stalk. Since the 1990s, hemp cultivation restarted in the Northeast Netherlands due to Dutch policy. In the course of time, several hemp derivatives have (again) been marketed by entrepreneurs, attempting to utilize specific characteristics of hemp components (e.g. moisture regulative capacity) for becoming widespread. Several factors from the theoretical framework play a role herein, among which regime stability, promoting the learning outcomes.

Starch plastics
For decades, starch derivatives are being used as adhesives in food recipes and coatings. In the 1990s, also stimulated by Dutch policy, the Dutch cooperative AVEBE managed to develop functional starch plastics out of potatoes (AVEBE, 2015). Starch is found as granules in several crops and has clear advantages such as biodegradability in the natural cycle when converted into bioplastic (Lörcks, 1997). In the Netherlands, starch plastics are used to produce various items, ranging from foams to dog bones. The uptake of starch plastics, however, may be considered troublesome, having to cope with regimes.

Poly lactic acid (PLA)
PLA is typically obtained via the fermentation of starch (from crops like sugar cane) into lactic acid that is then polymerized, representing another class of plastics (Imre & Pukánszky, 2013). PLA received much attention as an alternative to synthetic plastics (Food & Biobased Research Wageningen University, 2015) and, though from a relatively small base, demand for PLA is expected to rise substantially in the upcoming years (Bos & Sanders, 2013; Nova Institute, 2013). Currently, the Dutch firm Corbion is global market leader in lactic acid production. Given that the development of a strong Dutch bioplastics industry is believed to be a true possibility (Deloitte, 2014), PLA is included in this research project as the central biobased case for learning.

Table 3.1 – Overview selected case studies

Cases Selection criteria	Empirical part 1 Wind-turbines	 Industrial hemp	 Starch plastics	Empirical part 2 Poly lactic acid (PLA)
Involvement multiple firms, located in the Netherlands	V e.g. Lagerwey, NedWind, EWT, WES	V e.g. HempFlax, Dun Agro, Pantanova	V e.g. Rodenburg, Paragon Pet Products, AVEBE, PaperFoam	V e.g. Corbion, Synbra, NatureWorks
Recent sectoral development	V 1970-2015	V 1990-2015	V 1990-2015	X 2000-2015
Instructive for biobased sector	V	V	V	V
Innovative practices	V	V	V	V
Mixture in (Dutch) success	-/+	-/+	+/-	-/+
General statistics				
Number of firms	< 25	< 10	< 10	10 – 15

The selected cases should be able to provide learnings regarding biobased sectoral development. Where the wind-turbines case can be seen as a benchmark case, the other cases represent trajectories which had their own dynamics, developed over a longer period of time, and are (sub-)sectors of the biobased economy. In addition, the cases differ in scale, and include multiple firms which experienced developments from the beginning.

3.1.3 Data sources

Interviews and documents are the main sources of information. This study favored *qualitative methods* (over quantitative methods) as they are most helpful in examining cases in a detailed way (Bryman, 2008). For building the cases, documents laid the groundwork, after which a *combined approach* of documents and conducting interviews is applied. This study explicitly integrated *triangulation of evidence* since the case study design is the sole methodology. This way, profound understanding of the cases is gained. Note that the development during the interviews, with regard to aspects brought in by the researcher and the refinement of these aspects, did not outweigh the preliminary work that was performed and came forward in each interview. The case studies were approached in a similar manner *(preparation, exploration, conversation*) for creating *overlap in data*, thereby giving the researcher a head start in analysis (also see paragraph 3.3.3) (Eisenhardt, 1989).

Documents

Documents refer to a broad category of *documentary information* such as formal studies, articles appearing in the media, or internal records. In this study, documents provide the *groundwork* for the case studies. Groundwork implies that a *dossier* is built for each case with information regarding the factors of the theoretical framework. The documents provided (partial) answers to particular questions, and also guided further explorations of cases. If for example a report highlighted an important event in a case, then this finding provided directions for further research. Two options are distinguished for gathering additional information: (1) through searching extra documents, or (2) by adding predetermined questions to the interview schedule (section 3.2.2). Each case is approached in a similar manner: *preparation, exploration, conversation*. Documents laid the initial groundwork of a case (preparation), after which this groundwork provided directions for additional information gathering via documents (exploration) or via interviews (conversation). Table 3.2 displays the search words used in the preparation phase of this thesis.

Table 3.2 – Search words for the preparation phase

Section	Factor	Variables	Search words
Niche development	Market	Customer jobs	Application, customers, early adopters
		Gains	User wants, demand
		Pains	User needs
	Technology	Readiness	Bottleneck, progress, development
		Maturity	Experimentation, R&D, valley of death
	Visioning	Robustness	Vision, expectation, invention
		Specific	Convergence
		Quality	Enthusiasm, perseverance
	Value	Pain relievers	Customer satisfaction

	proposition	Gain creators	Performance, advantages
		Products and services	Offer, bundle
		Differentiation	Unique selling points, differentiation
	Finances	Business model focus	Cost driven, value driven, business model
		Economies of scale and/or scope	Cost leadership, scale effects, specialization
		Variable versus fixed costs	Cost structure, variable costs, fixed costs
		Pricing model	Turnover, pricing
		Return on investment	Margin, returns, profit, balance
Regime stability	Actor involvement	Game players	Stakeholders, government, NGOs, policy
		Rule followers	Participation, support
Landscape pressure	Stabilizing effects		Environment, protection
	Destabilizing effects		Disruptive, pressure, macro-level
Momentum			Consensus, breakthrough
Innovation diffusion			Acceleration, rapid development, diffusion

Since documents can provide specific details to corroborate information from other sources (Yin, 2003), this study used documents in parallel to interviews. It is considered beneficial that documentation is stable (as it can be reviewed repeatedly), is exact (as it contains names, references and details of events), and has broad coverage (meaning it includes a long span of time, many events, and many settings) (Yin, 2003). The usefulness of documents is, however, criticized as every document is written for some *specific audience and purpose* (Verschuren & Doorewaard, 2010), likely to be different from our research objective. Hence reliability of the source is evaluated by the researcher when using so-called *secondary resources*.

Interviews

Besides documents, this study relied on interviews. Interviews are 'guided conversations' (Whiting, 2008) between two or more people where questions are asked to elicit information. Interviews are chosen as these are generally easier for the respondent when the questions are mainly open-ended (Hancké, 2010). The interviews in this study served *two goals*: (i) to extract new information regarding the literature-based factors, and (ii) to verify information that was retrieved from documents or other interviewees. The interviews were *semi-structured* as this left room to ask the respondent follow-up questions. The latter was conducive for fully comprehending the subjects of matter. Overall, interviews provided information in factors via the experiences of interviewees. It was assumed that these experiences were embedded in the tacit knowledge of the interviewees.

The majority of interviews were conducted face-to-face. Face-to-face interviews were preferred over telephone or online chat as the former tends to better 'engage' respondents in the process (Bryman, 2008; Opdenakker, 2006). Interviewees also might experience the subjects under study as complex, or even old, so that they needed time to recall facts like the course of events. Also the *ability to observe social cues* of interviewees, e.g. signs of puzzlement (Opdenakker, 2006), seem to have benefitted the quality of the information flow. Note that if questions were restated or explained by the researcher as a reaction on social cues, this was handled in a standardized way as far as possible.

Expert selection

The majority of respondents in empirical part 1 were active at commercial firms. For verifying the findings from empirical part 1, merely respondents from high-profile commercial firms were included in empirical part 2. Per case in empirical part 1 the following expert selection criteria were applied:

1. At least one respondent is active in a knowledge institution (applied research)
2. At least one respondent is active in the government
3. At least one respondent is active at a commercial firm
4. Respondents need to have profound knowledge of the focal sector
5. Respondents need to be willing to cooperate within the time span of the research project

Criteria 1-3 accounted for the inclusion of three important stakeholders influencing innovation trajectories, also known as the so-called golden triangle in innovation (Rijksoverheid, 2015). Firstly, *knowledge institutions* produce basic and applied research, both vital for learning (Vinding, 2001). Examples are research institutes, consultancy firms and/or technological institutes. Secondly, as described in chapter 2, the *government* has a specific role in innovation as they are for instance able to stimulate innovations while discouraging the use of (polluting) counterparts. Thirdly, *commercial firms* are responsible for marketing the innovations. For increasing the likelihood of including respondents from commercial firms with a knowledge base that is useful, focus lied on contacting those commercial firms with an *own production facility* (and thus were not merely a trading office). Otherwise, respondents were likely to fall short on for example technological knowledge as the manufacturing might be outsourced. For instance no specific respondents from NGOs were included due to the view that these were less crucial in the selected case studies. Note that the role of NGOs did come to light during data gathering, but not through the inclusion of a specific interviewee. The fourth criterion referred to the desired knowledge base of respondents as these were (sometimes) asked to *transcend beyond the own firm* in their answers.

3.1.4 Case study interview

Following the structure of the theoretical framework, the interviews in empirical part 1 composed of five sections: niche development, regime stability, landscape pressure, momentum, and innovation diffusion. The sections naturally flowed right into each other during the interviews, starting with questioning the factors related to niche development. Since it was questionable that every interviewee had profound knowledge of *all* factors, flexibility in data collection was applied. Consequently, the five sections, composing of nine factors in total, were addressed via an interview schedule including (1) a common part, and (2) a flexible part of question items. Unlike common part questions, the questions from the flexible part were *not asked to all interviewees*. If for example an interviewee was able to provide new insights into the factor of matter based on the common part questions, then the flexible part was applied also. In the view of the researcher, this procedure (1) respected interviewees' knowledge base, and (2) provided the researcher levers to act on this knowledge, promoting an interviewee's added value for the research.

Common part

The common part comprised of open questions and dichotomous questions for exploring the knowledge base of interviewees. *Dichotomous questions* represent 'fixed alternative' questions that have two possible responses, mostly a contrast (Hancké, 2010). By presenting the interviewees a choice between two responses, that covers the essence of a factor, this *challenged the interviewee* to review his statements and sharpen their answer. At most two open questions were predetermined and always one dichotomous question is stated by the researcher per factor in the common part. Where the *open questions* invited the interviewee to think, reflect and give opinions, the dichotomous questions sharpened and finalized the discussion of a factor.

Flexible part

The flexible part included follow-up questions for clarification. Follow-up questions emerged during the interview, but were also predetermined. The number of predetermined questions varied per factor, depending on the operationalization of factors into variables (section 3.2). During the fieldwork, the researcher added predetermined questions to the flexible part; a legitimate approach when a study is trying to understand each case individually and in as much depth as possible (Eisenhardt, 1989).

Regarding the process of interviewing, focus lied on *active listening*. In contrast to passive listening, active listening implies that the researcher demonstrates verbal and non-verbal listening signs. Examples of *non-verbal signs* refer to an active posture, eye contact, and smiling as affirmation that the researcher has understood the message. Regarding *verbal listening signs*, the researcher focused on *positive reinforcement* such as nodding. In addition, *clarification* by the researcher was essential as well as *summarizing* the main points of the conversation, giving interviewees the chance to correct if necessary.

Topic list

For verifying the findings from empirical part 1, interviews are conducted in empirical part 2 using a topic list. The *topic list* functioned as a checklist for assuring that all subjects were discussed *and* in a similar manner. Because a semi-structured approach was applied, and topics were non-hierarchical, respondents remained freely to elaborate on subjects, stimulating the richness of the information flow. In total 10 topics were selected, of which most (5) related to the section niche development. Per topic, the respondents were asked to give their statement a quantitative value by means of a *Likert-type scale*, with 5 values to choose from. The values assisted the researcher in interpreting the statements from the respondents.

3.1.5 Interview protocol

For reliability purposes (Yin, 2003), the procedures and general rules that should be followed while conducting the interviews are described. The complete interview protocol can be found in the appendices.

Prior to the interview, the selected interviewees and/or companies are contacted via either telephone, or email. Call and email protocols have been used. Subsequently, at least one week before the interview, a subject list concerning the content of the interview is shared through email. *At the start of the interview*, a round of introduction is requested and the research project is briefly explained. An elaborated explanation should be prevented here as the information that is required for the interviewee is initially restricted. Each interviewee is asked whether they grant permission to record the interview. *During the interviews*, interviewees are encouraged to explore their experiences in a sensitive manner, but they should not be 'probed'. The researcher is free to bring in aspects or events which according to documents or other interviewees were important, and present it as an open question in order to further examine these. This procedure is considered beneficial for building the cases (Eisenhardt, 1989). Note that steering the answers of interviewees is avoided at all times. *Upon closing the interview*, interviewees are asked if they would like to add something of relevancy, and for instance whether the interviewee can share relevant company documents. For each interview, field notes concerning the key learnings are written, preferably right after the interview when the information is still 'fresh'.

3.2 Operationalization

This section covers the process of operationalization. The process of operationalization entails the translation of abstract factors into measurable variables. For making the literature-based factors observable in real-life, the researcher first clarified each factor. For every factor, a definition was provided using literature. This definition led the researcher in searching (valid) variables, measurable terms, to formulate question items. In this sense, the question items may be considered a *derivative of the theoretical framework*, enabling the case study analyses. For reasons of clarity, the operationalization process for the factor Value Proposition is presented next.

Operationalizing value proposition

The value proposition represents the role of an inventor's offering in innovation trajectories. In business model concepts, it is posited that the market and the value proposition of an inventor should match if the inventor is to capture value. This requirement is conceptualized via the Value Proposition Canvas (Strategyzer, 2015) and is referred to as the *Product/Market Fit*. The Value Proposition Canvas distinguishes three variables that make up value propositions (Strategyzer, 2015): products and services, gain creators, and pain relievers. *Products and services* refer to the products the value proposition is built around. *Pain relievers* describe how products alleviate customer pains, such that they eliminate or reduce undesired costs, situations and/or risks. *Gain creators* describe how products and services create customer gains. Coherent with the operationalization of the factor Market, pain relievers and gain creators respectively refer to how users' needs and wants are satisfied by the offering of a *group of particular firms*. Furthermore posited in business model concepts is that value propositions should differentiate firms from rivals when seeking to solve customer problems and satisfy customer needs (Osterwalder & Pigneur, 2010). If the offer of an inventor is less compelling than what (existing) competitors offer, the innovation process of the inventor will likely stagnate. Table 3.3 presents the operationalization scheme of the factor Value Proposition.

Table 3.3 - Operationalization scheme of the factor Value proposition

Factor	Variables	Question items based on variables
Value proposition	(Blank, 2014) a. Pain relievers b. Gain creators c. Products and services (Osterwalder & Pigneur, 2010) d. Differentiation	**Open / follow-up** To what extent did the offering satisfy user wants/needs? (Product/Market Fit) (O3.Val) What were the outcomes of the innovation compared to the dominant design? (e.g. in performance) (F2.Val) How did the inventors differentiate their offering from competitors? (O4.Val) What were the unique selling points of the innovation? (F3.Val) **Dichotomous** Was the value proposition effective (1) or ineffective (0) in developing user demand for the innovation while differentiating the innovation from competitors? (D2.Val)

The complete operationalization process and formal interview schedule can be found in the appendices.

3.3 Empirical data analysis

This section covers the data analysis. In paragraph 3.3.1, the data set is described. In paragraph 3.3.3, the approach in data analysis is presented. In paragraph 3.3.2, the quality of the data set is discussed with regard to validity and reliability concerns.

3.3.1 Data set

For each case, a data set was compiled that functioned as a *dossier*. At first, the dossiers mostly contained information from secondary resources, regarding the nine factors of the theoretical framework. Later, the experiences of interviewees regarding the factors as well as other information from documents and/or interviews were added to the data set. For empirical part 1, 18 open questions, 8 dichotomous questions and a varying number of follow-up questions were asked per interviewee. For empirical part 2, interviewees linked 10 quantitative values to their statements on open questions (see appendix). The data set mainly composes of *rich and deep data* as a result of the qualitative methods chosen.

For increasing the added value of each dossier, the researcher often considered the information that was and was not yet obtained (or confirmed) during the empirical research. The construction of a *timeline* was deemed helpful in this process, to outline the information available with regard to a case study. Overall, the data set needs to be understood as an integrated whole that provided *contextual understanding of the individual case studies*. In writing down the results, the researcher benefitted from the triangulation of evidence. Typically, for example, key points in time and issues were identified because data sources showed clear overlap, helping the researcher judge as to which findings needed to be included in the report. Also the quantitative values given by the respondents in empirical part 2 helped the researcher in identifying the main findings and writing down the results. The period of data collection spans September 2015 – March 2016.

3.3.2 Data analysis

The theoretical framework provided the structure for the data analysis in empirical part 1, so that the analysis of factors moved logically from one to the next. In analyzing the individual case studies, the researcher identified which factors within the framework influenced the focal innovation trajectories. Focus lied on extracting from the results those factors which influenced why innovations were or were not doing well, illuminating aspects that might be instructive for biobased sectoral development. Here, using theory and experience, attention was paid by the researcher, supervisor and assigner in signaling which factors turned out to be practically relevant and which possible alternative explanations may exist.

Built on the individual case study analyses, comparisons were later used to make judgments as to which findings were representative for the three cases and/or had high-impact on individual case studies. The format for this so-called cross-case analysis was again provided by the theoretical framework. In empirical part 2, the verification of the key findings from empirical part 1 was deemed to identify the findings with broader applicability, likely to influence sectoral development in the biobased economy at large. After summarizing the main findings, recommendations in line with the analyses were formulated.

3.3.3 Quality

For the evaluation of case study research, the research design criteria – validity, reliability, and replicability – are often played down (Bryman, 2008). Table 3.4 discusses the research design criteria in relation to this study.

Table 3.4 - Research design criteria

Internal validity refers to the issue of whether the measurements which are devised to gauge a factor, really tap into that factor (Bryman, 2008). For increasing the internal validity, this study consulted a broad domain of literature and subsequently integrated various literature-based concepts to make sure that the theoretical framework approaches real-life as good as possible. Then, several sources of literature have provided (definitions for) factors which influence an innovation's trajectory of sectoral development. Hence the link between data and concept is viewed to have no problems. At the minimum, for all factors *face validity* was established, meaning that the measurements *reflect* the content of the factor in question (Bryman, 2008). Here, other people with experience in the field (e.g. the supervisor) performed as judge. Furthermore, by triangulating data, the findings from for example interviews (which tend to rely on subjective understanding) are corroborated with empirical evidence that measures the same thing from an alternative source. This way, the information that is obtained is contextualized (Hancké, 2010), increasing the credibility of the results.
External validity deals with the problem of knowing whether a study's findings are generalizable beyond the immediate assessment project (Yin, 2003). As discussed in paragraph 3.1.1, external validity of case studies is often questionable due to a limited number of frequently similar cases (Verschuren & Doorewaard, 2010). To improve the external validity, multiple strategically selected case studies are executed. In addition, the gathered data is compared *within and across cases* in order to increase the validity of multiple case studies (Eisenhardt, 1989). Key is to learn which factors influence innovation diffusion, within the selected research objects.

Reliability is concerned with whether the *results* of a study are *consistent* (Bryman, 2008). Since this research is building cases by triangulating data, the information originates from different sources and is subsequently reported in a coherent whole. This may result in potentially less transparent individual findings. As a response, the researcher constructed a database and transcribed each interview. Nevertheless, the consistency of measures might be harnessed due to the design of the interview schedule. The appliance of the flexible part namely depends on the researcher's assessment of the knowledge base of an interviewee regarding a factor. If the answers given by an interviewee are judged by the researcher to be of little added value, the flexible questions for this factor are skipped for this particular interviewee.
Replicability refers to the repeatability of the *methods* used (Hancké, 2010). The systematic approach of this research (e.g. the use of an interview protocol, predetermined questions), and its documentation (e.g. the spelling out of procedures in detail, operationalization, the constructed database), will most likely result in comparable findings when other researchers want to look for answers *in the same way* this study did.

- Empirical part 1 -
Case study results and analyses

This empirical part elaborates on the results and analyses of the cases industrial hemp, wind turbines, and starch plastics. It seeks to answer the research question: *Which factors influenced the development of the three cases (results), and what can be derived from comparing these factors (analysis)?* Firstly, the results and analyses of the fieldwork are presented per individual case. Secondly, a cross-case analysis is performed.

4. INDUSTRIAL HEMP: *HEMP REINVENTED (1990-2015)*

This chapter covers the results and analysis of the case industrial hemp. Firstly, the results are presented. Secondly, an analysis by means of the theoretical framework is provided.

4.1 Results

For decades hemp cultivation was absent in the Netherlands, but interest in hemp returned due to problems in agriculture in the 1980s and 1990s. Reductions in agricultural support by the European Union had made the cultivation of several crops loss-making for Dutch farmers, who saw little chances to sustain their income levels. The idea was raised that the cultivation scheme should be extended with an extra crop that could (i) be included in the rotation schemes and (ii) find an application in non-food industries. Starting in the 1980s, government-sponsored **development programs** were initiated around crops such as potato, flax and hemp.

In the development programs involving hemp, **new applications using hemp fiber** were realized like bio-composites, insulation material and other nonwovens. The applications were claimed to have huge market potential but the results of the development programs did not legitimize a roll-out of the industry. The programs had covered only few technical characteristics of the new-found applications and did not consider standardization issues in production. Moreover, as the programs were strongly supply-driven, market demand was not taken into account. The results proved to be exaggerated, resulting in overly enthusiastic stakeholders.

Inspired by the environmental benefits of hemp, the processing firm HempFlax was founded in the Peat Districts in 1994. Since the 1970s, hemp was heavily subsidized (up to ~800 EUR per hectare) by the EU. Backed up by these subsidies, HempFlax' owner could convince a number of farmers to start growing 140 hectares of hemp; this meant the re-launch of commercial hemp cultivation in the Netherlands. Prior to the disappearance of hemp in the 1930s, hemp straws - consisting of fibers, hurds (shives), and seeds - were processed into a broad variety of products. Based on this history, HempFlax' owner selected several promising hemp products to re-introduce to the marketplace.

For over half a decade, HempFlax lacked demand. Following the development programs, the Dutch paper industry was the designated user of the high quality hemp pulp out of bast fibers. Unfortunately, this industry was not interested in hemp as a renewable local feedstock; paper is a commodity product and wood was and is a much cheaper input material. Ultimately, the first order for bast fibers was placed by a Turkish specialty paper factory in 1998.

As sales remained scarce, HempFlax tried to develop new product-market combinations. For the hemp hurds (shives), HempFlax developed an outlet as animal bedding, mainly for horses and pets, but still without any market pull. In this period, it was beneficial that dried hemp can be stored for three years. Until the year 2000, **almost all harvested hemp was stored in barns** in Oude Pekela (Peat Districts) due to **continuing low demand**.

The enthusiasm diminished gradually, especially since market parties and (local) authorities associated hemp with psychoactive substances and were non-supportive to HempFlax. When HempFlax' owner considered quitting in 1999, a second Dutch processing firm named Hempron was founded; an initiative by HempFlax' former processing manager, a local farmer who initially contributed in setting up HempFlax. Now, knowing the potential of hemp, the former processing manager was looking for opportunities to turn things around in the hemp sector with Hempron.

Luckily, the demand for hemp products improved by the year 2000. Firstly, the **German automotive industry** gained interest in bio-composites for interior applications due to a change in environmental policy in Germany.

Hemp fibers were now preferred over synthetic fibers from the viewpoint of recycling, especially by German medium-class and luxury-class vehicle producers. The launching customers were BMW and Mercedes, and more clients followed shortly after. Secondly, hemp fibers were increasingly processed into specialty pulp for the **cigarette industry**.

Major problem in the **overall economy of hemp utilization**, however, was that most outlets focused on fibers (representing only ~25% of the straw), while hurds (~55% of the straw) found no high-quality applications. This problem in valorization enlarged given that hemp fibers were predominantly destined to users who did not pay much. To illustrate this: HempFlax supplied ~2.000 tons of fiber to the paper and cigarette industries in 2002, and sold only ~1.200 tons of fiber to the more lucrative automobile industry. Hempron supplied the paper and cigarette industries with ~600 tons of fiber that year. In the absence of an optimized total plant yield, the Dutch processors had to decrease costs if they were to make a profit.

Cost reductions were to be achieved via improvements in techniques and machinery. The cost price of hemp products is constituted of two main components: (i) costs for cultivation and (ii) costs for processing (including logistics). Since **hemp was not grown for over 50 years**, the pioneer HempFlax had to renew both the techniques and machinery for harvesting and processing. Various bottlenecks in harvesting - related to the toughness of the fibers, the height of the stems, and the harvesting period – were encountered and solved by trail-and-error.

One example of this technological development process can be found in hemp harvesting. Given the relatedness of flax to hemp, the first hemp was harvested with a flax harvesting machine. This machine, however, was not designed for dealing with the robustness of hemp stems and malfunctioned. In turn, a new machine was designed (and patented) by HempFlax, and constructed by a German machine builder around 1997. This way, and also by commissioning research at Dutch research institutes (e.g. TNO) and universities (TU Delft, Wageningen UR), several cost reductions were achieved in cultivation over the years.

The costs for processing remained relatively high, largely due to the hemp being voluminous what increased transportation costs. HempFlax initially chose to apply traditional processing techniques, e.g. for separating the fibers from the stem, resulting in relatively high labor costs. Later, Hempron realized advanced techniques (e.g. to process hemp already on-land) with the help of an investing agency; a high risk endeavor given the uncertain payback time. Advancements were made, but costs remained too high for becoming profitable.

Meanwhile, a sequence of changes in hemp support diminished interest in hemp cultivation. In 1998, the relatively high hectare premium for hemp growers was lowered by the EU after fraud by Spanish and Irish farmers; hemp was cultivated solely for subsidies without any intention of processing. As of 2001, the hectare premium became pegged to grain yield in the respective region, further lowering support to levels that were comparable to alternative crops (~300 EUR per hectare). As compensation, it was agreed that processors received aid for processed fiber (90 EUR per ton), meaning that the risks of cultivating hemp increased.

Prior to the introduction of processing aid, hemp growers received a fixed premium per hectare, irrespective of yield. Because cultivation is subject to variables which influence the yield (e.g. weather circumstances), fixed premiums are beneficial for a grower as they represent guaranteed income. These guarantees changed as of 2001. Now, the processors started receiving variable support so that they, in turn, could offer growers a competitive price for their yield while the support for alternative crops remained untouched. This increased the **competition for cropland** at the expense of hemp cultivation area.

A turbulent period followed in the Dutch hemp sector. The supply of hemp was relatively low and insufficient to meet annual sales. In this period, HempFlax was able to benefit from large amounts of hemp in storage, but this advantage did not apply to Hempron who also lacked funds to import hemp straw. Sales stagnated for Hempron, and the firm ultimately discontinued in February 2003. One month later, HempFlax announced **two takeovers**: Hempron and Vernaro (Germany). With the takeover of the bankrupt Vernaro, HempFlax broadened its customer base to delivering fibers for the aviation and aerospace industry, as well as the construction and textile industries (HempFlax, 2003).

Following the takeovers, HempFlax was one of the largest hemp processors in North-West Europe. In the view of HempFlax, up-scaling was the only way to safeguard continuity for sales and attain the economies of scale for making a profit. For the first season, HempFlax invested greatly in expanding the production capacity (e.g. 1.2 million EUR for a French processing line) and contracted a record number of hemp growers (total acreage

~2.400 hectares). Confidence in HempFlax was very high at this time, particularly since HempFlax paid a fair price for the harvests of former-Hempron growers, who had gotten into financial problems in the absence of a client. However, around the same time, subsidies were granted to the bio-fuel industry, meaning that growing maize became relatively more profitable for German and Dutch farmers. This induced a downfall of the areal hemp in these countries in the years to come.

The confidence of the public and farmers in the hemp sector diminished (further) in 2004. That year the police visited HempFlax' factory in Oude Pekela under the suspicion that the company had distributed non-certified hemp seeds to their contracted farmers. In a press release the entrepreneur stated that HempFlax would remain active on the condition that Dutch authorities started to adequately support the promising hemp sector. This cry for help wasn't answered. Almost all employees were fired with permission of the authorities, as the entrepreneur could show that HempFlax never made any profit prior. Thus HempFlax became inactive as of 2005. From that year, the entire Dutch hemp sector was practically inactive with only one processing firm, named Dun Agro, founded in 2004 by the former processing manager of HempFlax and former owner of Hempron, processing on a relatively small scale.

The subsequent years were characterized by **private and public initiatives** to sustain the continuation of hemp growth in the Peat Districts; the hemp sector had obtained social-economic importance for the region. The initiatives were initiated by Daglicht Productie and led to a large-scale re-evaluation of the sector's potential in 2006, partly funded by the Agenda for the Peat Colonies. Conclusions included that hemp needed to be accepted by the marketplace - hemp was still negatively associated with psychoactive marihuana - and techniques for harvesting and processing needed to be updated before positive business results could be generated. At the same time, several improvements to techniques were already suggested based on foreign applied practices.

In particular Dun Agro benefitted from these suggestions and upgraded its techniques accordingly. Furthermore, a cooperation of local hemp farmers named Natuurvezel Unie (NVU), also started by Daglicht Productie, felt strengthened in the ambition to takeover HempFlax and set up a new initiative in hemp. A deal was never sealed but HempFlax' owner regained its interest in industrial hemp and reactivated the firm. In the period 2004-2008, only less than 300 hectares were grown with hemp (CBS, 2015). By the year 2009, ~900 hectares of hemp were again cultivated in the Netherlands (CBS, 2015), and the acreage would keep getting larger as a result of business development.

After years of struggling with the overall economy of hemp utilization, a breakthrough followed after Dun Agro started to harvest **hemp flower buds in 2012**, in addition to fibers and hurds. Already in the 1950s, Israeli researchers had documented the presence of several substances in the flower buds of marijuana. Moreover, since the 1990s, under license of the Dutch government, substances from marijuana (e.g. THC and CBD) were won by Dutch companies like Bedrocan for medical appliances. In response, in 2006, Daglicht Productie conducted the first experiments to extract **cannabidiol (CBD)**; a substance with high therapeutic potential in various symptoms and diseases (e.g. epilepsy, diabetes, Alzheimer's disease, psychosis) (EIHA, 2014).

In cooperation with Daglicht Productie and TU Delft, a Dutch pharmaceutical company (FeyeCon) successfully implemented a clean-tech CO2 extraction technique for the extraction of CBD. The owner of Daglicht Productie, also a former employee of HempFlax and now managing director of Pantanova, took a lease of Dun Agro's farmland to produce the necessary feedstock for the experimental CO2 extraction. Six years later, the relatively lucrative substance CBD took a flight, especially in the US. Dun Agro timely saw the opportunity to generate extra income: marketing the processed flower buds from hemp currently enables Dun Agro to cross-subsidize its activities in hemp fiber and hurds. In addition, Dun Agro can offer more growers a feasible lease for using their land, demonstrating the increase in hemp cultivation area on account of Dun Agro in recent years.

An increasing number of scientists and companies are now interested in CBD, and also HempFlax started to harvest flowers. Expectations are that competition will strongly increase in the relatively small market for CBD and therefore Dun Agro already focused on new applications. Two such applications include a health drink, a juice made out of **hemp leaves**, and prefab hemp panels, made out of lime and hemp hurds, for the construction of buildings. Hopes are particularly high for a strong increase in demand from the domestic building industry (see below).

Hemp abroad

Parallel to the Dutch hemp sector, the European market was developing. In the early 1990s, hemp cultivation in the EU took practically exclusively place in France (~6.000 hectares). Unlike most other countries that restarted to cultivate hemp as of 1993 (EIHA, 2005), France never outlawed hemp cultivation since the French paper industry intensively relied on hemp pulp (and still does). As a result, Europe's leading hemp processing firm named Laroche originates from France. Laroche, being active for over 60 years, delivers complete configurations for preparing fibers for spinning as well as for nonwovens. One of the processing lines provided by Laroche is currently operational at HempFlax. Also Belgium companies started with relatively strong knowledge positions given their expertise in the flax business. Dun Agro currently operates on a Belgium processing configuration. Some market parties thus had a head start in hemp.

The relatively stronger knowledge positions of some market parties did, however, not result in enhanced international cooperation. In many cases, market parties were inclined to take on individual approaches. An example can be found in development of cultivars. In countries with a milder climate like the Netherlands (sea climate), the summers are not warm enough to economically harvest hemp seeds for extra added value per hemp straw; market parties in such climates then focus on cultivars which deliver high fiber quality. However, in the EU, only French cultivars were readily available until 1995 (Meijer, 1995). Several countries, including the Netherlands, initiated own breeding programs in order to develop (or select) the most productive cultivar for their respective climates.

Since the year 2000, cooperation among market parties strongly improved. At this time, seven processors from the EU countries Great Britain, the Netherlands (HempFlax), Germany and Italy, started an informal federation for sharing the latest developments in industrial hemp. Since 2005, this federation is officially known as the **European Industrial Hemp Association (EIHA)**. Yearly, international conferences are organized to facilitate the exchange of trends and techniques. At the 2015 international conference, over 230 hemp experts from all over the world were participating.

Within Europe, production is currently centered in France, the UK, Romania, Hungary and the Netherlands. Previously, Germany had a large hemp sector but due to land competition for **biofuel crops**, only ~500 hectares were left in 2014 as almost everything moved to France (where seed production makes the hemp business lucrative). In 2014, ~17.000 hectares of hemp were grown in the EU; the largest acreage since the 1998 fraud case. Remarkable is the growing share of seed production, but this is thus not on account of the Dutch hemp sector. In terms of cultivated land, Europe is still clearly lagging behind North America and China (both cultivate tens of thousands of hectares of hemp).

Regarding the applications of European hemp, a shift can be observed in the distributions of hemp fibers and hurds between 2001 and 2010 (see table 4.1). Although the dominance of the main markets for hemp fibers and hurds did not change, much larger shares of fibers and hurds were applied in building materials (primarily insulation and concrete). Further **expansion is expected** beyond 2015.

Table 4.1 - Distribution of hemp fibers and hurds in Europe between 2001 and 2010

Hemp component	Market segments	Shares 2001	Shares 2010	Expectations 2015+
Fibers	Pulp & Paper	80 %	55%	Stagnation
	Insulation	5%	26%	**Expansion**
	Bio-composites	15 %	15%	**Expansion**
	Technical textiles	>1%	4%	Stagnation
Hurds	Animal bedding	95%	62%	Stagnation
	Construction (concrete)	5%	15%	**Expansion**
	Others (particle boards, combustion)	>1%	22%	Stagnation

Sources: EIHA (2005, 2012), personal communication (Dun, 2015)

Promising markets

Growth of the market segments insulation and particularly construction is deemed promising for the Dutch hemp sector. A strong increase in demand from the domestic building industry, a large industry whose business and associated materials are highly polluting, would represent an outlet for hemp hurds and a significant improvement of the home market; Dun Agro and HempFlax currently export ~95% of their volume in hemp.

Marketwise, hemp insulation and concrete have potential in replacing their conventional alternatives. In contrast to conventional building materials, materials out of hemp are renewable, biodegradable and relatively light weight. In addition, the materials **sequester CO2** and have excellent **thermal regulative properties**. Where the latter improves health to the users during the entire use-phase of a building, the former reduces the environmental impact. Major problem, however, is that builders hold on to a strict set of demands for applying building materials.

As compared to the relatively new hemp insulation and concrete, conventional alternatives have gained advantages as they were already in a position in which they were widely implemented. This position namely made that the (properties of these) **conventional materials became increasingly embedded** in regulations, infrastructures and systems such as construction routines. As a consequence, builders no longer choose conventional materials purely on the basis of a calculation of costs and benefits; other factors like vested interests became important as well.

An example can be found in the effect of knowledge build-up by builders. For decades, builders have invested in knowledge of their workers that directly related to the application of particular concretes. In the absence of market-pull for the implementation of hempcrete, most builders appeared to be reluctant to alter their choice of material; standard practices are easier and less risky. Moreover, the conservative building industry favors to innovate incrementally and was involved in **routine-buying behavior**. Therefore, new building materials need indisputable evidence of their properties and have to outperform conventional materials in order to be applied at large-scale.

Interestingly, the situation slightly changed for the better since the crisis year 2008. Induced by the building crisis, large builders such as VolkerWessels started to re-evaluate their ways of doing business in search of cost reductions and increased distinctiveness in the marketplace. Although short term goals (survival) prevailed over long term goals (e.g. reducing environmental impact), these searches also involved the consideration of new building materials. Slowly but inevitably, the general notion emerged that sustainable building was becoming a license to operate. This change was stimulated by the start of the governmental **2010 Sustainable Buying Policy.**

In this policy, sustainable building was given advantages over conventional building. An example can be found in the renewed tendering system for public building projects. In each tender, environmental performance indicators became linked to for instance fictitious discounts on the offer price of a respective builder. Imagine that a tender rewards CO2 reduction. A sustainable project with a value of €1.000K and a CO2 performance ladder 5 (the highest ladder) was now granted a 10% discount on the offer price (ladder 4, 7%; ladder 3; 3%). Regardless of other specifications, this meant that the sustainable project would win the tender of a conventional project with a value of €950K but without a CO2 discount advantage. Sustainable builders now started to be able to sell their projects for a higher price (economic motive). Expectations are that projects will be increasingly judged on their environmental performance, instigating a new set of problems that leads to sub-optimal solutions in building projects and hampers the roll-out of projects.

Firstly, the increasing importance of environmental performance indicators leads to perverse effects. In the example of the public tendering system, builders tend to choose materials which according to a specific indicator contribute most to a positive score of their project and cease to look for alternatives which are potentially better in total. Secondly, corporate decision-makers lack striking power and appear to be risk-evasive. An example on national level can be found in the negotiation of a covenant for the concrete chain. Since 2012, 30 national parties (e.g. producers of concrete, demolition partners, project developers, building concerns, NGOs) are working together on reducing the environmental impact of this chain but the process stagnated at the point of committing to ambitions and determining how to realize these. The problem of risk-evasion has been also holding back individual projects by these parties.

Status quo

At present, several processes are occurring in the Dutch hemp sector, making its future both promising and uncertain. One decade ago, ideas concerning the replacement of conventional materials with hemp could hardly attract the interest of potential users, especially that of large companies. In recent years, however, similar ideas are increasingly put into consideration by such firms from an economic and environmental standpoint.

If a business case can be made by potential users, then hemp is an evident option for replacing their conventional materials. These recent possibilities for hemp demonstrate an improved acceptance of hemp products in the marketplace, mainly attributed to today's importance of environmental issues like climate change, water use, and carbon emissions. The relatively high level of acceptance instigated new initiatives in hemp which aim to set up production chains for varying applications.

One initiative aims to develop **textile** applications out of hemp for replacing cotton, given that cotton has a huge environmental impact (e.g. extreme water use). The direct participants are Pantanova (formerly Daglicht Productie), Dun Agro, Texperium and Stexfibers. The latter is located in Arnhem, and developed a steam explosion technique for softening hemp fibers, allowing the fiber to be processed on common machinery for high quality textiles. The first pilot-scale tests were positive, and negotiations have commenced with potential users (e.g. AkzoNobel).

Another initiative focuses on **composites** and is also negotiating terms with potential users like Royal TenCate (geo-textiles), NPSP (fiber-enforced sheets) and Vencomatic Group (hemp packaging). Other initiatives aim to develop hemp as **animal feed** and look to spread the use of **hemp-lime-construction**. Unlike hemp insulation that is up to 4 times more expensive as glass wool, 'hempcrete' is price-competitive to standard concretes and has a relatively large impact on the environmental performance of a building. Therefore, experts are seeing great potential in hempcrete but large-scale applications have not been realized in the Netherlands to date.

Major obstacle in the roll-out of hempcrete is the insufficient practical underpinning of most benefits attributed to the product. In spite of initiatives like Hennep2House, Agrodome and Grow2Build, only ~10 solitary hemp houses exist in the Netherlands, mostly built by eco-minded users. Because none of these houses are being monitored, none of the houses is able to confirm the claimed added values in practical situations. Illustrative for the newly occurring processes: the province of Leeuwarden has for example announced their interest for the construction of ~30-40 hemp houses in the neighborhood Zuidlanden, presenting a potential breakthrough in hemp-lime-construction.

In the light of more practical examples of successful hemp applications, the hemp sector expects to generate interest of (more) investors. There are already plans to start a third hemp processing firm in the province of Gelderland. The province embraced the Green Deal Natuurvezels, initiated by Pantanova and Value Mediation Partners, and will present a major program focused on hemp and other fiber crops in spring 2016. Expectations are that the Dutch hemp cultivation area is able to increase from ~1.700 hectares at the end of 2014 to 5.000 hectares in 3-5 years from now.

Opposite to the claimed potential of hemp products, expectations are that the growing of hemp could disappear in the Netherlands due to increasing competition for cropland. Competition further increased since all subsidies for hemp were abolished in the last three years. In the absence of subsidies, the marginal costs for cultivation and the sales price become leading in a grower's crop choice; an unfavorable situation for hemp. In recent years, growers increasingly considered alternative crops like grains and heavily subsidized biofuel crops like maize instead of hemp.

In order to make growers cultivate hemp, processors need to compensate for the higher revenue of other crops. However, good-arable cropland becomes scarcer in the Netherlands, partly because of the current ground lease system, driving up the prices of Dutch cropland. Already since 2008, after a new director was installed, HempFlax started to import low-cost hemp from Eastern European countries. Moreover, HempFlax bought own cultivation land in Romania and plans are to expand the cultivation area there.

While the competition for cropland increases, market demand is still not quite as hoped for by the Dutch processors. For strengthening the competiveness and attractiveness of hemp products and cultivation in the Netherlands, possibilities can be found in supporting production chains but it would be wiser to further stimulate market demand.

Modest developments in market demand can be observed, for instance in the building industry, but hurdles are to be taken before hemp products are broadly applied on large scale. With an increasing embeddedness of the conventional materials, and weak economic motives to implement sustainable solutions, the majority of potential users had no intention of changing their business. Therefore, reality in 2015 is that most potential users favor the appliance of polluting conventional materials over hemp materials while the Dutch hemp sector is experiencing difficulties to escape its state of infancy.

4.2 Analysis

4.2.1 Innovation diffusion

In the innovation trajectory of industrial hemp, a number of niches (see table 4.2) can be identified that correspond with different hemp products. The hemp products have been unable to rapidly develop and become widespread in the absence of momentum for the niches under study. In the early 1990s, hemp products were becoming (widely) accepted among certain stakeholders (e.g. policymakers, farmers), but the processes stagnated in attracting other key stakeholders (e.g. users). Hemp products were predominantly marketed in supply-driven approaches while users associated hemp with psychoactive marijuana and/or were still content with their standard choice of material. Only recently, particular niches are starting to gather momentum via market-driven initiatives as a result of changes in regime stability.

4.2.2 Niche development

Crux in the niche development of hemp products is that entrepreneurs require sufficient user **demand for different hemp components** for creating a viable business case. Consequently, the entrepreneurs needed to **operate in different niches simultaneously** for reaching niche maturity. Analysis shows that most hemp products were able to pass the level of R&D niche, but have not yet been able to outgrow the level of technological niche as users stick to their dominant designs. One application that did evolve into a market niche is the case of cannabidiol (CBD) for the pharmaceutical industry.

Technology

The majority of technologies is available at full commercial scale (table 4.2), largely due to the relatively easy to solve technological problems in developing hemp products. The innovation processes benefitted from trial-and-error learnings by entrepreneurs, commissioned research and the dissemination of (foreign) research results.

Table 4.2 – Technology readiness in industrial hemp

Application	TRL (0-9)	Technology status	Progress
Textiles	6	Prototype system	Technology tested in industrially relevant environment
Construction	7	Demonstration system	System prototype operational at pre-commercial scale
Bio-composites	9	Full commercial application	Technology available for users
(Specialty) pulp	9	Full commercial application	Technology available for users
Insulation	9	Full commercial application	Technology available for users
CBD extraction	9	Full commercial application	Technology available for users

Market

Hemp processors developed several product-market combinations (PMCs) but mostly without any demand pull, given that users associated hemp products with psychoactive marijuana and/or were still content with their standard choice of material. This demonstrates a **lack of alignment of** demand and technology. After a hesitant start, demand for hemp derivatives did slowly develop, favoring the stabilization of niches. However, users in particular industries often still prefer their dominant designs over hemp products (see table 4.4), indicating that hurdles are to be taken before demand is effectively developed there. Analysis shows that without user preference, niches are unlikely to reach maturity.

A further analysis is made by investigating the influencing factors of niche development.

Visioning

In the early phase of development, several actors were attracted to the hemp business on the basis of relatively high expectations. This led to a convergence of expectations in the niches. However, as years went by, the lack of practical results (e.g. a balance in finances) made that the expectations diminished. Throughout the development of the niches under study, expectations regarding hemp were volatile, and **only recently able to provide legitimacy** to actors to sufficiently invest in hemp applications.

Table 4.3 – Early expectations in industrial hemp

Early expectation	Actor	Source of change
Exploiting business opportunities	Industry	Results exaggerated
Hemp straw provides extra income via non-food outlets while the deep and fine rooting system of hemp improves the quality of cropland	Farmers	Changes in direct support > increased cultivation risks
Hemp products are promising sustainable replacement options for a variety of products	HempFlax	Low market acceptance > low market demand

Finances

Major problem in the financial aspects of entrepreneurs refers to the **overall economics of hemp utilization**. In the absence of an optimized plant yield, even when subsidies were still available for niche protection, it turned out almost impossible to achieve a positive return on investment after processing. In the meantime, **growers increasingly consider alternative crops and biofuel crops** instead of hemp due to further increasing competition for cropland; **opportunity costs** affect the decision-making of growers and make them decide to cultivate other crops than hemp. The latter is by no means only a Dutch phenomenon; practically the entire **German hemp growing- and processing markets moved to France,** where hemp seeds can be harvested economically due to climate reasons, for generating extra income.

Value proposition

For over a decade, most potential users were unresponsive to offerings as their acceptance of hemp products was generally low. However, the performance of hemp products is increasingly able to attract the interest of users as years passed. At present, demand can be developed if a business case is possible according to the standards set by respective users, although offerings remained predominantly ineffective in developing demand by early-2016 (see table 4.4).

Table 4.4 – Overview offerings in industrial hemp

Users	Added value claimed by inventor	Dominant design	Performance	Effectiveness in developing user preference
Pharmaceutical: CBD	Therapeutic effects	THC	(+) Hardly psychoactive	Effective
Specialty paper	Mechanical properties	Wood	(+) High quality	Effective
Automobile	Biodegradability	Synthetic fiber	(+) Renewable (-) competition with flax, jute, kenaf and sisal fiber	Ultimately effective
Textile	Energy-efficient production	Cotton	(+) Overall competitive (+) significant less water use	Ineffective; breakthrough expected
Building: hempcrete	Thermal regulative capacity, sequesters CO_2	Concrete	(+) Overall competitive (-) lack of underpinning claimed benefits	Ineffective; breakthrough expected
Building: insulation	Thermal regulative capacity, sequesters CO_2	Glass fiber	(+) Energy-efficient production (-) huge price gap	Ineffective
Paper	Mechanical properties	Wood	(-) Price gap	Ineffective
Farmers	Crop rotation value	Sugar, potato, grains, maize	(+) Fine rooting system (-) price gap	Ineffective; farmers require compensation

4.2.3 Momentum

One market niche that managed to break through is the niche encompassing CBD extraction technology. Due to the problems in reaching niche maturity, the other niches were unable to develop and gather momentum. The hemp products namely encountered dominant designs given that **hemp products aim at replacing (conventional) products** in existing markets. As compared to the relatively new hemp products, conventional products were embedded because they already had **general acceptance** of the marketplace (e.g. on technical features). This acceptance contributed to the phenomenon of standard-setting and directed the way products compete with each other.

Analysis shows that the offerings of hemp products need to follow the standards of dominant designs and must outperform their conventional counterparts on the basis of these standards in order to acquire significant market share; solely being able to demonstrate environmental advantage is not enough for developing demand. Particular hemp applications (CBD, specialty pulp, bio-composites) have been able to make use of changes in the dominance of their established alternatives. Interestingly, though users were not always immediately enthusiastic, the availability of a **proof of principle** (e.g. via conducted experiments) allowed demand to develop. The opposite is observed in the building industry where the roll-out of hempcrete is hampered by the lack of such (de facto) proof.

Currently, there seem to be ample opportunities for the niches to make use of cracks in their respective regimes. However, in the absence of both market pull and strong economic motives, most potential users of hemp products have little intention of changing their dominant designs.

4.2.4 Regime stability

Most dominant designs have been rather stable since the 1990s, given that their standards won allegiance of the marketplace already. From the year 2000 onwards, landscape developments do increasingly force actors like the government to start sharing new standards which disfavor dominant designs from an environmental stance.

Slowly, potential users start to **re-evaluate their routine choices** of material on the basis of standards other than those in which the dominant designs rule, caused by changes in **policy (e.g. 2010 Sustainable Buying policy) and increased public environmental awareness**. The potential users, for instance builders and textile producers, start to feel discomfort, encouraging them to embark on a search for alternative materials which could strengthen their (environmental) performance as a business, e.g. by reducing their carbon footprint or water use.

The niches under study, however, were frequently not able to make use of these cracks in regimes. Problems in niche development related to obstacles in regulations (licensing), risk management, and the absence of niche protection. All in all, this contributed to inertia as regimes were found to have an internal resistance to change.

4.2.5 Landscape pressure

The public awareness of environmental issues is increasing and puts potential users under pressure, inducing follow-up actions by market parties across industries. These parties are now observed to make **proactive decisions in response to environmental issues,** whereas they formerly merely changed their common practices (on behalf of the environment) if this was made mandatory, e.g. through regulations. The message of sustainability is thus slowly starting to resonate across industries, driven by environmental public awareness.

This awareness is also changing the setting in the sectors of construction – i.e. building, infrastructure and industrial -, instigating a new consensus that facilitates the adoption of sustainable products. Recent examples include the negotiation of covenants, the increasing importance of environmental performance indicators (e.g. in tendering systems), and a wide array of sustainability-driven initiatives and companies being established in construction. Altogether, the developments demonstrate that changes occur in the setting which can result in a shift in the use of more sustainable materials, among which potentially hemp materials.

5. WIND TURBINES: *A NEW WIND IS BLOWING (1970-2015)*

This chapter covers the results and analysis of the case wind turbines. Firstly, the results are presented. Secondly, an analysis by means of the theoretical framework is provided.

5.1 Results

After the 1973-oil supply squeeze, alternative renewable resources such as wind energy were extensively discussed in the Netherlands. Referring to the Dutch windmills-tradition, the development of energy producing wind turbines was viewed to be a promising course in lowering the national dependency on foreign energy sources, and may develop into a new industry. The Netherlands had to become an international frontrunner in wind turbine production, for which no particular problems were foreseen (e.g. in production). To back up the development of wind turbines, the Dutch government initiated the **1976-1985 National Research Program Wind Energy (NOW)**.

The NOW-program aimed primarily at the development of **large-scale applications of huge (i.e. multi-megawatt) wind turbines**, considering that wind energy was expected to make a significant contribution to the national energy provision. Withal, **relatively large turbines are cheaper per kWh installed than small ones** because the gains from additional (electricity) yield exceed additional investment costs for erecting larger wind turbines. For this reason, large-scale turbines can better meet thresholds for cost-effectiveness. However, developing the technology required for reliable, cost-effective wind turbines proved to be more difficult than anticipated.

A major problem in wind turbines related to the common applied gearbox technology. Here, gear wheels (from large to small) transform the slow rotational force of the rotor into a fast rotational force for the power generator. Given that all gear wheels, regardless of wheel size, suffer equivalent friction in movement, this resulted in accelerated erosion of the smaller gear wheels, causing the gearbox to malfunction. Erosion was an important hurdle in creating reliable systems, especially in large-scale turbines with their stronger frictions.

Stork and Fokker, both main participants in the NOW-program, were unable to overcome the technological problems and lost faith in developing large-scale turbines, resulting in the discontinuation of the NOW-program in 1985 (Kamp, 2002). The program failed to deliver reliable, multi-megawatt turbines as the technological jump was too large. Nonetheless, a solid base of technical know-how (e.g. in fatigue properties, load effects) was provided by the program.

Meanwhile, a number of Dutch turbine producers pioneered the development and production of wind turbines. In 1976, **NedWind** was founded acting on potential business opportunities in wind. 3 years later, **Lagerweij** felt challenged by the need of finding alternative energy sources and started business. By the year 1982, **11 turbine producers** were active in the Netherlands; generally small firms producing relatively small-sized wind turbines. The development of larger wind turbines was namely too costly for these wind pioneers, for a variety of reasons.

Firstly, Dutch turbine producers were unable to run serial production and transform learnings into cost savings per unit, due to a lack of market demand (Wolsink, 1996). Sales had taken off when oil prices increased following the 1979 (second) oil crisis, especially of solitary wind turbines installed by farmers and small companies. However, when the oil prices dropped again after 2 years, interest in wind turbines also dropped. Sales stagnated, and funders became more hesitant, resulting in insufficient funds for the further development of wind turbine technology.

Secondly, Dutch turbine producers were unable to link up with the established energy sector for developing their turbine designs (Breukers & Wolsink, 2007). Therefore, most turbine producers did not implement the generated knowledge from the NOW-program and instead incrementally improved their designs by trial-and-error. Although advancements were achieved, costs remained far too high. For instance Lagerweij had to restart the company in 1985, after they upgraded their 10 kW turbine with a rotor diameter of 10 meters to an 18 m/80 kW turbine. The general notion emerged that if a strong Dutch wind sector was to be created, policy had to become more market-oriented.

For supporting the market, one decade after the first Dutch turbine producer was founded, the government launched the 1986-1990 Integral Program Wind Energy (IPW). The basic aim of this policy was to enable the installation of 1.000 MW by the year 2000. Hence that investment subsidies for turbine buyers were introduced, as well as support for turbine producers in case advanced concepts were applied (EZ, 1986). Remarkably, though most turbine producers were still improving the reliability of their turbine designs, **technological jumps in turbine generator capacity** occurred in quick succession (Agterbosch, 2006).

Reasons were that (i) investment subsidies were dependent on turbine generator capacity while (ii) the amount of subsidy per kW decreased annually. Prior to IPW, only wind turbines with a capacity of less than 100 kW were certified. By the end of the program, five Dutch producers had certified turbines of 500 kW or more: WindMaster (500 kW, 6 units; 750 kW, prototype), NedWind (500 kW, series), Holec (550 kW, prototype), Newecs 45 (1.000 kW, routine operation) (IEA, 1992). However, note that these **Dutch turbines were optimized regarding generator capacity instead of optimum yield, taking into account additional factors such as turbine reliability and life span**. Notwithstanding, the home market was given an impulse as the investment subsidies attracted new large investors (electricity companies, private and institutional parties) to installing wind power.

The roll-out of wind projects remained, however, limited because project developers started to encounter obstacles in finding suitable locations for the erection of wind turbines; the so-called **siting problems**. Civilians and environmental organizations increasingly protested against the installation of wind turbines because of their 'dominant and disturbing presence in the landscape'. The protests focused on noise, shadow casting, visual pollution and also bird endangerment. Due to these protests, **problems in local planning** enlarged.

Since the early 1980s, corresponding to the Dutch government's top-down approach in wind energy, large-scale wind projects had been planned while taking little regards of local interests (e.g. environmental, economic). In combination with the preference of the Dutch government for large-scale wind projects over a diversity of small-scale projects, this resulted in **reluctance of licensing authorities and other stakeholders** regarding wind projects in general (Kamp, 2002).

For example, municipal councils, deciding on building permits, but also provinces, were not inclined to cooperate since they were not taken into account in the national policies (Wolsink, 1996). As of 1985, the main project developers were electricity companies, but their inexperience in negotiating with local stakeholders undermined their credibility, leveraging the problems. Attempts to overcome the problems in planning (for example, provinces gained formal authority over municipal councils in 1991) did not achieve the desired effects. Siting problems were seen as the main reason for failing consecutive national wind targets, and more importantly, hampered the formation of a strong home market for Dutch wind turbine producers.

Competition in the Dutch wind sector increased when foreign turbine producers entered the market in the late 1980s. Dutch turbines were typically outperformed on reliability and size, resulting in **better price-performance ratios for the Danish, and later also German designs**. These relatively large sized turbines had a huge advantage, as most Dutch **municipal councils preferred wind projects with larger turbines,** if wind turbines had to be erected at all; the siting problems had made the installation of relatively small solitary turbines in the Dutch landscape almost impossible (Kamp, 2002).

To be able to match the competitive advantages of foreign turbine producers, **Dutch producers also developed larger turbines but the majority of companies went bankrupt in that attempt**. Even Lagerweij, who did not focus on electricity companies as potential buyers and had sold hundreds of 75-80 kW wind turbines to farmers and small companies, was forced to develop larger turbines. In 1995, Lagerweij introduced a 750 kW prototype based on revolutionary Direct Drive technology (gearless), but it would take 3 more years to put the turbine into production. Meanwhile, foreign wind turbines were increasingly favored over Dutch turbines (see table 5.1).

Table 5.1 – Market share installed capacity (MW) per manufacturer in the Netherlands

Manufacturer	Market share installed capacity (MW) in period/year	
	1986-1992	1998
NedWind (Netherlands)	53% (48 MW)	49% (20 MW)
WindMaster (Netherlands)	27% (25 MW)	0
Lagerweij (Netherlands)	9% (9 MW)	0
NEG Micon (Denmark)	11% (10 MW)	28% (11,5 MW)
Vestas (Denmark)	0	14% (5,7 MW
Bonus (Germany)	0	5% (2,1 MW)
Enercon (Germany)	0	4% (1.5 MW)

Sources: IEA (1993, 1998)

The realization of well-developed Danish and German turbine production industries can be attributed to strong home markets. Both countries considered a **stable home market** to be of great importance for the development of wind turbine technology early on. Since the late 1970s, the Danish government had been supporting their private, small turbine producers with investment and production subsidies. Moreover, for establishing a steady growth of installed capacity, the Danish government for example initiated 3-5 year agreements with electricity companies to install multi-megawatt wind projects from 1985 onwards (IEA, 1995). The German government started to stimulate its startups via stable financial support systems, focused on yield, since the mid-1980s (Wolsink, 2007). At these timings, the Dutch government was still unresponsive to its private turbine producers.

Dutch governmental policies would later prove to be also much less effective in supporting the domestic turbine industry, partly due to volatile support and perverse incentives. For instance the 1996-2004 REB system exempted renewable energy from an ecotax, thereby leveling out the price gap between 'green' and 'grey' electricity. Although this strongly stimulated households' demand (from 16.000 green electricity consumers in 1996 to 1.4 million in 2002), the Dutch production was unable to comply. In 2002, only 26% of the green electricity was produced domestically (Van Rooijen & Van Wees, 2006). While imports increased, **Dutch tax money mainly flowed towards foreign electricity companies as they could not be excluded from the tax benefits due to EU regulations**.

By the year 1997, only three Dutch wind turbine producers were left: Lagerweij, WindMaster and NedWind . Encouraged by the Dutch government, the last remaining Dutch turbine producers had been **negotiating terms for a merger for 2 years but without success**. In 1998, Lagerweij acquired the demised WindMaster. In the same year, NEG Micon took over NedWind, and moved the production to Denmark. From that point, only one Dutch turbine producer was active, and the market kept asking for larger turbines.

Aimed at finally developing multi-megawatt Dutch turbines, **Zephyros** started business in the year 2000. Zephyros, owned by Lagerweij (45%), BVT (45%, Germany) and Triodos Bank (10%), planned to further develop the Direct Drive technology of Lagerweij as it was deemed promising, particularly in terms of reliability. Goal was to develop a 5 MW offshore wind turbine as strong market growth was expected in offshore wind parks around the North Sea.

After 2 years of R&D, a satisfactorily running 70 m/2 MW onshore prototype was sold to Eneco. The next step was the development of a 5 MW turbine but Zephyros ran out of working capital after BVT and Lagerweij ran into problems. Lagerweij had been selling its 55 m/750 kW turbines to Germany, Spain and Japan (IEA, 2001); a huge commercial success for the firm. Lagerweij, however, **went bankrupt in 2003 after it had sent 70 untested turbines** to Japan. The turbines appeared to have technological problems once deployed, and the order was never paid.

Comeback

Dutch turbine producers would come back based on the intellectual property of Lagerweij/Zephyros, **aiming to answer specific demands** of relatively small customer segments. In 2004, Emergya Wind Technologies (EWT) started business after it bought the exclusive rights of Lagerweij's 750 kW model. Currently, **EWT builds wind turbines ranging from 750 kW to 2 MW.** For generating sales, EWT focuses on wind **projects up to a few turbines**; projects that are often considered too small by leading turbine producers like Siemens, Mitsubishi/Vestas, and General Electric.

Also in 2004, Wind Energy Solutions (WES) was founded based on Lagerweij's 80 kW and 250 kW turbines. **WES now builds turbines ranging from 50 kW to 250 kW** to be installed at farms, industrial areas, schools, and small communities. In addition, WES produces a hybrid wind diesel turbine for remote, isolated grid areas like islands or mountainous areas. In these areas, diesel aggregates often provide for electricity and WES' relatively low-cost hybrid turbine is successful in replacing these aggregates.

To date, EWT and WES are quite successful in their respective customer segments; **segments which they are 'forced' to target** because project developers and funders prefer foreign firms in relatively large wind projects based on company size. **Company size, often measured via the track record and financial position of a turbine producer, is regarded crucial as wind projects are capital-intensive** (~1.5 million EUR per MW installed onshore) and have lifespans of over 15 years.

Regarding track record, it can be stated that the more turbines are installed by a specific producer, the higher the perceived reliability of its turbines is. From the viewpoint of a project developer, this is most interesting as reliable turbines tend to have more operational hours and require less maintenance; maximizing the return on investment.

Additionally, project developers and (especially) funders are risk-averse, and thus search for **financial guarantees** which increase the probability of a turbine producer's continuity. One such indicator is a constant, relatively **large cash flow**. Altogether, this makes that the relatively new, smaller Dutch turbine producers can be technologically capable of installing large-scale wind projects but find themselves outplayed by relatively larger foreign turbine producers.

Parallel to the onshore activities of EWT and WES, the development of offshore turbines continued via Zephyros. Zephyros planned to offset the relatively high costs of offshore wind placement by lowering the costs for installation, operation and maintenance. Therefore, Zephyros had for example **patented a method to create overpressure in turbines** in order to keep salt out, reducing erosion. After Zephyros ran out of working capital, the province of Noord-Holland was found willing to provide financial support to Zephyros in return for the intellectual property (IP) rights of the firm. At this time, in 2006, **DarwinD** was founded.

Because the province only paid for the salaries of the staff, DarwinD was merely a research company in response to the observed needs for a dedicated offshore wind turbine; offshore turbines were mostly updated versions of onshore turbines. Ultimately, after takeovers by Econcern and Harakosan (Japan), the IP rights of the 2 MW Direct Drive turbine were bought by XEMC (China) in 2009. XEMC/DarwinD erected ~1.600 (Zephyros) 2 MW turbines on China's mainland and currently offer both multi-megawatt onshore and offshore turbines.

Offshore

In the meantime, offshore wind placement was developing in the Netherlands. Offshore wind power was first considered and researched as a diversification option in energy in the 1970s and 1980s. Although corresponding with the large-scale thinking about energy systems in these periods, offshore wind power was regarded too capital-intensive for a broad roll-out (Verhees *et al.*, 2015). This view changed in the 1990s when policymakers gradually came to see **offshore wind as a promising solution to the onshore siting problems**. The 1991-1995 TWIN program articulated the first (long-term) offshore wind target, 200 MW by 2010, and issued the first subsidy for offshore wind.

The resulting Dutch experimental 2 MW wind park in the Ijsselmeer, an artificial lake, began supplying electricity to the grid in 1994; at that time, the world's second offshore wind park. Following the pioneering 2 MW lake experiment, a feasibility study into a 100 MW 'near shore' wind park was commissioned by the Dutch government in the year 2000. Conclusions of this study included that the plan was technologically feasible and economically viable if supported via subsidy; enthusiasm among stakeholders peaked at this time.

Corresponding to the enthusiasm among policymakers, the government set an ambitious wind target of 6.000 MW by 2020 and announced to search for market parties to construct the first Dutch Offshore Wind park Egmond aan Zee (OWEZ), sited 10 km off the coast. Besides providing lessons for wind parks further at sea (outside 12-miles zone), **experiences with OWEZ would enable the government to draft an effective policy for future offshore wind parks**. Unexpectedly, huge interest was already generated from the private sector (Verhees *et al.*, 2015).

For example **two consortia** named *North Sea Wind Power* (Siemens, Essent, Eneco, Rabobank, Heijmans, Van Oord, Profin) and *Noordzeewind* (Shell, NUON, ING, Jacobs Comprimo) publicly announced their interest in developing OWEZ. Furthermore, several project developers (e.g. NUON, Evelop, and E-connection) proactively filed requests for building and exploiting offshore wind parks. Also Dutch offshore companies were highly enthusiastic about the prospect of a well-developed home market in offshore wind.

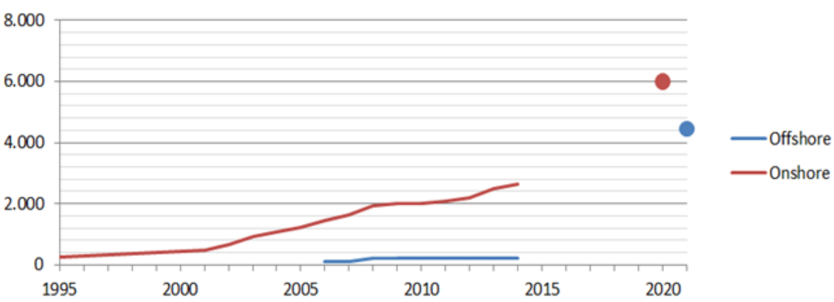
The **Dutch offshore industry** is internationally leading in the oil- and gas industry (Maritiem Nederland, 2015), but the finiteness of this customer segment is expecting to become increasingly apparent in the upcoming decades, resulting in diminishing demand for activities for Dutch offshore companies. Reputed for their experience with the relatively difficult weather circumstances and high safety regulations of the North Sea, large Dutch offshore companies like Smulders (monopile construction) and Van Oord (foundation installation and cable laying), but also less known companies with a lot of expertise, started looking to apply their **fossil-based expertise in the offshore wind sector**.

Unfortunately, one year after the feasibility study, the processes in Dutch offshore wind already stagnated. Initial major problem was that no licensing system was yet developed by the government when requests were already being filed. In response, the application process was temporarily closed in 2001, but it took until late 2004 before a new system was introduced. Delays resulted from the optimal license system being debated while governmental decision making was inefficient and slow (too many ministries responsible, other priorities such as liberalization of the energy market in 2004 and redesigning the failed 1996-2004 REB system). In the **continued absence of a license system, project developers and investors had to wait longer than desired and commenced projects in other countries**; for example Evelop had now acquired a license for an offshore wind park in the UK.

Another major problem in offshore placement referred to **inconsistent policies**. Multiple examples (e.g. 2004-2006 MEP, 2008-2011 SDE, 2012 SDE+) can be found wherein support for offshore (and onshore) wind altered or seized as a result of a new coalition coming to power. Because these changes create uncertainty in the relatively long trajectory from planning to completion (easily 6 years) of a wind park, and wind parks are very capital-intensive, such changes were most inconvenient for project developers; **the Dutch wind sector could only guess what was going to happen next**. By the year 2014, only 228 MW offshore wind capacity was installed.

Plagued by licensing issues, the built of OWEZ (108 MW) by Noordzeewind had only begun in late 2005. E-connection was granted a license for the Q7 zone (120 MW) in 2002, and generated its first electricity 6 years later. In the 2008-2011 SDE subsidy scheme, 12 more offshore wind parks were granted licenses but only two projects (Luchterduinen, 129 MW; Gemini, 2x300 MW, 85 km off coast) were indeed granted subsidy; a requirement for the erection of wind turbines as **the 'grey' electricity price per kWh (~6 cents EUR) cannot be matched by the prices for onshore wind (~9-10 cents EUR) and offshore wind (up to 17 cents EUR)**. Added to the 228 MW offshore installed capacity, 2.645 MW was installed onshore in 2014 (CBS, 2015); in sum less than half of the 6.000 MW overall wind target by 2020 (see figure 5.1).

Figure 5.1 – Dutch national wind targets for 2020 and 2023



Source: CBS, 2015

Adjustments

To increase the Dutch national installed capacity of wind power, policymakers adopted a new approach. The major **2013 energy agreement** was presented in which the energy targets were redefined - 6.000 MW onshore wind by 2020 and 4.450 MW offshore wind by 2023 – and, more importantly, it was described how to reach these new (mandatory) targets. Regarding Dutch offshore wind power, a **phased tender process** foresees in the broad roll-out.

In the period 2015-2019, wind projects with a total capacity of 3.500 MW will be called in tenders systematically, given that ~950 MW offshore capacity is already either planned or built in 2015 (see table 5.2). Prior to the phased tender process, the Dutch home market in offshore wind lacked stability with tenders being called once in a while (e.g. when a new coalition brought up plans with offshore wind). Currently, the Dutch wind sector is provided a basis consisting of annual tenders, justifying investments which increase the chance of winning over assignments by market parties.

As a precondition for the roll-out of offshore wind by the government, the Dutch wind sector representative NWEA agreed on the implementation of cost reduction objectives in the maximum offer prices of tenders. Costs are required to decrease by 40% in 2020 as compared to 2010. Per kWh, this means a cost reduction from ~17,4 cents EUR (baseline) to ~10 cents EUR (market weighed reduction) (TKI Wind op Zee, 2015).

Table 5.2 – Overview phased tender process in offshore wind

Start / realization	Capacity (total 3.500 MW)	Location
2015 / 2019	2x350 MW	Borssele 1&2
2016 / 2020	2x350 MW	Borssele 3&4
2017 / 2021	2x350 MW	Dutch Coast: Zuid Holland 1&2
2018 / 2022	2x350 MW	Dutch Coast: Zuid Holland 3&4
2019 / 2023	2x350 MW	Dutch Coast: Noord-Holland 1&2

Regarding Dutch onshore wind power, a 2013 agreement between the government and provinces foresees in the accelerated deployment. In this agreement, the 6.000 MW onshore wind target has been translated to which province realizes what specific amount of wind capacity. Prior to these **province-level targets**, wind targets were primarily set on a national level and both provinces and municipalities were free to draft their own energy policies. This procedure contributed to siting problems, especially since wind energy proved to be a politically sensitive theme; multiple local stakeholders express opinions on wind energy and influence politicians at their turn.

Consequently, politicians often preferred to postpone or alter decisions regarding wind projects, particularly in times of election, slowing down project developers. This situation seemingly improved now provinces were (finally) given formal responsibility for installed wind power capacity. According to plan, each province has appointed locations for wind projects which allow for the installation of wind capacity equivalent to their respective target (RVO, 2015).

In addition, project developers became **obliged to maximize the social acceptance of stakeholders** by implementing tools (e.g. financial participation of civilians) and methods (e.g. multifunctional spatial use of wind energy along dikes, highways, and near sluices). In response, in late-2014, the NWEA and several environmental organizations agreed on a code of conduct which regulates the involvement of the community in wind projects. The aforementioned, recent developments facilitate the process of planning of onshore wind projects; in 2014, already an additional 865 MW was granted SDE+ subsidy and another 825 MW was under consideration (RVO, 2015).

Looking ahead

Modern society intensively and increasingly relies on electricity. To meet demand, electricity is produced in enormous volumes, making that price differences in energy resources strongly affect revenue levels. Electricity, either renewable (green) or a mix of oil/gas/coal and renewable (grey), is however generic and considered to be an impersonal product as the processes behind electrical power cannot be distinguished. Consequently, sustainability is often subordinate to economic gains.

A recent example can be found in the sharp increase in the combustion of the highly polluting coal due to the relatively low prices for coal nowadays (CBS, 2015). **Pricing differences, however, mainly seem to influence fossil energy resources because installed capacity of wind power has grown steadily over the last four decades**. At present, several promising developments can be observed in the Dutch wind sector but it remains to be seen how these will enfold for Dutch companies.

Dutch turbine producers will have to convince project developers and funders of selecting their turbines instead of those of foreign producers. Apart from the turbine production industry, various Dutch offshore companies are hoping to provide their services in offshore placements. All in all, the Dutch wind sector will have to meet their competitors head-on as **Dutch industrial policy, as a trading nation, favors a role for market forces over protectionism**.

5.2 Analysis

5.2.1 Innovation diffusion

Four niches can be identified in Dutch wind turbines (see table 5.3). Interestingly, inventors firstly aimed at developing as large as possible onshore wind turbines, corresponding to a single niche. In the course of niche development, however, new niches (e.g. offshore wind) emerged, as well as new market niches (e.g. relatively smaller onshore wind projects as targeted by EWT and WES) within the original niche.

Unfortunately, the Dutch niches encountered difficulties breaking through. Analysis shows that foreign turbine producers outperformed Dutch turbine producers in the 1990s, instigating **user preference for foreign turbines** ever since. While wind power is currently becoming widespread, the role of Dutch turbines is namely expected to remain marginal in both offshore and large-scale onshore wind projects, as a consequence of **standard-setting by project developers and funders**.

5.2.2 Niche development

A major problem in niche development was that Dutch wind turbine technology was unable to develop, due to insufficient demand in the early phases of niche development (1970s/1980s). The lack of sales disfavored a timely stabilization of the Dutch niches – mainly technological niches – leading to competitive advantages for foreign turbine producers, whom did outgrow the stage of technological niche based on a stable home market. Reflecting on the case study, foreign turbine producers subsequently gained dominance in the Dutch market based on standard-setting (first via price-performance ratio, and later company size), hampering the (further) development of Dutch turbine producers.

Remarkably, after the turn of the century, the new cases of EWT and WES did evolve into market niches, indicating that **business opportunities hardly ever fade away**. A similar phenomenon is observed in the uptake of offshore wind projects where the Dutch offshore industry is now implementing their fossil-based expertise.

Technology

The early development of Dutch wind turbine technology was sub-optimal as the **Dutch inventors were muddling through in technological development**, largely due to the government being unresponsive to the needs of the (fragmented) domestic wind sector. When the first (perverse) Dutch support measures were introduced in the mid-1980s, **Denmark and Germany were already protecting and stimulating their niches via stable support systems**, aimed at improving the optimum yield of turbine systems instead of merely generator capacity like volatile Dutch support systems did. Analysis shows that **as years passed, foreign turbines became more technologically advanced**, resulting in competitive advantages based on price-performance ratio, and later company size.

A second round of development of offshore wind turbine technology was realized by the turn of the century. Although a frontrunner position was obtained around the year 2001 - demonstrated by the conducted experiments and filed patents - this position was again lost in the absence of a continuous progress in development.

Table 5.3 – Technology readiness in wind turbines

Application: range	TRL (0-9)	Technology status	Progress
Offshore	8	First of a kind commercial system	Systems complete and qualified
Onshore: 50 – 250 kW	9	Full commercial application	Technology available for users
Onshore: 750 kW – 2 MW	9	Full commercial application	Technology available for users
Onshore: 2+ MW	9	Full commercial application	Technology available for users

Market

Pioneers in Dutch wind turbine production were initially **unable to generate sufficient sales** for creating a viable business case. One reason was that oil price fluctuations caused volatility in demand for wind power (1970s/1980s). Remarkably, at times of relatively high interest for wind power, niche development remained restricted, as surging **demand could not be effectively translated into Dutch turbine deployment.** Reasons relate to the role of value proposition (users preferred foreign turbine designs) and actor involvement (the governmental regulatory framework was instable with regard to licenses and subsidies).

Nowadays, due to the capital intensity of wind projects, **foreign turbine producers enjoy user preference based on their company size and associated financial guarantees**. This makes that the relatively small Dutch turbine producers hardly benefit from the recent impulse to the Dutch home market. For instance EWT is capable of constructing large-scale wind projects, but typically foreign turbine producers are contracted. Therefore, **EWT and WES focus on wind projects up to a few turbines, avoiding the international competition on too high standards.**

A further analysis is made by investigating the influencing factors of niche development.

Visioning

The early expectations with regard to both onshore wind in the 1970s and offshore wind in the 1990s were relatively high. **Performance, however, did not measure up to these expectations** (see table 5.4), negatively affecting the development of the respective niches. For example, the large-scale thinking about onshore placement by the Dutch government proved to be too optimistic, hampering technological development in the Netherlands. Following the most recent impulse to the Dutch home market, expectations are again relatively high and provide legitimacy to several actors to invest in wind power.

Table 5.4 – Early expectations in wind turbines

Early expectation	Actor	Source of change
Large-scale applications of multi-megawatt onshore wind turbines are the way to go	Government, industry (e.g. Stork, Fokker)	Technological jump too great, reluctance of stakeholders
Business opportunities in onshore wind	Turbine producers, project developers	Volatile user demand, persistent technological problems
Experiences with OWEZ enable the draft of an effective policy for future offshore wind parks	Government	Immediate interest generated from private sector > licensing process closed
Business opportunities in offshore wind	Offshore industry, turbine producers, project developers	Regulatory instability

Finances

One crucial financial aspect in realizing wind projects relates to the dependency on subsidies. Without subsidies, project developers do not commence the construction of a wind project, as a positive return on investment cannot be realized. This **dependency on subsidy was a major issue in niche development since Dutch regulatory frameworks were volatile**. Additionally, **the high level of uncertainty that came with each regulatory change slowed down wind initiatives**, in particular because project developers require multiple years between planning and completing a wind project.

Furthermore, Dutch turbine producers were **unable to run serial production and lower their costs per unit by implementing learnings, due to a lack of sales**. The latter also resulted in funding issues given that payback periods remained highly uncertain in the Dutch wind sector. Recently, in stark contrast to the prior situation wherein the wind sector could only guess what was going to happen next, **multiple wind projects are announced and will be erected up to 2023. This way, interested market parties are finally provided with a solid base for investing substantial funds in the Netherlands**.

Value proposition

Reflecting on the case study, the offerings of Dutch turbine producers were predominantly ineffective in obtaining user preference (see table 5.5). Product differentiation initially focused on price-performance ratio, and Dutch turbine producers were outperformed by international competition on this criterion. **Later, Dutch turbine producers were also outperformed on company size as foreign rivals had acquired relatively strong track records and financial positions, largely due to their earlier obtained market positions**. Only EWT and WES have become effective in answering demands of relatively smaller users, albeit through avoiding foreign rivals which target larger user segments.

Table 5.5 – Overview offerings in wind turbines

Users (inventor)	Added value claimed by inventor	Dominant design	Performance	Effectiveness in developing user preference
Isolated grid areas (WES)	Wind-diesel hybrid power	Diesel aggregates	(+) Attractive payback period (+) robust design	Effective
Electricity companies; up to a few turbines (EWT)	Renewable, clean energy	Oil, coal, gas, nuclear	(+) Environmental friendly (-) price gap	Ultimately effective
Offshore (Zephyros > XEMC/DarWinD)	No siting problems	Onshore wind power	(-) Huge price gap (-) technologically challenging	Ultimately effective
Farmers and small companies (e.g. Lagerweij, NedWind)	Independence in electricity	Electricity from utilities	(-) Price gap	Initially effective
Electricity companies; multiple turbines	None	Foreign wind turbines	(-) Price-performance ratio (-) company size (-) siting problems	Ultimately ineffective

5.2.3 Momentum

The niches under study were unable to develop in such a way that they could effectively compete with their dominant alternatives, i.e. other energy sources but primarily foreign wind turbine designs. This, in spite of relatively high enthusiasm among stakeholders at different timings, made that the **niches lacked the stability for gathering momentum**, necessary for reaching a breakthrough, thence **leaving cracks in the energy regimes unused** (see below).

Exemplary is the case of offshore wind where, induced by the onshore siting problems, stakeholders gradually became more enthusiastic on offshore placement. Following the positive first Dutch lake experiment and near shore park announcement by the government, enthusiasm peaked. **Multiple stakeholders became eager** to commence the construction of offshore wind projects **and teamed up (e.g. consortia were formed) in order to realize a breakthrough**. A breakthrough of the offshore wind niche in the Netherlands, however, never occurred as developments were strongly decelerated by hurdles in regulations and volatile support systems.

At present, cracks in the energy regimes are still apparent – for instance the combustion of coal is heavily debated in combination with climate change – and although this is likely to be favorable for wind energy solutions, the Dutch inventors are unlikely to benefit from this. Users have choice and prefer foreign turbine producers over Dutch turbine producers based on company size, largely for reasons related to **risk management**.

5.2.4 Regime stability

When wind power was introduced in the early 1970s, a variety of energy sources (e.g. nuclear, oil, coal, natural gas) existed which were dominant to wind energy. These designs have been rather stable because of **relatively strong cost advantages over wind energy; crucial given the homogeneity of the end product, electricity**. However, as of the 1970s, the dominance of fossil-based energy resources (nuclear, oil, coal, and in minor extent natural gas) started to weaken for a variety of changing reasons (e.g. political, industrial, economic, environmental).

Analysis shows that actors increasingly share the standards of renewable energy resources as renewable technologies – in particular solar photovoltaic, but also wind energy – have demonstrated significant cost reductions over the last decades, narrowing the price gap with power generated from fossil fuels and nuclear reactors. With a **declining cost advantage for the (polluting) dominant designs in energy**, and the increasing pressure from an environmental stance in particular, energy regimes increasingly feel discomfort.

Nonetheless, in spite of several actors (e.g. the government, NGOs) involved in discouraging the appliance of the dominant designs, **actors were often insufficiently aligned in facilitating the niches under study**, evidently leading to relatively weakly developed niches in the Netherlands. In this sense, actor involvement hampered the formation of stable Dutch (market) niches while cracks in energy regimes did exist.

5.2.5 Landscape pressure

Environmental issues like global warming make that the broader setting is slowly changing, resulting in pressure on the stability of energy regimes. A number of examples illustrate this phenomenon. The governments of industrialized countries are for instance negotiating terms for combating climate change via **universal climate agreements** (e.g. such as in Kyoto, Paris). Regarding the Paris summit, 195 national governments had until October 2015 to publish their road maps in policy for reducing greenhouse gas (GHG) emissions, and energy provisions evidently play a major role herein.

Analysis shows that the sense of urgency is increasing. For example internationally leading market parties (e.g. Shell, BP) started contributing to public discussions such as the financial bubble in oil, and the likeliness of ever fully exploiting oil reserves in relation to climate concerns. In addition, expectations are that **fossil-oriented investments become less likely to meet the new standards of funders**. For example APG, subsidiary of the pension fund ABP, one of the largest pension funds in the world, recently adopted a new investment strategy for managing their clients' pension assets and boosts investments in sustainable funds and companies and encourages firms to improve their social policies. Against this background, the focus on the overall performance of energy resources intensifies, resulting in **greater windows of opportunity for renewable technologies**.

6. STARCH PLASTICS: *THE POTATO STARCH RECIPE (1990-2015)*

This chapter covers the results and analysis of the case starch plastics. Firstly, the results are presented. Secondly, an analysis by means of the theoretical framework is provided.

6.1 Results

Increasing concerns about waste problems in the 1980s made several (typically European) companies decide to start developing bioplastics. Bioplastics are based on renewable raw materials and can offer benefits regarding waste management in comparison to conventional (synthetic) plastics. The development in the Netherlands of bioplastics out of potato starch, also known as starch plastics, started in the early 1990s by potato farmer cooperative **AVEBE**. For offering their members a better return for agricultural surpluses, AVEBE diversified its portfolio from processing starch for food applications, textiles, and glues towards developing starch plastics.

A share of 3-5% of the total plastics market was the rough estimate of the market potential for starch plastics arrived at by the board members of AVEBE, whom set up a large-scale project for effectuating their 1991-corporate strategy. AVEBE opted for becoming a global player in the production and supply of granulate, the intermediate product for starch plastics. The goal set by AVEBE was to develop a **starch based, 100% biodegradable granulate for injection molding, sheet extrusion, vacuum molding and film blowing.** These are common transformation techniques in conversion industries. To assist in application research and equipment, AVEBE contracted the Agrotechnological Research Institute (**ATO-DLO**).

Two major issues, however, emerged in the development process. Firstly, starch plastics had the functional problem of **water sensitivity,** as moisture quickly softened the material, strongly reducing the number of potential applications. Secondly, the starch granulate was unable to deliver the fluid properties required for the transformation techniques, i.e. it had **limited viscosity**.

Potato starch consists of two polymers, amylose and amylopectin, of which amylose prevents starch from becoming plastic-like. Hence the granules could only be transformed in a relatively thick material that – although suitable for injection molding and sheet extrusion – proved unfit for vacuum molding and film blowing; techniques that would provide access to the relatively large customer segments in plastics, i.e. bags and foils. The first granulate, named **Paragon®** was launched in 1995, together with the first injection molded products.

The first market introduction by AVEBE was a starch esophagus blocker for animal slaughter. Unlike synthetic blockers, **starch blockers were eatable and did not have to be removed** before the esophagus was processed into dog- or cat feed. The product became a hit with over 70% of the **Dutch slaughtering houses** applying it. More products like **golf tees, tomato clips, plant pots and shooting clays** were developed but their uptake was hampered by **performance and pricing issues**. Nonetheless, the resulting articles and press releases caused a breakthrough in Paragon®-production.

The American firm **TFH**, a producer of nylon dog chews, showed a strong interest in Paragon®. Unlike nylon, Paragon® could be eaten, promoting **repeat purchasing**. TFH promptly bought the annual capacity of AVEBE's pilot installation (500 tons) for testing, and filed application patents. In the following period, expectations peaked at AVEBE, primarily because Paragon® production needed up-scaling to prevent any sold out.

In 1997, AVEBE built the world's first factory for the commercialized production of potato starch granulate (capacity 4.000 tons p.a.). By that time, AVEBE was an expert in granulate production and injection molding conversion. The next step was to improve the fluid properties of Paragon® so that it could be vacuum molded and film blown, thereby fully utilizing the market potential of starch plastics. However, expectations met their turning point turned towards the turn of the century.

For years, AVEBE focused on finding a renewable, 100% biodegradable resource that could be blended with starch for overcoming the issues of water sensitivity and limited viscosity. In 1997, this search resulted in the **first film blown products using a blend of starch and poly lactic acid (PLA).** Huge interest from potential customers was generated but since PLA was relatively expensive, **no deals were closed**. In turn, AVEBE hoped to complete the development of homogeneous, amylopectin potatoes for (at least) upgrading the fluid properties of Paragon®.

Unfortunately, in 1999, after 8 years of research into **amylopectin potatoes** by AVEBE, the Ministry of VROM withdrew the license for cultivating amylopectin potatoes because they were 'genetically engineered'. Following the **license withdrawal,** AVEBE wrote off ƒ20 million for R&D investments and compensation since 300 farmers were compelled to destroy their crops. Simultaneously, **AVEBE was losing terrain in bioplastics**, largely because AVEBE firmly held on to their vision of a renewable, 100% biodegradable solution for replacing plastics like PE.

Blending starch with synthetics was not considered an option by AVEBE as it meant a sub-optimal solution to the waste problems. Consequently, AVEBE would never market film blown products. AVEBE did for instance sheet cast products like banking cards, chewing gum strips and bag clips, but the functionalities remained unsatisfactory. Throughout the 1990s, AVEBE and ATO-DLO performed **pioneering research into the optimization of starch plastics** but the notion slowly emerged that their vision was a bridge too far.

International competition

More companies pioneered the development of bioplastics – in particular ICI, Warner Lambert, Novamont, Biotec Biolog, Cargill/Dow, and Purac – and produced a diversity of bioplastics in the 1990s. Actually, the first renewable, biodegradable bioplastic was already commercialized by Imperial Chemical Industries (ICI, England) in the 1980s. ICI's produce, a biopolyester (PHB, PHA) obtained via microbial fermentation of sugar or glucose, was named Biopol®. In the early 1990s the firm Wella used Biopol® to make its shampoo bottles in Germany. Although the relatively high costs of Biopol® eventually led to a temporary closure of production, this biopolyester inspired later bioplastics producers, as it was both water resistant and well-moldable.

Regarding international competition in starch plastics, Novamont (Italy) and Biotec Biolog (Germany) were AVEBE's most direct competitors. Unlike AVEBE, **Novamont and Biotec Biolog did choose to blend starch with synthetics for overcoming the problems inherent to applying starch**. Novamont was founded in 1990 and produced their first Mater-Bi® film blown bag two years later. Also in 1992, Biotec Biolog marketed their first BIOPUR® starch foam tray. Three years later, this German company introduced their refuse bag out of BIOPLAST®, certified as the first ever compostable bioplastic in 1997. From that point, it became harder for other bioplastics producers to deceptively claim biodegradability (see table 6.1).

Table 6.1 – Producers of bioplastics in the 1990s

	Not biodegradable	Biodegradable
Fossil-based	Regular (synthetic) plastics such as PE, PP, PS, PC, PVC	BASF (Ecoflex®)
Partly biobased (fossil-based and biobased)	Novamont (Mater-Bi®, 1st generation)	Biotec Biolog (BIOPLAST®)
Biobased (100% renewable)		AVEBE (Paragon®), ICI (Biopol®), Biotec Biolog (BIOPUR®)

SunTray

Since the early 1990s, the Dutch firm **SunTray** was developing **starch food containers** as an answer to the littering problem with food packages. Based on a 'waffle baking' production process, the entrepreneur had built an machine but the high water content in starch caused the molds to jump open when heated, leading to **numerous rejected (foamed) food containers**. In addition, there was a problem with the starch food containers being sensitive to water. When SunTray contacted AVEBE for the supply of potato starch, AVEBE was nevertheless impressed by the achievements of the startup, and took part in SunTray in 1992.

AVEBE was interested in developing a new outlet for potato starch, but creating demand for the food containers appeared to be harder than anticipated, in spite of technological improvements to the products. Fast food stores like snack bars, canteens and cafes had little interest in the food containers, as they were **both voluminous and relatively expensive in comparison to synthetic containers**. Furthermore, only few customers asked for alternative packaging while a switch to alternative packaging was not made mandatory.

To the contrary, the **added value of starch plastics was publicly being questioned by NGOs** like Natuur&Milieu and Milieudefensie in the 1990s. One persistent public debate linked starch plastics' ability to decay in nature to **legitimizing littering**. This viewpoint was supported by the Dutch Ministry of Environment; like many environmentalists they were not convinced of the advantages of **sustainable disposables**. While the arguments undermined the main features of starch plastics, AVEBE had difficulties managing this dispute.

For turning things around at SunTray, after the original owner had left, AVEBE started targeting store owners which wanted to position themselves as frontrunners in sustainability. The food containers were given a distinctive look (oval shape, light yellow color) and various studies (e.g. LCA) were conducted for supporting the environmental claims. SunTray was furthermore provided assistance by an AVEBE-subsidiary named **Vertis**. Sales, however, remained too low and SunTray discontinued in 1995.

Reorganization

In the late 1990s, **AVEBE got into financial problems** due to its corporate diversification strategy and associated high risk investments (e.g. in tapioca factories in Asia and South-America, amylopectin potatoes). This financial situation made AVEBE's owners decide that the cooperative would return to its core business. Hence in subsequent years **the highest bidder could buy each loss-making activity, also including bioplastics by the year 2003.** The decision can be attributed to the **mismatch between the value-oriented Paragon® and the volume-driven structure of AVEBE**.

Annually, potato starch comes in at AVEBE that needs to be sold before the next harvest. In line with this volume-driven approach, sales employees were rewarded on the basis of volumes sold. Sales employees therefore preferred selling high quantities of standard starch derivatives over efforts to sell high value-small volume Paragon®, partly because they lacked the know-how for supporting granulate converters. It meant that although promising markets were found for Paragon®, **sales remained too low to pay off the R&D costs**.

Following the research carried out by AVEBE, the development of starch plastics in the Netherlands did continue: Rodenburg Biopolymers and PaperFoam were founded in the second half of the 1990s and later also Paragon Pet Products started business.

Rodenburg Biopolymers

Led by AVEBE's estimation of the market potential for starch plastics and promising publications by ATO-DLO, the distributor Rodenburg got the idea to transform its **by-products from the potato industry** into starch plastics, levering their profitability. In 1998, Rodenburg contracted ATO-DLO for the development of starch plastics. The first experiments were conducted using steam potato peels, an abundantly available by-product that was cheap and contained starch. One year later, the first granulate named **Solanyl®** was introduced with great enthusiasm.

Similar to AVEBE, Rodenburg opted to become a global player in the production and supply of granulate. They asked potential customers what functionality (hard, flexible, strong, weak) they would like their end products to have, after which Rodenburg developed the composition. Aiming for products with a short lifespan so that biodegradability could deliver functional advantages, Rodenburg initially investigated **horticultural products**. Surprisingly, two issues hindered a wide uptake of Solanyl®.

Firstly, due to the protein in steam potato peels, a chemical reaction ignited in the transformation process that gave a **mal odor** to end products. Rodenburg spent years conducting experiments to remove or mascade the smell. The solution was eventually found in an alternative, more expensive resource (white starch) in 2003.

Secondly, once converted the compositions were not always consistent. This **inconsistency** resulted from different specific weights of the mixed granules (e.g. Solanyl® with PLA), causing the compositions to de-blend in transit. This problem was solved only by 2006 when Rodenburg managed to successfully modify and blend in one run. These unexpected issues got **Rodenburg financially stressed as a result of underutilization of capacity**.

In 2001, two years after Solanyl® was launched, Rodenburg had built the world's second largest bioplastics factory. Subsidies helped to finance the factory but Rodenburg now had 12.000 tons capacity that needed to be filled annually. In the absence of sufficient market demand, **Rodenburg headed on a different course to generate income**. As of 2001, based on a technique that was borrowed from AVEBE, Rodenburg started modifying starch for **drilling fluid systems** for the oil- and gas industry (e.g. Halliburton, Ramco). By 2003, Rodenburg produced 6.000 tons of **Flocgel LV®**, and even operated on full capacity.

Rodenburg furthermore contacted EcoSynthetix in 2005 and started selling **Bio-latex®** for the paper and paperboard industry. Bio-latex® is produced out of starch nanoparticles, under the license of ATO-DLO. Still, **bioplastics has a marginal share in the total output of Rodenburg**, and the 2001-factory has never been used to produce bioplastics; the production takes place on a pilot installation that was installed in 1999. Interestingly, more recently the market situation slowly improves, according to Rodenburg; where the environmental benefits of Solanyl® used to be subordinate to its relatively higher costs and specific weight, other examples are seen.

Rodenburg for instance developed the packaging for a premium chocolate bar producer. Compared to their current packaging, the cost price of Solanyl® was higher, but since a **carbon emission** reduction of 55% was achieved, expectations are positive for a contract as of 2016, making it the first large customer of Rodenburg in almost two decades. Status quo, however, **remains that Rodenburg produces a wide diversity of low-volume starch plastic products,** largely because the firm keeps finding itself in the position in which it needs to invest in the end product in order to close deals.

Potential customers typically always ask for a **proof of principle** as they 'need' to assure whether a product out of Solanyl® delivers. To demonstrate functionalities, a mold is required and investing in costly molds by Rodenburg is a risky endeavor, preceding any contractual agreement between the customer and Rodenburg. Banks hardly give out loans without such contracts, the more since Rodenburg just managed to continue its business, after its **technically bankruptcy in 2013**. Sporadically a contract is closed, but then the question is raised whether there is a **business case,** as the low volumes prevent investments to be earned back within a reasonable timespan.

PaperFoam

When SunTray discontinued in 1995, employees of Vertis whom had worked on the SunTray project pursued their research as they foresaw a market opportunity for an innovative foamed packaging which could potentially replace polystyrenes (EPS). After three years of experimentation, the water sensitivity of starch was improved by forming a **bio-composite material** made of starch, natural fiber, water and a secret pre-mix, and the technology was upgraded to a **one-step baking process based on injection molding**. Both were patented by Vertis and named **PaperFoam®**. Vertis set up a separate company to oversee the implementation in 1998.

As the marketplace appeared harder to convince than anticipated, the firm PaperFoam **first needed to demonstrate that their packaging indeed worked**, particularly given the critical role of packaging in the acceptance of end users. One year after PaperFoam was founded, it was granted a subsidy in the European Commission's **LIFE programme**. A demo-plant was built in order to prove PaperFoam's capability of producing various kinds of packaging (EC, 2002). At the end of this LIFE programme in 2001, the results exceeded expectations; PaperFoam® proved to be a breakthrough in terms of functionality and production efficiency.

Compared to equivalent packaging out of petroleum and pulp, PaperFoam® significantly lowered the energy-intensiveness in production, resulting in **carbon emission reductions up to 85%** (EC, 2002). PaperFoam® is furthermore lightweight, 100% biodegradable and contains no toxins, allowing the material to be disposed in any waste process (paper recycling, composting, and combustion). **Dissemination of the results generated worldwide publicity** via press releases, articles, exhibitions, and multiple awards among which the reputed Worldstar 2003.

PaperFoam aimed to generate a global network of licensees, mostly packaging companies, for more rapidly introducing their technology. In attracting licensees, it was advantageous that the production process of PaperFoam operates on relatively cheap and compact units, requiring only a modest investment to start a production line. Because of the modular set-up, production capacity can also be increased incrementally, reducing the risk of costly over-capacity (EC, 2005).

Simultaneously, launching customers were found in the non-food chain: Bosch, Packard, Siemens, Ascom and Detewe; all active within the LIFE-programme. Because the generated orders mostly included **specialty fittings** for luxury goods which regularly change shape and then require a new mold, PaperFoam also started focusing on replacing more **mainstream products with longer technology cycles** like CDs and DVDs (Refdag, 2011). Major companies like Universal Music Group and Sony BMG went for PaperFoam as they could produce **in bulk and at low cost**, whereas earlier suppliers of sustainable products could not.

Other firms got attracted to PaperFoam for its qualities in design. For example AMD contracted PaperFoam for improving the **anti-piracy qualities** of their hard-drive packaging. By combining design tools (e.g. CAD), sharp lines can be added which form inimitable features for other sustainable materials. Apple for instance turned to PaperFoam in search of an **unusually shaped** innertray for its products (iPod Nano and Video, as of 2005; iPhone, as of 2008). Finding a launching customer in food packaging, however, proved to be complex. Only in 2011, in partnership with **Rondeel**, the first egg boxes were marketed in different **colors** and shapes.

At present, PaperFoam produces for a wide variety of clients, but barriers to an even wider uptake exist. Despite current production facilities in Malaysia, the United States and the Netherlands, PaperFoam® is voluminous, hampering cost-effective deliveries (Conscious, 2015). For increasing the availability, PaperFoam plans to build new factories in other regions (China, Eastern Europe). Other barriers relate to positioning (as a high marketing value packaging option against relatively low costs, PaperFoam cannot compete on price with conventional materials in low value packaging) and the stability of properties (as PaperFoam is not applicable in high-humidity conditions). In spite of these challenges, PaperFoam is 'baking' its way to more sustainable packaging globally.

Paragon Pet Products

As a result of the 2003 management buy-out of AVEBE, two former employees of AVEBE set up a separate company to effectively continue the Paragon business, and **Paragon Pet Products** was founded. The entrepreneurs opted to find unique properties of starch plastics and exploit them. In the meantime, they **supplied granulate towards customers like Pedigree Pal and Nylabone/TFH**, which injection molded their end products themselves. After one year, however, the entrepreneurs noticed they had obtained specialized know-how at AVEBE as **most customers needed intensive instructions for transforming granulate**.

Hence the entrepreneurs decided to **integrate forward for upgrading the profitability of their activities**. As of 2004, Paragon Pet Products designed, manufactured and supplied dog chews to companies under **private label**. For attracting private label companies, a wheat-based granulate was developed and patented; wheat starch is a relatively cheap resource in comparison to potato starch, enabling the chews to be marketed at **attractive pricing levels**. The chews were furthermore given **specially designed shapes** which not only helped to develop and clean dog teeth, but also **appealed to dog owners**, who actually buy the chews. **In 2012, ~15% of production was destined for the home market and ~85% was exported, mainly towards the United States** (WUR, 2012).

A step-wise development of the firm was initiated based on a smart production facility using state-of-the-art machinery. One mold could for instance produce multiple chews in a single injection, without loss of material, and the modular set up allowed production units to be incrementally added. In developing this production process, it was beneficial that the entrepreneurs could cooperate with **DEMAG**, a supplier of premium injection molding machines, who had supported AVEBE prior, e.g. via interesting buying conditions. Once the production line turned out cost-efficient and profitable, it became a matter of **duplication in order to generate more profit**.

In 2014, after 11 years of providing services, the firm eventually launched their **own brand** named **Whimzees®**. This new brand was differentiated from the existing activities under private label by using potato starch as a resource instead of wheat, and new dog chews were designed (e.g. a tooth brush, hedgehog). In positioning Whimzees®, great care was given to **trends in food** like clean label, fun, and health improving (e.g. contains fibers, no gluten in potato starch), and explaining what the ingredients were, why they were added and why specific shapes were chosen for **winning over the dog owners' trust**. The chews now increasingly find their way to pet stores, do-it-yourself stores and garden centres, especially in the United States, and Paragon Pet Products even refused to supply the world's largest retailer, **Wal-Mart**, on behalf of responsible company growth.

Synthetic dominance

Starch plastics are the largest type of bioplastics, albeit that their share in the total plastics market still amounts to less than 1% (2015). Successful introductions in large, price-competitive markets remained scarce, largely as **starch plastics often fail to directly compete with plastics on performance and pricing, simultaneously.** For example high engineering plastics exist which are resistant to water, heat, chemicals and sliding at the same time, underlining that **starch plastics still have a whole lot of catching up to do in the field of chemistry**. Consequently, multinationals in plastics like Bayer (Germany) and Sabic (Saudi-Arabia) consider starch plastics inferior to plastics, and do not regard them a short-term alternative. **Diminishing oil-supplies are also not considered a major problem yet by multinationals** as plastics production requires only <4% of the oil on the global market annually.

Bioplastic producers point towards the role of **public awareness** for instigating other (more sustainable) choices in plastics. However, supporting bioplastics and discouraging the use of plastics prove to be difficult undertakings, especially in the absence of one designated bioplastic for replacing large plastics. One example refers to the relatively high taxes on waste for synthetic plastics, implemented as of 2016, believed to primarily harm the pricing levels for end consumers. Another example refers to the governmental goal of lowering the 3 billion free plastic gas used in the Netherlands annually. Therefore, it became mandatory for retailers to ask 10 cents EUR per bag for all bags as of 2016. Were, prior, plastic bags a service to the customer, the bags now remarkably became items of revenue for retailers since they may keep the payments.

On the whole, plastics may offer functionalities which are difficult to match by starch plastics. Starch plastics find their way to the market due to specific qualities or other advantages inherent to starch. For example, starch-based **capsules** pre-empt chips or medicine to be brought into animals. Also entirely new concepts using starch plastics emerged such as **Pharmafilter®**, a project aiming to make hospitals collect their waste in starch plastics, where the bioplastic's ability to naturally decay is then used in a fermentation process for providing 'green' electricity to the hospital on location. All in all, stating whether the prospects for starch plastics are rosy or fairly dismal remains an open question, even after two decades.

6.2 Analysis

6.2.1 Innovation diffusion

A number of niches can be distinguished in the Dutch development of starch plastics (see table 6.1). In their process of niche maturation, analysis shows that **starch plastics often fail to directly compete with conventional plastics on performance and pricing, simultaneously**. Two Dutch cases – PaperFoam and Paragon Pet Products – were observed to be rapidly spreading their innovations among users, largely because they do outperform their dominant designs. Stating whether these innovations will set new standards and replace existing regimes or form new ones is still premature.

Reflecting on the case study, windows of opportunity for niche development did exist for the other niches, but hurdles are to be overcome before many more users adopt bioplastics (current market share in total plastics market: >1%). Analysis did show that landscape developments increasingly pressure the plastics regimes from an environmental stance, resulting in (larger) cracks from which the starch- and bioplastics products could benefit.

6.2.2 Niche development

A major problem in the development of the niches under study concerns the inability of starch plastics (e.g. Solanyl®) to obtain user preference. Interestingly, since the early 1990s, **demand does seem readily available on the conditions that (i) a value proposition is appealing and (ii) a proof of principle is available**. In this sense, crux in niche development can be found in the supply-side of starch plastics, here not forgoing that dominant designs strongly complicate the creation of appealing offerings by inventors, because the **standards on performance and pricing are set high by incumbent parties**; found to be a critical source of regime stability (see below). Unlike foreign bioplastics producers in the 1990s, Dutch entrepreneurs merely succeeded in marketing starch plastics for which relatively much smaller markets exist than for film blown bags and foils.

Analysis furthermore showed that the niches encompassing injection molded products and bio composites outgrew the stage of technological niche, sometimes after **inventors made discoveries they were not in search for**. For example Vertis had not expected to find an innovative foamed packaging in the rejected SunTray food containers; an occurrence that was unexpected **but changed their course of development in a beneficial way**.

Technology

Technological issues with starch plastics categorically slowed down niche development, particularly in the early 1990s. At that time, starch plastics were still oversensitive to water, reducing the number of potential applications for AVEBE. Besides, it was not technologically feasible to convert Paragon using all common transformation technique. Because **AVEBE refused to blend starch plastics with synthetics** for improving the properties of starch plastics as this was not in line with their vision (see below), and failed to solve the observed issues otherwise, e.g. via starch-PLA-blends and amylopectin potatoes, AVEBE would never market film blown products. **AVEBE eventually lost their frontrunner position** in technology to foreign rivals like Novamont which pragmatically did blend starch with synthetics. Currently, all technologies are available for users (see table 6.1).

Table 6.1 – Technology readiness in starch plastics

Application	TRL (0-9)	Technology status	Progress
Granulate supply (for all transformation techniques)	9	Full commercial application	Technology available for users
Foils and bags (based on film blowing)	9	Full commercial application	Technology available for users
Injection molded products (e.g. dog chews, blockers)	9	Full commercial application	Technology available for users
Bio-composites (based on injection molding)	9	Full commercial application	Technology available for users

Market
Analysis shows that demand for starch plastics was created where dominant designs were outperformed on both pricing and performance, like explicitly occurred with the esophagus blocker and dog chews. Other innovations were not accepted by users (e.g. shooting clays, food containers) or were never marketed (e.g. film blown products) as users **could not be activated solely on the basis of environmental claims** (e.g. biodegradability, LCA studies) and the offering thus remained unsatisfactory.

Interestingly, users are observed to increasingly value environmental benefits. For example Rodenburg trusts on contracting a large market party because a switch towards Solanyl®, although being a relatively costly bioplastic, significantly reduces the carbon footprint of this food manufacturer. **Precondition for persuading potential users is the availability of a proof of principle,** demonstrating that the starch plastic indeed justifies a broad roll-out by the respective user. Also PaperFoam first required the construction of a demo-plant for showing the (de facto) possibilities of their packaging, after which huge interest was generated from users.

A further analysis is made by investigating the influencing factors of niche development.

Visioning
The early expectations with regard to the (market) potential of starch plastics were relatively high and **attracted more entrepreneurs and other actors** (see table 6.2). For example, the expectations of AVEBE attracted Rodenburg to invest in developing bioplastics, and also PaperFoam and Paragon Pet Products started business as a result of the research carried out by AVEBE, sharing similar expectations and continuing the development of starch plastics after AVEBE ceased their activities herein. Regarding the latter, it can be debated whether AVEBE should have ignored starch-synthetic-blends on behalf of a more step-wise development towards reaching their vision of replacing plastics, the more since other **Dutch inventors embraced occurrences which were unanticipated but positively changed their innovation pathway**.

Table 6.2 – Early expectations in starch plastics

Early expectation	Actor	Source of change
Huge market potential of starch plastics estimated at 3-5% of the total plastics market	AVEBE	100% biodegradable solution for replacing plastics a bridge too far > performance and pricing issues
The (voluminous, foamed) food containers of SunTray could not be effectively marketed	AVEBE, Vertis/PaperFoam	Vertis foresaw an innovative foamed packaging for replacing polystyrenes (EPS)
Becoming a global player in the production and supply of granulate	Rodenburg	Underutilization of capacity due to continuing low demand for Solanyl solutions > performance and pricing issues
Finding unique properties of starch plastics and exploiting them as a supplier of the granulate	Paragon Pet Products	Specific technical know-how acquired > forward integration for upgrading the added value of activities in dog chews

Finances
The importance of achieving a positive return on investment during an innovation trajectory was illustrated by AVEBE. Their pioneering research into the optimization of starch plastics ceased - even though promising markets were found for Paragon® - because sales remained too low for paying of the R&D costs. When Rodenburg, however, experienced difficulties in creating a viable business case out of starch plastics, they headed on a different course (i.e. selling Flocgel LV®, Bio-latex®) to generate income. It can thus be derived that **inventors must seek to generate turnover for continuing their innovation trajectory**, e.g. by temporarily picking low-hanging fruits, **regardless of whether this (temporarily) deviates from the designated pathway.**

Furthermore, the development of PaperFoam and Paragon Pet Products benefitted from a **modular set-up of production processes**. Because their production capacities could be increased incrementally, this reduced the risk of costly over-capacity (á la Rodenburg). For attracting licensees by PaperFoam, it was found beneficial that a technology operates on relatively cheap units, requiring only a modest investment to start a production line.

Value proposition
Analysis shows that a number of offerings were able to (ultimately) develop user preference (see table 6.3), revealing that **starch plastics need to be more than just substitutes** for products made from synthetics. Distinct

feature of starch plastics is biodegradability, but product **differentiation solely on the basis on sustainable features appeared insufficient** for winning allegiance of the marketplace; unless a starch plastic is competitive on both performance and pricing, distinct features can differentiate an innovation from those of competitors. Paragon Pet Products also showed that products can be differentiated from (sustainable) alternatives via their **resources** (e.g. wheat, potato) and **smart communication**; Whimzees® intends to win the dog owners' trust by pointing out trends in food and herewith creates value.

Table 6.3 – Overview offerings starch plastics

Users (inventor)	Added value claimed by inventor	Dominant design	Performance	Effectiveness in developing user preference
Slaughtering houses (AVEBE)	Biodegradability	Synthetic esophagus blockers	(+) Eatable; did not have to be removed before processing (+) price-competitive	Effective
Private label producers (AVEBE, Paragon Pet Products)	Biodegradability	Synthetic dog chews	(+) Eatable; interesting from the viewpoint of repeat purchasing	Effective
Dog owners (Whimzees, Paragon Pet Products)	Health	Private label dog chews, synthetic chews	(+) Trends in food (e.g. fun, no gluten) (+) health improving: shapes help to develop and clean dog's teeth	Effective
Diverse clients (PaperFoam)	Functional advantages due to biodegradability, economies in production	Synthetic or pulp packaging	(+) Qualities in design (e.g. anti-piracy, unusual shapes/colors, secret-premix) (+) savings in production (CO_2) (+) price-competitive, light weight	Ultimately effective; proof of concept required
Diverse clients (Rodenburg)	Functional advantages due to biodegradability	Plastics, blends with synthetics	(-) Price gap (-) higher specific weight (+) savings in production (CO_2)	Ineffective; breakthrough expected
Fast food stores (SunTray)	Biodegradability	Synthetic food containers	(-) Voluminous (-) price gap (-) legitimization act of littering	Ineffective
Golf tees, plant pots and shooting clays (AVEBE)	Functional advantages due to biodegradability	Plastics, blends with synthetics	(-) No business case possible due to pricing and/or performance issues	Ineffective

6.2.3 Momentum

The Dutch niches embedding injection molded products and bio composites reached the necessary stability for gathering momentum. Their relatively strong development can be attributed to the innovations' effectiveness in competing with dominant designs; the performance and pricing were at least equivalent, while functional advantages provided for distinct added value. In the case of dog chews, this added value refers to the eatable aspect of the starch recipe, stimulating repeat purchasing. A further uptake of the innovations is currently hampered by issues relating to responsible company growth, positioning, consumer awareness, and cost effectiveness in logistics.

Stakeholders did become enthusiastic on other starch plastics at different timings, but the **niches appeared unable to benefit from windows of opportunity because the technologies were insufficiently developed for meeting the standards of users**. Particularly regretful herein were the choices of AVEBE in developing film blown products, the largest market in plastics. Recently, changes in the stability of plastics regimes are observable (see below), but the Dutch niches did not yet benefit accordingly; momentum is nowadays gathered only in the relatively small markets for injection molded products.

6.2.4 Regime stability

Since starch plastics were introduced to the marketplace in the 1980s, starch plastics encountered dominant designs including plastics and later also starch-synthetic blends. The plastic regimes proved to be rather stable, mainly because (the relatively small-sized) producers of **starch plastics, and bioplastics in general, have difficulties matching the relatively high properties of plastics**. An example was given of high engineering plastics which demonstrate that bioplastics still have a whole lot of catching up to do in the field of chemistry.

Given the absence of one designated alternative for large plastics and the variety of bioplastics available, **actor involvement remained sub-optimal in carrying the rule-sets of promising bioplastics**. The resulting uncertainty is for instance exerted via hesitance of the Dutch government that is looking to stimulate bioplastics but is forced to act carefully in applying levers as long as it unsure which bioplastic may be considered the best investment.

Various companies and top scientists (e.g. James H. Wang) are nevertheless profiling themselves with certain bioplastics and mobilize resources for their development, stating bioplastics are ready to replace common plastics. However, at present, always a reason comes up, mostly related to pricing (in combination with specific weight), why promising alternatives have not yet been widely adopted by users. Meanwhile, regardless of that some 'greener' plastics (e.g. Ecovio®, Ecoflex®) were added to the fossil-oriented product ranges, multinationals in plastics like Sabic and BASF continue their businesses as usual and also do not consider bioplastics a short term alternative within 20 years.

Altogether, given that finding an alternative for plastics is not an easy task, **inventors try utilizing the added values of starch plastics for a more value-driven approach in competing with dominant plastics, or to create new outlets** (e.g. Pharmafilter®, capsules). In this attempt, starch plastics producers feel strengthened by the increasing concerns about climate change and the associated importance of carbon footprint (see below); **replacing plastics by starch plastics can result in significant savings in carbon emissions by companies, which recently turn out to value variables such as pricing slightly less relevant in the light of strong carbon foot print improvements**.

6.2.5 Landscape pressure

In response to environmental concerns, changes in the landscape can be observed, which slowly but inevitably pressure the stability of plastics regimes via actor involvement. Actors were observed to become activated due to environmental concerns such as climate change, at their turn activating other actors to do the same. One illustrative example can be found in the 2015-historical ground breaking climate case of Urgenda. Urgenda and 900 co-plaintiffs won a lawsuit for better Dutch climate policies, forcing a national government to adopt more stringent actions in reducing their (considerable) share in global emissions. The court agreed that Dutch politicians need to make a true effort in realizing a sustainable economy, considering the enormity of the dangers of climate change posing us. Awaiting the outcome of the appeal, expectations are that stricter regulations on emissions will be implemented for speeding up the sustainable transition, enlarging the window of opportunity for bioplastics producers as companies will embark on a search for more sustainable materials. In this sense, landscape developments are found to pressure regimes, particularly from the viewpoint of carbon emission while niches in bioplastics benefit from relatively (much) lower carbon emissions (e.g. in production). Analysis shows that these niches are becoming increasingly able to benefit from reductions in carbon emissions when replacing conventional plastics, as also recently demonstrated by Rodenburg's Solanyl®.

7. CROSS-CASE ANALYSIS

This chapter covers the cross-case analysis. Based on a mobilization of findings from the case studies, the cross-case analysis describes to what extent the practical results are consistent with the factors from the theoretical framework and/or constitute new knowledge with regard to our conceptualization of biobased sectoral development. Firstly, the key findings are presented. Secondly, conclusions are drawn for empirical part 1.

7.1 Overview key findings

An overview of the representative and/or high impact findings influencing biobased sectoral development is provided in table 7.1, after which a further elaboration on findings from this table can be found.

Table 7.1 - Key findings from empirical part 1

Factor	Representative and/or high impact finding	Explicitly observed in...		
		Hemp	Wind turbines	Starch plastics
Niche development	Insufficient alignment of demand and supply for stabilizing the niches	V	V	V
	Niches typically embed innovations which strive to comply with the market requirements, i.e. licenses, guarantees, and the standards of regimes	V	V	V
	Market requirements tend to increase over time	V	V	+/-
	Achieving high technological readiness levels is not enough to create demand, as **appealing value propositions** are required	V	V	V
	Relatively high expectations (of positive returns and growth) provided legitimacy to more entrepreneurs and other kinds of actors to invest in the innovations, e.g. in time, money, strengthening the hype-status	V	V	V
	Early expectations tended to be too optimistic, resulting in skepticism when results did not deliver up on expectations	V	V	V
	A viable business case for entrepreneurs promotes niche stabilization: - Market-driven approaches facilitate the user acceptance of initiatives - Forward integration can provide inventors with extra added value - A modular set-up of production processes prevents costly over-capacity	V V V V	V V +/- +/-	V V V V
	Niche protection by the government was limited, slowing down niche development	V	V	V
	The development of market niches easily takes up to decades	V	V	V
	The relative value of environmental benefits in cost-benefit assessments is rising, but users cannot be activated solely on the basis of these claims	V	V	V
Regime stability	Regimes have an internal resistance to change due to embeddedness, vested interests, and risk-aversion	V	V	V
	Dominant designs became increasingly embedded in regulations, infrastructures and systems, promoting routine-buying behavior	V	V	V
	Once a dominant design has been established in a market, its high standards become the benchmark for innovations in this particular market	V	V	V
Landscape pressure	Changes in the landscape activate actors which increasingly value the (new) standards of innovations and create cracks in regime stability	+/-	V	V
Momentum	Momentum enables innovation diffusion	+/-	+/-	V
	The presence of both niche maturity and cracks in regime stability enables the gathering of momentum by stabilized (market) niches	V	V	V
	In the absence of momentum, niche development stagnates	V	V	V
Innovation diffusion	Innovation diffusion (endogenous variable) encompasses the spreading of niches at the regime level	+/-	+/-	V

7.1.1 Niche development

Reflecting on the case studies, the niches tended to rather easily outgrow the stage of R&D niche, after which **niche development frequently stagnated at the stage of technological niche due to an insufficient alignment of**

demand and supply. Since SNM literature claims that niche development depends on an increasing alignment of the market (i.e. demand) and a certain technology, the mentioning of supply in combination with demand is particularly interesting as it represents a broader term than solely a certain technology and highlights the role of additional forces in achieving niche maturity.

Analysis shows that niches only scarcely stabilized because - often in spite of achieving high technological readiness levels - demand remained limited. In the example of starch plastics, demand seemed readily available for inventors in the early 1990s, but then the technologies could not yet deliver up on promise, indeed disfavoring niche development. Remarkably, when higher technological readiness levels were achieved, though, demand remained marginal. Referring to SNM theory, niche development may thus require that the market and technology become increasingly aligned, but **technology is not the sole force in making users prefer innovations.**

Innovations needed to comply with the 'market requirements' for creating demand. Consequently, **niches typically embed innovations which strive to comply with the market requirements**, i.e. licenses, guarantees, and outperformance of the standards set by existing products, in order to reach niche maturity. Reflecting on the case studies, niche development is slowed down as the **market requirements are often set high by (incumbent and/or foreign) rivals.** For example hempcrete holds great promise in replacing (polluting) standard concretes, but demand is limited as the inventors are unable to provide the guarantees required by potential users. Niche development is furthermore slowed down because the **market requirements tend to increase over time** (see below), imposing rising thresholds for innovations in obtaining user preference as time passes, leveraging the complexity and duration of niche development further.

Analysis does show that **experiments can provide the proof of principle that is required by users**, whom are generally risk-averse (see below) and 'need' to assure that an innovation indeed functions. In line with SNM theory that proposes experiments (i.e. pilot, demonstration) for stimulating the alignment of market and technology, examples were found in which experimental results persuaded users to commence adoption, like occurred with PaperFoam technology. Contrariwise, experiments hampered the uptake of innovations when results were unsatisfactory, like observed in hemp insulation, often in light of the high market requirements. Next, the influencing factors of niche development are discussed.

Visioning, value proposition, finances

First the factor Visioning, i.e. the articulation of visions and expectations, is discussed in relation to niche development. In line with SNM theory, relatively high expectations of innovations in the early phase of niche development attracted the interest of more entrepreneurs and other actors. In particular **expectations of positive returns and growth strengthened the hype status of innovations**, like explicitly occurred with starch plastics in the AVEBE-period. Led by AVEBE's rough estimate of the market potential for starch plastics, for example Rodenburg got the idea to start developing bioplastics, who at their turn received subsidies for their promising efforts. Hence it can be derived that visions and expectations may be considered 'support mechanisms for triggering further actions', as claimed by Raven (2005). However, analysis shows that expectations tended to be too optimistic in the light of the high market requirements, leading to skepticism among actors when results did not (timely) deliver up on the expectations. This underlines that **expectations are perishable**, and herewith also the legitimacy to actors to provide adequate support to innovation trajectories.

Secondly, the factor Value proposition, describing aspects of an inventor's offering, is discussed. Analysis shows that problems in niche development referred to problems in developing effective value propositions by inventors. Without an effective value proposition, inventors could not get users to prefer their innovations such that the technological niches could develop into market niches. In an effective value proposition, **sustainable products need to be more than just substitutes for their alternatives**. However, product differentiation solely on the basis on distinct sustainable features (e.g. biodegradability, renewability) appeared insufficient for winning allegiance of the marketplace. Distinct features of products only provided added value when the market requirements were fulfilled. Remarkably, **associated with the tendency of market requirements to increase over time, product differentiating features were found to shift over time**. In the example of wind turbines, turbine designs were initially differentiated from each other on the basis of price-performance ratios. Later, these ratios were incorporated in the set of market requirements, after which differentiation started to take place based on company size, including the track record and financial position of a turbine producer. Overall, the factor Value proposition proved relevant in explaining the availability of demand for a particular innovation, the more since achieving high technological readiness levels by itself turned out to be insufficient in steering demand.

Thirdly, this study proposed the factor Finances as an influencing force of niche development. Analysis shows that problems in niche development can refer to problems in the financial aspects of innovation trajectories. Analysis shows that **market niches typically encompassed innovations that generate sufficient revenue for achieving a balance in finances, while in the absence of (expectations of) a positive return for inventors and/or entrepreneurs, niches were unable to attain the stability that is inherent to market niches**. Achieving a positive return can, however, be complicated, as explicitly observed in the case of industrial hemp where entrepreneurs needed to operate in different niches with different plant components, simultaneously, for becoming cost-efficient. Analysis shows that most innovations compete in price-competitive markets (e.g. plastics, construction, energy), making the cost-base of inventors critical in realizing price-competitiveness. Analysis shows that niches benefitted from a step-wise development of firms, in particular via **forward integration** (providing inventors with extra added value) and a **modular** set-up of production processes (preventing costly overcapacity).

7.1.2 Regime stability

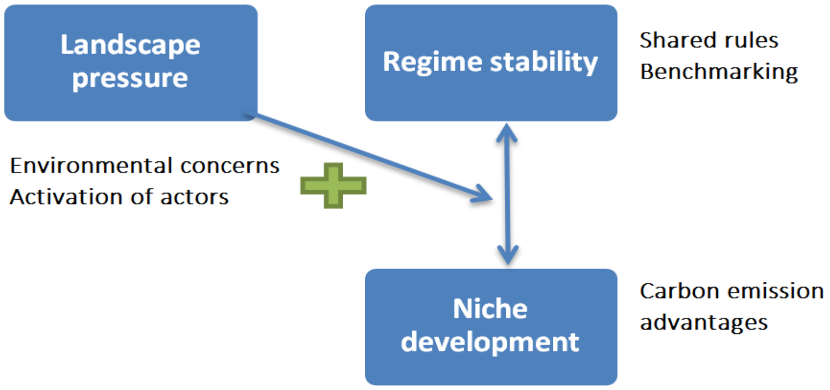
Reflecting on the case studies, innovations were confronted with (the emergence of) dominant designs which gained general acceptance in the market as the standard. For instance cotton in textiles, traditional concretes in construction, and plastics in packaging all had won allegiance of the marketplace. This position made that the (properties of these) designs became increasingly **embedded** in regulations, infrastructures and systems, **promoting routine-buying behavior**. Literature claims that the concept of rules is central herein, representing a regime's so-called shared structure (i.e. routines, norms, systems etc.) that guides and frames actor behavior, e.g. in innovation (Raven, 2005). Analysis shows that **actors have the tendency to carry the (shared) rules of regimes** and herewith contribute to regimes' internal resistance to change, **hindering (the emergence of) cracks**. For dominant designs, rules were observed to be well-articulated (e.g. through systems such as working procedures) and stable (e.g. incorporated in infrastructures), what strengthens the entanglement of actors since they have reached an alignment on these rules. For example in the case involving industrial hemp, users stick to their dominant designs because **standard practices are perceived easier and less risky, altering the cost-benefit assessment to the advantage of dominant designs**. In line with MLP, this entanglement due to the alignment of rules between actors 'entrenched' these actors in becoming game players, largely because they are tempted to (re)produce the rules of regimes as they have become shared.

Analysis furthermore shows that dominant designs favor regime stability via **benchmarking**. While the benchmark is often set high by (incumbent) parties, innovations must follow and outperform (e.g. the properties of) dominant designs in order to be considered by potential users. Reflecting on the case studies, this phenomenon proves to be a **critical source of regime stability**; innovations often cannot match their respective vested counterparts right away, hindering crack formation while, as described earlier, the market requirements for instigating user preference tend to increase over time.

7.1.3 Landscape pressure

Literature on SNM and MLP claimed that regimes are stable as long as their rules are carried by actors, though, interaction with the broader setting of the landscape can activate actors to decide otherwise. Analysis shows that actors are slowly breaking away from the rule sets of regimes in response to environmental concerns, and induce actions which are to the benefit of (challenging) alternatives (in niches). Hence it can be confirmed that, in this research project, **landscape pressure is relevant as an influencing factor of niche-regime interaction**. Interestingly, while analysis shows that regimes resist changes of rules that primarily are to the advantage of niches, landscape developments are beyond the direct influence of actors, and thereby also (locked-in) regimes.

Figure 7.1 – Practical relevance landscape pressure



In particular concerns about climate change appear to have increased strongly over the last decade and make actors (in regimes) increasingly (feel) discomfortable from the perspective of environmental features (e.g. carbon emissions, water use). Recent examples include the 2015-Urgenda lawsuit, the 2015-Paris negotiations for universal climate agreements between governments, and changing investment strategies of pension funds. In addition, market parties were found to be re-evaluating their routine choices on the basis of features (e.g. water use, carbon emissions) other than those in which the dominant designs rule, caused by changes in regulations and support (e.g. 2010 Sustainable Buying Policy). In this sense, environmental concerns activated actors, like policymakers, to become game players and issue measures which disrupt regimes and/or stimulate niches via their (environmental) performance. The sense of urgency is increasing, and market parties were observed to make proactive decisions in response to environmental issues, whereas they formerly merely changed their common practices (on behalf of the environment) if this was made mandatory.

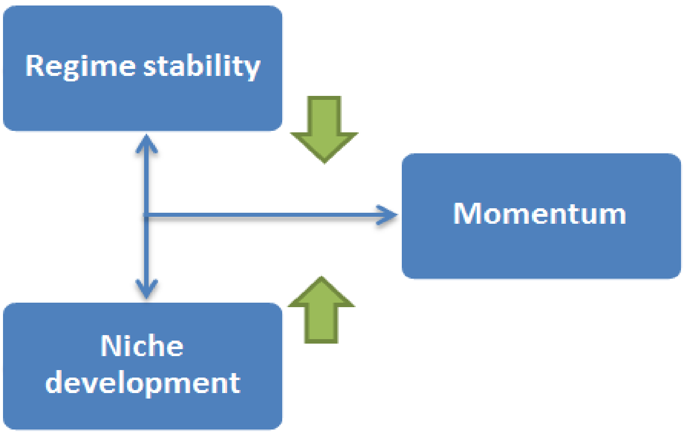
7.1.4 Momentum

In addition to SNM and MLP approaches in research, this study proposed the factor Momentum to be included in the theoretical framework for increasing the understanding of innovation pathways. Assumed is that momentum is a precondition for innovation diffusion, that is positively related to the latter, such that when momentum is gathered by niches, the embedded innovations should be able to diffuse. Reflecting on the case studies, three niches were found, encompassing cannabidiol (CBD) in hemp, injection molded dog chews, and bio-composites in starch plastics, which were able to gather momentum, initiating the breakthrough of the innovations. Hence it can be confirmed the **gathering of momentum by niches is positively related to innovation diffusion**, though, the practical relevance of the latter remains questionable (N=1 out of 3) (see below).

Analysis shows that the **presence of both niche maturity and cracks in regime stability are critical in gaining momentum** by the focal niches. In line with Grin, Rotmans & Schot (2010) whom stated that (market) niches may grow when the stability of a regime lowers, i.e. when cracks emerge, **a niche solely made use of cracks when the niche itself stabilized** (see arrows in figure 7.2). For example the niche embedding the pharmaceutical product CBD was able to grow because CBD is hardly psychoactive in contrast to its dominant design THC - providing CBD with a distinct added value - and is lucrative, enabling the entrepreneurs to create a viable business case. It can thus be derived that niche-regime interaction provides for the possibility to grasp momentum by (stabilized) niches, and this corresponds to the proposed function of momentum.

Contrariwise, **niche development stagnated in the absence of momentum**, underlining that problems in innovation diffusion refer to problems of niches in attaining momentum. Analysis shows that **the niches under study typically lacked the required stability for gathering momentum** – among others due to the presence of dominant designs in the existing markets in which most innovations were introduced, and/or inadequate niche protection - **leaving windows of opportunity frequently unused**. Illustrative is the case involving wind turbines where multiple stakeholders became eager to get involved in offshore wind placement and teamed up (e.g. consortia were formed) for realizing a breakthrough. Maturing of this niche in the Netherlands, however, never occurred due to hurdles in regulations and volatile support systems. All in all, it can be stated that the function of momentum was relevant for understanding practices.

Figure 7.2 – Practical relevance momentum as a function



Interesting to note is that under pressure of the landscape, cracks in regimes were observed to get larger, imposing an increasing likelihood for (biobased) innovations in achieving diffusion via momentum as time passes.

7.1.5 Innovation diffusion

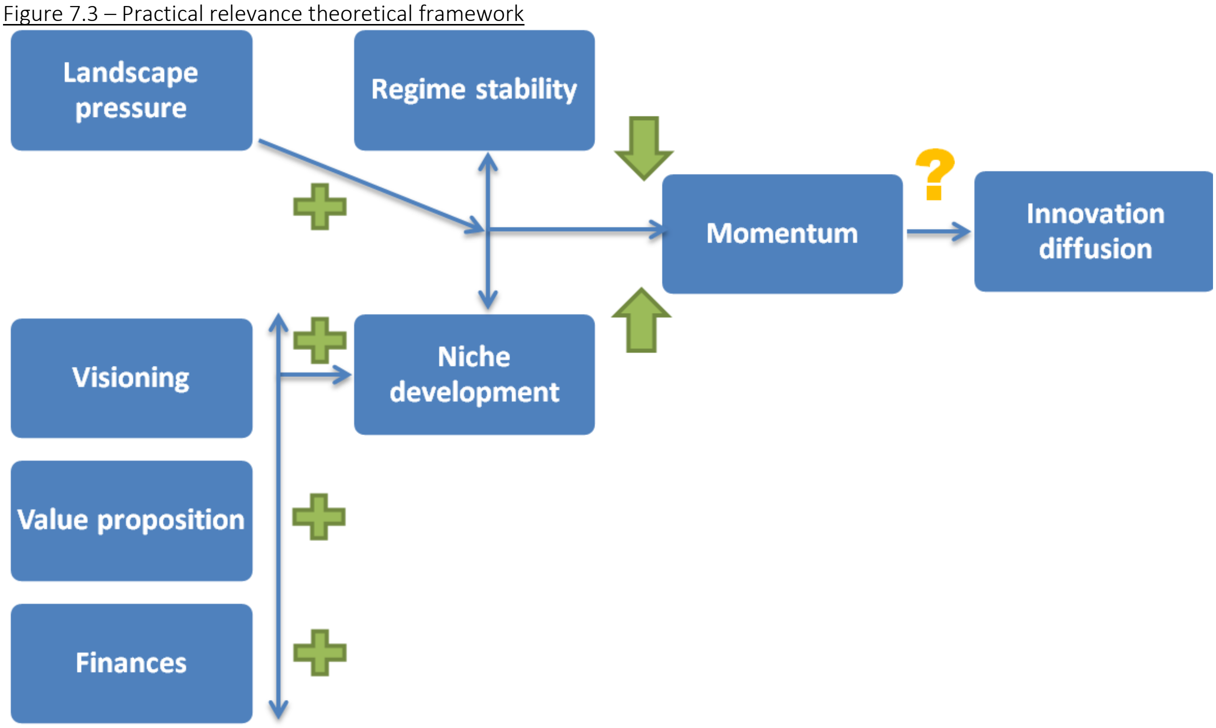
Innovation diffusion (endogenous variable) is defined as the *spreading* of a niche such that that it is replacing an existing regime, in which it is embedded, or forms a new regime. It is posited that when an innovation achieves to diffuse, it is changing an existing sector or becomes an alternative to one. As stated earlier, three focal niches gathered momentum, as they effectively made use of cracks in regimes, making them rapidly spread among users, highlighting sectoral evolution. Analysis furthermore shows that these innovations are setting new standards, alike regimes. At the same time, none of the niches proved able to replace an existing regime or become a vested alternative at the sectoral level by early-2016.

Given the modest representation of the factor Innovation diffusion in wind turbines and industrial hemp, the **practical relevance of the factor Innovation diffusion remained questionable** in this research. When we turn to the biobased situation, it can be argued that the lack of innovation diffusion is inherent to the current situation of the biobased economy. This makes the **modest representation of innovation diffusion something that could be expected**, the more because case studies were selected based on a mixture of their success.

7.2 Conclusion

It can be concluded that the theoretical framework was relevant for understanding practices as the **framework seems to capture essential aspects of transition practices**. Generally, it can be stated that actors seek to develop their (market) niches while looking to benefit from cracks in regimes, hopefully promoting a wide uptake of their innovations by gaining momentum. More specifically, in addition to (more widely used) SNM and MLP approaches in research, this study put forward the function of momentum, and insights from business model concepts, which worked well in explaining innovation pathways. Analysis shows that while cracks were present in most regimes, the niches under study remained typically unable to benefit from this as of early-2016. The relevancy of the factor Innovation diffusion was less convincingly confirmed (N=1) in practice, not foregoing that its modest representation is something that could be expected. Conclusion therefore is that the **framework turned out to systematically extract factors from real-life regarding the development of innovations towards evolving into a sector**. Figure 7.3 visualizes the practical relevance of (proposed) literature-based factors influencing innovation diffusion.

Figure 7.3 – Practical relevance theoretical framework



Exogenous variables *Endogenous variable*

The findings from this empirical part (table 7.1) function as the groundwork for the next empirical part, in which the findings are verified in the poly lactic acid (PLA) case.

- Empirical part 2 -
Verification results and analysis

8. POLY LACTIC ACID: *POLY-POSSIBILITIES IN PLA (2000-2015)*

The case poly lactic acid (PLA) is used in this chapter to verify the findings from empirical part 1, to identify the learnings of this research project for biobased settings. It seeks to answer the research question: *Which factors are influencing the development of the PLA case, and what can be learned from comparing these factors with the findings from empirical part 1?* In paragraph 8.1, the results and analysis of the PLA case are presented. Note that respondents have predominantly discussed the factors in their current settings, instead of focusing on their development over time, given our aim to provide levers for policymakers to act on the status-quo. In paragraph 8.2, conclusions are drawn regarding the broader applicability of the findings from empirical part 1.

8.1 Results and analysis

8.1.1 Innovation diffusion

In the innovation trajectory of poly lactic acid (PLA), six niches were identified which correspond with PLA applications (see table 8.1). Similar to what is observed in empirical part 1, **PLA products are setting new standards** concerning, for example, carbon footprint, alike regimes, but in the absence of momentum for the respective niches. Consequently, by early 2016, the focal niches have been unable to replace existing regimes or form new ones. The respondents also disagree that PLA is (already) rapidly becoming widespread.

8.1.2 Niche development

Two (out of six) niches have been able to grow towards the stage of market niche, as users started to prefer the innovations (see table 8.3). Regardless of achieving high technological readiness levels in the remaining technological niches (see table 8.1), user demand is being limited, among others due to disfavorable pricing levels for PLA, hindering niche stabilization there. Respondents claim that the market pull for PLA is relatively weak, partly because support for bioplastics is suboptimal (see below).

Technology

Currently, all technologies are available for full commercial application (TRL9) (see table 8.1), indicating that the niches in PLA should be able to develop from a technological perspective. Analysis, however, shows that in the majority of (technological) niches the market and technology insufficiently aligned for becoming stable, as the market development lagged behind. Referring to SNM theory, and similar to what is observed in empirical part 1, it may be derived that niche development requires that the market and technology become increasingly aligned, but that **technology is not the sole force in making users prefer innovations.**

One example wherein technological advancements did stimulate niche development refers to Corbion's 2012 **high heat-resistant PLA**. Whereas standard PLA (first generation, NatureWorks) is proven to withstand temperatures of 55-65°C, high heat PLA (second generation) delivers much better heat resistance (100-140°C), allowing the material to be used in new, more demanding applications like electronics and automotive; applications that are also of a higher value than disposables.

Table 8.1 – Technology readiness in PLA

Application	TRL (0-9)	Technology status	Progress
Medical (based on medical PLA)	9	Full commercial application	Technology available for users
Packaging (mostly standard PLA)	9	Full commercial application	Technology available for users
Foodservice ware (mostly standard PLA)	9	Full commercial application	Technology available for users
Automotive (mostly high heat PLA)	9	Full commercial application	Technology available for users
Electronics (mostly high heat PLA)	9	Full commercial application	Technology available for users
Textiles and nonwovens (standard and high heat PLA)	9	Full commercial application	Technology available for users

At the same time, analysis shows that **niche development in PLA is being slowed down by the complexity of**

developing technologies. Two major technological steps make up the production process of PLA. The first concerns corn or sugar to lactic acid-technology that has developed incrementally over the last 80 years, among others under direction of the Dutch firm Corbion (formerly CSM). The second concerns the lactic acid to PLA-technology. Already in the early 1980s, the first PLA conversion process was implemented by Corbion for medical PLA, but that process proved to be unfit for bulk production. In 2001, Cargill Inc. ultimately pioneered the production of PLA on a commercial scale (capacity 140kT p.a., later upgraded to 150kT p.a.) under the trade name NatureWorks. Remarkably, Cargill Inc. launched their first project to develop corn-based PLA already in 1988, but it took **multiple stages in moving the technology from R&D to being marketed with each stage having its own technical and financial requirements**; after first having developed key processes on a laboratory-scale, a pilot plant was constructed, followed by a demo-plant (1994, 5.000 metric tons p.a.) before the technology was implemented in a commercial PLA-factory (Vink *et al.*, 2003).

Besides the lengthy process of technological development, respondents claim that **entrepreneurs in PLA are risk-averse, disfavoring rapid technological advancements and potentially niche development**. The 2001-plant built by Cargill Inc. applied for example first generation Ingeo® production technology, a 'proven technology' according to NatureWorks, instead of a 'later technology' with additional eco-profile improvements but also a higher risk profile. Only in 2009, after 8 years of service, NatureWorks upgraded their lactic acid production process to second generation technology for increasing the energy and resource efficiency (NatureWorks LLC, 2009).

Market

Entrepreneurs initially foresaw market opportunities for PLA as a high-value low-volume **single use disposable** for medical appliances (1980s). In the course of niche development, however, (standard) PLA became a **commodity polymer** and more niches emerged, as both other applications as a disposable were found (e.g. in packaging and foodservice ware) and more durable applications (e.g. in automotive) became technologically feasible. While the respondents claim that hereby **particular true added value applications for PLA are found, little market pull appears to exist for PLA** (see table 8.3)**.** For stabilizing their niches, entrepreneurs therefore currently search for (new) applications, wherein PLA offers true added value, and/or ways, such as via cheaper feedstock, for increasing the price-competitiveness of PLA as compared to synthetic plastics like PP and PS (see below).

A further analysis is made by investigating the influencing factors of niche development.

Visioning

Reflecting on the case study, an **increasing variety of actors (e.g. entrepreneurs, policymakers, users) now shares the expectations of PLA, boasted by expectations of the (market) potential of PLA**. In particular PLA's annual growth figures in the range of 15-20% over the past decade provide legitimacy to actors to invest in the innovation, facilitating the development of niches in PLA. Also Corbion's recent announcement regarding being on track for constructing a 75kT p.a. PLA plant, scheduled to open in Thailand in 2018 (Corbion, 2016), is deemed to strengthen the (market) expectations of PLA further. The **respondents strongly agree that the relatively high expectations of PLA attract both entrepreneurs and other actors**. For example LaCoppa (ATI) recently introduced PLA coffee capsules for replacing aluminium capsules, and also the Dutch firm Dyka developed a piping system for rainwater based on high heat PLA in addition to its PVC-based pipes.

At the same time, the respondents agree that **early expectations of the (market) potential of PLA were overly optimistic (see table 8.2)**, challenging the perseverance of actors as extra efforts had and/or have to be made. For example NatureWorks expected that users would be more enthusiastic about (standard) PLA at the time of it becoming available in bulk in the year 2001. Also when Synbra entered the PLA-business in 2006, they faced more difficulties in attracting users than anticipated, especially when the 2008-economic crisis began.

Table 8.2 – Early expectations in PLA

Early expectation	Actor	Source of change
The biodegradable PLA is primarily fit as a single use disposable	Corbion, NatureWorks	Technological improvements enabled more demanding applications
Huge market potential for PLA, being a biopolymer	Entrepreneurs	Little market pull exists for PLA, largely due to economic reasons
Netherlands has to become internationally leading in bioplastics	Policymakers	USA, Asia, and Latin America attract most production facilities via close-to-market measures (European Bioplastics, 2015)

Finances

Problems in the development of the niches in PLA strongly refer to problems with financial aspects. One major issue in PLA refers to the relatively high cost base of producing PLA. In comparison to synthetic plastics like PS, **PLA relies on more costly resources, has a higher specific weight, and lacks efficient scale in production, collectively adding up to relatively high costs**. The resulting negative pricing differences for PLA as compared to (cheaper) alternatives, mostly synthetic plastics, prove to be huge obstacles in making users prefer PLA. Respondents also agree that it all boils down to money; most inconvenient since the largest markets in plastics (e.g. packaging) are highly price-competitive, making the element of pricing critical for niche development.

For leveling out the observed pricing differences, entrepreneurs in PLA focus on feedstock diversification, feedstock being the largest cost component in PLA-production. For example NatureWorks is investing in **methane to lactic acid technology**, a designated route for completely skipping the costs for cultivation. Corbion, on the other hand, focuses on obtaining scale and capacity for increasing the price-competitiveness of their PLAs, and plans to appropriate more value via **forward integration**, i.e. by becoming a PLA producer.

Meanwhile, the bioplastics industry has high hopes for a **level playing field in plastics**, to be created by the Dutch government, e.g. via taxes on CO2, as bioplastics generally have cost disadvantages as compared to synthetic plastics. Unfortunately, strong measures for supporting bioplastics such as PLA have not been issued as of yet.

Value proposition

Eight offerings in PLA were identified, of which three (already) obtained user preference (see table 8.3). Similar to what is observed in empirical part 1, **niche development in PLA depends on whether dominant designs are outperformed on both pricing and performance, simultaneously, or PLA properties deliver true added value**. Analysis, however, shows that PLA products typically fail to directly compete with their dominant designs as the standards are set high, particularly on pricing. Consequently, by early 2016, **user preference was merely obtained in niches encompassing PLA products striving to deliver added value, such that the added value can 'compensate' for the relatively higher costs for PLA**. For example the niche embedding fruit- and vegetable packaging was able to outgrow the stage of technological niche as the PLA material prolonged shelf-life (see table 8.3). For bags, currently by far the largest market in PLA (>70% in total PLA volume, and expected to rise further), PLA also attracts users as it offers a number of benefits: PLA is biobased, transparent, and recyclable.

Overall, PLA products are typically positioned as **both biobased and biodegradable plastics**. PLA being biobased is foremost associated with renewability and a favorable carbon footprint. Today the carbon footprint of PLA is 0.5 kg CO2-equivalent per kg polymer (cradle to gate), as compared to PS (2.2), PET (2.0), and PP (1.7) (Plastics Europe, 2016). Another benefit relates to the PLA being **biodegradable (and recyclable)** at the end-of-life phase. The respondents claim that since these are **relatively easy to define and quantify benefits**, this facilitated user acceptance, e.g. of brand owners from the viewpoint of branding opportunities. The respondents agree that the availability of proof of principle is critical in closing actual deals.

Table 8.3 – Overview offerings PLA

Application (inventor)	Added value claimed by inventor	Dominant design	Performance	Effectiveness in developing user preference
Packaging: bags	Biobased, biodegradability	Synthetic bags, blends with synthetics (e.g. bio-PE), paper bags	(+) Encouraging organic waste collection and reducing littering (dual-use) (-) price gap	Ultimately effective
Packaging: fresh fruit and vegetable	Biobased, biodegradability	Synthetics, blends with synthetics	(+) Prolonging shelf-life (+) stiff material enabling weight reductions (-) price gap	Ultimately effective
Foodservice ware	Biobased, biodegradability	Synthetics, blends with synthetics (e.g. bio-PET), cardboard	(+) Closed-loop recycling (e.g. at festivals and sport events) (-) price gap	Ultimately effective
Automotive (Corbion)	Biobased, biodegradability	Natural fibers, plastics: polyesters (PET), polystyrenes	(+) Reduced carbon footprint (+) great impact resistance (+) high gloss and colorability (-) price gap	Ineffective; breakthrough expected

Electronics (e.g. tablets, mobile phones, 3D printing) (Corbion)	Biobased, biodegradability	Synthetics, blends with synthetics	(+) Reduced carbon footprint (+) mechanical recycling (+) high gloss and colorability (+) great scratch resistance (-) price gap	Ineffective; breakthrough expected
Textiles and nonwovens	Biobased, biodegradability	Cotton	(+) Closed-loop product lifecycle (fashionable in the textile industry) (-) price gap	Ineffective; breakthrough expected
Packaging: foam (Synbra)	Biobased, biodegradability	Polystyrene foams	(+) Reduced carbon footprint (-) price gap	Ineffective; breakthrough expected
Medical (Corbion)	Biodegradability	Natural fibers, synthetics	(+) Fall apart in harmless substances (-) price gap	Initially effective

Resource: Corbion (2016)

8.1.3 Momentum

In the presence of dominant designs, none of the (market) niches in PLA was able to attain the required stability for gathering momentum. As described earlier, this **lack of stability can be strongly attributed to the relatively high cost base of PLA, resulting in negative pricing differences for PLA**. We derived that this is most inconvenient since pricing levels often turn out to be critical in whether or not user preference is obtained in the highly price-competitive markets for PLA. In line with this analysis, the respondents disagree that PLA products are currently able to effectively make use of the disadvantages of dominant designs, notably synthetic plastics and blends like bio-PE and bio-PET (drop-in chemicals); PLA counterparts which are dominant over PLA from a pricing perspective. Therefore, taking into account the steady annual growth figures of PLA, we derive that PLA products are indeed spreading among users, albeit that the focal innovations have been **unable to rapidly develop**, i.e. reach innovation diffusion, in **the absence of momentum** for the respective niches.

8.1.4 Regime stability

PLA products were confronted with dominant designs which gained general acceptance in the market as the standard. Similar to what is observed in empirical part 1, analysis shows that this position of dominant designs facilitates inertia due to a variety of reasons. First, **the standards of dominant designs, predominantly synthetic plastics, have become the benchmark against which innovations need to compete**. The respondents claim that particularly the (technical) performance and pricing of innovations in comparison to the benchmark direct as of to what extent users get attracted to other offerings. Following the price gap between PLA and synthetic plastics, we derive that the **standards are (indeed typically) set too high for innovations, thus scaffolding regime stability**.

Second, besides from benchmarking, regime stability stems from users' general tendency towards risk-aversion. Similar to what is observed in empirical part 1, analysis shows that **users like brand owners often perceive the introduction of bioplastics as a high-risk endeavor, making them stick to their (safer) common choices of material**. The respondents strongly agree that the position of synthetic plastics resists changes that disfavor their appliance. Also, in recent years, a number of reports involving **mistaken ideas and beliefs concerning PLA**, and bioplastics in general, were put out in public. Examples include claimed issues with the flammability of bioplastics, and negative effects on the recycling system when bioplastics become widespread. Regardless that the reports were in fact falsities, the respondents claim that users interpreted these reports as unnecessary and unwanted risks. The respondents furthermore claim that **innovative practices in plastics are limited because of risk-aversion**, hampering change. For example, in 2012, the German retailer Lidl introduced biobased shopping bags, but when NGOs started criticizing this move in material, Lidl promptly returned to business as usual, i.e. solely marketing plastic bags, to prevent any loss of turnover (vested interests).

Interestingly, cracks in regimes are becoming increasingly apparent. Analysis shows that users like packaging companies slowly embark on a search for alternative materials which could strengthen their (environmental) performance as a business, especially from a carbon footprint point of view. **We derive that the relative value of environmental benefits is on the rise, being a standard other than those in which dominant designs rule, leading to the enlargement of cracks and/or emergence of new ones.** Analysis shows that multinationals in synthetic plastics are becoming more actively involved in bioplastics, underlining that plastic regimes start to feel discomfort, though it remains unsure to what extent their involvement is beneficial. At the one hand, BASF (Germany) marketed its first compostable plastic already in 1997, and recently entered promising **joint ventures** with the

Dutch bioplastic companies Avantium (for producing bio-PET), and Corbion (biobased succinic acid). On the other hand, the respondents argue that the multinationals in synthetic plastics (e.g. Sabic) benefit from a gradual transition towards bioplastics, relating to their large assets in plastics becoming redundant and/or stranded otherwise, making them not the designated companies for leading the developments in bioplastics.

Meanwhile, the **role of the Dutch government in disrupting regimes and stimulating the niches is claimed to be ineffective**. Examples include ambiguous regulations (e.g. for compostability), inadequate support (e.g. as a launching customer in bioplastics, via carbon emission tax), and a lack of expectation setting towards users and producers. Regarding the lack of expectation setting, the respondents claim that the government does not yet explicitly support bioplastics, e.g. by ensuring users that the pros of bioplastics outweigh the cons, similar to what the Dutch government did for wind energy, solar energy, electric cars and biodiesel. Consequently, instead of making users realize that the uptake of bioplastics is a matter of time, for example, the aforementioned falsities could form barriers in making users prefer bioplastics. It can be derived that **with the proper policy tools, the Dutch government can increase the dynamics in niche-regime interaction, taking into account that niche protection in bioplastics is currently limited**. The respondents also strongly disagree that the Dutch government is currently stimulating PLA products in an effective way.

8.1.5 Landscape pressure

Similar to what is observed in empirical part 1, the message of sustainability is slowly starting to resonate in the plastic regimes, making actors increasingly (feel) discomfortable from the perspective of environmental features. In particular **large users of synthetic plastics are getting disturbed as a result of the environmental concerns, mainly since stringent actions by governments in reducing their considerable share in global emissions are getting more likely**; actions which would be primarily to the benefit of niches encompassing sustainable alternatives like bioplastics. We derive that changes in the landscape activate actors – in this example both market parties and policy makers - which increasingly value the (new) standards of innovations and create cracks in regime stability.

The respondents strongly disagree that developments in PLA are *accelerated* by increased public environmental awareness. The respondents for example claim that the sense of urgency of policymakers may be considered too low for issuing significant change in the short term, e.g. via regulation, though, in realizing carbon emissions reductions, the contribution of the biobased economy is increasingly regarded crucial. One respondent, however, strongly agrees and states that in the absence of increased environmental awareness, any development in PLA would be far less likely due to the negative pricing difference for PLA.

The 2015-macroeconomic outlook for the biobased economy confirms that a large-scale transition is taking place that depends on varying aspects. The 2015-report concluded that the **biobased transition is foremost sensitive to fossil fuel prices and CO2 tax levels; the rate of technical change and trade of biomass are shown to be less influential** (LEI Wageningen UR and Copernicus Institute of Utrecht University, 2016). The respondents also claim that fluctuating oil prices strongly affect the implementation of bioplastics, creating a **difficult and turbulent environment when the fossil fuel prices are relatively low, as is occurring nowadays**. The future up-scaling of new technologies, e.g. methane to lactic acid, are deemed to speed-up the biobased transition. However, as compared to the 2009-macroeconomic outlook, the **technological development was slower than assumed**, as it takes more time for technologies to benefit from greater economies of scale and technological learning (LEI Wageningen UR and Copernicus Institute of Utrecht University, 2016).

8.2 Conclusion

This empirical part 2, verified in the case of PLA several findings from empirical part 1. It enabled to confirm the **practical relevance of the findings** as well as the **broader applicability of the theoretical framework**, covering essential aspects of transitional practices: innovation diffusion, i.e. sectoral development, depends on whether innovations (in niches) are able develop such that they gather momentum. In their development, however, niches interact with a broader environment - regimes and the landscape - that influences the progress in niche development. An overview of the verification of findings from empirical part 1 in the PLA case is provided in table 8.4, after which a further elaboration on findings from this table can be found.

Table 8.4 - Verification findings from empirical part 1 in PLA case

Factor	Findings	Explicitly observed in…			
		Hemp	Wind turbines	Starch plastics	PLA
Niche development	Insufficient alignment of demand and supply for stabilizing the niches	V	V	V	**V**
	Niches typically embed innovations which strive to comply with the market requirements, i.e. licenses, guarantees, and **standards of dominant designs**	V	V	V	**V**
	Market requirements tend to increase over time	V	V	+/-	**+/-**
	Achieving high technological readiness levels is not enough to create demand, as **appealing value propositions** are required	V	V	V	**V**
	Relatively high expectations (of positive returns and growth) provided legitimacy to more entrepreneurs and other kinds of actors to invest in the innovations, e.g. in time, money, strengthening the hype-status	V	V	V	**V**
	Early expectations tended to be too optimistic, resulting in skepticism when results did not deliver up on expectations	V	V	V	**+/-**
	A viable business case for entrepreneurs promotes niche stabilization	V	V	V	**V**
	Niche protection by the government was limited, slowing down niche development	V	V	V	**V**
	The development of market niches easily takes up to decades	V	V	V	**V**
	The relative value of environmental benefits in cost-benefit assessments is rising, but users cannot be activated solely based on environmental claims	V	V	V	**V**
Regime stability	Regimes have an **internal resistance to change** due to embeddedness, vested interests, and risk-aversion	V	V	V	**V**
	Dominant designs became increasingly embedded in regulations, infrastructures and systems, promoting routine-buying behavior	V	V	V	**+/-**
	Once a dominant design has been established in a market, its high standards become the **benchmark** for innovations in this particular market	V	V	V	**V**
Landscape pressure	Landscape pressure activates actors which increasingly value the (new) standards of innovations and create cracks in regime stability	+/-	V	V	**V**
Momentum	Momentum enables innovation diffusion	+/-	+/-	V	**+/-**
	The presence of both niche maturity and cracks in regime stability enables the gathering of momentum by stabilized (market) niches	V	V	V	**+/-**
	In the absence of momentum, niche development stagnates	V	V	V	**V**
Innovation diffusion	Innovation diffusion encompasses the spreading of niches at the regime level	+/-	+/-	V	**+/-**

8.2.1 Niche development

Inventors and/or entrepreneurs in PLA seek to develop their niches towards market niches, but have frequently been unable to do so, by early-2016. The majority of niches (4 out of 7) identified in the case of PLA (table 5.3) is currently in the phase of **technological niche**. These niches were unable to attain the required stability for evolving into a market niche in the absence of a viable business case for the entrepreneurs in PLA.

The entrepreneurs in PLA have difficulties in making users prefer their innovations, largely because PLA products have cost disadvantages as compared to (fossil-based) counterparts in the markets for PLA. Reflecting on both empirical parts, the **issue of pricing** proves itself to be a challenging market requirement for innovations to comply with, even more than complying with the market requirements on performance. Regarding the issue of performance, the high technological readiness levels in the case of PLA demonstrate that the technologies are available for users. However, similar to what is observed in empirical part 1, achieving high technological readiness is insufficient to create demand, as appealing value propositions are required by entrepreneurs.

Appealing value propositions in PLA were created where niches delivered added value, such that the **added value 'compensates' for the relatively high price of PLA**. The case of PLA provided three niches wherein user preference was ultimately developed (see table 8.3). One example includes the niche embedding fruit- and vegetable packaging that was able to outgrow the stage of technological niche as the PLA material prolongs shelf-life, providing an economic as well as an environmental motive to users. It may be concluded that this combination is crucial in niche development, as users cannot be activated solely on environmental benefits.

The case of PLA, however, confirms that the relative value of environmental benefits in cost-benefit assessments of actors is rising. Conducive for niche development is that **environmental benefits tend to involve standards wherein regimes typically fail to rule**.

Furthermore conducive for niche development in PLA are the **relatively high expectations of PLA** nowadays. Reflecting on empirical part 1, the question however arouses whether the expectations in PLA can be delivered upon within a reasonable timespan, before the expectations of actors start to diverge and the attention for PLA diminishes.

Unfortunately, the Dutch government provides **limited protection** to the niches in PLA. Examples were found of ambiguous regulations, inadequate support, and a lack of expectation setting in PLA. Reflecting on both empirical parts, the government has been involved in stimulating the creation of R&D and technological niches, e.g. via subsidies for the construction of plants. However, the government has been less effective in stimulating the development of technological niches towards market niches, partly **policy tools seem to focus on technological development rather than on market development**. Reflecting on both empirical parts, examples were found wherein the government acts as a leading customer (industrial hemp), and sets expectations in the market (wind turbines), but these examples are (too) scarce.

All in all, problems in niche development seem to relate to **problems of entrepreneurs in creating a viable business case, having to cope with regimes**. Remarkably, while the cases of starch plastics and PLA include comparable regimes and started roughly simultaneously in the early-1990s, they ended up being different by early-2016. Unlike the niches in PLA, two market niches in starch plastics are now rapidly spreading at the level of regime, irrespective of cost disadvantages as compared to fossil-based plastics for both starch plastics and PLA. For making users prefer their innovations, the entrepreneurs in starch plastics deliver **true added value** via functional advantages (e.g. qualities in design) and trends in food (e.g. health. The entrepreneurs could also benefit from a **modular set-up** of production processes, requiring relatively modest investments to start and expand their production facilities, in contrast to the entrepreneurs in PLA. It may be derived that the entrepreneurs in starch plastics were better capable of creating a viable business case because of this.

8.2.2 Regime stability

In the presence of regimes, niche development in PLA is being slowed down. While niches encompassing PLA products typically aim to replace regimes, they first need to comply with the standards of regimes in order to be considered by users. We called this phenomenon of standard-setting by regimes, **benchmarking**. Reflecting on both empirical parts, benchmarking surfaces as a critical source of regime stability since innovations typically fail to compete on the standards of regimes, hereby providing legitimacy to users to continue carrying the regimes. In particular the issue of pricing makes that users stick to their regimes, leveraging the complexity of creating a viable business case by entrepreneurs.

Besides benchmarking, users seem to favor regimes over niches due to reasons related to **risk-aversion** and **vested interests**. For example, potential users of PLA stick to their regimes because they perceive the adoption of PLA products as a high-risk endeavor (risk-aversion) that also might result in a loss of turnover when altering the product portfolio (vested interest). Reflecting on both empirical pars, it may be concluded that regimes have gained advantages as they have already become widespread; advantages which alter the cost-benefit assessment of users to the advantage of regimes. In total 24 niches and associated regimes were identified in this study, of which 8 niches were able to evolve into market niches based on user preference by early-2016. This illustrates that 16 niches (two third) were unable to attain user preference in the presence of regimes.

8.2.3 Landscape pressure

Developments in the landscape are found to influence the niches in PLA as well as their respective regimes. For example the current relatively low oil prices slow down the niche development in PLA while (frequently) scaffolding the stability of (fossil-based) regimes. At the same time, concerns about the environment are activating actors (e.g. policymakers, users) to make new product choices and/or more stringent decisions on behalf of the environment. Reflecting on both empirical parts, actors are particularly being activated from a carbon footprint point of view. For example in the market for plastic bags, currently by far the largest market in PLA, PLA attracts users as it offers environmental benefits as compared to fossil-based plastics: PLA is biobased (associated with a favorable carbon footprint), and recyclable. It may be concluded that landscape pressure activates actors which increasingly value the (new) standards of innovations and create cracks in regime stability.

8.2.4 Momentum and innovation diffusion

In the presence of regimes, none of the (market) niches in PLA was able to attain the required stability for gathering momentum. Reflecting on both empirical parts, it may be concluded that the niches under study in this thesis are typically unable to effectively make use of the cracks in regime stability. The case of PLA shows that PLA products are spreading among users, albeit that the focal innovations have been **unable to rapidly develop**, i.e. reach innovation diffusion, in **the absence of momentum** for the respective niches. Similar to what is observed in empirical part 1, **PLA products are setting new standards** concerning, for example, carbon footprint, but most lack momentum. Consequently, by early 2016, the focal niches have been unable to replace existing regimes or form new ones. This research project herewith shows that **the time it takes for niches to develop into market niches easily takes up to decades**. Note that both momentum and innovation diffusion helped to conceptualize sectoral development, though their representation in practice remained only modest in this research project. The latter could, however, be expected as developmental problems in biobased sectoral development were the main reason for starting this research.

9. CONCLUSIONS, DISCUSSION AND RECOMMENDATIONS

This final chapter makes the findings in this study conclusive. It seeks to answer the research question: *How is the theoretical framework represented in practice and what are recommendations for policymakers?* The research objective is to compare and derive factors influencing biobased sectoral development in the Netherlands by learning from comparable Dutch trajectories. Firstly, conclusions are drawn upon the sub- and main research questions. Secondly, the discussion is presented. Lastly, recommendations are provided.

9.1 Conclusion sub-research questions

This section presents the answers to the sub-research questions. For more elaborated answers, the reader will be referred to the accompanying chapters. The general research question of this research project is: "'What can be learned regarding the development of a biobased sector in the Netherlands from comparable Dutch trajectories?" Before answering the general research question, the sub-questions (SQ) are answered first:

SQ 1: What are the literature-based factors influencing the development of a biobased sector that together constitute the theoretical framework?

This study seeks to grasp the complexity of innovation trajectories towards biobased sectoral development by constituting a framework for approaching and understanding factual innovation diffusion practices (chapter 2). The theoretical framework is based on a broad literature study on concepts of Strategic Niche Management (SNM) (section 2.1), the Multi-Level Perspective (MLP) (section 2.2), and business model concepts (section 2.3).

Using SNM, innovation trajectories are conceptualized as a three-stage process of *niche development* (paragraph 2.1.1). This study included *market* and *technology* in the theoretical framework as factors for operationalizing niche development (paragraph 2.1.1). Drawing on SNM and business model concepts, niche development is deemed to be managed via three factors: (i) *visioning* (paragraph 2.1.2), (ii) *value proposition* (paragraph 2.3.2), and (3) *finances* (paragraph 2.3.2). It has been assumed that if adjustments of factors work out positively for the research object in the framework, similar adjustments can be helpful in steering the research object in reality (paragraph 2.1.3).

Built on MLP, innovation diffusion (endogenous variable) is conceptualized as being dependent on three levels: the level of niches, regimes, and the landscape (paragraph 2.2.1). MLP explicitly states that innovation diffusion is not the outcome of dynamics at any specific level, but occurs as a result of interactions between levels (paragraph 2.2.2). By means of literature study on the concepts *regime stability* (paragraph 2.2.3) and *landscape pressure* (paragraph 2.2.4), this study approached *innovation diffusion* as the outcome of interplay between niches, regimes, and the landscape. Whether a niche can diffuse in order to replace an existing regime, in which it is embedded, or become a viable alternative to one, is posited to depend on *momentum* (paragraph 2.2.2).

Figure 2.7 displays the theoretical framework, presenting the set of exogenous variables which are proposed being related to the endogenous variable (section 2.4).

SQ 2: Which factors influenced the development of the three cases (results), and what can be derived from comparing these factors? (analysis)

Multiple case studies are carried out in this research project, aiming to signal *key factors in/or patterns* that explain and can systematically help forward biobased sectoral development in the Netherlands (section 1.1). The case study research concerned industrial hemp (1990-2015), wind turbines (1970-2015), and starch plastics (1990-2015) (chapters 4 to 6). The development of each case was influenced by several factors, simultaneously. For the individual case results and analyses, readers are referred to the accompanying chapters.

Based on a comparison of factors from the three cases in empirical part 1, the cross-case analysis describes to what extent the practical results are consistent with the factors from the theoretical framework (chapter 7). In general, it can be stated that actors indeed seek to develop their niches, while looking for potential to benefit from cracks in regimes, in the hope to promote a wide uptake of their innovations by gaining momentum. However, niche development typically stagnated at the stage of technological niche (paragraph 7.1.1), having to cope with regimes which gained general acceptance in the market as the standard (paragraph 7.1.2). Interestingly, landscape pressure was found to increasingly influence niche-regime interaction (paragraph 7.1.3).

Nonetheless, by early-2016, only three niches were able to gather momentum so that they are now diffusing at the regime level, i.e. change existing sectors or constitute new ones. These focal niches were able to attain the required stability for gathering momentum because the respective entrepreneurs deliver true added value to users, based on functional advantages, inherent to the resource (paragraphs 7.1.2 and 7.1.4). We derived that:

- The theoretical *framework systematically indicates relevant factors in real-life regarding the development of innovations, evolving into a sector* (section 7.2).
- With 16 less promising out of 19 niches, it must be concluded that the factual presence of the factor Innovation diffusion remained modest.
- The so-called valley of death in innovation is apparent in the niches under study in this thesis.
- While examples were provided of the government effectively stimulating niche-interaction, niche protection by the Dutch government was often lacking.

Table 7.1 provides an overview of the key findings from empirical part 1 (section 7.2). Figure 7.3 displays the practical relevance of the (proposed) literature-based factors influencing innovation diffusion (section 7.2).

SQ 3: Which factors are influencing the development of the PLA case (results), and what can be learned from comparing these factors with the results from empirical part 1? (analysis)

Empirical part 2 verified in the case of PLA several findings from empirical part 1 (chapter 8). The development of the PLA case was (again) influenced by several factors, simultaneously (section 8.1). By early-2016, PLA products are spreading among users, albeit that the focal innovations have been unable to rapidly develop, i.e. reach innovation diffusion, in the absence of momentum for the respective niches (paragraphs 8.1.1 and 8.1.4). Consequently, the focal niches have been unable to replace existing regimes or form new ones. Two out of six niches in PLA did grow towards the stage of market niche, as users started to prefer the innovations (paragraph 8.1.2). Regardless of achieving high technological readiness levels in the remaining technological niches, demand is being limited, largely due to disfavorable pricing levels for PLA, hampering niche development there (paragraph 8.1.2). Overall, none of the niches in PLA was able to attain the required stability for gathering momentum in the presence of regimes (paragraphs 8.1.3 and 8.1.4). It appeared that the position of regimes facilitates inertia in the markets for PLA (paragraph 8.1.4). At the same time, large users of synthetic plastics are getting disturbed due to environmental concerns, mainly since stringent actions by governments in reducing their global emissions are getting more likely (paragraph 8.1.5). We derived that:

- The practical relevance of the findings from empirical part 1 is confirmed as well as the broader applicability of the theoretical framework.
- Both momentum and innovation diffusion helped to conceptualize sectoral development, though their representation in practice remained only modest in this research project. The latter could, however, be expected as problems in biobased sectoral development were the main reason for starting this research.
- In particular the issue of pricing makes that users stick to their regimes.
- Environmental benefits tend to involve standards wherein regimes fail to rule.
- Entrepreneurs with biobased innovations best seek true added value applications.
- Policy tools seem to focus on technological development rather than on market development.
- With the proper policy tools, the Dutch government can increase the dynamics in niche-regime interaction.

Table 8.4 provides an overview of the verification of findings from empirical part 1 in the PLA case.

9.2 Conclusion general research question

A combination of theoretical and empirical research methods has been used to answer the general research question: ‘’*What can be learned regarding the development of a biobased sector in the Netherlands from comparable Dutch trajectories?”* The following conclusions are drawn:

This research project described developments in four cases related to innovations which could be instructive for the biobased economy at large. Looking back at over 25 years of biobased innovations, it may be concluded that the transition to biobased products is highly complex, with different factors, simultaneously influencing the innovation trajectories towards sectoral development.

It has been confirmed that entrepreneurs with biobased innovations require a viable business case for developing their niches (sections 7.1 and 8.2). In creating a viable business case by entrepreneurs, achieving a balance in finances and getting users to prefer their respective innovations are found to be important aspects of innovation trajectories advancing niche development (paragraph 8.2.1). Furthermore, the role of visioning within innovation trajectories is disclosed as an important factor influencing niche development (paragraphs 7.1.1 and 8.2.1). For all four cases, relatively high expectations (of positive returns and growth) provided legitimacy to more entrepreneurs and other kinds of actors to invest in the innovations, e.g. in time, money, facilitating niche development. At the same time, it has roughly been confirmed that the (early) expectations tended to be too optimistic, resulting in skepticism when results did not deliver up on expectations (in time). This study, however, showed that the development of market niches easily takes up to decades (paragraph 8.2.4), indicating that there is a large discrepancy between the time needed by niches to develop and the perishability of expectations.

The complexity and duration of niche development was leveraged by the presence of (predominant) regimes which gained general acceptance in the market as the standard (paragraph 8.2.4). As a consequence, biobased innovations need to follow and outperform the (high) standards set by regimes, for example on pricing, in order to be considered by users. However, it appears that biobased innovations tend to have cost disadvantages as compared to existing products, partly due to relatively high feedstock costs (paragraph 8.2.1). We derive from the cases that entrepreneurs with biobased innovations best seek true added value applications such that the observed price gap can be compensated for by the added value it brings. It has furthermore been confirmed that entrepreneurs with biobased innovations are locked out by users via benchmarking, risk-aversion and vested interest of users (paragraphs 7.1.2 and 8.2.2). We derived that these problems are pivotal for the studied biobased innovations, slowing down their uptake towards sectoral development.

Interestingly, after the year 2000, the developments at the regime level and at the level of niches have increased considerably. The pressure on regimes is building up, resulting in more apparent cracks in the stable regimes. From the analyses, we derive that most niches were not sufficiently able to attain the required stability for making use of these cracks, by early-2016 (paragraph 8.2.4). Consequently, momentum was not yet gathered by most niches, though multiple breakthroughs are expected in the upcoming years (paragraphs 7.1.4 and 8.2.3).

The research project indicates an important role for the government in stimulating the further development of niches towards sectoral development. It has been roughly confirmed that momentum is positively related to innovation diffusion (paragraph 7.1.4). Given that momentum depends on the interplay between regimes and niches, this suggests that policy instruments can focus on disrupting regimes, supporting niches, or both, for strengthening the transition to biobased products. However, the government's stimulating measures focused mainly on the creation and development of R&D and technological niches, while the third category, market niches, need support as well, e.g. via governmental target setting (section 8.2.1). We derived a number of recommendations for policymakers (section 9.4).

In sum, it has been confirmed that the fossil based economy is partially being substituted by the biobased economy, with good opportunities for the government to strengthen the developments. This study chose to integrate business model concepts in the conceptual bases of SNM and MLP for increasing the understanding of innovation trajectories. Built on the case studies this resulted in a *condensed listing of factors influencing biobased sectoral development in the Netherlands (table 8.4), in fact, guidelines that are important to consider when developing policy for the biobased economy.*

9.3 Discussion

This study experiences seven limitations. The first two limitations concern the literature study, where the empirical research enabled the researcher to refine particular learnings from the literature study. First, the SNM-literature is not clear-cut on the definition of the arrows, presented in figure 2.1, typically used to visualize niche development in various studies (for instance Geels, 2004). Second, this study stressed the factor momentum as a function of both niche development and regime stability. Although being helpful in explaining the course of innovation trajectories, the function had modest (scientific) value in this qualitative research. A more quantitative approach in studying niche-regime interaction might suit the proposed function better.

A third limitation concerns external validity. The case study design, by default, makes it uncertain whether this study's findings are generalizable beyond the immediate cases studied. This problem is dealt with as much as possible by executing multiple, strategically selected case studies. A sample of cases was chosen that were different in scale, experienced their own dynamics, but all (sub-)sectors of the biobased economy. Notwithstanding, the selected cases do not represent the entirety of biobased sectors in the Netherlands, let alone, those of other European countries. In addition, different countries tend to have different market characteristics and policies put in place, harnessing the generalizability of findings across Europe. Note, however, that the central issue of concern was not on generalizable findings but how one could improve the understanding of particular biobased sectoral developments by involving management literature. Corresponding to this view, we selected poly lactic acid (PLA) as the central biobased case for learning.

Fourth, the windmill-case differed categorically from the biobased cases. The development of wind turbines was selected as a benchmark case, involving a renewable energy technology. The problems in the early development of wind turbines were strongly related to technological malfunctioning. Such problems were less apparent in the biobased case studies. The inclusion of another biobased case, replacing the wind turbines, case could improve the representativeness of this study’s findings. Note, however, that th reflection on effects of capital-intensiveness of wind turbine production and deployment, e.g. with regard to standard setting by project developers and banks, and the influence of risk-aversion, could provide distinct learnings for the capital-intensive (bio-) chemical industry.

A fifth limitation concerns the reliability of the research, referring to whether the results are consistent. The explicit triangulation of evidence supports the consistency of measures. During the interviews, however, a development was observed with regard to aspects brought in by the researcher, and the refinement of these aspects. This personal development may have affected the consistency of measures. The latter might be further harnessed as a consequence of the flexible part in the interview schedule, consisting of follow-up questions which were only asked if the interviewer thought suited, i.e. when follow-up question items respected the interviewee’s knowledge base. In each interview different flexible questions for different factors were skipped.

Sixth, the issue of pricing surfaced in all conducted interviews, often in relation to costs for feedstock and (possibilities for) governmental policy. In many markets wherein sustainable products aim to replace products, such as in construction and plastics, it all seemed to boil down to money. The empirical results show that the pricing level of an innovation was frequently a good predictor for its success in the marketplace, regardless of environmental added value being delivered. The *studied* literature is, however, not extensive on this leading role of pricing in mature markets.

Seventh, counter to SNM literature, niche protection was observed for mature technologies. The Dutch government supported the implementation of particular sustainable technologies due to the governmental objective to stimulate renewable energy. Examples are offshore wind energy, biodiesel, and electric-powered engines. The government started protecting these niches such that they could develop, regardless of cost disadvantages in comparison to regimes.

9.4 Recommendations for policymakers

Suggestions for policymakers are provided on the basis of the results and analyses from this research project:

1. <u>Make explicit the expectations about bioplastics</u>. Government-initiated expectation setting, level playing field, and collective learning can align different actors in supporting bioplastics, as explicitly observed in sustainable energy technologies including wind energy. For example, following the governmental wind target of 6.000 MW by 2020 and the announcement to search for market parties to construct the first Dutch offshore wind park (OWEZ), two major consortia were set-up and several other project developers proactively filed requests for building and exploiting wind parks (section 5.1). When developing a clear vision and setting expectations, it should be acknowledged that actors think differently about bioplastics, with the potential of resulting in conflicting interests between different actors.

2. <u>Increase the use of landscape pressures in policy as an engine for bringing about change</u>. The results showed that when policy tools and destabilizing pressures on regimes are geared to one another, policy tools can activate actors in starting to support challenging alternatives (in niches). For example, in the case of industrial hemp (section 4.1), the governmental 2010 Sustainable Buying Policy encourages builders to embark on a search for alternative materials which strengthen their (environmental) performance in projects, e.g. by rewarding reductions in CO2 or water use. For all four cases, environmental standards seem to activate actors in considering new choices, especially from a carbon footprint point of view, typically being a standard other than those in which regimes rule (section 8.2).

3. <u>Stimulate demand rather than production chains.</u> For strengthening the competiveness and attractiveness of biobased products, possibilities can be found in supporting production chains. The results, however,

suggest that it is wiser to *(further) stimulate demand by creating an environment that is conducive for niche development*. The results, especially the niches in starch plastics and PLA, suggest that the potential for momentum rises when biobased innovations seek true added value applications (sections 6.1 and 8.1). Unfortunately, the appropriate environment is frequently lacking. For example regulations are issued which allow certified plastics to be composted in the Netherlands. However, since municipalities were left free to deviate from this regulation, plastics are restricted from being composted in particular areas. The latter represents an exemption that hampers the uptake of compostable plastics, for instance because brand owners have difficulties in dealing with and communicating end customers such exemptions, because their products are sold and promoted nationwide.

4. Strive for setting expectations which are realistic. There is a large discrepancy between the time needed by niches to develop and the perishability of expectations (section 8.2), as explicitly observed in wind turbines. For example, the large-scale thinking about onshore wind placement by the Dutch government proved to be too optimistic, leading to shifts in the attention of actors when the innovations did not timely deliver up on promise (section 5.1 and paragraph 5.2.2). As a consequence, among others, the main participants in the government-sponsored development program, Fokker and Stork, lost their interest, negatively influencing the studied niches in wind turbines in the Netherlands. Verbong and Geels (2007) came to a similar conclusion on the basis of their study on renewable energy trajectories in the Netherlands, and suggest that many innovation trajectories follow a so-called hype-disappointment cycle. This highlights the need of *searching for tangible evidence in order to sustain expectations during an innovation trajectory*.

5. Foster a variety of innovative technologies over a longer period of time. The results showed that innovation trajectories are unpredictable when the course of niche development and the time it requires is concerned, as explicitly observed in starch plastics. For example, the niche encompassing injection molded products was able to rapidly develop after the entrepreneurs made discoveries they were not in search for, e.g. forward integration (section 6.1 and paragraph 6.2.2).. Meanwhile, policymakers are held accountable for any support given, and need to be able to show results, at least, within their governing period of four years. Policymakers are therefore advised to *search for ways to support various technologies in various use environments at the same time*. As described earlier, niches need protection over a relatively long period of time for them to evolve into market niches, and ultimately regimes. Likewise, Bos *et al.* (2008) argues that niches need time to develop and that it is unrealistic of governments to expect results of technological development within four years.

6. Stimulate multi-level interaction, that is, between innovations in niches, established sectoral regimes, and the broader societal landscape. The theoretical framework applied in this research project captured essential aspects of transitional practices, demonstrating that innovation trajectories can be approached as a result of interactions between levels. Policymakers are advised to consider the interaction-based multi-level conceptualization when issuing new or adjusting policy, such that *for each level the proper policy tools* are implemented, collectively, contributing to achieving a specific target.

WORKS CITED

Agterbosch, S. (2006). *Empowering wind power. On social and institutional conditions aff ecting the performance of entrepreneurs in the wind power supply market in the Netherlands.* Utrecht: Copernicus Institute for Sustainable Development and Innovation.

Blank, S. (2014, October 24). *Steve Blank*. Retrieved June 14, 2015, from www.steveblank.com: http://steveblank.com/2014/10/24/17577/

Boehle, M., Roucan-Kane, M., & Bröring, S. (2011). Future agribusiness challenges: strategic uncertainty, innovation and structural change. *IFAMA volume 14, issue 5*.

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.

Bos, H. (2008). *Agificatie en de Biobased Economy.* Wageningen: PropressGrafiko.

Bos, H., Slingerland, M., Elbersen, W., & Rabbinge, R. (2008). Beyond agrification: twenty five years of policy and innovation for non-food application of renewable resources in the Netherlands. *Biofuels, Bioproducts & Biorefining 2*, 343-357.

Bos, L. H., & Sanders, P. J. (2013). Raw material demand and sourcing options for the development of bio-based chemical industry in Europe. Part 1: estimation of maximum demand. *Biofuels, Bioprod. Bioref. 7*, 246-259.

Breukers, S., & Wolsink, M. (2007). Wind power implementation in changing institutional landscapes: an international comparison. *Energy Policy 35*, 2737-2750.

CBS Statline. (2015, June 29). *CBS Statline*. Retrieved July 13, 2015, from CBS Statline: http://statline.cbs.nl/Statweb/publication/?DM=SLNL&PA=70802ned&D1=0,3&D2=a&D3=16,33,50,67,84,101,118,135,152,169,186,203-206,208-210,212-214,216-218,220-225&HDR=T,G1&STB=G2&VW=T

Chesbrough, H. (2006). Open innovation: a new paradigm for understanding industrial innovation. In H. Chesbrough, W. Vanhaverbeke, & J. West, *Open innovation: researching a new paradigm* (pp. 1-27). Berkeley: Oxford University Press.

Chesbrough, H. (2010). Business model innovation: opportunities and barriers. *Long Range Planning 43*, 354-363.

Conscious. (2015). *Conscious Company Magazine*. Retrieved September 18, 2015, from http://www.consciouscompanymagazine.com/blogs/press/42182913-paperfoam

Coombs, R., & Hull, R. (1998). 'Knowledge management practices' and path-dependency in innovation. *Research Policy 27*, 237-253.

Corbion. (2015). *www.corbion.com.* Retrieved July 29, 2015, from www.corbion.com: http://www.corbion.com/media/203221/eubp_factsfigures_bioplastics_2013.pdf

Dawson, B. (2007). *The Impact of Technology Insertion on Organisations.* HFIDTC.

Drury, C. (2012). *Management and cost accounting.* Hampshire, United Kingdom: Cengage Learning.

EC. (2002). *Public Report PaperFoam® LIFE project.* European Commission.

EC. (2005). *www.ec.europa.eu.* Retrieved September 19, 2015, from European Commission: http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=search.dspPage&n_proj_id=1310&docType=pdf

European Bioplastics. (2015). *European Bioplastics*. Retrieved April 19, 2015, from http://en.european-bioplastics.org/environment/sustainable-sourcing/feedstock/

European Bioplastics. (2015, January). *www.european-bioplastics.org.* Retrieved July 29, 2015, from www.european-bioplastics.org: http://en.european-bioplastics.org/wp-content/uploads/2011/04/fs/Packaging_eng.pdf

European Union. (2014). *Enabling synergies between European Structural and Investment Funds, Horizon 2020 and other research, innovation and competitiveness-related Union programmes. Guidance for policy-makers and implementing bodies.* Brussels: Publications office of the European Union.

EZ. (1986). *Integraal Programme Windenergie 1986-1990.* Retrieved September 11, 2015, from Tweede Kamer der Staten-Generaal: http://resourcessgd.kb.nl/SGD/19851986/PDF/SGD_19851986_0007748.pdf

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

Geels, F. W. (2011). The multi-level perspective on sustainability transitions: responses to seven criticisms. *Societal Transitions 1*, 24-40.

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

Groningen, E. v., & Wilterdink, R. (2002). *Teelthandleiding vezelhennep.* Dronten: CAH Dronten.

Hancké, B. (2010). *Intelligent Research Design. A guide for beginning researchers in the social sciences.* New York: Oxford University Press.

Harmsen, P., & Hackmann, M. (2012). *Chemische bouwstenen voor biobased plastics. Biobased routes en marktontwikkeling.* Wageningen: Propress.

HempFlax. (2003, March 21). *Biobased News.* Retrieved September 11, 2015, from www.news.bio-based.eu: http://news.bio-based.eu/hempflax-bv-takes-over-competitors-hempron-en-vernaro/

Hoogma, R., Kemp, R., Schot, J., & Truffer, B. (2002). *Experimenting for sustainable transport: the approach of strategic niche management.* London and New York: Spon Press.

Huijben, J., & Verbong, G. (2013). Breakthrough without subsidies? PV business model experiments in the Netherlands. *Energy Policy 56*, 362-370.

IEA. (1992). *Wind Energy Annual Report 1991.* Studsvik, Sweden: NUWEC.

IEA. (1995). *Wind Energy Annual Report 1994.* Colorado, United States of America: NREL.

IEA. (2001). *Wind Energy Annual Report 2000.* Colorado, United States of America: NREL.

Imre, B., & Pukánszky, B. (2013). Compatibilization in bio-based and biodegradable polymer blends. *European Polymer Journal 49*, 1215-1233.

Jacobides, M. G., Knudsen, T., & Augier, M. (2006). Benefiting from innovation: Value creation, value appropriation and the role of industry architectures. *Research Policy 35*, 1200-1221.

Jansma, J., Israël-Hoevelaken, B., & Wubben, E. (2014). *Analysing the usefulness of Strategic Niche Management on the cases Agromere and AlgaePARC.* Wageningen.

Johnson, G., Whitington, R., & Scholes, K. (2012). *Fundamentals of strategy.* Essex: Pearson Education Limited.

Johnson, G., Whittington, R., & Scholes, K. (2012). *Fundamentals of strategy. Second edition.* Edinburgh Gate: Pearson Education Limited.

Jørgensen, U. (2012). Mapping and navigating transitions—The multi-level perspective compared with arenas of development. *Research Policy 41*, 996-1010.

Kamp, L. (2002). *Articulations of sustainability in the development of wind power in the Netherlands.* Delft, The Netherlands: Delft University of Technology.

Lagerweij, H. (2012, June 28). Henk Lagerweij 'ik kan het niet laten'. (W. Devenijns, Interviewer)

LEI Wageningen UR and Copernicus Institute of Utrecht University (2016). *Macroeconomic outlook of sustainable biorenewables innovations in the Netherlands. The future of the Dutch bio-based economy.* Delft: BE-Basic Foundation.

Levinthal, D. (1998). The slow pace of rapid technological change: gradualism and punctuation in technological change. *Ind Corp Change 7*, 217-247.

Loorbach, D., & Raak, R. v. (2006, July 11). *Erasmus University Rotterdam.* Retrieved May 15, 2015, from www.eur.nl: http://repub.eur.nl/pub/37247/

Lörcks, J. (1997). *Starch-based plastic material.* Emmerich, Germany: BIOTEC.

Mankins, J. C. (2009). Technology readiness assessments: a retrospective. *Acta Astronautrica 65*, 1216-1223.

Meijer, E. d. (1995). Fiber hemp cultivars: a survey of origin, ancestry, availability and brief agronomic characteristics. *Journal of the International Hemp Association 2*, 66-73.

Mittal, V., Akhtar, T., Luckachan, G., & Matsko, N. (2015). PLA, TPS and PCL binary and ternary blends: structural characterization and time-dependent morphological changes. *Colloid and Polymer Science 293, issue 2*, 573-585.

NatureWorks LLC. (2009, October). *Natureworks LLC.* Retrieved April 22, 2016, from www.natureworksllc.com: http://www.natureworksllc.com/~/media/News_and_Events/NatureWorks_TheIngeoJourney_pdf.pdf

Negro, S. O., Hekkert, M. P., & Smits, R. E. (2007). Explaining the failure of the Dutch innovation system for biomass digestion - a functional analysis. *Energy Policy 35*, 925-938.

NRC. (1998, May 12). *www.nrc.nl*. Retrieved November 2, 2015, from NRC Handelsblad: http://www.nrc.nl/handelsblad/1998/05/12/windturbinefabrikant-wijkt-uit-naar-zee-en-buitenland-7398791

Osterwalder, A., & Pigneur, Y. (2002). *Business models and their elements.* Lausanne, Switzerland.

Osterwalder, A., & Pigneur, Y. (2003). *Towards Business and Information Systems Fit through a Business Model Ontology.* Lausanne: Ecole des HEC, University of Lausanne.

Oxford Dictionaries. (2015). *Oxford Dictionaries*. Retrieved April 19, 2015, from www.oxforddictionaries.com: http://www.oxforddictionaries.com/definition/english/biodegradable

Oxford Dictionaries. (2015). *Oxford Dictionaries*. Retrieved April 19, 2015, from http://www.oxforddictionaries.com/definition/english/industry

Panteia. (2014). *Entrepreneurship in the Netherlands. The Top sectors.* Zoetermeer: FWA Drukwerk.

Perman, R., Ma, Y., Common, M., Maddison, D., & McGilvray, J. (2011). *Natural Resource and Environmental Economics.* Pearson Education Limited.

Philips, F. (2007). On S-curves and tipping points. *Technological Forecasting & Social Change 74*, 715-730.

PlasticsEurope. (2015). *PlasticsEurope.* Retrieved April 2, 2016, from www.plasticseurope.org: http://www.plasticseurope.org/documents/document/20150227150049-final_plastics_the_facts_2014_2015_260215.pdf

Policonomics. (2015). *Policonomics*. Retrieved April 19, 2015, from http://www.policonomics.com/industrial-organization/

Raven, R. (2005). *Strategic niche management for biomass : a comparative study on the experimental introduction of bioenergy technologies in the Netherlands and Denmark.* Eindhoven: Eindhoven University Press.

Refdag. (2011). *www.refdag.nl.* Retrieved September 19, 2015, from Refdag: http://www.refdag.nl/nieuws/economie/paperfoam_bakt_ze_groen_met_zetmeel_1_535742

Rijksoverheid. (2015). *www.rijksoverheid.nl*. Retrieved July 15, 2015, from www.rijksoverheid.nl: http://www.rijksoverheid.nl/onderwerpen/ondernemersklimaat-en-innovatie/investeren-in-topsectoren

Rogers, E. M. (1983). *Diffusion of Innovations. Third edition.* New York: The Free Press.

RVO. (2015). *Monitor Wind op Land. Tweede editie; stand van zaken tot december 2014.* Den Haag, The Netherlands: RVO.

Schild, P. (2014). *European Commission website.* Retrieved May 10, 2015, from www.ec.europa.eu: http://ec.europa.eu/research/conferences/2013/energy_infoday/pdf/session_3_summary_of_the_calls_open_in_2014_-_philippe_schild.pdf

Schot, J., & Geels, F. W. (2008). Strategic niche management and sustainable innovation journeys: theory, findings, research agenda, and policy. *Technology Analysis & Strategic Management vol.20, No. 5*, 537-554.

Schot, J., & Geels, F. W. (2008). Strategic niche mangement and sustainable innovation journeys: theory, findings, research agenda, and policy. *Technology Analysis & Strategic Management. Vol. 20, No. 5*, 537-554.

Seyfang, G., & Smith, A. (2007). Grassroots Innovations for Sustainable Development: Towards a New Research and Policy Agenda. *Environmental Politics Vol. 16, No. 4*, 584-603.

Soest, J. v., Hulleman, S., Wit, D. d., & Vliegenthart, J. (1996). Crystallinity in starch bioplastics. *Industrial Crops and Products 5*, 11-22.

Teece, D. J. (2010). Business models, business strategy and innovation. *Long Range Planning 43*, 172-194.

TKI Wind op Zee. (2015, January 22). Workshop kostenreductie offshore wind.

Unruh, G. (2000). Understanding carbon lock-in. *Energy Policy 28*, 817-830.

Van der Laak, W., Raven, R., & Verbong, G. (2007). Strategic niche management for biofuels: analyzing past experiments for developing new biofuel policies. *Energy Policy 35*, 3213-3225.

Van Rooijen, S., & Van Wees, M. (2006). Green electricity policies in the Netherlands: an analysis of policy decisions. *Energy Policy 34*, 60-71.

Verhees, B., Raven, R., Kern, F., & Smith, A. (2015). The role of policy in shielding, nurturing and enabling offshore wind in The Netherlands (1973-2013). *Renewable and Sustainable Energy Reviews 47*, 816-829.

Verschuren, P., & Doorewaard, H. (2010). *Designing a Research Project.* The Hague: Eleven International Publishing.

Vinding, A. L. (2001). *Firms and knowledge institutions - the innovation potential in low-tech sectors and small firms.* Aalborg, Denmark: DRUID/IKE Group.

Vink, E. T., Rabago, K. R., Glassner, D. A., & Gruber, P. R. (2003). Applications of life cycle assessment to NatureWorksTM polylactide (PLA) production. *Polymer Degradation and Stability 80*, 403-419.

Vroman, I., & Tighzert, L. (2009). Biodegradable polymers. *Materials 2*, 307-344.

Wageningen UR. (2012, May 2). *www.groenegrondstoffen.nl.* Retrieved July 15, 2015, from www.groenegrondstoffen.nl: http://groenegrondstoffen.nl/downloads/Infosheets/Bioplastics%20zetmeel%20eigenschappen.pdf

Wageningen UR. (2015). *Wageningen UR, for quality of life*. Retrieved March 27, 2015, from www.wageningenur.nl: http://www.wageningenur.nl/en/Expertise-Services/Research-Institutes/food-biobased-research/Expertise-areas/Biobased-materials/Bioplastics.htm

Wageningen UR Food & Biobased Research. (2012, October 19). *www.wageningenur.nl*. Retrieved March 23, 2015, from Wageningen UR: http://www.wageningenur.nl/nl/show/Breakthrough-in-biobased-economy-heatresistant-PLA.htm

Whiting, L. (2008). Semi-structured interviews: guidance for novice researchers. *Nursing Standard 23*, 35-40.

Witkamp, M. J., Raven, R., & Royakkers, L. (2011). Strategic niche management of societal innovations: the case of social entrepreneurship in the Netherlands. *Technology analysis & strategic management 23*, 667-681.

Wolsink, M. (1996). Dutch wind power policy. Stagnating implementation of renewables. *Energy Policy 24*, 1079-1088.

WUR. (2012, April). *www.wur.nl*. Retrieved September 17, 2015, from Wageningen UR: http://www.wageningenur.nl/en/show/Biobased-doggy-snack-turns-into-worldwide-hit.htm

WWF International. (1999). *The impact of cotton on fresh water resources and ecosystems.* Zurich: WWF Switzerland.

Yunus, M., Moingeon, B., & Lehmann-Ortega, L. (2010). Building social business models: lessons from the Graheem experience. *Long Range Planning 43*, 308-325.

Zott, C., & Amit, R. (2010). Business Model Design: An Activity System Perspective. *Long Range Planning 43*, 216-226.

APPENDICES

Appendix 1 Overview respondents

Case study industrial hemp

Lars van der Meulen, VolkerWessels
Albert Dun, Dun Agro, formerly HempFlax
Martin Berg, CNVU
Roel Bol, Ministry of Economic Affairs
John Verhoeven, Grow2Build, WUR
Rene Sauveur, Pantanova, formerly Daglicht Productie

Case study wind turbines

Paul Boeding, Ministry of Economic Affairs
Max ter Horst, EWT
Peter Eecen, ECN
Jeroen Kok, Eneco Wind
Bart van Neerbos, Hydrautrans

Case study starch plastics

Aaik Rodenburg, Rodenburg Biopolymers
Vincent Lamberti, AVEBE
Diane Pluijmers, Oost-NV, formerly AVEBE
Henk Jaap Meijer, HENAN food systems, formerly AVEBE
Remy Jongboom, Biotech Biolog, formerly ATO-DLO and Rodenburg Biopolymers

Case study poly lactic acid

Erwin Vink, NatureWorks
Jan Noordegraaf, Synbra
Francois de Bie, Corbion Purac

Appendix 2 Definitions and concepts

Prominent terms in the research objective

- Factors can be defined as elements that bring about certain effects or results.
- Comparable refers to being alike to some degree. It is important to distinguish between comparable and identical given that the latter indicates a perfect fit between research objects, and this will not be achievable.
- Trajectories relates to the paths followed by innovations. Thus, *comparable Dutch trajectories* implies that this research will investigated several innovation pathways which are instructive for the biobased transition.

Other

- Biodegradable packages: objects that are capable of being decomposed (without leaving harmful substances) through the action of living organism such as bacteria (Oxford Dictionaries, 2015). The European standard for biodegradability only applies to industrial composting units and does not set out a standard for ordinary composting conditions. The meaning of biodegradable differs from compostable as compost-friendly packages include organic matter that decomposes to natural elements without any intervention of biological agents.
- Bioplastics: ''plastics materials based on renewable raw materials that are often more sustainable than petrochemical (traditional) plastics'' (Wageningen UR, 2015). There is a distinction between bioplastics based on first, and second and/or third generation feedstock. First generation feedstock refers to food crops, such as sugar cane or corn, being used for the production whereas second and third generation bioplastics use non-food crops (European Bioplastics, 2015). In this study, the focus lies primarily on first generation feedstock, currently the most efficient feedstock, as it can be seen as ''an enabling technology that will facilitate the transition to later generations of feedstock'' (European Bioplastics, 2015, Noordegraaf, 2015).
- Competitive advantage: a source of value both greater than the costs of supplying them and superior to that of rivals (Johnson, Whitington, & Scholes, Fundamentals of strategy, 2012).
- Rate of success: success can be defined as ''the accomplishment of an aim or purpose'' (Oxford Dictionaries, 2015). Within the context of this thesis, success refers an innovation succeeding in changing an existing sector or forming a new one.
- Transition: ''the process or a period of hanging from one state or condition to another'' (Oxford Dictionaries, 2015). In the context of this research, transition is related to both system transition and substitutive industry convergence (Boehle, Roucan-Kane, & Bröring, 2011).

Appendix 3 Interview protocol

Prior to the interview, the selected interviewees and/or companies are contacted via either telephone, or email. Initial contact by telephone is preferred over email given the possibility to quickly respond on questions and hopefully make an appointment. Call and email protocols have been used. Subsequently, at least one week before the interview, a subject list concerning the content of the interview questions is shared with the interviewees via email. At the same time, each interviewee is asked whether they grant permission to record the interview. The researcher collects information on the interviewee and him/her organization in order to anticipate on the 'interviewee's world'. This is considered important as the researcher tends to go in-depth in each case regarding the factors of the theoretical framework.

At the start of the interview, a round of introduction is requested. Here, the researcher introduces the researcher's study background and an introduction of the interviewee is asked for. Subsequently, the research project is briefly explained. An elaborated explanation should be prevented here as the information that is required for the interviewee is initially restricted to: 'this study tries to analyze innovation diffusion, and more precise the development and diffusion of the technology towards sectoral development'. Interviewees are asked whether they allow that the conversation is taped as this enables high quality reproduction of their given answers. In order to let respondents know what is made of their words when written down, the following ground rule is adopted: interviewees can be literally cited if this contributes to the subject of matter.

During the interviews, interviewees are always encouraged to explore their experiences in a sensitive manner. However, interviewees should not be 'probed' in such a way that the interviewee may start feeling uncomfortable. Note that steering the answers of interviewees is avoided at all times. In case an interviewee is finished with his/her discussion of a factor and appeared to have missed for example an aspect or event that, according to documents or interviewees, was important. Then, the researcher is free to bring in this aspect or event and present it as an open question to the interviewee in order to further examine the role of this aspect or event. This procedure is considered beneficial for the process of building cases (Eisenhardt, 1989). Since the theoretical framework provides a clear structure for the questionnaire, the goal is to hold on as much as possible to this structure. If a respondent does deviate from the factor of subject, the respondent is free to elaborate on other subjects as long as these relate to the factors of the theoretical framework. Otherwise, without interrupting the interviewee, the researcher should tactfully return the interviewee to the subject of interest.

Upon closing the interview, interviewees are asked if they would like to add something of relevancy. Another question concerns whether the interviewee can share relevant company documents if possible. In addition, the interviewee is asked who else they would recommend for an interview. For each interview, field notes concerning the key learnings are written, preferably right after the interview when the information is still fresh. Ultimately, each interview will be summarized and analyzed.

Appendix 4 Operationalization

Following the structure of the theoretical framework (figure 2.7), the case study interview composes of five sections which should naturally flow right into each other during the interview. The interview starts with questioning the factors related to *niche development* (section 1). Subsequently, the role of the *regime stability* (section 2) is taken into account, particularly in relation to niche development, and then the role of landscape pressure is discussed (section 3). Whether or not technologies are able to gain *momentum* (section 4) should be the function of the former sections, and result in the outcome of *innovation diffusion* (section 5). Next, the factors from the theoretical framework are operationalized. Per factor, open questions (O), follow-up questions (F), and dichotomous questions (D) are predetermined.

Section 1) Niche development

The first section of the interview addresses niche development. Niches develop according to a three-stage process, stimulated by an increasing alignment of *market* and *technology*.

Market

Market represents the *user demand* for a particular technology. The Value Proposition Canvas distinguishes three variables that make up markets (Strategyzer, 2015): customer jobs, gains, and pains. *Customer jobs* describe what a specific customer segment is trying to get done. *Gains* refer to the benefits the customer expects, desires or would be surprised by. *Pains* describe the negative emotions, undesired costs and situations and risks that the customer experiences or could experience. For reasons of clarity, gains and pains are respectively referred to as the wants and needs of users (i.e. customers). The following table represents the operationalization of the factor market

Factor	Variables	Question items based on variables
Market	(Strategyzer, 2015) a. Customer jobs b. Gains c. Pains	**Open / follow-up** Which wants/needs did users have? How did these change? (O1.Mar) Who are the main users? (F1.Mar) How did user demand develop for the innovation? (O2.Mar) **Dichotomous** Were the customer wants/needs realistic (1) or unrealistic (0)? (D1. Mar)

Technology

Technology describes the development of an invention from a technological point of view. The progress in the development of inventions can be described using the *TRL methodology* of the European Commission (European Union, 2014). TRL stands for Technology Readiness Level and composes a 10-level scale. Each level characterizes the technology status, from idea (level zero) to *first* full commercial application (level 9), by means of parameters which are set for each stage of progress. The following table presents the TRL scale.

Level	Stage	Parameters
TRL 0	Idea	Unproven concept, no testing has been performed
TRL 1	Basic research	Basic principles observed. Principles postulated and observed but no experimental proof available
TRL 2	Technology formulation	Technology concept formulated. Concept and application have been formulated
TRL 3	Applied research	Experimental proof of concept. First laboratory tests completed
TRL 4	Small scale prototype in lab	Technology validated in laboratory environment ("ugly" prototype)
TRL 5	Large scale prototype	Tested in intended environment. Technology validated in industrially relevant environment
TRL 6	Prototype system	Technology demonstrated in industrially relevant environment. Tested in intended environment close to expected performance
TRL 7	Demonstration system	System prototype demonstration in operational environment at pre-commercial scale
TRL 8	First of a kind commercial system	System complete and qualified. Manufacturing issues solved
TRL 9	Full commercial application	Actual system proven in operational environment (competitive manufacturing). Technology available for consumers

Analytically, the TRL levels allow for a more in-depth analysis of the progress of a technology. The TRL levels in the previous table are marked according to the three phases of innovation: *R&D* (blue), *experimentation (i.e. pilot/demonstration)* (orange), and *commercialization* (green).

Note that 'technology readiness' does not necessarily fit with 'maturity' (Dawson, 2007). For example an invention that is technologically ready for full commercial application (TRL 9) does not necessarily enjoy *user preference* and thus not always a market exists for it. In SNM, matureness is perceived as the outcome of the alignment of market and technology. The following table presents the operationalization of the factor technology.

Factor	Variables	Question items based on variables
Technology	(European Union, 2014) a. Readiness b. Maturity	**Open / follow-up** How did the technology develop from R&D to being marketed? (O7.Tech) To what extent became the 'valley of death'' in innovation apparent? (F10.Tech) What was the level of difficulty regarding bottlenecks in the innovation process? (F11.Tech) What facilitated the innovation process from a technological point of view? F12.Tech) What hampered the innovation process from a technological point of view? (F13.Tech) **Dichotomous** Was a continuous progress in the development of the product present (1) of absent (0)? (D4.Tech)

Drawn from literature, visioning, value proposition, and finances are selected to be studied as influencing factors of niche development. Next, the three influencing factors of niche development are operationalized.

Ad. 1 Visioning

Visioning refers to the role of visions and expectations in steering niche development. In SNM, it is posited that actor expectations are important in the early development of technologies as visions and expectations can provide legitimacy to actors to invest time when a technology does not yet have any market value (Raven, 2005). Expectations are likely to contribute to niche development if they become (Hoogma *et al.*, 2002; Raven, 2005): (1) *more robust*, i.e. shared by a larger variety and number of actors, (2) *more specific*, e.g. if expectations are too general they do not provide guidance, and (3) *of a higher quality*, e.g. actor expectations are substantiated by more experiments. The following table presents the operationalization of the factor visioning.

Factor	Variables	Question items based on variables
Visioning	(Hoogma *et al.*, 2002; Raven, 2005) a. robustness b. specific c. quality	**Open / follow-up** Which visions/expectations did actors have? How did these change? (Raven, 2005) (O8.Vis) What was the source of these changes (e.g. learning from experiments, governmental policy)? (Raven, 2005) (F13.Vis) What were the expectations in the early phase of development? (F14.Vis) To what extent were expectations shared by an increasing variety of actors? (F15.Vis) **Dichotomous** Were expectations able (1) or unable (0) to attract and provide legitimacy to actors to invest in the innovation, in particular in the early phase of development? (D5.Vis)

Ad. 2 Value proposition

Value proposition represents the role of the offering of inventors in steering niche development. In BMP, it is posited that the market and the value proposition of an inventor should match if the inventor is to capture value. This requirement is conceptualized via the Value Proposition Canvas (Strategyzer, 2015) and is referred to as the *Product/Market Fit*. The Value Proposition Canvas distinguishes three variables that make up value propositions (Strategyzer, 2015): products and services, gain creators, and pain relievers. *Products and services* refer to the products the value proposition is built around. *Pain relievers* describe how products alleviate customer pains, so how they eliminate or reduce undesired costs, situations and/or risks. *Gain creators* describe how products and services create customer gains. Coherent with the operationalization of market, pain relievers and gain creators respectively refer to how users' needs and wants are satisfied by the offering of a group of particular firms.

In BMP literature, it is also posited that value propositions should differentiate the firm from competitors when seeking to solve customer problems and satisfy customer needs (Osterwalder & Pigneur, 2010). If the offer of an inventor is less compelling than what (existing) competitors offer, the innovation process of the inventor will likely stagnate. The following table presents the operationalization of the factor value proposition.

Factor	Variables	Question items based on variables
Value proposition	(Blank, 2014) a. Pain relievers b. Gain creators c. Products and services (Osterwalder & Pigneur, 2010) d. Differentiation	**Open / follow-up** To what extent did the offering satisfy user wants/needs? (Product/Market Fit) (O3.Val) What were the outcomes of the innovation compared to the dominant design? (e.g. in performance) (F2.Val) How did the inventors differentiate their offering from competitors? (O4.Val) What were the unique selling points of the innovation? (F3.Val) **Dichotomous** Was the value proposition effective (1) or ineffective (0) in developing user demand for the innovation while differentiating the innovation from competitors? (D2.Val)

Ad. 3 Finances

Finances represent the financial aspects which influence niche development. The financial aspects are conceptualized as an influencing factor at the level of a group of particular firms. Finances compose of the sub-factors: *cost structure* and *revenue streams* (Osterwalder & Pigneur, 2010). Where the latter concerns the pricing model, the former addresses the business model focus, economies of scale and scope, and the actual structure of costs (variable, fixed). As part of strategic cost management, expected rates of return influence the decision-making of actors regarding whether or not to undertake investments (Drury, 2012; Osterwalder & Pigneur, 2003). Therefore, the estimation of the *size of opportunities and markets* may be considered crucial in innovation processes, and has been added as a sub-factor of Finances. The following table presents the operationalization of the factor finances.

Sub-factors	Variables	Question items based on variables
Cost structure Revenue streams	(Strategyzer, 2015; Osterwalder & Pigneur, 2010). a. Business model focus b. Economies of scale and scope c. Variable versus fixed costs (Osterwalder & Pigneur, 2010) d. Pricing model	**Open / follow-up** Is the business more cost driven (leanest cost structure, low price value proposition) or value driven (focused on value creation, premium value proposition)? (Fin.F1) To what extent did the inventors have economies of scale and/or economies of scope? (Fin.F4) How do the fixed costs relate to the variable costs? (Fin.F6) How was the pricing in relation to the costs? How did this change? (Internal) (Fin.O1) How was the balance in profit in relation to capital invested? (Return on investment) (Fin.O2) How did (potential) returns on investment impact the innovation process? (Fin.F5)
Size of opportunities and markets	(Drury, 2012) e. Return on investment (ROI)	**Dichotomous** Was the innovation capable (1) or incapable (0) of providing a balance in finances via competitive offerings (in pricing and/or value)? (Fin.D1)

Section 2) Regime stability

The second section of the interview addresses regime stability. Regime stability represents the entrenchment of actors and infrastructures as the result of alignment between the rules of actors. This alignment gives regimes an internal resistance to change that accounts for the lock-in of existing production systems (Schot & Geels, 2008; Geels, 2011; Grin, Rotmans, & Schot, 2010). However, if inventors are to gather momentum, a decrease in regime stability is required.

For reasons of clarity, question items will refer to *dominant designs* instead of regimes when questioning regime stability. A *dominant design* is known as a product that gained ''*general acceptance* as the *standard* on technical features that other market players must follow if they wish to acquire significant market share'' (Utterback, 1994). It can be derived that when a dominant design has established, allegiance of the marketplace has been won by this product and its technological features have become the (de facto) standard. According to Utterback & Abernathy (1975), who first introduced the concept, the emergence of a dominant design in a market directs the way firms compete in this market.

Prior to addressing the factors regarding regime stability, a number of general question items are added to the interview schedule for identifying the dominant designs and their influence with regard to standard setting.

Factor	Question items
Regime stability	Which dominant designs were important? (O9.Reg) Why were these designs dominant? (sources of stability) (F16.Reg) To what extent did the dominant design(s) set standards for the innovation? (O10.Reg)

In MLP, it is posited that landscape pressure can decrease regime stability via actor involvement. Next, the factors actor involvement and landscape pressure are operationalized.

Actor involvement

Regimes gain stability by the way actors are entangled in the (re)production of rules (Grin, Rotmans, & Schot, 2010). Actor involvement describes the way actors are involved in the regime. Two ways are identified in which actors can be involved (Jørgensen, 2012): as game players, or as rule followers. In contrast to rule followers, game players are actors which attempt to break away from the existing rule-set (related to the old technology) and/or start sharing new rules (related to a new technology) (Jørgensen, 2012). Thence regime stability refers to the state of a regime in which game players are entrenched in their behavior by rule followers. The following table presents the operationalization of the factor actor involvement.

Factor	Variables	Question items based on variables
Actor involvement	(Jørgensen, 2012) a. Game players b. Rule followers	**Open / follow up** How did stakeholders influence the dominant design(s)? (e.g. provide support, intervene) (O11.Act) To what extent were stakeholders able to lower the dominance of the design(s)? (F16.Act) What was the role of the government? (F17.Act) How did actors stimulate the innovation? (O12.Act) To what extent did the government provide protection for the innovation? (e.g. via subsidies) (F18.Act) What could actors do more? (F19.Act) **Dichotomous** Was the involvement of actors in facilitating the innovation, in particular via lowering the dominance of particular designs, high (1) or low (0)? (D6.Act)

Section 3) Landscape pressure

Landscape pressure represents the macro-level factors that influence regime stability and niche development. The nature of their relationship with the landscape is either stabilizing or destabilizing (Grin, Rotmans, & Schot, 2010). In particular destabilizing effects on regimes are important as they can induce cracks in the regime, and herewith windows of opportunity for niche development (Grin, Rotmans, & Schot, 2010). The following table presents the operationalization of the factor landscape pressure.

Factor	Variables	Question items based on variables
Landscape pressure	(Grin, Rotmans, & Schot, 2010) a. stabilizing effects b. destabilizing effects	**Open / follow-up** Which macro-level factors influenced the innovation? (O13.Land) To what extent did macro-level factors activate stakeholders? (e.g. induce follow up actions) (F20.Land) **Dichotomous** Did macro-level factors induce strong (1) or weak (2) pressure on dominant design(s) via the involvement of actors? (D7.Land)

Section 4) Momentum

The fourth section of the interview addresses momentum. In MLP, it is stated that the development and diffusion of new technologies is the outcome of interactions between levels (Raven, 2005). Momentum may be considered the *impetus* for the process of rapid development and diffusion of a technology. A niche gathers momentum when the stability of a regime decreases, referred to as the emergence of *cracks*, while the niche itself stabilized (Grin, Rotmans, & Schot, 2010). Hence it is posited that momentum is a function of niche development and regime stability. The following table presents the operationalization of momentum.

Factor	Variables	Question items based on variables
Momentum	(Grin, Rotmans, & Schot, 2010) a. Niche development b. Regime stability	**Open / follow-up** When did stakeholders become more enthusiastic on the developed technology? (O15.Mom) Did experiments with the innovation result in any changes in the dominance of other designs? (F21.Mom) What are crucial factors for innovations to break-through? (O17.Mom) When did stakeholders team up to realize the break through? (F22.Mom) **Dichotomous** Was the innovation able (1) or unable (0) to make use of changes in the dominance of other designs? (D8.Mom)

Section 5) Innovation diffusion

Lastly, the fifth section of the interview addresses innovation diffusion, the endogenous variable in this research project. Where momentum allows for the 'spreading' of the new technology, innovation diffusion refers to process of a new technology in which its use becomes *(widely) accepted and spread* (Rogers, 1983). The following table presents the operationalization of innovation diffusion.

Factor	Question items based on variables
Innovation diffusion	**Open / follow-up** How did the innovation spread among users? (O18.Dif) How was it demonstrated that the technology was becoming widely accepted? (F22.Dif) What are crucial factors for technologies to rapidly develop? (O19.Dif) **Dichotomous** Was the innovation able (1) or unable (0) to rapidly develop towards becoming a sector? (D9.Dif)

Appendix 5 Interview schedule

Details

Name: ………………………………………………………………………………………….

Function: ………………………………………………………………………………………….

Company: ………………………………………………………………………………………….

Date: ………………………………………………………………………………………….

Place: ………………………………………………………………………………………….

Background (Dutch)

Dit interview is onderdeel van een onderzoek dat gaat over hoe biobased sectoren in Nederland vooruit te helpen. En dan met name, hoe ontwikkelen die sectoren zich. Om dit te leren kijken we naar recente innovatieve sectoren. Het gaat hier om mijn afstudeeronderzoek aan Wageningen Universiteit, in samenwerking met het Ministerie van Economische Zaken.

Besloten is vier sectoren te bekijken, aan de hand van een theoretisch model. Het model bestaat grofweg uit vijf hoofddelen, wat de achtergrond vormt voor de vragen aan jou/jullie. Idealiter focust dit interview zich op de ontwikkeling van de innovaties/sector in de loop der tijd.

Question items

Box 1 presents the question items for section 1, niche development.

Box 1 –Niche development *(20-25 minutes in total)*

Market

O1.Mar	Which wants/needs did users have? How did these change?
F1.Mar	Who are the main users?
O2.Mar	How did user demand develop for the innovation?
D1. Mar	Were the customer wants/needs realistic (1) or unrealistic (0)?

Value proposition

O3.Val	To what extent did the offering satisfy user wants/needs? (Product/Market Fit)
F2.Val	What were the outcomes of the innovation compared to the dominant design? (e.g. in performance)
O4.Val	How did the inventors differentiate their offering from competitors?
F3.Val	What were the unique selling points of the innovation?
D2.Val	Was the value proposition effective (1) or ineffective (0) in developing user demand for the innovation while differentiating the innovation from competitors?

Finances

O5.Fin	Is the business more cost driven (low price value proposition) or value driven (focused on value creation, premium value proposition)?
F4.Fin	If O5.Fin = 'cost driven' → to what extent was the pricing of the innovation competitive in comparison to the pricing of the dominant design?
F5.Fin	If O5.Fin = 'value driven' → to what extent was the value being offered competitive in comparison to the dominant design?
O6.Fin	How was the balance in profit in relation to capital invested? (Return On Investment)
F6.Fin	How did (potential) returns on investment impact the innovation process?
F7.Fin	To what extent did inventors have economies of scale and/or economies of scope?
F8.Fin	How do the fixed costs relate to the variable costs?
D3.Fin	Were inventors capable (1) or incapable (0) of achieving a balance in finances via competitive offerings (in pricing and/or value)?

Technology

O7.Tech	How did the technology develop from R&D to being marketed?
F9.Tech	To what extent became the 'valley of death'' in innovation apparent?
F10.Tech	What was the level of difficulty regarding bottlenecks in the innovation process?
F11.Tech	What facilitated the innovation process from a technological point of view?

F12.Tech	What hampered the innovation process from a technological point of view?
D4.Tech	Was a continuous progress in the development of the product present (1) of absent (0)?
Visioning	
O8.Vis	Which visions/expectations did actors have? How did these change? (Raven, 2005)
F13.Vis	What was the source of these changes (e.g. learning from experiments, governmental policy)?
F14.Vis	What were the expectations in the early phase of development?
F15.Vis	To what extent were expectations shared by an increasing variety of actors?
D5.Vis	Were expectations able (1) or unable (0) to attract and provide legitimacy to actors to invest in the innovation, in particular in the early phase of development?

Box 2 presents the question items for section 2, regime stability.

Box 2 – Regime stability *(10-15 minutes)*	
O9.Reg	Which dominant designs were important?
F16.Reg	Why were these designs dominant? (sources of stability)
O10.Reg	To what extent did the dominant design(s) set standards for the innovation?
Actor involvement	
O11.Act	How did stakeholders influence the dominant design(s)? (e.g. provide support, intervene)
F16.Act	To what extent were stakeholders able to lower the dominance of the design(s)?
F17.Act	What was the role of the government?
O12.Act	How did actors stimulate the innovation?
F18.Act	To what extent did the government provide protection for the innovation? (e.g. via subsidies)
F19.Act	What could actors do more?
D6.Act	Was the involvement of actors in facilitating the innovation, in particular via lowering the dominance of particular designs, high (1) or low (0)?

Box 3 – Landscape pressure *(5-10 minutes)*	
O13.Land	Which macro-level factors influenced the innovation?
F20.Land	To what extent did macro-level factors activate stakeholders? (e.g. induce follow up actions)
D7.Land	Did macro-level factors induce strong (1) or weak (2) pressure on dominant design(s) via the involvement of actors?

Box 4 presents the question items for section 3, momentum, addressing the developed technology.

Box 4 - Momentum *(5-10 minutes)*	
O14.Mom	When did stakeholders become more enthusiastic on the developed technology?
F21.Mom	Did experiments with the innovation result in any changes in the dominance of other designs?
O15.Mom	What are crucial factors for technologies to break-through?
F22.Mom	When did stakeholders team up to realize the break through?
D8.Mom	Was the innovation able (1) or unable (0) to make use of changes in the dominance of other designs?

Lastly, box 5 presents the question items for section 4, innovation diffusion.

Box 5 - Innovation diffusion *(5-10 minutes)*	
O17.Dif	How did the innovation spread among users?
F23.Dif	How was it demonstrated that the technology was breaking through?
O18.Dif	What are crucial factors for technologies to rapidly develop?
D9.Dif	Was the innovation able (1) or unable (0) to rapidly develop towards becoming a sector?

The interview has come to an end. Thank you for your cooperation.

Do you want to add something of relevancy?
Do you have available relevant documents?
Is there anybody you would recommend for this interview?

Appendix 6 Call and email protocols

This appendix includes the applied call protocol (A) and email protocols (B). In total, two email protocols were applied, of which one concerns a participation request (B1), and the other the confirmation of participation (B2). The latter also involves the sharing of specific information about the interview with the interviewee. All three protocols are written down in Dutch.

A) Call protocol (Dutch)

a. Opening	1. Goedendag, u spreekt met Raymon van den Heuvel, van Wageningen Universiteit 2b. Indien geen contactpersoon → Samen met het Ministerie van Economische Zaken bekijken we de ontwikkeling van [betreffende sector]. Weet u wie binnen uw bedrijf ons hier meer over kan vertellen? 2a. Indien wel een contactpersoon → Ik ben op zoek naar [naam contactpersoon] Indien gevraagd waar het over gaat → Vanuit [Naam organisatie, persoon] is [naam contactpersoon] aangeraden. Het gaat over een onderzoek naar [sector] in samenwerking met het Ministerie van Economische Zaken.
b. Introductie en reden contact	3. Ik ben bezig met mijn afstudeeronderzoek aan Wageningen Universiteit en werk hiervoor samen met het Ministerie van Economische Zaken. Het onderzoek gaat over hoe biobased sectoren in Nederland vooruit te helpen. Hiervoor kijken we onder andere naar [betreffende sector]. En dan met name, wat gebeurd er? Wat was belangrijk? En wat is er nodig voor die doorbraak? 4. Verschillende opties → We zijn benieuwd naar het perspectief vanuit [de ondernemer[; [jullie bedrijf was/jijzelf was] reeds in een vroeg stadium actief in de sector]. Ik ben daarom benieuwd naar jouw/jullie kijk op ontwikkelingen.
c. Verdieping (optioneel)	5. Om het iets helderder te maken: we bekijken vier sectoren, en gebruiken hierbij een theoretisch model, waarop ook de interview vragen zijn gebaseerd. De ontwikkeling van de sector staat centraal, en wie of wat dit beinvloedde over tijd.
d. Verzoek deelname	6. Graag zou ik u voor een uurtje bezoeken om een aantal vragen te stellen. Bent u bereid te helpen? 7a. Indien medewerking → Dat is heel mooi. Voorafgaand zal ik met u de onderwerpen delen per email. 7b. Indien afwijzing → In ieder geval bedankt voor uw tijd. Heeft u wel nog tips voor andere personen binnen of buiten uw organisatie?
e. Beloning (optioneel)	8. Naast uw input, zullen ook andere bedrijven en experts worden benaderd om de sector uit te diepen. 9. Nadat de resultaten zijn geanalyseerd, levert dit een beeld op per sector, welke zeker bekeken gaat worden in Den Haag. 10. Het 'verhaal' van de sector kan ik, indien gewenst, met u delen.
f. Afronding	11.Kunnen we gelijk een afspraak maken? 12. Heeft u voor mij uw emailadres? Dan stuur ik u een email, en heeft u ook gelijk mijn emailadres. 13. Tot sprekens. Een fijne dag gewenst.

B1) Email protocol - Participation request (Dutch)

Onderwerp: Deelname interview afstudeeronderzoek Wageningen University / MinEZ

Geachte [naam],

Als onderdeel van mijn afstuderen aan Wageningen University voer ik een onderzoek uit naar hoe de ontwikkeling van biobased sectoren in Nederland vooruit te helpen. Door te kijken naar de ontwikkeling van (vergelijkbare) innovatieve sectoren, waaronder [betreffende sector], willen we lering trekken uit welke factoren in/welke patronen belangrijk zijn in de volwassenwording van een sector. Hierin werk ik samen met het Ministerie van Economische Zaken in Den Haag.

[Naam bedrijf] is reeds in een vroeg stadium toegetreden tot de markt van [betreffende sector/markt]. Om meer te weten te komen over de ontwikkeling van deze sector, zou ik graag iemand van uw bedrijf meenemen in mijn afstudeeronderzoek. Derhalve wil ik vragen of u in een eenmalig interview van maximaal 60 minuten enkele vragen mag stellen. Centraal staat de ontwikkeling van de sector aan de hand van een aantal factoren, welke ik vooraf zal delen. Mocht u mogelijk een andere persoon binnen uw organistie meer geschikt vinden, dan kunt u mij hierover berichten.

Uw bijdrage is zeer gewenst voor het onderzoek. Na afronding kan ik de rapportage met u delen. U heeft dan uw sector in beeld.

Ik hoor graag van u.

Met vriendelijke groet,

Raymon van den Heuvel
Wageningen University
(T) 06 55 48 40 16
(T) 06 24 28 22 02
(E) r.vandenheuvel@minez.nl

B2) Email protocol – Confirmation of participation (Dutch)

Onderwerp: Deelname interview afstudeeronderzoek Wageningen University

Beste [naam],

Bedankt dat u wilt helpen aan het onderzoek Hierbij bevestig ik onze afspraak op [datum], om [tijd], te [locatie] over de ontwikkeling van de [betreffende sector] in Nederland. Doel is om lering trekken uit welke factoren in/welke patronen belangrijk zijn geweest in de ontwikkeling van de sector. Als onderzoeksperiode houden wij aan [periode: bijv. 1990-2015].

Tijdens het interview komen verschillende factoren aan bod die mogelijk de ontwikkeling van de sector hebben beinvloed. Deze factoren zijn verdeeld over 4 hoofddelen (welke zijn afgeleid van Strategic Niche Management theorie). Ter voorbereiding zal ik hierna de 4 hoofddelen toelichten.

- Deel 1: vragen over factoren die van invloed kunnen zijn geweest op de innovatie op weg naar volwassenheid. Volwassenheid is een fase waarin er gesproken kan worden van een business case voor de bedrijven. Vragen gaan over de rol van de:
    - Markt (wensen en behoeften, ontwikkeling marktvraag)
    - Waarde propositie (belofte, unique selling points, match marktvraag)
    - Financiele aspecten (marge, return on investment)
    - Technologie (bottlenecks, valley of death, ontwikkelingen)
    - Visies en verwachtingen (vroege verwachtingen, overeenkomstigheid visies stakeholders)
- Deel 2: vragen over de mogelijke invloed van een dominant ontwerp die de standaard is in de markt. Dominante ontwerpen kunnen standaarden zetten in de markt die vervolgens de ontwikkeling van de sector sturen en beinvloeden. Vragen gaan over de bron van dominantie en de invloed hiervan op de innovatie. Andere vragen gaan over de:
    - Stakeholders (betrokkenheid, verdiensten, rol overheid)
    - Macro-level omgeving (invloed, activering stakeholders)
- Deel 3: vragen over momentum, het theoretisch punt dat beslist of een innovatie in staat is om wel of niet door te breken. Vragen gaan over cruciale factoren hierin en de invloed van de innovatie op het dominante ontwerp.
- Deel 4: vragen over diffusie, het breed verspreid raken van de innovatie. Vragen gaan over hoe de innovatie zich verspreid, hoe dit proces zich toont en wat cruciale factoren voor brede verspreiding zijn.

Indien u data of documenten ter beschikking heeft, die mogelijk van waarde zijn en bijvoorbeeld een bepaalde ontwikkeling (in prijs, gebruik) laten zien, dan is dit welkome informatie. Alle gegevens (data, documenten, interviews) worden discreet behandeld en kunnen indien gewenst anoniem verwerkt worden.

Mocht u vragen of opmerkingen hebben, neem gerust contact op.

Met vriendelijke groet,

Raymon van den Heuvel
Wageningen University
(T) 06 55 48 40 16
(T) 06 24 28 22 02
(E) r.vandenheuvel@minez.nl

Appendix 7 Confrontation empirical part 2

	Statement interviewees	Likert scale (1-5) per interviewee		
		A	B	C
Niche development	Success in the marketplace depends on whether an innovation is at least equivalent to the existing products (e.g. synthetic plastics) available	4	3	3
	Relatively high expectations attracted more entrepreneurs and other stakeholders	4.5	5	4
	Product demonstrations create demand	4	3	5
	The early expectations were too optimistic	4	5	4
	Governmental support for PLA is effective	1	2	1
Regime stability	The position of existing products hampers change	4	4	5
Landscape pressure	Developments in PLA accelerate as a result of increased environmental awareness	**1.5**	**1**	**5**
	Existing synthetic plastics are pressurized as a result of increased environmental awareness	2	5	3
Momentum	PLA products are effectively making use of the disadvantages of existing products	2	1	3
Innovation diffusion	PLA products are rapidly becoming widespread among users	2	1.5	3

Maximum number of points per statement = 15

Total score 1-3 The respondents strongly disagree
Total score 4-6 The respondents agree
Total score 7-9 The respondents are neutral
Total score 10-12 The respondents agree
Total score 10-15 The respondents strongly agree

Two outliers identified, both regarding the factor Landscape pressure