Investments in Renewable Jet Fuels

Barriers and opportunities for investors

MSc Thesis (30 ECTS)

Energy Science

06-11-2015

Oskar Meijerink[1]

Under supervision of

Dr. Martin Junginger; Associate Professor Utrecht University[2]

Sierk de Jong MSc.; Researcher Utrecht University and SkyNRG[2]

Dr. Raphael Slade; Research Fellow Imperial College London[3]

Dr. Evangelos Gazis; Research Assistant Imperial College London[3]

Second Reader

Dr. Simona Negro; Assistant Professor Utrecht University[2]

[1] oskar.meijerink@gmail.com, +31613685918, Bisschopssteeg 113, 3584 SC Utrecht, The Netherlands

[2] Copernicus Institute of Sustainable Development, Utrecht University

[3] Centre for Environmental Policy, Imperial College London

Intentionally left blank

Acknowledgements

During the past 6 months I have been given the opportunity to work in close cooperation with Imperial College London and Utrecht University. This has provided me with insights in technological development in two different political environments. For this opportunity, I would like to thank several persons.

I would like to thank Sierk de Jong, for making me interested in Renewable Jet Fuels in the first place. As a day to day supervisor you were always available for discussion about the right direction of the thesis. Furthermore, Evangelos Gazis and Raphael Slade, thank you for setting the right circumstances at Imperial College London. Additionally, I would like to thank Martin Junginger and Simona Negro for being my first and second supervisor at Utrecht University and guiding me on the academic side of the thesis. I would like to thank everyone at the Centre for Environmental Policy, especially the research team in room 1312, for providing me with feedback and making me feel at home in London. You have been a big inspiration for the three months I was around. Matthee le Cointre deserves a mention for his extensive reviews of my work.

A final word of thanks to all the interviewees willing to cooperate in this thesis. Your interesting insights and sharp comments have been the base for this thesis and therefore I owe you my gratitude.

I hope you, as a reader, will enjoy reading this thesis and will get an insight ino the challenges of financing the Renewable Jet Fuel sector.

Intentionally left blank

Context

Master program Energy Science

Energy Science is a master program organised by the Department of Innovation, Environmental and Energy Sciences, Copernicus Institute and is part of the Graduate School of Geosciences at Utrecht University. This two-year master program provides its students with a deep understanding on the analysis and modelling of energy systems. Furthermore, a detailed insight into current and future energy technologies and the broader context of energy economics and policies is provided in the courses. I currently finished all mandatory courses within the System Analysis track of the program. Additionally I followed several elective courses: "Fossil Resources", "Sustainable Entrepreneurship" and an elective at Wageningen University: "Strategic Change Management and Innovation".

Climate-KIC master label

Climate-KIC is founded by the European Institute of Innovation and Technology (EIT) to enhance climate entrepreneurship. This institute tries to stimulate climate research and the master label is one of the tools to stimulate students on this topic. This master thesis fits the goals of Climate-KIC and the master label because it helps to understand and enhance the supply-chain of a sustainable fuel. With this understanding, future policy makers can more effectively make the transition to a low carbon future in Europe.

Imperial College

This research will contribute to the RENJET project, a Climate-KIC funded research focusing on the identification of opportunities for the development of Renewable Jet Fuels (RJF) supply-chains in Europe. Its specific aim is to assess how and under what preconditions RJF can be made available to the aviation sector in Europe in the short to medium term (2020 to 2030/2035 respectively).

Additionally, this MSc Project will be a valuable contribution to the research of Evangelos Gazis, an Imperial College London post-doc researcher. He is assessing the drivers of innovation within the emerging RJF sector and therewith improving the understanding of the mechanisms behind the development and market diffusion of novel technologies and products.

Evangelos Gazis will assess the position of different stakeholders in the innovation system of RJF. Stakeholders in policy development, aviation industry, fuel industry and academia will be interviewed to gain insights in the technological innovation system of aviation biofuels. The role of investors in this system is however not examined, this thesis fills this gap. To align the thesis with the research at Imperial College London, the thesis is partly (3 months) written in London.

Intentionally left blank

Abstract

Stimulating investments to enhance the development of advanced biofuels has been a challenge for many years. Previous studies showed general reasons for the lack of investments and provided recommendations for better policies. However, these studies have often a wide technological focus and do not take different investor goals into account specifically. Therefore, this thesis puts the investors perspective central to find barriers and opportunities that influence investments into the Renewable Jet Fuel (RJF) sector. In order to do so, first an insight in the relative representation of three investor types (public, private, strategic) in the advanced biofuel sector is provided. This is followed by an assessment of the Technological Innovation System (TIS) to find the factors influencing investors. The third and final objective is to identify clear barriers and opportunities that influence investments in the RJF sector.

Academic and grey literature was used to obtain insights in the activity of investor types in the advanced biofuel projects. The TIS was systematically analysed with a structural research, an analysis of the phase of development and a function analysis. Finally, the barriers and opportunities are identified by conducting interviews with investors and relevant stakeholders from the RJF sector. The results indicate that strategic and public investors are driving investment in the current projects while private investors remain hesitant to invest. The reason for this early involvement of strategic investors is twofold: The aviation industry wants to grow sustainably from 2020 and the expectation exists that mandates are going to control the market in the future. On the other hand, private investors are put off by the high risks in the projects, due to uncertainties about policy, feedstock issues and the low oil price. The analysis also showed that the legacy of failed biofuel projects and the low knowledge level of investors about biofuels have a negative influence on investments in Renewable Jet Fuels.

Based on these results, implications are found for theory and policymakers. The focus on investors within the TIS framework enabled the researcher to include external factors and create more specific policy recommendations. This method also helped to build upon the new body of literature regarding non-economic factors influencing the investment decision making process. For policymakers this thesis showed the importance of stable policies that enable a level playing field to create fair competition between different biofuel technologies. Furthermore, an independent knowledge network should be created to educate investors as well as policy makers about the progress of RJF to overcome the biased information from project owners or intermediaries

Table Of Contents

List of Figures

List of Tables

Intentionally left blank

1 Introduction

The aviation industry is expected to grow by 4,5% each year up to 2050 (Hamelinck et al., 2013). This growth and the increasing need for a sustainable alternative for the fossil-based jet fuels results in an increasing demand for Renewable Jet Fuels (RJF). RJF can theoretically, as ordinary road transport biofuels, be produced from any renewable biological carbon feedstock. The feedstock's widely used in the road transport sector, are food crops such as rapeseed, palm or soy oils (Berndes et al., 2010; Sims et al., 2010). Although the use of these feedstock's for the production of biofuels has successfully been proven in existing projects (EBTP, 2015), these so-called first-generation biofuels are not desirable for the aviation sector due to their, poor sustainability performance, high costs and restricted scale-up possibilities (Sims et al., 2010). An alternative is available in the form of advanced biofuels. Advanced biofuels have non-food competitive biomass as a feedstock and have better scale-up opportunities which makes the biofuels potentially cheaper (EBTP, 2015). Advanced biofuels will therefore be the topic of this thesis. To avoid confusion in the remainder of this thesis the terms 'biofuels' and 'advanced biofuels' are used interchangeably for: 'advanced biofuels'.

Although advanced biofuels have better opportunities than first generation biofuels, the development has been less prosperous than anticipated (Janssen et al., 2013). Despite numerous policy interventions and the willingness of the aviation industry to use RJF (IATA, 2014; Janssen et al., 2013). According to previous studies, this less prosperous development is caused by various reasons such as: high costs of feedstock, technological set-backs and financial challenges (IATA, 2014; Lee et al., 2013). As the aviation industry is a very cost-competitive sector, RJF need to be price competitive with conventional jet fuels (Gegg et al., 2015; Hamelinck et al., 2013). In order to reach this competitive price, R&D is needed to proof technologies, lower their production costs and eventually reach commercial scale (Ragwitz & Miola, 2005; Rogers, 1962). Financial sources are needed to fund the R&D development, demonstration facilities and market development (Gegg et al., 2015; Heisey et al., 2011; Roberts, 2013).

The availability of financial resources has been lagging across the entire biofuel supply-chain and has been indicated as one of the reasons for the less prosperous deployment of advanced biofuels (EBTP, 2015; Gegg et al., 2015). Although the investments in the clean-tech sector have exponentially increased; from nearly $30 billion in 2005 to $160 billion in 2012, investments in the biofuel sector have been lagging and even had to deal with a decline in absolute investments since 2012 (E2 Environmental Entrepreneurs, 2014). The difficulty of attracting investments to new technologies have been topic of research in several studies. Dow et al., (1992) stated that investors have a natural aversion against too large risks and uncertainty, which make them hesitant to invest in new technologies like RJF (Dow et al., 1992). While, Bürer & Wüstenhagen (2009) investigated the influence of policies on the investment decision making process, finding that policies should be altered to the type of investor involved in technologies. The availability of early stage funds has been discussed in academic literature as well. On the one hand there is a side stating that there is not enough risk capital available to stimulate early stage ventures

(Mason & Harrison, 2001). Others say that financial resources are available, but investors are unable to find projects that meet their investment criteria (Mason & Harrison, 2002; Nicholson, 2000; Queen, 2002). This gap of investments is often filled by governments using public money to invest in early-stage technologies or creating tax-incentives to stimulate private investments (Hekkert & Negro, 2009; Mason & Harrison, 2002).

Research has thus been done on the availability of financial resources to emerging technologies and specifically biofuels (Janssen et al., 2013; Mason & Harrison, 2002). However, two gaps can be identified in these studies. First, the studies focused on public (E2 Environmental Entrepreneurs, 2014; Kleer, 2010), private (Feeney et al., 1999; Mason & Harrison, 2002; Nicholson, 2000) or strategic investments (Rajagopal et al., 2009) without considering the three combined in one research. Analysing all three together can provide a holistic overview of the investments in the biofuel sector, enabling the assessment of the relative contribution of each group. Traditionally it has been assumed that the way investor make their decision is based on rational, economic reasons. However, recent research shows that investors might use other reasons, e.g. prior investments or organizational culture, to make investment decisions (Masini & Menichetti, 2013; Wüstenhagen & Menichetti, 2012). This thesis build on these first findings and tries to fill this second gap in literature by analysing the investment decision making process in the RJF sector. This results in the following question to be answered:

What is the current state of investments in the advanced biofuel sector and what are opportunities and barriers for investors to invest in the Renewable Jet Fuel sector?

In order to get a sound answer on this research question, the research will be divided in three sub-questions:

SQ1: What kind of investors are currently active within the advanced biofuel projects?

SQ2: What is the state of the Technological Innovation System of advanced biofuels, with a focus on Renewable Jet Fuels?

SQ3: What are barriers and opportunities that influence investors to invest in the Renewable Jet Fuel sector?

By exploring the investment decision making process using a Technological Innovation System (TIS) analysis, more factors outside the traditional risk and economic reasoning can be analysed systematically. The innovation literature has developed the TIS, to get a thorough understanding of a technology and its influencing factors (Bergek et al., 2008; Carlsson & Stankiewicz, 1991; Jacobsson & Johnson, 2000; Negro et al., 2012). The TIS can be defined as: "The set of actors and rules that influence the speed and direction of technological change in a specific technological area" (Bergek et al., 2008; Hekkert et al., 2007). The TIS builds on the insight that innovation is a collective activity between actors. Development of such an innovation takes place within the context of a wider system. The success of innovations is to a large extent determined by how the innovation system is build up and how it functions (Bergek et al., 2008; Hekkert et al., 2011). As the TIS includes investments, it can be used to assess investments in a wider system which helps to systematically determine influencing factors around investments in the advanced biofuel sector.

The first sub-question will be answered by reviewing existing academic and grey literature on about current biofuel projects. The United States of America and Europe are chosen as the geographical boundary as these regions include the most significant players in the development of biofuels (Sims et al., 2010). The second sub-question is analysed by applying the TIS method of analysis on the advanced biofuels and focus on RJF specifics when relevant. As advanced biofuels and RJF have very similar characteristics and RJF specific projects only exist sporadically, a wider focus on advanced biofuels is chosen for the project and TIS analysis. The third sub-question will be answered by conducting interviews in both the UK and the Netherlands with investors and important actors in the RJF supply-chain to on the one hand validate the results found in the TIS analysis and on the other hand find clear barriers and opportunities for investments in the RJF sector (Feeney et al., 1999; Queen, 2002).

This thesis has two major contributions to scientific literature. Possible new insights on the investment decision making process can systematically be discovered using the TIS analysis. Furthermore, the TIS is until now used to map the innovative dynamics of the biofuel sector in general (Jacobsson & Bergek, 2004; Suurs & Hekkert, 2009a). Specifically focussing on investors within the TIS has not yet been done as such and will give new insights on the use of the TIS framework. These insights could help to counter recent criticisms on the TIS framework, as external factors can better be taken into account and more specific policy recommendations can be drawn (Markard et al., 2015). The results of this thesis also have implications on the field of renewable technology policy making. With new insights in the barriers and opportunities for investors, policy makers can better adapt their policy on enabling future renewable technology investments. At last, this thesis can be used to stimulate investments in RJF.

This thesis continues with an elaboration on the theories used (section 2), followed by section 3 in which the methodology is discussed. After the method the results of the thesis are extensively described (section 4). The discussion and conclusion (section 5 and 6) make up the complete thesis.

2 Theory

The theory underlying this thesis consists of two main bodies of literature. In section 2.1 the different investor types distinguished in this thesis are discussed. This is followed by the theory of Technological Innovation Systems. In section 2.3 the two theories are integrated and the conceptual model is shown.

2.1 Investments

This section elaborates on investments and the differences that exist between types of investments. Schumpeter (1934) was one of the first to point out that an entrepreneur needs credit to create new combinations and ultimately innovation. Investors are considered to be a crucial player for economic development (Fagerberg et al., 2006). Financial resources can have different origins, which will be discussed in the following (Wüstenhagen & Menichetti, 2012).

2.1.1 Public investments

Public investments occurs in the form of loans, grants and operational expenditure subsidies. Projects or technologies with high risks and low returns are considered to be in need of public funding since private funders are hesitant to invest in such technologies (Queen, 2002). Recent literature has shown the importance of public funding to overcome the high risks in the early phase of development. In most of the disruptive technologies public funding was at the base of driving innovation (Mazzucato, 2011; Wüstenhagen & Menichetti, 2012). However, critics reveal that public spending could lead to lower R&D investments of strategic firms, hereby influencing the market mechanism and possible unnecessary spending of public money (Lemer, 1996). The goal of public investments is to stimulate a certain technology or to reach a certain goal, which the market is not willing or not able to do; e.g. reduce emission levels.

2.1.2 Private investments

Private investors are in this thesis defined as individuals and (development) banks who invest for the purpose of generating revenue from the investment. Private investments are considered to be the primary source of external equity capital for new firms to develop. The firms that require small amounts of equity capital, e.g. start-ups and entrepreneurs, are dependent on business angels (Feeney et al., 1999). After the companies develop, venture capitalist step in to accelerate the company to a commercial stage (Hellmann & Thiele, 2014). A third group of private investors, Private equity, normally steps in at the moment technologies are getting substantial market growth and are proven to be working (Wüstenhagen & Menichetti, 2012).

2.1.3 Strategic investments

Besides private and public investments to stimulate fundamental research, large organizations can also stimulate technologies and innovation themselves (Fagerberg et al., 2006). Christensen (2013) has published about the dilemma large organizations face when they need to decide on investing in disruptive technologies. Such disruptive technologies often commercialize in less significant markets, making it hard to convince the customer and shareholders of the need for the new technology. This results in hesitancy of organizations to invest in technologies that might disrupt their own existing market share. By not investing however, the companies face the risk of losing their entire market share when the technology is eventually brought to market by another organization (Christensen, 2013). For an organization to survive, it is thus of importance to on the one hand innovate on your current business activities and on the other hand invest in possible breakthrough innovations, the so-called ambidextrous organization (O'Reilly & Tushman, 2004). Due to these considerations, strategic investments is often associated with investments taking place in the latest phases of development (Wüstenhagen & Menichetti, 2012). However, if organisations decide to invest in breakthrough innovation, it is often in the form of fundamental research which occurs in the early phases of development. Therefore strategic investments are important throughout all the development phases (Klette et al., 2000). The goal of strategic investors is thus driven by strategic factors to survive as a company, which can be driven by policies, mandates or the forecast of a larger market share.

2.2 Technological Innovation System

The factors influencing these three investor groups are in this thesis captured using the Technological Innovation System (TIS). The origin of this TIS can be found in literature that tried to ensure long-term and disruptive innovations, as advanced biofuels, to diffuse successfully (Van De Ven, 1993). To describe and develop the diffusion of technologies the Innovation Systems approach is developed (Bergek et al., 2008; Foxon et al., 2005; Hekkert et al., 2011).

Innovation systems occur with different focal points. An innovation can be based on a geographical area or be limited by a sector or technology. This thesis focusses on a framework around the specific technology of advanced biofuels. To analyse such technology the Technological Innovation System (TIS) is seen as the most appropriate to use. (Bergek et al., 2008; Jacobsson & Johnson, 2000; Negro et al., 2012). The technological innovation system approach is strong for analysing technological development and allows the researcher to find weaknesses in the system (Bergek et al., 2008; Suurs & Hekkert, 2009b). The downside of the TIS might be that policy recommendations remain rather generic and external factors are hard to take into account in the TIS, this is solved in this thesis by including complementary literature on investments as suggested by Bening et al., (2015)

The TIS theory has developed substantially over time. This thesis uses the TIS as defined by Hekkert et al. (2011) with additional insights from Bergek et al. (2008). As these academics have included different approaches from other academics into their analysis tool, which has been proven to work in many case studies (Jacobsson & Bergek, 2004; Jacobsson & Johnson, 2000; Negro et al., 2012). The TIS can be divided into three sections: structural analysis, phase of development and function analysis. These sections are closely interconnected and should not be seen as linear steps, although the phase of development can, for example, give an indication which functions are more important than others. The entire analysis is iterative and the three sections need to be combined to indicate possible barriers in the system. For example, the bad fulfilment of a function can have its origin in a missing structural component. Identifying barriers and opportunities from the TIS is further discussed in section 2.2.4.

2.2.1 Structural analysis

Actors

It is the actors that, through choices and actions, are able to create, diffuse and use new technologies (Hekkert et al., 2011). Actors in a TIS can be very diverse, the actors not only include firms directly involved in the supply-chain, but also universities, public bodies, interest groups and investors (Bergek et al., 2008). These actors influence each other, therefore it is important to not only look at investors and its influencing actors but also the other actors that might indirectly influence investors. It is also important to realise that with different technologies come different actors, not every TIS will therefore have the same set of actors involved. However, a broad categorization can be made, these groups grasp the essential actors within a TIS and will be the attributes of research in this thesis (Hekkert et al., 2011);

- Knowledge development
- Education
- Industry
- End-Market
- Government bodies and Supportive organizations

Technological Trajectories

Technological trajectories can be seen as different technological designs of a certain product or service which develop over time. In some cases, especially in the early stages of a new technology, different technological trajectories can exist next to each other. It is important to note, especially with highly complex technologies such as RJF, that technological trajectories also include factors as: costs, safety and reliability. Such factors are of large importance when trying to understand the relation between technological change and the role of actors within the TIS (Hekkert et al., 2011).

Networks

The third structural component of the TIS is networks, both informal and formal networks. Such networks are based on actors and the relations between them. The networks play an important role in the development of technologies, markets and institutional set-up. The formal networks such as: public-private partnerships or technology platforms are often easy to indicate. However, informal communities such as professional networks or customer interest are as important as the formal ones, but might be more hidden (Bergek et al., 2008; Hekkert et al., 2011).

Institutions

The last component of the TIS structure is institutions, they come in the form of; norms, laws, regulations or routines. Institutions can work as a driving force for technologies, however might hamper them as well. Often, institutions need to adjust to new technological development in order to let the technology diffuse successfully. The institutions often vary among the state of development of the TIS, especially in the early stages of development institutions might not yet been structural or even inexistent (Bergek et al., 2008).

2.2.2 Phase of development

The theory of the phase of development goes back to the product life cycle and diffusion of innovation, a topic of research for multiple influential academics (Klepper, 1996; Rogers, 1962; Utterback & Abernathy, 1975). They stated that diffusion is: "The process by which an innovation is communicated through certain channels over time among the members of a social system". This broad definition of diffusion of innovation led to scientists investigating the so called product life cycle (Rink & Swan, 1979). The development phases show the sales or adoption of an innovation over time, from the moment it first enters the market until it is fully adopted by the market (Buzzell, 1966). Within the development model five phases can be distinguished, shown in Figure 1.

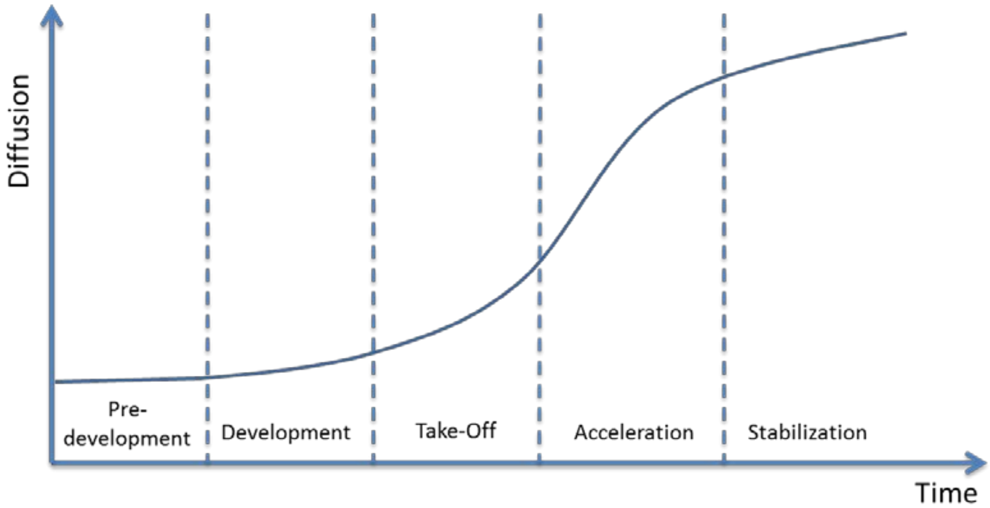

Figure 1. Phases of development

During the different phases of development the structure of the innovation and therewith the actions that take place differ. Therewith also the functioning of the innovation system and the factors influencing investments differ (Bergek et al., 2008). If a function is missing or unfulfilled, the build-up of a good innovation system and the right mix of investors can be hampered (Hekkert et al., 2011). A deeper elaboration on this functioning of the TIS is elaborated upon in the next section.

2.2.3 Function analysis

The structure of a TIS will indicate the different components present in the TIS, while the phase of development can show the specific functional needs of the technology in a certain phase. Just having the components and the needs will not give insights on the strength or the performance of the TIS (Bergek et al., 2008). Numerous academics have thought about ways to measure this performance of the TIS (Bergek et al., 2008; Foxon et al., 2005; Hekkert et al., 2007). The function analysis is developed in order to analyse the *activities* that take place in the innovation system and therewith overcome the problem of only focusing on static and structural components (Hekkert et al., 2007). These activities can better include factors that take the firm or entrepreneurial level into account, which helps to grasp the dynamic process of technological change (Hekkert et al., 2007). Different functions are proposed by academics, in this research the distinction suggested by Hekkert et al. (2011) will be used, since this distinction is the most up to date and covers the functions as suggested by other academics as well. Seven functions can be distinguished, briefly discussed in the following. Note that the functions do have some overlap with the structural analysis of the TIS. However, in contrast to the structure, these functions focus on the activities performed within instead of only the availability of the actors (Hekkert et al., 2011).

F1: Entrepreneurial experimentation

New technologies develop under uncertainty, this uncertainty can be reduced by active actors who innovate and further develop the technology. Without such experimentation the TIS will eventually stagnate and stop developing. It is important to note that entrepreneurial experimentation is not only determined by the number of new or small firms but to a wider definition of entrepreneurial activity e.g. new combinations at existing incumbents.

F2: Knowledge development

This function is considered to be the centre of the TIS, since it entails the knowledge incorporated in the TIS. The knowledge can be of different origin, e.g., scientific, technological or market knowledge.

F3: Knowledge exchange

This function encompasses the networks in place in the TIS. These networks should allow actors to exchange their knowledge in order to learn from each other. Knowledge exchange leads to specialized intermediate goods and service providers, which helps the industry forward in both costs and efficiency. Networks between industry and universities to exchange fundamental knowledge and between industry and users to explore the user demands, are both important.

F4: Guidance of the search

In order for a TIS to develop, numerous actors have to make the decision to enter the TIS. Without the right incentives in place, actors will not enter the market. When actors are eventually involved in the technology it is important to steer the actors towards successful market diffusion. Besides regulations set by the government to steer a technology, the vision of experts is an important determinant of analysis as well.

F5: Formation of markets

Market places are needed to diffuse the technology to the market. Due to high costs and inefficient production, new technologies have problems to compete with established markets. The markets of an emerging technology may therefore hardly or not even exist. The phase of development analysis is useful for this function to determine the need for successful technological development. For example an early phase of development asks for a launching customer, or 'niche markets'. This early market is used to learn and is followed by a 'bridging market' eventually reaching 'mass market', this stage will be reached decades after the formation of the initial market. In this function, both the actual market development and the concepts that drive market formation need to be analysed.

F6: Mobilization of resources

The TIS can only develop when a range of resources are mobilised, these resources are needed to support the other functions in their activities (e.g. financial resources to develop knowledge). Besides the financial capital, as is the topic of this research, this function also entails the mobilisation of human capital and complementary assets such as services and network infrastructure.

F7: Counteracting resistance to change

Legitimacy is needed to create support around the TIS, a technology which is not appropriate or desirable will not be funded or supported by politics and public. Legitimacy is often associated with institutional alignment; this can be both by manipulating 'the rules of the game' as well as by conforming to them.

2.2.4 Identify barriers and opportunities from TIS

The combination of the structural analysis, phase of development and functions provide an insight in the performance of the TIS. In the methodology, the way of measuring this performance is explained. With these insights from the TIS, barriers can be distinguished that hamper the investments and therewith development of the technology. Such barriers, or malfunctioning of the TIS, can occur in different forms; there can be the lack of structural components as well as a lack of quality of the function. When an underperforming function is determined, it is thus necessary to step back to the structure analysis and see whether the right structure was in place to support the function accordingly. The results from this barrier identification process results in recommendations for policymakers as well as specific actors who have influence on the barrier. It is important to realize that the origin of the barrier also determines what approach is needed in the policy making process. For example, if the function knowledge exchange is not fulfilled sufficiently this could be due to a lack of industry-university networks but also due to the fact that actors within projects do not disclose any information to potential investors. These two examples of different barriers within one function ask for different recommendations and show the importance of including the three parts of the TIS carefully in the analysis (Hekkert et al., 2011).

2.3 Connecting theories

2.3.1 Influence of phase of development on functions and investor type

As discussed in the phase of development section, a different phase asks for different functional needs. Hekkert et al., (2011) created an analytical framework that states which functions are important during which phase of development, presented in Figure 2. This thesis uses this framework as a guideline to discover important influencing factors around function 6; resource mobilisation. In some phases resource mobilisation may not be fully developed, this can occur if the focus during this phase is on other functions. However, in order for the function resources mobilisation to develop it is of large importance that the other supporting functions are in place and performing well, creating the circumstances for investments to flow into the TIS. Therefore, a full analysis of the important functions is needed to conclude whether the technology is ready to make the step to the next phase.

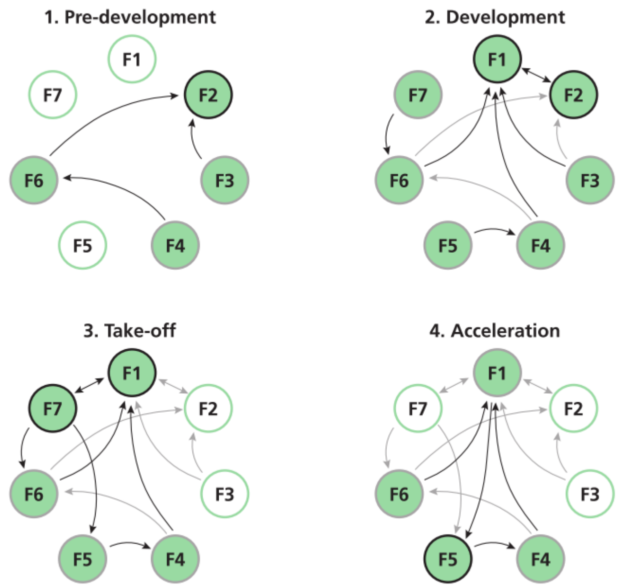

Figure 2. Functional patterns per phase (Hekkert et al., 2011)

The other connection between the phase of development and investors is the fact that different phases not only have a different functional pattern, a different phase also asks for a different type of investor, this is presented Figure 3 (Bürer & Wüstenhagen, 2009; Wüstenhagen & Menichetti, 2012). This differences occur due to the different goals the investors pursue, as e.g., public investors might have a goal of lowering emissions, and although the technology might not yet be profitable for the market, the government invests anyway. While private investors aim for high profits thus take risks in the market entering phase. Strategic investors want to avoid this large risk and invest for the existence or extension of their company (Bürer & Wüstenhagen, 2009; Grubb, 2005). It is however important to note that these indicate the dominant types of funding, it is often the case that strategic or private investors invest in a project as well, when public investments are the primary source of funding. It is further important to note that public funding is seen as grants or loans for capital investments. Public funding through policy making is an external factor influencing all investors. This might also occur in the stabilisation phase by e.g. tax-incentives to stimulate market pull innovations (Bürer & Wüstenhagen, 2009).

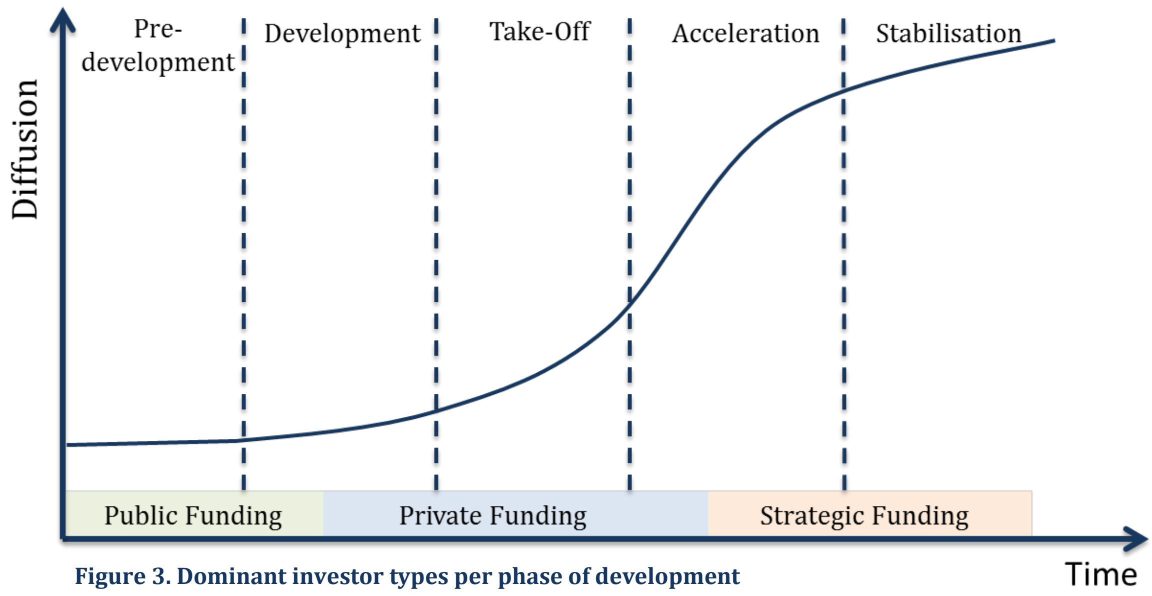

Figure 3. Dominant investor types per phase of development

2.3.2 Conceptual model

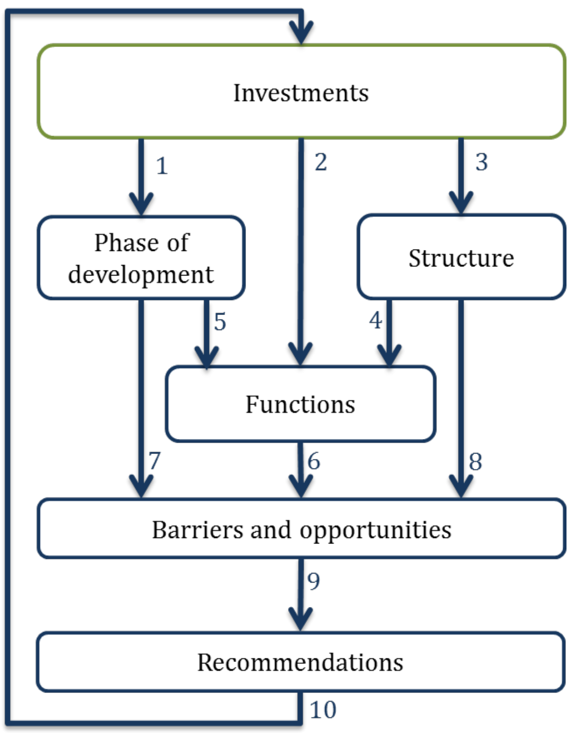

Figure 4. Conceptual model investments in TIS

Figure 4 shows the connection of investments with the concepts of the TIS. The arrows represent the different relations between the concept. Investments are incorporated within the structure of the TIS as actors in the structure, e.g. banks and private capital (1). The Investments are also found in the functions as 'Resource Mobilisation' (2). During the phases of development investments can have different origins and goals to fulfil as shown in Figure 3 (3). The phase of development influences the relations between the functions (4). Also the structure has, as stated in section 2.2.4., an influence on the performance of the functions (5). When barriers are indicated in the analysis, these can have a different origin; Barriers can exist due to underperformance of the functions (6), underdeveloped structure (7) or due to the fact that a certain investor type is absent during a specific phase of development (8). This results in barriers and opportunities (9) that could be taken away with recommendations for policymakers or specific actors in the TIS. These recommendations can take away the barriers and result in more (effective) investments in the Renewable Jet Fuels sector (10).

3 Methodology

To get an answer on the research question and the supporting sub questions a combination of research methods was used. In this section, for each sub-question, a detailed explanation on the research design, data collection and data analysis is provided.

3.1 Part 1

SQ1: What kind of investors are currently active within the advanced biofuel projects?

3.1.1 Research design

This question focusses on the projects producing advanced biofuels. As there is only a very limited number of projects in Renewable Jet Fuels, an analysis on only RJF projects would be less informative and insufficient to show investor involvement. Therefore, advanced biofuels in general was chosen as the unit of analysis for this sub-question. The United States of America and the European Union form the geographical boundaries of this thesis. These regions do not create a representative sample of the entire industry. However, these regions are front runners and the most significant players in the development of biofuels (Sims et al., 2010). Therefore, these regions provide the most relevant overview of the current state of investments in the sector.

3.1.2 Data collection

The data of the projects was collected by searching academic as well as grey literature, in the form of industry reports. The biofuel project database of the *IEA bioenergy task 39* was used as a starting point for the data collection as this database provides a comprehensive overview of advanced biofuel projects (IEA Bioenergy, 2015). In order to create a more holistic database, other sources were used to add upon this database. The following terms were used to find other projects in academic literature: alternative OR second generation OR advanced AND biofuels. Furthermore, the industry magazines Biofuels Digest and Biomass Magazine were consulted to find the latest developments regarding the projects. After the projects were gathered, the project websites were visited to find data about investor involvement. Projects were included in the from the start of advanced biofuel production until 2017, because the development of advanced biofuels started only recently (Janssen et al., 2013). 2017 was taken as the upper limit in order to include planned projects. Planned projects give a first indication in which direction the market is moving and are thus of valuable insight for the development of the sector. The projects were only included if information could be found about 1) investment partners of the project, 2) the feedstock used in the project and 3) the used technology should have the opportunity to be used as aviation biofuel in the future. The list of projects used in this thesis is presented in appendix A.

3.1.3 Data analysis

For every project it was determined whether one of the three investor types: Public – Private - Strategic, was active in the project. An investor is seen as active when there is actual financial capital assigned to a certain project. An off-take agreement is therefore not considered to be an investment, as this is no capital assigned to the project but only an agreement to take of the end-product. A project could have multiple active investors. A project could for example, receive governmental funds in the form of a loan guarantee as well as funding from a private investor. Due to the cautiousness of investors to publish such information and thus the lack of information available, it could only be stated whether a certain investor type is involved, without stating the monetary amount each investor contributed to a project.

Besides the investor involvement, every project is labelled with one of three project goals; Pilot, Demonstration and Commercial. This distinction is based on the existing IEA database and was used to show the purpose of each project. Plotted over time this can give an insight in the development of the sector. To determine what the purpose is of each project the following criteria were used:

Pilot

- No continuous operation
- No full production process, only certain technological steps are tested/demonstrated
- The fuel is not per definition put out on the market

Demonstration

- An aim for continuous operation
- Entire production process is covered in the project
- The fuel is sold on the market
- The project does not per definition work under economic objectives

Commercial

- Continuous operation
- The fuel is sold on the market
- (Aim for) economic objectives to run the project

The results of this analysis also give an indication of the phase of development the project is in, the connection between these two analyses is explained in section 3.2.2 under: phase of development. After determining the phase of development of the projects the investor involvement was compared to the theoretical distribution of investors in each of the phases of development. This data was used to show whether investors were involved earlier, later or more intensively than expected from theory.

3.2 Part 2

SQ2: What is the state of the Technological Innovation System of advanced biofuels, with a focus on Renewable Jet Fuels?

3.2.1 Research design

The Technological Innovation System was used to analyse the development of advanced biofuels and find the characteristics influencing investments. The wider focus on advanced biofuels is chosen because advanced biofuels and RJF have similar characteristics and the information on RJF only is too limited to analyse the TIS. A more specific focus is put on RJF within the TIS when the characteristics of advanced biofuels in general and RJF are too far apart. In most TIS analyses an event history analysis is used to describe the TIS, due to the extensiveness of such method and the specific focus of this thesis on investment, an event history analysis is outside the scope of this research. Therefore the aim of this TIS analysis is not to be comprehensive but to give a characterization of the industry and focus on investments. Therefore the structure description is focused on providing an insight and give context while the TIS is extended with a more extensive focus on investors in order to better include contextual factors (Hekkert et al., 2011).

3.2.2 Data collection and analysis

The TIS was analysed according to the theory presented in section 2. First, the structure was analysed. Followed by the phase of development analysis. The TIS analysis was completed with the analysis of the functions. Information regarding the structural analysis was gathered from academic and grey literature. Interviews were conducted with experts and investors to check whether the functions are in place and sufficient activities are taking place within the function. In the following for every component a more detailed description of analysis is provided.

Structure

The structure is analysed by elaborating on four distinct components of the TIS. In the following the components are presented with determinants used to map the components (Bergek et al., 2008; Hekkert et al., 2011).

Technological Trajectory

This component is analysed using a database created by Imperial College London. This database covers five technological trajectories to produce advanced biofuels which could be developed into RJF:

- Hydro processed Esters and Fatty Acids (HEFA)
- Fischer-Tropsch (FT)
- Direct sugars to Hydrocarbons (DSHC)
- Alcohol to Jet (ATJ)
- Hydrotreated Depolymerised Cellulosic Jet (HDCJ)

Every technological pathway was assigned with a fuel readiness level to show its commercial development. The Commercial Aviation Alternative Fuel Initiative (CAAFI) created the criteria for evaluation of RJF. This resulted in a fuel readiness level from 1 – 9, where 1 is just the basic principles of a technology and 9 is a full scale operational plant (Bauen et al., 2009; CAAFI, 2010). This method has been applied on RJF by Mawhood et al., (2014) and results from this analysis were used in this thesis to give an indication of development progress. To determine the market potential and therewith attract investor interest it is also important to know whether a technology has been certified by American Society for Testing and Materials (ASTM). This ASTM approval allows airlines to use RJF in their flights.

Actors

All actors could have an influence on investments, therefore a wide variety of actor groups were analysed and described, see Table 1.

Table 1. Actor groups and measurement

Actor group	Measurement
Knowledge Development	State of the knowledge system by analysing Web of Science publications and Citation
Education	Description of Industry-University Collaborations
Industry	Descriptions of actors in the value-chain
End-Market	Description of actors creating demand for RJF
Government bodies and supportive organisations	Description of involvement of government bodies and supportive organisations

Networks

Actors can be linked to other actors when there is a collaboration existing between the actors. This can be presented in a graphical representation of reality which can show the interconnectedness of the actors in the TIS (Hekkert et al., 2011). As this goes outside the scope of this thesis, the network analysis consists of a brief overview of existing networks within the advanced biofuel sector to show the most important characteristics.

Institutions

The analysis is based on formal institutions found in the projects as: norms, laws, regulations. The more difficult to measure informal institutions such as routines are analysed during the function analysis by interviewing experts.

Phase of development

The phase of development is analysed for every project independent of each other in order to be able to graphically show the projects per phase of development. The phase of development is analysed by asking the questions as stated in Table 2. If the answer is yes go to the next question until the answer is no, the project is situated in the first phase of development where the answer is no (Hekkert et al., 2011). The project purposes from section 3.1.3 are next to this method used to give an indication of the phase of development a project is in. However, it is important to note that for example a project with a commercial purpose does not per definition have successful commercial application in the market and might thus be in the development phase instead of the take-off phase. As this is not an arbitrary process, assigning the phases of development to projects is discussed with other researchers at both Imperial College London and Utrecht University.

Table 2. Phase of development and questions to determine the phase

Phase of Development	Question to ask
Pre-Development	Is there a working prototype?
Development	Is there any commercial application?
Take-Off	Has there been substantial market growth?
Acceleration	Is the market growth stabilizing?
Stabilization	

TIS Functions

All functions could influence the function resource mobilisation, either direct or indirect. Therefore this thesis included all functions in the analysis. The functions were analysed by analysing industry reports and interviewing experts (list of interviewees presented in methodology part 3). In Appendix B the factors to determine the activity within a function are presented. For each function is was determined whether activity was positive (green function symbol), negative (red function symbol) or, neutral when both positive or negative activities were found (orange function symbol). Per function also the influence on other functions is stated. If, for example function 2 has a negative influence on function 1 this was indicated with (-F2 -> F1). This is eventually shown in a model in which all relations in the TIS are indicated with either a positive (+), negative (-) or neutral (0) influence. As some functions can be of different importance during different phases of development, in this overview the most important relations are discussed. Also the relation of certain relations to a possible missing structural element is discussed at this functions model (Bergek et al., 2008; Hekkert et al., 2011). As it is a qualitative analysis, the assignment of positive or negative activities was determined by the researcher using the factors from Appendix B. To create a reliable analysis nonetheless, the process of determining positive, negative or neutral activity or influence was closely discussed with another Imperial College London researcher.

3.3 Part 3

SQ3: What are barriers and opportunities that influence investors to invest in the Renewable Jet Fuel sector?

3.3.1 Research design

This last sub-question is used to complement the findings of SQ1 and SQ2. Also it is used to obtain insights in the opportunities and challenges regarding investments in the RJF sector. Giving a cross check on the results found in SQ2. This sub-question is answered by using a qualitative study. A qualitative study helps to get deep knowledge and enables to generate new insights from different actors (Saunders et al., 2011).

3.3.2 Data collection

The qualitative study consists of a number of in-depth interviews with investors and key-actors in the TIS (Table 3). Furthermore three conferences on the topic of investments in renewable technologies were attended by the researcher to gain insights in the topic and talk to potential investors (Table 4). The interviewees to verify results from the TIS analysis were selected based on the outcomes of the structure analysis performed in SQ2. Investors from every investor category were interviewed, not only investors who already have invested in Renewable Jet Fuels but also investors that chose to not invest are taken into account. The only criterion is that the investor has affinity with investing in the 'Renewable Energy sector' in general, to ensure the interviewee was aware of the specific aspects of this industry.

Table 3. Interviewees, names, companies and roles in RJF supply-chain

#	Name	Organisation	Role
1	Stewart McMahon	Green Investment Bank	Private Investor
2	Kirsty Hamilton	Chatham House	Public Investor
3	Britt Boughey	Beryl Renewables	Strategic Investor
4	Robbert Boyd	IATA	Expert
5	Mark Riedy	Kilpatrick Townsend & Stockton LLP	Expert
6	Geraint Evans	ETI	Public Investor
7	Ausilio Bouen	Imperial College London	Expert
8	Douglas Bradley	Climate Change Solution	Expert
9	Daan Dijk	Rabobank	Private Investor
10	Adrian Scholtz	KPMG	Private Investor
11	Brian Banes	Flagship Investments	Private Investor
12	Matthias Spöttle	Ecofys	Expert
13	Jennifer Gilbert	Grant Thornton	Private Investor
14	Jonathon Counsell	British Airways	Strategic Investor
15	Ignaas Caryn	KLM	Strategic Investor
16	Claire Curry	Bloomberg New Energy Finance	Public Investor
17	Adam Workman	350 Investments	Private Investor
18	Gertjan Kramer	Shell	Strategic Investor
19	Nigel Tait	Shell	Strategic Investor
20	Peter Bachmann	SEP Investments	Private Investor
21	Philip Marchand	Total	Strategic Investor

Table 4. Attended events

Event	Date	Host organisation
IEA Special Report on Energy and Climate Change	28-06-2015	KPMG
Investments in Renewable Heat	08-07-2015	Grant Thornton
IP opportunities and barriers for investors	13-07-2015	JA Kemp

The interviews were conducted face-to-face, by phone or Skype in the United Kingdom and the Netherlands, those locations were chosen because of the partners involved in this research. Interviews by phone where used to contact important stakeholders in the rest of Europe and the United States. The interviewees were contacted by e-mail first; followed by a phone-call to increase the response rate. Semi-structured interviews were conducted as these can give valuable in-depth information. This technique makes use of open-ended questions, in order to give the interviewee the chance to come up with narrative answers. Further, semi-structured interviews allowed the interviewer to steer the conversation which enabled the interviewer to get better insights in underlying problems, resulting in valuable qualitative data (Bryman, 2012; Saunders et al., 2011). Moreover triangulation is reached by asking the same question to a variety of actors which resulted in higher reliability of the findings (Yin, 2009). A brief outline of the questions is provided in Appendix C.

3.3.3 Data analysis

Interpreting the gathered data from interviews is a key step in order to take valid conclusions. An iterative method of analysing data was used in this thesis, this meant constant comparison and corrections between codes and data were made. First, all the interviews were fully transcribed into raw transcripts[4]. The transcripts were then coded. The coding was done using Nvivo, a program that allows systematic assignment of codes to sections of text. This first round of coding is done without connecting it to the known barriers for investors found in theory. This was done to prevent the researcher from becoming biased. Also the first interviews were analysed by both the author and an Imperial College Researcher to gain higher internal reliability. The last point of the data analysis is the reconnection with theoretical concepts for investments decision making, in order to create a theoretical and empirical based overview of opportunities and barriers influencing investments in the RJF sector.

[4] Some interviewees stated there comments confidentially, therefore the transcripts are not included in the thesis. The transcripts can be provided on demand by contacting the research if the validity of the results is in doubt.

4 Results

The results are divided in three sections, in line with the sub-questions. The first section will provide an overview of the current advanced biofuel projects and the investor activity within these projects. This gives the reader a first insight on the order of magnitude of projects and investors involved within these projects. The next section elaborates on the Technological Innovation System of the advanced biofuel sector and specifics on RJF to provide an overview of influencing factors. In this final section the TIS is translated into distinct barriers and opportunities that the current RJF supply-chain faces in attracting investors.

4.1 Part 1 – Industry analysis

In this section, an overview of the advanced biofuel industry is described. This section consists of two parts. The first shows the development of projects over time. The second entails the classification of the industry projects in the phases of development and connects these phases of development to the investor activity.

4.1.1 Development over time

A total of 56 projects, that met the restrictions formed in the methodology, was found in the advanced biofuel sector. The projects are equally divided over the US (27 projects) and the European Union (29 projects). In appendix A the list of projects is provided. These results are meant to give an indicative overview and succeed in this objective. However, the reader should keep in mind that projects might exist in other areas of the world or change quickly over time, due to the infancy of the sector.

Table 5. Number of projects in scope of this research

	# Projects
Europe	29[5]
US	27[6]
Total	56

[5] European Union project sources (Abengoa, 2013; Beta Renewables, 2013a, 2013b, 2014; BioGasol, 2015; Bioliq, 2014; Borregaard, 2015; Butamax, 2015; Chempolis, 2015; District Energy, 2013; ENI, 2014a, 2014b; EUDP, 2014; Fortum, 2015; Futurol, 2012; Greasoline, 2015; IEA Bioenergy, 2015; Karlsruhe Institute of Technology, 2013; Lane, 2012, 2014a, 2015g; Neste Oil, 2015; Peter Haug, 2015; Preem, 2014; Renew, 2008; Scottish Bioenergy, 2012; Solena Fuels, 2014, 2015; SP Biofuels, 2014; St1 Biofuels Oy, 2014; Steeper Energy, 2015; Sunliquid, 2014; UPM Biofuels, 2015; Viguie et al., 2013)

[6] US project sources (Abengoa Bioenergy, 2011; Abengoa Solar Inc., 2013; Abengoa, 2014; AliphaJet Inc., 2012; AltAir Fuels, 2015; Aquatic Energy, 2015; Beta Renewables, 2013a; Business Wire, 2015; Cobalt, 2015; Cool Planet, 2014; Culverwill, 2015; Diamon Green Diesel, 2012; DuPont, 2013, 2015; Emerald Biofuels, 2015; Fulcrum Bioenergy, 2015; Gas Technology Institute, 2015; Green Car Congress, 2012; Green Star Products, 2015; Harrington, 2015; INEOS Bio, 2011; Iowa Energy Center, 2014; Jessen, 2014; Lane, 2014b, 2014c, 2014d; Lanzatech, 2015; Macias, 2011; NREL, 2009; POET DSM, 2014; Proctor, 2015; Research Triangle Institute, 2015; Sapp, 2014; Tyson Foods, 2014; Virent, 2015; Winters, 2013; Zeachem, 2015)

A division in project purpose is made for both of the investigated regions. The three project purposes, as explained in the methodology, provide an insight in the aim of the built or planned projects in the sector. It should be noticed that some projects in 2015 and all projects in 2016 and 2017 are still planned facilities[7]. These projects still face challenges before they will get online, these challenges will be discussed in part 2 and 3 of these results. The planned projects are included to provide an insight in the activities in the sector and shows what the direction of development is likely going to be. Figure 5 shows the advanced biofuel development of the European Union. The development started in 2004, with the first pilot and demonstration facilities. It took up to 2010 before the first commercial plant was established. While the pilot and demonstration facilities development stagnate around 2013, the commercial facilities became more apparent.

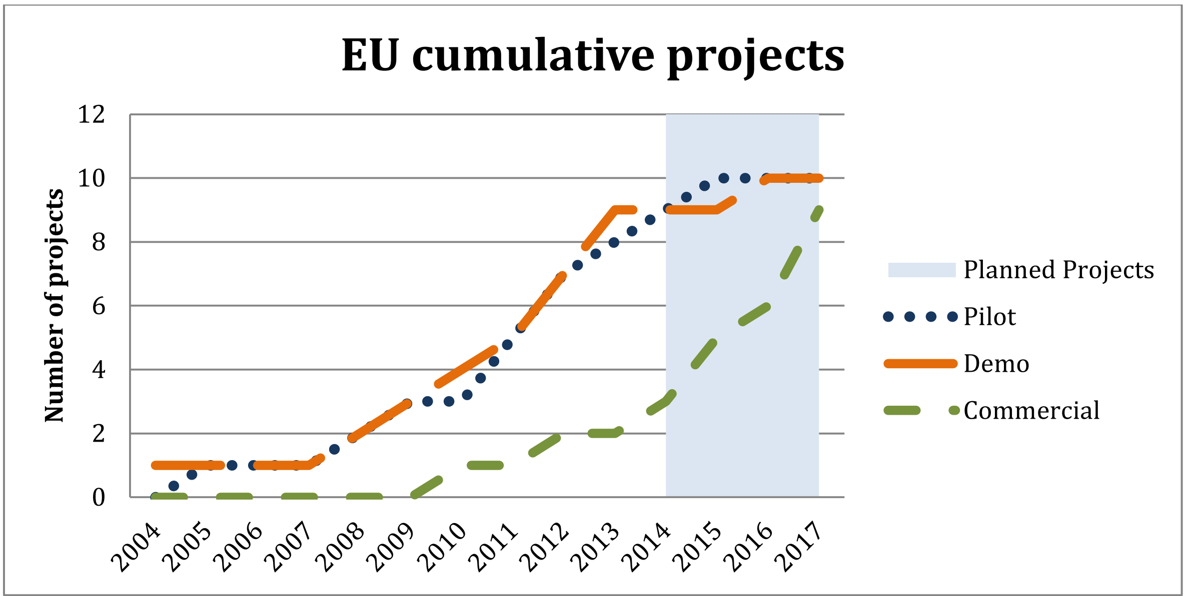

Figure 5. Cumulative projects in the European Union

The United States situation is showing a similar trend as can be seen in Figure 6, the biggest difference to the European situation is that the development started in 2007 and commercial facilities started right after the first pilot and demonstration facilities came online. The same note holds for the US; some projects in 2015 and all projects in 2016 and 2017 are still in development or under construction[6]. It is interesting to see that there are more planned projects with a commercial purpose than projects with a pilot and demonstrative purpose from 2016 onwards, while in the EU pilot and demonstration projects seem to remain the dominant projects until 2017. This might be caused by a difference in investor focus or circumstances. As this cannot be concluded based on this data, this information is tested within the qualitative interviews described in part 2 and 3 of this results section.

[7] Appendix A shows the list of projects and specific information about purpose, phase of development and investor involvement.

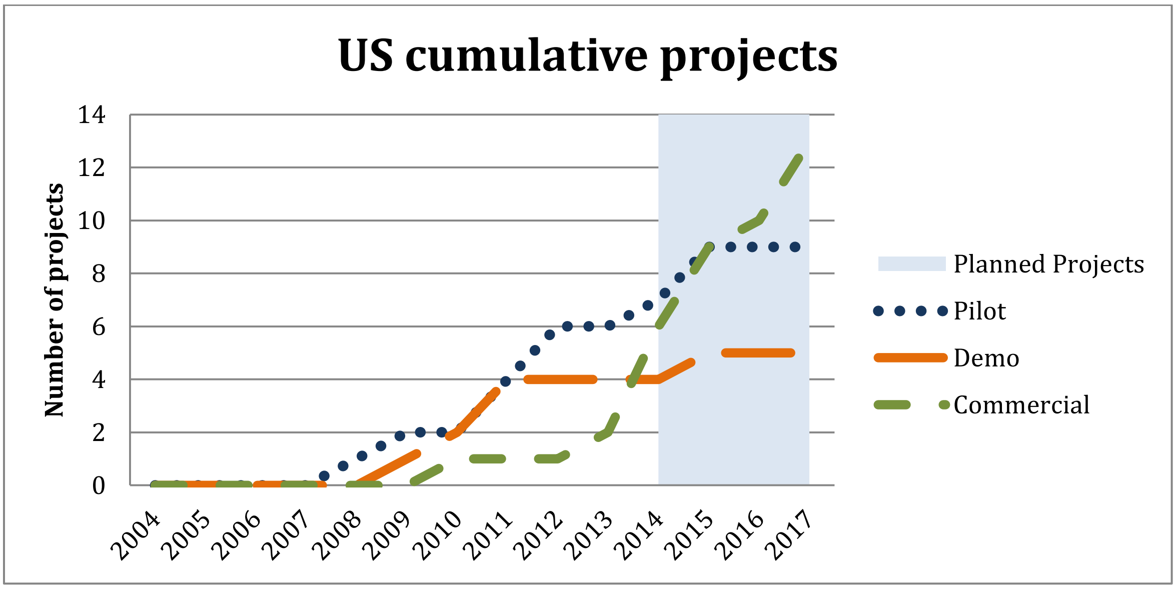

Figure 6. Cumulative projects in the United States

The conclusion that can be drawn from both graphs is that the advanced biofuel sector is still in its infancy. With the majority of projects still being pilot or demonstration projects, and projects with a commercial purpose only exist scarcely or are still in planned status. It should also be noted that some of the commercial projects currently operational, are often projects based on the first generation technologies incrementally adjusted to include advanced biofuel feedstocks in the production process (ENI, 2014b; Neste Oil, 2015). This enables them to be put under the advanced biofuel terminology, but might not be of large influence on the advanced biofuel technologies. Distinctions on technological pathways will be further discussed in the TIS analysis of this thesis.

4.1.2 Phase of development of projects

The last section presented the purpose of the projects over time; in this section the projects are categorized in the phases of development. The purpose of projects has some overlap with the phase of development indication, however the project purposes were specified by the aim of each project, while the phases are determined on the development in the market. So e.g. a project with an commercial purpose can still be in the development phase, because although there might be continuous operation (criteria to be categorized as a product with commercial purpose) the project does not have any commercial sales (question to be categorized in the take-off phase). As can be seen in Figure 7, the projects have developed up into the take-off phase, the last two phases have not been reached at this moment in time. The majority of projects are in the pre-development and development phase, with only four projects defined in the take-off phase[8]. As can be seen the projects in the pre-development phase are almost completely operational, while 10 out of 33 projects in the development phase are still planned. The projects in the take-off phase are all still planned.

[8] Appendix A shows the list of projects and specific information about purpose, phase of development and investor involvement.

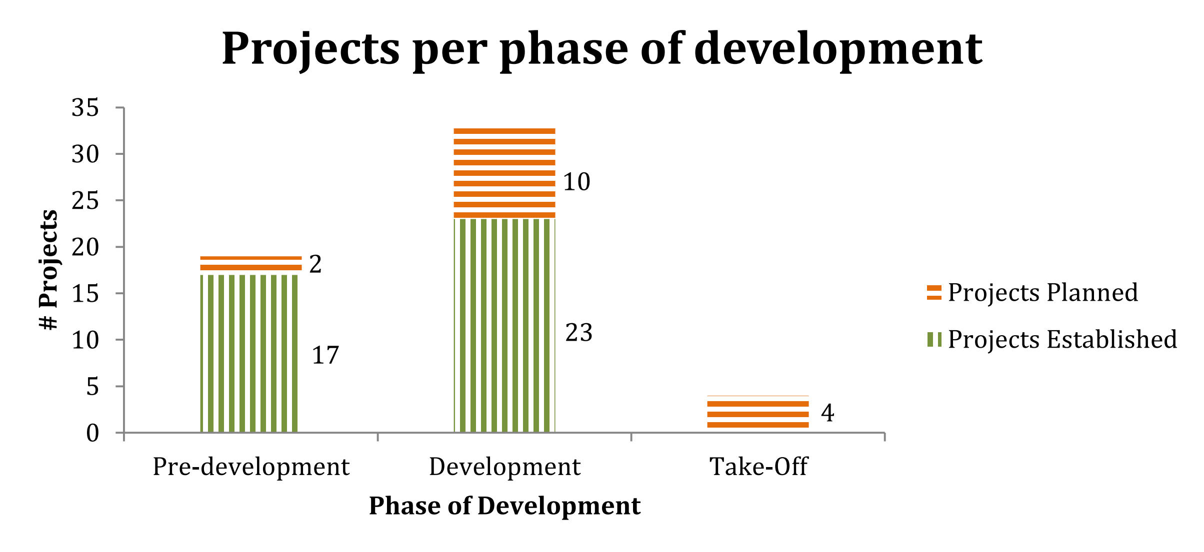

Figure 7. Projects classified in phase of development

4.1.3 Investor activity in the sector

The activity of every investor type is determined for each project. It is possible that in one project both a public investor (e.g. a grant from the Department of Energy in the United States), as well as a strategic investor (e.g. the equity investment United Airlines did in Fulcrum) is active. The investor information of each project is placed in the different phases of development.[9]

Figure 8 shows the activity of each investor type in every phase. The bars represent the activity of each investor type relative to the other types of investors. In other words, in the pre-development stage 68% of the projects receive public investments, while private and strategic investors where present in 21% and 63% respectively. The bar chart in Figure 8 shows these shares normalized to 100%. It should be kept in mind that the take-off phase only includes four projects, where public and strategic investors are active in 3 of the projects and private investors in 2. As this number of projects is too small to draw representative conclusions I focus on the first two phases. In line with the theoretical distribution, as presented in the theoretical section, public investors play a significant role in the first two phases. The theory states that public investments are needed to stimulate technologies important for society, e.g. lowering emissions, which are not financially attractive due to their infancy, this is confirmed by the investment activity in this thesis and shows the infancy of the advanced biofuels technologies (Grubb, 2005; Wüstenhagen & Menichetti, 2012). It is further interesting to notice that strategic funders are more active in the early phases than one would expect from the theory. Theory states that strategic investors often try to avoid large risks and invest to secure the existence or extension of their company (Grubb, 2005; Wüstenhagen & Menichetti, 2012). The results in this thesis seem to indicate that the existence of the company is threatened as such, that the strategic investors make investments in an earlier stage, taking more economical risks. A final point of interest is the low activity of private funding in the early phases. According to theory, private

[9] See appendix A for specific investor information on each project

investments should take the industry from the pre-development phase through to the acceleration phase (Wüstenhagen & Menichetti, 2012). At this moment that does not seem to happen sufficiently; confirming the feel in the market that is it difficult to attract private investors into the advanced biofuels sector (EBTP, 2015; Gegg et al., 2015).

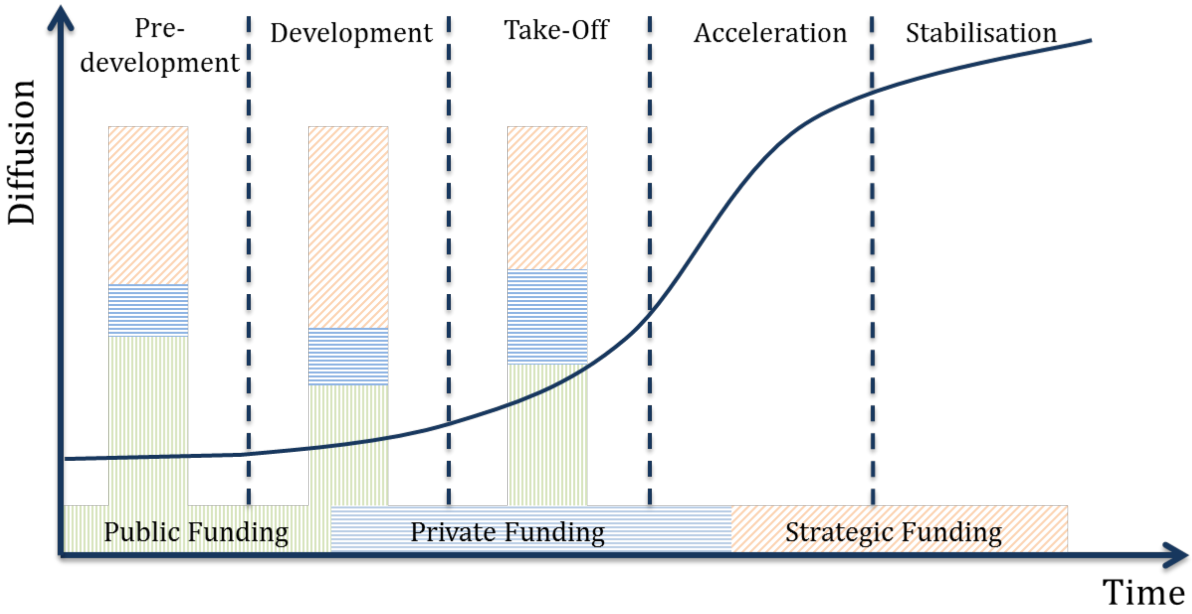

Figure 8. Combined distribution of investors with theoretically assumed distribution[10]

[10] More descriptive graphs on this data can be found in appendix D

4.2 Part 2 - Technological Innovation System

In this part the TIS of the advanced biofuel sector in general is analysed, however in some relevant sections RJF is discussed specifically to discuss the elements that distinguish RJF from other biofuel applications.

4.2.1 Structural

Technological pathways

The different technologies will not be elaborated upon extensively, since this is beyond the scope of the research and literature on this topic already exists (Mawhood et al., 2014; Sims et al., 2010). However the technologies are touched upon briefly to get an insight in the different pathways and the challenges each of the pathways face. Broadly three categories of feedstock can be distinguished in advanced biofuels:

- Oil-Containing biomass & readily available oil
- Lignocellulosic Biomass
- Sugar & Starch Biomass

Each of the feedstocks can be converted into biofuels through one or several technologies. For every technological pathway the Fuel Readiness Level and ASTM approval is mentioned in the title and discussed in detail in the text.

Hydro processed Esters and Fatty Acids (HEFA) (FRL: 6-8, ASTM Approved)

The oil-containing biomass is a widely used feedstock and can be converted into biofuels with the HEFA pathway. A lot of the current commercial facilities producing biofuels are based on this HEFA pathway (AltAir Fuels, 2015; ENI, 2014b; Neste Oil, 2015). This is due to the fact that this technology is well-developed for first generation biofuels. It might therefore only be considered as an advanced biofuel technology, if the feedstock does not conflict with the use of land for food producing purposes. HEFA thus should use non-food related oils e.g. used cooking oil and animal fat to be considered an advanced pathway. Although this pathway has been certified at ASTM already and is the furthest developed pathway, it has its limitations due to the limited availability and high prices of sustainable feedstock (IATA, 2014).

Fischer-Tropsch (FT) (FRL: 6-8, ASTM Approved)

Fischer-Tropsch synthesis is a relatively well developed technology, in some reviews still known as Biomass-to-Liquid, as it has been applied to coal and natural gas for years. This technology can process the more widely available lignocellulosic biomass. This can be for example: woody biomass, agricultural residues and municipal solid waste. To move from the traditional coal gasification towards biomass gasification some development regarding syngas cleaning is still needed (Brown & Brown, 2013). UPM and BioTfuels are currently using this technology in their facilities (UPM Biofuels, 2015; Viguie et al., 2013). Solena is another project using FT, interesting to follow due to their specific RJF focus, this project is however still only planned and on-hold waiting to close investments (Solena Fuels, 2014, 2015). The FT technologies are ASTM approved, however the industry is still waiting on the first project to produce FT biofuels continuously, therefore significant developments are needed before wider commercialisation can take off (Mawhood et al., 2014). Furthermore, the FT pathway can produce numerous co-products such as diesel, but also power and heat. This is further discussed in the functional analysis.

Direct sugars to Hydrocarbons (DSHC) (FRL: 5-7, ASTM Approved)
DSHC is a relatively new pathway. The technology converts sugary feedstock such as sugarcane, sweet sorghum and maize to fuels. As this is widely available in Brazil, Total and Amyris created a large consortium making biofuels using this technology. Due to the geographical focus of this thesis, this project was not included in the project analysis part of this thesis. Although this technology can produce fuels, according to Total with a relatively competitive price, there are some challenges (Lane, 2015a). The ASTM approval only holds for a 10% blend-in of jet fuels, due to the limitations of the fuel on density and boiling range (SkyNRG, 2015).

Alcohol to Jet (ATJ) (FRL: 4-6, Not ASTM Approved)
This pathway includes several technologies that produce biofuels from biomass through an alcohol intermediate. Both lignocellulosic and sugar & starch biomass feedstock can be used. Although the technologies are quite mature, most of the industrial applications use this technology to reach an intermediate product instead of biofuels (Mawhood et al., 2014). The projects that do exist, e.g. Lanzatech in the United States, are still in the pilot phase (Lanzatech, 2015). Developments are ongoing to get ASTM approval, this is currently not yet realised (Mawhood et al., 2014).

Hydrotreated Depolymerised Cellulosic Jet (HDCJ) (FRL: 6, Not ASTM Approved)
This pathway includes different conversion technologies to convert biomass to biofuels. These technologies include; pyrolysis, hydrothermal liquefaction and hybrid processes. The common ground of these conversion processes is the fact they generate bio-oils that still need to be upgraded in order to produce a useful drop-in fuel (Mawhood et al., 2014). This upgrading happens through hydro processing, which is an expensive process. The feedstocks used are similar to the feedstocks used in Fischer-Tropsch. Interesting note for this pathway is that one of the largest project in advanced biofuels was KiOr which used this technology, however this firm went bankrupt when trying to scale up its activities.

Actors
The advanced biofuel industry is still an upcoming sector resulting in vibrant markets with constantly changing dynamics and different actors entering and leaving the industry. Therefore, no consistent database that tracks these actors exists (Solecki et al., 2011). The actor analysis is therefore based on the project analysis as presented in part 1 of this results and complemented with literature and industry reports.

Knowledge development

Knowledge creation is considered to flourish within a so-called Trip Helix model, this model assumes close cooperation between three actor groups; universities, companies and governments (Hekkert et al., 2011). Starting with universities' academic knowledge a brief analysis on published items shows the quick development of knowledge in the last decade. Searching on "Advanced Biofuels" provides insights as shown in Figure 9.

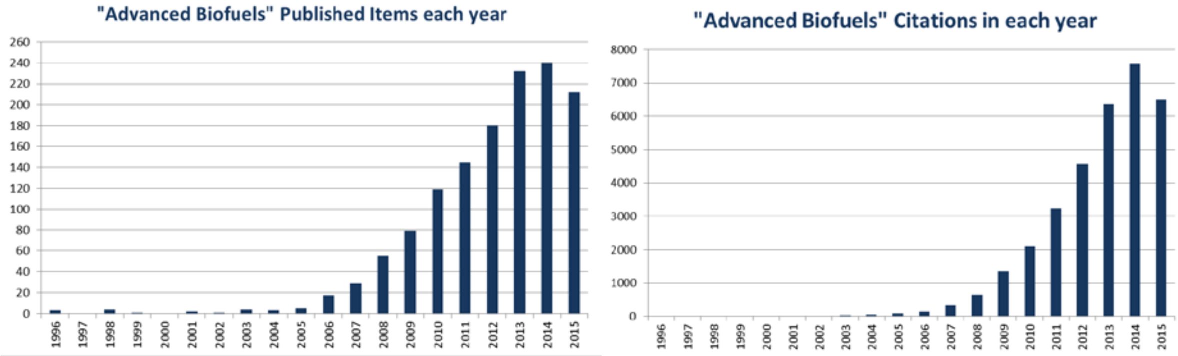

Figure 9. Web of Science publications and citations on topic of 'Advanced Biofuels'[11]

When searching on the topic of "Renewable Jet Fuels", Figure 10, we see similar shaped graphs with a slightly later starting point and less articles and citations. Both the advanced biofuels and RJF knowledge state, show the recent start and large growth of the industry of the last years.

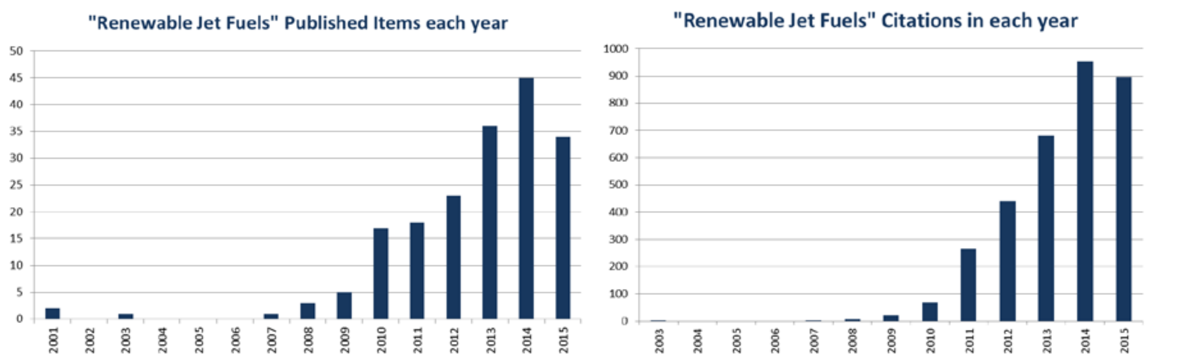

Figure 10. Web of Science publications and citations on topic of 'Renewable Jet Fuels'[11]

Numerous research institutes are working on translating this academic knowledge into pilot or demonstration plants. Sweden was one of the first to get a pilot plant operational (2004) by SP technical research institute of Sweden in collaboration with the Swedish Institute of Agricultural and Environmental Engineering (SP Biofuels, 2014). Only a year after the pilot plant of Vienna University went online (Renew, 2008). The Karlsruhe Institute of Technology, is also working on a pilot facility in collaboration with an industrial partner Chemieanlagenbau (Karlsruhe Institute of Technology, 2013). In the United States we see similar developments, with the Research Triangle Institute and National Renewable Energy Laboratory (Janssen et al., 2013; Research Triangle Institute, 2015). Both projects as well as numerous other industrial pilot and demonstration plants received substantial public investments from the Department of Energy.

[11] Note that 2015 is not complete, as it only takes published items and citations into account up to 20-10-2015

Education

It is unclear what the amount of graduates is that moves into the advanced biofuel sector. Another indication for education is the institutes sharing the knowledge to educate the industry. There are numerous educational conferences on advanced biofuels and RJF in particular; The national advanced biofuels conference and expo is held each year in the United States, the Biofuels International Conference is held in Portugal this year (Biofuels international expo & conference, 2015; NABC&E, 2015). The conferences often have either an academic or an industrial approach, getting the right mix remains hard to establish. Besides the conferences there is numerous educational websites gathering all relevant news on the topic of advanced biofuels. The Biofuels Digest and Biomass magazine are among those educational websites and organize their own conferences as well (ABLC Next, 2015). A platform on which academic and industrial knowledge is gathered and shared is the Bioenergy 2020 program, a European union funded program, providing an overview of advanced biofuel projects (IEA Bioenergy, 2015). The knowledge exchange programs are mostly biased by the industry, as they have an interest in receiving investments or pushing the technology. It is therefore hard, for investors, to obtain objective information about the development of advanced biofuels.

Industry

Oil majors

Advanced biofuels can be interesting for oil majors as the development of the sustainable counterpart of conventional oil products can either be seen as a threat to their current business or as essential to enhance future sustainable business. However, involvement of oil majors in advanced biofuels has not been very extensive at this point in time. Total has been involved in collaboration with Amyris (Lane, 2015a). Neste Oil is another European oil company focussing on the deployment of biofuels, they established a major role in first generation biofuels in Europe and is slowly moving towards advanced biofuels at this moment (Neste Oil, 2015). Shell is the largest investor among the oil majors in the advanced biofuel market, they have been involved in some research development and aiming to build a pilot plant to test cellulosic ethanol production technologies (Roberts, 2013; Shell, 2015). Other major oil companies have either not been involved or pulled out from the advanced biofuel market, BP was in the period 2005-2008 the second largest oil major investor in advanced biofuels behind Shell, but pulled out all of its lignocellulosic ethanol production activities in January 2015 (Lane, 2015b; Roberts, 2013). Oil major investments peaked at $3 billion in 2011 but fell to $0.5 billion in 2012. Exxon's investment of 100 million US dollars, in the period 2005-2012, was only 1/6 of its 2009 commitment to invest $ 600 million in biofuels (Roberts, 2013).

Feedstock partners

Another industry group involved in the development of advanced biofuels is the feedstock providers. This group is not only important to secure a stable supply of feedstock into the supply-chain, it also has a self-interest in developing advanced biofuels in order to sell its feedstock more extensively in the future. An example of such behaviour is Johnson Timber, a provider of wood residues at the GTI Gas Technology Institute (Gas Technology Institute, 2015).

The company Waste Management even acted as a strategic investor by investing in the development of Fulcrum in order to secure their own ability to sell the feedstock (Fulcrum Bioenergy, 2015). These partners are especially strong in the regions where a lot of feedstock is available in surplus due to other industries such as the wood and paper industry.

Other Industrial Partners

In order to ensure economic viability numerous projects are co-generating other products. Power is fairly easy to supply with the production of advanced biofuels. The co-generation of chemicals is also popular in some advanced biofuel projects. BetaRenewables is using this technology in Europe, where e.g. Ineos is using a similar technology in the United States (Beta Renewables, 2014; INEOS Bio, 2011). Furthermore, numerous chemical providers are involved in the development of biofuels, to diversify their portfolio and see whether the technologies might be substitutes for their fossil-based chemicals. AkzoNobel, Cargill and DSM are some of the examples active in this field (Lane, 2014a; POET DSM, 2014; Virent, 2015). Industrial partners also entail the specific technology providers, who either have their own demonstration projects, e.g. DuPont (DuPont, 2015), or mainly focus on selling the biofuel technologies they developed to companies, e.g. UOP Honeywell (Lane, 2015i). The logistical partners include airports, to ensure the distribution of biofuels to the end consumer. The industry is still in its infancy and current biofuels are delivered on a batch basis. When supply becomes continuous it is vital that the industry is able to mix RJF into existing pipeline infrastructure. Experts from the industry say this is no problem and will be possible (Interviews).

End-market

The involvement of airlines in RJF is evident due to the need for market demand. This market development was found to be a major barrier in previous biofuel research (Suurs & Hekkert, 2009a). However, the market development has been very active in recent years (2014/2015). Airlines are the logical market developer for RJF and behave as such with numerous off-take agreements at planned commercial biofuel facilities. This creates an interesting enabling factor for the development of RJF in comparison to ordinary road biofuels. As there seems to be a large demand from the market, project owners can contractually agree on a price with airlines and therewith take away risks from the project financials. This results in investors to be more comfortable to invest in the projects. Among others, United Airlines and Cathway Pacific signed offtakes at Fulcrum, while both FedEx and Southwest Airlines are responsible for the off-take of all produced jet fuels from the Red Rock facility. Furthermore, AltAir realised an off-take agreement with United Airlines primarily focussing on RJF, and is coming online at the end of 2015 (AltAir Fuels, 2015; Hamelinck et al., 2013; Lane, 2015c, 2015g). Furthermore, British Airways signed a 10 year off-take agreement with Solena (Solena Fuels, 2014). It is important to note that these are all intentional agreements since none of the plants from which the off-take agreements are signed, are currently operational. Airlines not only sign off-take agreements they also invested in biofuel technology; Cathway and United invested in the development of Fulcrum in 2014 and 2015 respectively (Lane, 2015h). A big gap exists between the willingness of airlines to participate and the ability to let customers pay for this innovation. There are some trials; KLM has set up a KLM corporate Biofuel program enabling its corporate customers to pay the premium to fly on biofuels (KLM, 2012). Although there might be great willingness, single airlines just cannot afford to pay any premium price for biofuels, since this would have significant impact on their competitiveness (Hamelinck et al., 2013).

Government bodies and Supportive organizations

In Europe the most important organisation to support advanced biofuels is the European Union (Janssen et al., 2013). Also local governments support RJF development, as the Dutch government explicitly included RJF into the quota for the Renewable Energy Directive quota (Hamelinck et al., 2013). In the United States the Department of Energy is the largest funder of governmental grants to support biofuel research and development. The US Navy has an influential role because of their target to get half of all the energy from alternative sources by the year 2020 (Interviews). A description on the actions and programs of these governmental bodies and organizations is provided in the Institution part of this TIS.

Networks

In this section a brief overview of the networks to stimulate advanced biofuels is provided, note that many others may exist. This sections tries to give an overview of diverse networks with different goals within the industry. There is an airline oriented network: The Sustainable Aviation Fuel Users Group (SAFUG) consisting of 28 airlines, representing 33% of the worldwide commercial aviation fuel demand, committing the airlines to RJF. Other programs, such as the European Advanced Biofuels Flight Path Initiative focus on getting two million tonnes RJF in 2020 (Hamelinck et al., 2013). Another interesting organisation based in the Netherlands is SkyNRG, a company set up by KLM and Spring Associates, in 2010. SkyNRG does not own any facility to produce RJF but supplies RJF to airlines. SkyNRG stimulates the supply-chain development and is currently world leader in RJF supply. Another European network is the RENJET project, this Climate KIC funded project tries to find opportunities to deploy the RJF supply-chain. This is done in a close cooperation with research institutes, Utrecht University and Imperial College London as well as industry partners as KLM and Schiphol. Core-Jet is another European network that acts as a facilitator in the supply-chain and tries to bring public and private stakeholders together.

Institutions

Institutions can either be formal or informal, informal institutions are harder to find and those are therefore addressed in the functions section, where interviews are used to clarify such institutions. In this section a brief summary is provided on the institutions and regulations in the United States, European Union and Aviation Sector. Other research exists on more in-depth analysis of these regulations (Alberici et al., 2014).

United States of America

The United States have a Renewable Fuel Standard (RFS2) under which fuel suppliers are obliged to deliver a certain amount of their supply as biofuels (EPA, 2015). The fuel suppliers receive Renewable Identification Numbers (RINs), which can also be banked and sold if a supplier produces more than needed. The RFS2 sets targets based on volumes split by biofuel category; advanced biofuels, biomass-based diesel, cellulosic biofuel and renewable fuel (Alberici et al., 2014). Airlines are not obliged under this standard, however the fuels qualify for the refiners quota. Currently, discussion is going on about the future of RFS2 as the proposed obligation for coming years is lower than expected, potentially hampering the investments in advanced biofuels (Erickson, 2015). Other influential organisations in the United States are the Department of Energy investing in most of the advanced biofuels. Furthermore, the US Navy is a driver of investments with its 'Great Green Fleet' initiative to provide investments and cooperation on certification (Lane, 2015j). The US Department of Agriculture has a bio refinery program stimulating biofuel developments with loan guarantees.

Europe

The biofuels policy in the European Union is currently regulated within the Renewable Energy Directive (RED) started in 2009. The RED obliges EU members to have 10% renewable energy in transport in 2020. However this does not incentivise RJF specifically, even the opposite is happening since biofuels for road are incentivised by putting in obligations for suppliers of petrol and diesel without including RJF (Hamelinck et al., 2013). The Netherlands is the only European country in which RJF can contribute to the fulfilment of this quota obligation (Hamelinck et al., 2013). Besides these obligations there is a number of European investment subsidies, Horizon 2020 is the biggest EU research and innovation programme ever with nearly €80 Billion available from 2014-2020 including numerous biofuel projects (European Commission, 2014). NER300 is the other program stimulating project with financial incentives; however, 3 out of 5 projects have discontinued due to uncertainties in policy on the share of renewables in traffic fuels after 2020 (European Biofuels Technology Platform, 2015).

International Aviation

The International Air Transport Association (IATA) set a goal of having carbon-neutral growth after 2020 and reducing carbon emissions by 50% by 2050 compared to 2005 levels (Alberici et al., 2014). As fuel efficiency measures are limited and solar planes are still a long shot away, these goals seem to work as a self-imposed mandate (Lane, 2015j). ASTM is responsible for the approval of RJF, as indicated in the technological analysis. If a RJF technology does not receive this approval it will never end up on the market and development will be hampered. Another large organisation within the aviation industry is the International Civil Aviation Organization (ICAO). In contrary to the voluntary targets of IATA, ICAO is capable of developing a mandatory market based mechanism to force and stimulate RJF into the sector (Alberici et al., 2014).

4.2.2 Phase of development

As indicated in part 1 of the results, the advanced biofuel projects are indicated as being in the first two phases of diffusion; pre-development and development. The industry is very slowly reaching the take-off stage. Jacobsson and Bergek (2004) showed that the early phases can be seen as the formative period. During such formative period the industry is characterised by small markets, many entrants and high uncertainty in terms of technologies and regulations (Jacobsson & Bergek, 2004; Klepper, 1996; Utterback & Abernathy, 1975). The structural analysis confirmed these characteristics. However, since this thesis tries to find opportunities and barriers to stimulate future investments, it is important to get the industry ready to move into the take-off phase. Figure 11 shows the important functions in the first three stages of development. The functions around F6 (Resource mobilisation) will be central in the function analysis. As can be seen F6 influences F1 (Entrepreneurial experimentation) and F2 (Knowledge development and diffusion), while being influenced by F4 (Guidance of the search) and F7 (Counteracting resistance to change). However, in the development phase all functions are important and they all influence each other, since the malfunctioning of one of the functions might also hamper the next and so on. So while the other functions (F3 (Knowledge exchange) and F5 (Formation of markets)) might not directly relate to F6 they will be taken into account to include all possible influencing factors. The development and take-off phases are also interesting for this study as this is where the 'valley of death' is taking place. This influences investors because projects are at high risk due to the large demand for capital investment in plant and operations while still having a low level of returns from the slow initial stages of diffusion (Wood, 2012).

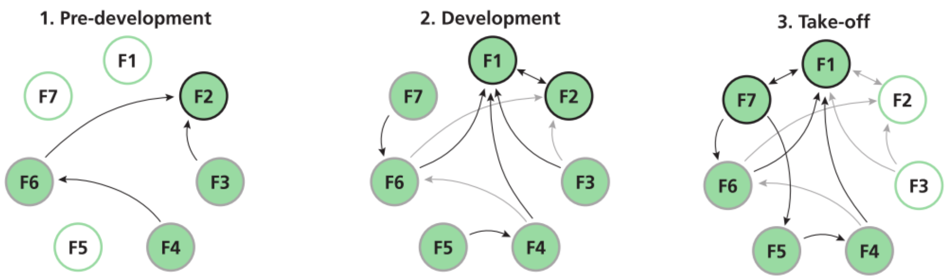

Figure 11. Function importance per phase of development

4.2.3 Function analysis

For every function the important activities within the functions are stated by quoting examples stated by the interviewees. Also, the relations with other functions are indicated by stating the effect (+ positive, or – negative) of one function on another (e.g.: +F4 -> F1). At the end of every function the score of the function is stated. The final part of this section concludes the analysis with the functions model and relates the performance of the functions back to the structure and phase of development of the TIS.

F1: Entrepreneurial experimentation

The structural analysis showed a good mix of actors of both research institutes as well as industry partners, however some actors especially from the aviation industry found the role of oil majors too marginal in current development (-F1): *"Apart from Total, Neste Oil and a little bit of Shell we do not see much movement within the oil majors."* (Strategic Investor). A reason for this more than average involvement of Total seems to lie in the specific project they are involved in, they got locked-in with high investments and there is no turning back: "*Another thing is Total did not start this venture thinking of getting it. It was just investing in a number of biofuel companies, suddenly Amyris got into problems and was about to go bankrupt, Total basically bailed them out. So Total is owed so much money by Amyris right now they really have no choice then to continue."* (Expert).

There is a positive influence of policy (+F4 -> F1) on the involvement of strategic investors, both oil majors and the aviation industry point out that their involvement is part of a strategy to meet up for the mandates put on fuel suppliers and possible aviation restrictions in future: *"We are at first instance big in biofuels because we are a big fuel retailer and given the mandates you are forced to sell a certain amount of biofuels."* (Strategic Investor). However for RJF in specific this does not yet work, due to the lack of mandates and the unequal playing field (-F4 -> F1), as indicated by multiple strategic investors: *"The primary issue we are trying to address is this level playing field with transport fuels. So in the UK and lots other places in the world there are incentives to produce ground transport fuels, currently these do not exist for jet fuels."* (Strategic Investor)

Furthermore, there seems to be a willingness in the market to get pilot and demonstration plants up to large-scale production, however this has been difficult due to the lack of financial resources (-F6 -> F1): *"So the challenge for the biofuels market is the technologies that are coming forward they might be proven on a very small scale and then they need up to a massive scale which is extremely expensive so as a sector you are asking investors to take a very large risk on scale up."* (Private investor). "*To take away risk and realise up-scale, there is two big requirements. That is security about feedstock for the longer term and that is also the need for capital investments to bring that refining capacity online."* (Strategic Investor)

F1

To conclude, F1 scores neutral (0), due to a variety of actors involved, especially the knowledge side (F2) is represented sufficiently with the numerous pilot and demonstration projects. However, the policies (F4) are not stimulating RJF due to the lack of clear policy and mandates which do not include RJF. Also there are currently not enough financial resources to develop the sector into large scale commercial production (F6).

F2: Knowledge development

Previous research showed that knowledge development for advanced biofuels was excluded from support programs for biofuels, due to the 'enormous risks' in the demand side (Suurs & Hekkert, 2009a). A lot has changed in the regard of knowledge development since this research. As shown in part 1 and in the structural analysis of this TIS, numerous projects to develop knowledge and prove technologies exist. However, the valley of death, which is the phase in the development of a technology just after proof of concept and before market introduction is still present throughout the advanced biofuels sector (Negro et al., 2012). The consequence is that knowledge stays in the R&D phase and the step towards commercial facilities is considered too large (Foxon et al., 2005; Winskel et al., 2006). This especially applies to the European situation as indicated by numerous private investors (-F2 -> F1): *"Applied research is lacking at the demonstration phase, it happens that a lot of universities have quite good technology transfer facilities nowadays, but it could be better. The US has more engagement. The one issue we have in Europe over the US is technologies are forced to spin out further away from universities' safety than they do in the US. While in the US they wait until they got to the point of reasonable sales"* (Private Investor). It is also mentioned that it is not a matter of research anymore, but only applying the research to develop the market: *"A lot of research has been done, but the last push to get to large scale production is often the stage that hampers development. RJF is, in my opinion, not a very high-tech sector. Most of the technology for these kind of fuels is developed quite well. However, the proof of concept is done, pilot phase is done and then scaling to an almost real life demo product is the current problem."* (Private Investor).

Knowledge development seems to be well established in the early phases of research resulting in current inefficient use of resources and low knowledge exchange (-F3 -> F2) due to repeated and scattered research: *"We see business plans and we are seeing academic research where people are doing things that were partially done 30 years ago the last time oil prices were really high. So you see a lot of recycling of concepts and ideas and that is partially good because people are getting trained or people are remembering what we have learned those decades ago. It is partially bad because we do not want to reinvent the wheel."* (Private Investor). *"I could think of twenty to thirty technologies that all basically trying to do the same thing. You know that is not really a very efficient way of developing a technology and actually trying to make sure that that technology ultimately becomes bankable. You just spread, say a fine pull of capital across a much larger number of technologies."* (Private Investor).

Contrary to this statement are the specific actors closely involved in the sector that still see the need for knowledge development especially in the advanced technology path-ways: *"There is still some research needed in the lignocellulose pathways which of course are not yet that far developed as the oil pathways. I think it is very promising but a lot of technical development and research is needed to make it affordable as well."* (Strategic Investor). *"I think Fischer-Tropsch and some of the biological routes are being close to a technology proven path-way, it is more a question of scale-up* *and costs. Pyrolysis on the other hand and algae, I think they still need to prove those technologies. Pyrolysis has made good advances but it is still not there in terms of upgrading the pyrolysis oil, so I mean there are technologies that could be available, there is still nothing that has been demonstrated at scale, and has proven cost acceptable or tolerable."* (Expert)

F2

To conclude, the knowledge development has been neutral in the development of advanced biofuels and RJF (Score: 0). Some technological pathways are well developed in the past and now need to be taken from their proof-of-concept to market development. While other pathways lack fundamental research and need extra research in order to proof or discard the technology. It seems that enough financial resources are flowing into knowledge development (+F6 -> F2), however due to lack of direction (F4) and knowledge exchange (F3), it does not lead to market deployment.

F3: Knowledge exchange

Knowledge exchange in the RJF supply-chain occurs between science and industry, as was indicated in the structure analysis, with numerous conferences and platforms both regional and international. Despite those events, stakeholders still indicate a lack of information, also investors clearly indicate a lack of good projects to invest in: *"I think that there could always be a better information platform, to basically try to aggregate the projects and communalise knowledge and information but I guess the problem is that investors, when they are go and spend all this time and money working on a project, they do not typically want to tell everyone else how they did it. So it should be a good thing for maybe the government to try to keep that type of record base and keep a track of projects. That at least then enables you to go and speak to these people."* (Private Investor). *"So I think it would be brilliant to have the same event where you invite investors and pension funds and other similar actors and give them the investor's point of view about bioenergy projects risks and returns, so they (the project owners) understand it, because they have a lot of misconceptions."* (Private Investor)

There also seems to be a mismatch between the investors that think they know about advanced biofuels and their problems, while they actually only know about first generation biofuels (–F3): *"So I think you probably have potentially some capable investors that feel they have vetted the market but maybe they have vetted it five years ago when it was ethanol and biodiesel. We are not looking at those anymore. So I would not say it is necessarily the research side of things but probably the widespread awareness to where the research is at and the maturity levels of some of these pathways."* (Expert).

In the introduction, the discussion regarding availability of resources and availability of good projects is touched upon as well. Both experts and private investors claim there are enough financial resources but a lack of direction (-F3); *"So the GIB (Green Investment Bank red.) was set up because there was not enough money in the market originally, and we were meant to provide liquidity to the market. Overtime liquidity has returned but we are still investing, and that's because the market failure we are now addressing is sort of information barriers and strategic choices rather than liquidity."* (Public Investor)

A final point of interest was the fact that conferences and exchange opportunities remain to be too academic, the industry focused knowledge exchange opportunities are lacking behind (-F3 -> F1): *"What I found is that academic events really stay academic, they bring their abstracts in, and business does not care about that stuff, business cares about how to make money. And what's commercial now and what's commercial tomorrow. Because 20 years ago, most of bioenergy was in the academic form, but now more and more of the technologies are becoming commercialized. And therefore industry has to play a greater role in this."* (Expert)

F3

To conclude there are numerous knowledge exchange projects with a diverse set of stakeholders involved. However, the specific differences and opportunities for advanced biofuels to translate academics to industry are insufficient. More independent platforms to show current states of development are needed and can be helpful to attract more investment and develop towards commercial facilities. Therefore knowledge exchange scores negative (-).

F4: Guidance of the search

The diverse interviewee groups agreed on the fact that long-term stable policy is necessary for technology development and is currently absent in the industry, causing uncertainty and hesitancy in the market (-F4 -> F6): *"The most impact full thing the governments can do in the next 10 years is to create stable and visible incentives and disincentives that support biofuels. You have to take away the kind of silly debates, get clear long term policy support for a transition period where the renewable alternatives are going to cost more than the petroleum based products."* (Private Investor). Especially the so-called 'stop and go' policies, constantly changing policies, have been indicated in the past as a big problem for developing technologies (Negro et al., 2012). This is supported by actors from inside the government as well: *"So the government has got a reputation of bringing in a subsidy, closing it early, making it smaller than it should be which makes it really tough to invest."* (Public Investor).

The biofuel sector should also learn from the mistakes made within the bioenergy policy making process regarding flexibility in feedstock and technology design. As stated by one of the experts this can have a negative influence on entrepreneurial experimentation (-F4 -> F1): *"The rules, regulations and guidelines on making biomass energy were put together with wood chips and pallets on their minds. Along comes pyrolysis oil which is a denser energy medium and infinitely more flexible than pallets. But if you then move back into the wording of the regulations, it does not qualify. There will be a whole bunch of areas where it simply does not qualify because the government people were not thinking about it at the time. So governments could really help development a lot by going back to the substances that may be allowed or what guidelines they have written."* (Expert).

F4

To conclude, direction of the search has a negative score (-), hampering both the stimulation of investments (F6) and entrepreneurial experimentation (F1). Furthermore as indicated at F2, there is an indirect influence on knowledge development due to the lack of direction, capital is scattered and inefficient use of capital occurs throughout the sector. As was indicated in the structural part, policies to include RJF in mandates only exist in the US and thus hamper RJF projects in the EU region.

F5: Formation of markets

The markets of advanced biofuels and RJF are substantially different. Advanced biofuels for road transports, face competition with electrification possibilities, making the market prospects very insecure. On the contrary, the possibilities to decarbonise the aviation sector are limited. Some research on radical changes is going on, however this is long-term and will not be reached in the distant future (Bauhaus Luftfahrt, 2015). Therefore, a demand for biofuels exists in the aviation industry due to the wish to decarbonise the sector (+F5 -> F4): *"I think the duty of aviation is that we are effectively a captive market because we do not have alternative technologies, we will be using liquid energy for 50 years, so it is quite attractive for the investment community."* (Strategic Investor). The same opinion is present among the oil majors: *"If we make scenarios for the future, there is only one thing we are certain of: the demand for hydrocarbons will be high for a very long time, especially in the heavy transport sector on both ground as well as in the air. So if you take this as a truth and want to be sustainable biofuels will be a very logical step."* (Strategic Investor).

It is also stated that this 'natural' demand would not per se positively influence policy makers (-F5 -> F4). *"Any target that the IATA or ICAO sets is not going to be very high, so they can probably just reduce weight, reduce the maximum allowance that people can take. So it would not surprise me that any target the industry brings does not really drives biofuel adoption that much."*(Expert). The development of RJF is even seen as part of a strategy of the airlines to show governments they are working on it, to avoid strict regulations enforced on the industry: *"So really the aim for airlines and what I track is their interest in biofuels I think, is really just for show, they are trying to show governments that they are doing something. And if they try and blend 2 - 3 % biojet into their fuels maybe the governments will leave them alone."* (Expert).

However the common opinion from the market remains that the alternative opportunities are limited and the need for alternative fuels to replace the very price volatile fossil resources is evident for the coming decades: *"We also want to get rid of this fuel price volatility I think that is maybe not a real a driver, due to the oil price at this moment, but we all know that can change fairly quickly so I think that is really the main very important economic driver as an airline that you want to become more independent of one fuel source."* (Strategic Investor).

F5

To conclude, the market for aviation fuels is positive (+). Although the market is complex to regulate, due the amount of stakeholders and its international character, the market remains large and alternative options do not exist on the short to medium term. Furthermore, although the current fossil oil price is low and currently works as a disincentive, the price volatility of conventional oil remains a problem at any price and therefore works as a driver for RJF.

F6: Mobilisation of resources

This function entails, besides financial resources, human and physical resources. Physical resources are interesting for the production of advanced biofuels, since the lack of good and sufficient feedstock has been a problem ever since the first generation of biofuels. There is the problem that feedstocks are bounded to local development as it is unsustainable to transport the biomass over large distances. *"Biomass competition is just going to be local. You just need to know within 100 km where you are going to build, what else could possibly be done there, and that's your competition. And if somebody builds a chemicals plant 500 km away, that really does not matter."* (Private Investor). Another issue with feedstocks is the quantity and price as experts stated in the interview: *"You look at feedstock wherever you can obtain them in sufficient quantities. the availability is clearly a challenge in terms of the suitable amounts available to scale up the technologies. Municipal solid waste is I think interesting, because there is the possibility of getting it, at least initially, at a negative cost."* (Expert).

In the case of financial resources there is a clear opinion that there is enough financial resources available ready to be invested in new technologies, however projects are lacking robustness according to the investors: *"I have noticed is that there is a huge amount of liquidity in the market. So there is a lot of money looking for a home but the challenge is there is basically a lack of good projects for that money to go to."* (Private Investor). It is also noted that there has been a positive change since the dip in investments in 2012, indicating a more positive mood on the market: *"It does depend on the mood of the market. How enthusiastic the market is to provide finance, and relatively it is much more enthusiastic than two or three years ago."* (Private Investor).

On the other hand, stakeholders close to biofuel projects are stating the difficulty of getting these available funds to invest in their projects (-F6 -> F1): *"You know investors claim the money is there, but it is really hard to get. Investors have money to invest, but a lot of them do not understand bioenergy or biomass, they simply do not understand it so they are not ready to invest in it. You will get a lot of projects that are really good projects. But they ca not draw the equity money to it. So yes there is lots of money, but no there is not enough understanding to what a bioenergy project needs and how safe it is."* (Expert)

To conclude, physical resources remains a large struggle in the development of biofuels in general (-F6). It further seems that financial resources are available, especially public funding towards knowledge development is sufficient (+F6 -> F2). However, the low understanding of biofuels at private investors results in a negative influence on commercial development (-F6 -> F1). Therefore, resource mobilisation gets a negative score (-).

F7: Counteracting resistance to change

Resistance towards biofuels has existed since the early start of biofuel developments in the 1970s (Ulmanen, Verbong, & Raven, 2009). The discussion on food competitive first generation biofuels has been fierce. This history is still a legacy the advanced biofuel sector has to carry around. There are multiple pressure groups trying to hamper further biofuel development, as there was a University of Minnesota scientist who claimed cellulosic ethanol to lead to more pollution-related deaths than gasoline (Bastasch, 2015). However, these groups are not on their own, RJF is a market that faces a lot of pressure from resistance groups. Market actors do take these groups serious and take them into account when making decisions (-F7 -> F5): *"There has been some really pointed debate in the US historically about food versus fuels. In China it has even been illegal now to use corn for these purposes. So there is some pretty emotionally charged and some powerful lobbying groups that get into this debate, for sure."* (Private Investor)

On the other hand, the debate on resistance can be a driver for companies to participate as well. In the advanced biofuel and RJF sector there is "a willingness to act", pressured by non-price factors such as customer pressure or national security concerns (+F7 -> F5, F1). Companies such as Coca-Cola and LEGO, enter the market of biomaterials, to market their sustainability (Lane, 2015j). Although the suggestion that airlines are investing in RJF for the reason of marketing is wrong according to one of the strategic investors: *"It is obviously not marketing, there is cheaper ways to market, a billion dollars buys you a lot of advertising. So it is just a strategic decision."*(Strategic Investor) A final remark on the influence of pressure group by a strategic investor was: *"How technologies are considered is absolutely important. I think, my own opinion, for the long term this technology can only take a sustainable position in the energy system if I know the right answer on all the sceptic questions."* (Strategic Investor)

F7

To conclude, the resistance to change for advanced biofuels has the negative history of first generation biofuels to deal with. Creating hesitancy at private investors to stay out of the sector (-F7 -> F6). On the other hand, the demand from consumers for sustainable products results in a large involvement of strategic investors in both the chemical and aviation industry (+F7 -> F5). Overall this function scores neutral (0).

4.2.4 Functions model

The results of the function analysis are graphically presented to show the performance of the functions and the relations between them (Figure 12). As concluded from the phase of development analysis, the RJF sector is situated in the development phase and the sector is slowly moving into the take-off phase. From this model we can conclude whether the sector is ready for this transition or whether certain functions not fulfilled sufficiently. F1 (Entrepreneurial activity) is considered the centre of the development and key to progress to the take-off phase (Hekkert et al., 2011). This function is negatively influenced by almost all functions it has a relation with. There is a substantial amount of activities going on in the pilot and demonstration projects. However, the activities in commercial biofuel facilities remain a challenge, as was already found in early advanced biofuel research (Suurs & Hekkert, 2009a). This thesis focusses on investments in the sector represented in the functions model by F6 (Resource mobilisation). The project and structural analysis showed that private investors are very hesitant to invest the first commercial projects. As indicated in theory by Bürer & Wüstenhagen (2009), private investors invest for the purpose of making a profit. In the case of RJF the private investors indicated in the interviews, the too high risks (e.g. feedstocks and competition with the conventional oil price) and limited successes of previous investments as barriers to this profit and therewith a barrier to invest. This gap on the financial side of resource mobilisation is partly covered by strategic investors. Although this group is indicated as having an aversion against high risks, they do invest in biofuel projects for the strategic purpose. Seeing the importance of possible breakthrough investments and the opportunity this might be for their organization if biofuels will be a success (O'Reilly & Tushman, 2004). Mandates have a positive influence on strategic investors as well, because they force suppliers to supply biofuels. However, due to the exclusion of RJF from the mandates in the EU, the mandates do stimulate biofuels in general while the production of RJF is not stimulated under these mandates.

The market development has in the form of off-take agreements an influence on the willingness of private investors to invest. They need to be convinced of the demand, to take away the risk of not selling the produced fuels. Although airlines signed numerous off-take agreements with planned projects, the off-takes agreements are based on conventional oil prices therewith not providing any competitive price advantage relative to conventional fuels. An indirect relation is the fact that both investors and experts indicated a lack of objective information sharing, the information that is shared remains to be too academic and subjective. Both private and strategic investors would like to see clear objective information on economic factors and the potential of the technologies. This results in a negative influence of F3 (Knowledge exchange) on both F2 (Knowledge development) and F1 (Environmental experimentation). So although strategic investors cover part of the lacking private investments, the overall trend shows a lack of financial resources. The functions are not fulfilled well enough to successfully make the transition towards the take-off stage. With a better fulfilment of F4 (Guidance of the search) and F3 (Knowledge exchange) to take away the resistance to change (F7), the trust of investors in biofuels could be recovered. This could result in more activities within F1 (Entrepreneurial experimentation) and would pave the way for successful commercial facilities.

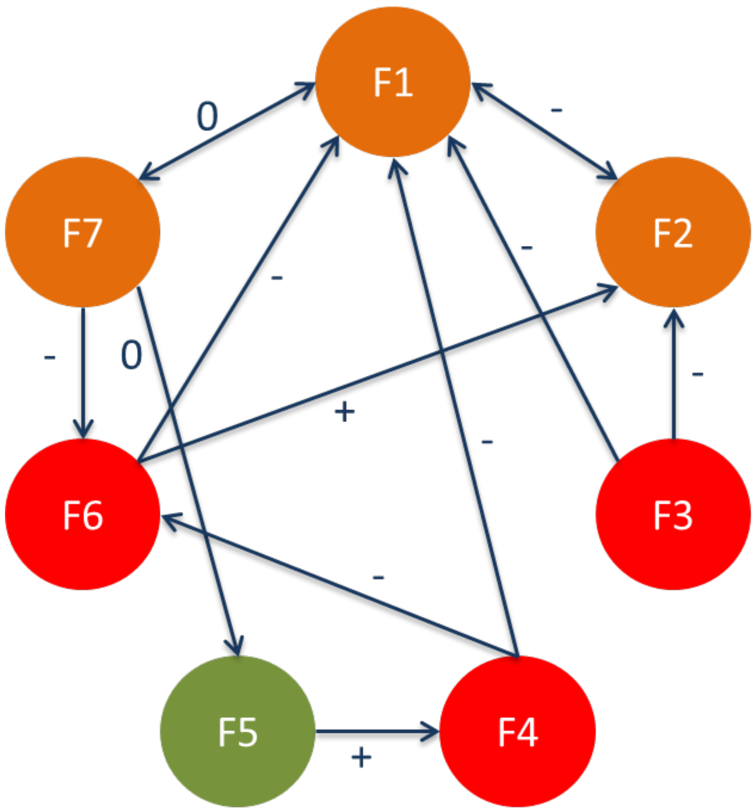

Figure 12. Functions model

4.3 Part 3 - Investment barriers and opportunities

The TIS analysis gave insight in the performance of the functions. In this section these functional performances are briefly summarized and translated into clear barriers and opportunities. Additionally a number of external barriers and opportunities are stated which were not touched upon in the functional analysis.

4.3.1 Barriers and opportunities

Policies

Policies have, as seen in F4 of the TIS, a lot of influence on the direction of the technology. The governmental influence can be a large barrier if it causes uncertainty, however if a long-term robust policy is established, investors will be attracted to the market due to the reduced risks. Policy was indicated in a TIS research in 2012, on the diffusion problems of renewable energies, as one of the barriers in advanced biofuels (Negro et al., 2012). Long term certainty is one of the key drivers for investors, as is suggested in industry reports, realistic achievable mandate levels are needed with a long-term (Lane, 2015d). A clear indication in the RJF market is that Europe is lacking this long-term policy hampering investments in the sector: *"Just talking about transport in general, until 2020 it is more or less clear. But it is completely open what happens after 2020. So for the biofuels there is a lot uncertainty in general. At least for the EU at the moment. That is obviously not helping the industry at all. They do not know, if they invest in a plant now, what is the status of policy in 2025. A slightly more clear vision would thus be helpful."* (Expert). It could be questioned however, whether long-term policies will ever be established. Due to the nature of changing political systems, there will always be some uncertainty. Therefore focus should not only be on 'as long-term as possible policies', but more on creating a level playing field for biofuel technologies: *"The primary issue we are trying to address is this level playing field with transport fuels. So in the UK and lots other places in the world there are incentives to produce ground transport fuels. currently they do not exist for jet fuels. We try to get equal incentives for jet fuels as well as ground transport fuels, that would be pretty key in attracting investments. They'll want to see not just clear carbon incentives, but also this signal from governments, that governments are supportive for renewable jet fuels."* (Strategic Investor)

Another point to address, as was touched upon in F5 of the function analysis, is the international nature of the aviation industry; it is complex and makes incentives hard to realise: *"The problem in aviation is its international nature, the consequence of that is that an international agreement will put up a very low cost ceiling of what is acceptable, but that will not drive the investments."* (Strategic Investor)

An example of a policy that could works as a driver is the possibility that the aviation industry put out their own regulations, which influence strategic actors to make the investment decision; FedEx wanted to claim the 'EU carbon credits' that do not yet even exist: *"They're thinking long-term and about the possibility of carbon regulation of aviation in the EU, and they knew that they could not just flip a switch and "go low-carbon" if the fuels were suddenly required."* (Lane, 2015c)

Knowledge exchange

Knowledge has been indicated in the function analysis as very important and sufficiently available in the sector. However investors often get biased knowledge, as the exchange of knowledge is being hampered. There seems to be a feel in the market that investors are not well informed on the technological pathways and the different opportunities these bring with them: *"There is definitely an education problem when you talk to people, even about any kind of alternative fuel they automatically assume ethanol and biodiesel, there is certainly education needed to build confidence that drop-ins are available."* (Expert)

Furthermore, the investors often only have a small set of specialists in the field of biomaterials. This strengthens the statement of the hesitancy due to previous biofuel investments. Because it is very likely that the one person responsible for the failures in other biofuel projects is still involved and thus extra critical on future applications in this field. *"The reality is that an investment team is comprised of you know, five or six individuals, and those individuals have experience in specific areas, and they will not be able to, not everyone can invest in everything. Purely because they do not have the experience behind it. And people tend to forget that human side of investments, you are not dealing with a company you are dealing with individuals."* (Public Investor)

To overcome this lack of knowledge within the investors, they often use external companies to provide due diligence on the project. However, the final decision remains with the small group of 'experts' within the investor itself: *"On every deal you have an independent technical advisor, which is an engineering firm which tells you if the technology is going to work, investors themselves do not have enough time or the skills to actually look at the technology underpinning the project is working or not. And thus rely very heavily on the advisors for that."* (Public Investor). These external advisors make their living on the lack of knowledge at both the investor and project side. Therefore, they are not very keen on establishing an open access information platform.

Although knowledge exchange is thus a large barrier and a better link between academic knowledge and investors should be stimulated. Better informed investors will not always lead to more investments, as investors who get informed will also be informed about possible bad sides of RJF which makes them more hesitant to invest.

Feedstock

Feedstock is indicated as a large barrier in the current supply-chain for all advanced biofuels. This has been topic of discussion in numerous previous biofuel researches and remains one of the biggest issues in the sector (Berndes et al., 2010; Cheng & Timilsina, 2011; Rajagopal et al., 2009). There are three main barriers regarding feedstocks: availability, location and price.

"The risk is the availability of the feedstock for the biofuels. I would think that that would be likely to be high on the agenda of any investor. If there is going to be availability for fuels and can you get contracts in place to secure the feedstock." (Private Investor). *"It is not just the reliability of feedstock it is the disjunction between costs on the feedstock side and the costs on the fuel side."* (Public Investor).

Then are there any opportunities for the RJF sector to focus on in order to solve these issues? Opportunities lie, regarding feedstock, within specific local regulations. The land-fill tax in the UK is an example of such policy, which creates opportunities as the waste feedstock get a negative price. *"Municipal solid waste is I think interesting, because there is the possibility of getting it, at least initially, at a negative cost."* (Expert) It is questionable however, whether this feedstock has the quality that is needed to produce biofuels. Also it is not sure how long this land-fill tax will remain to exist if suddenly the feedstock is of worth for biofuel production.

Off-Take agreements

The existence of off-take agreements at projects is a strong opportunity for investors to invest. As discussed in F5 of the function analyses airlines are willing to participate in RJF, this is partly due to the goals of IATA to have carbon neutral growth after 2020, and partly due to the possible RJF mandates that ICAO could create (Lane, 2015c). This is shown in the willingness of numerous airlines, at this moment 14 airlines have progressed to the point of signing an off-take or flying on a regular basis on RJF (Lane, 2015f). This is important to enhance investments: *"I think certainly for your first couple of plants you need an off-take agreement just because when you go to raise capital how are you going to evaluate the project if you do not have a base find of the product value, I mean you need something to base a number of sales on when you are looking at the forecast of a plant."* (Expert)

The downside and current barrier of off-take agreements is the fact that off-take agreements are based on fossil oil-prices. This does give some security to the income prospect for investors, however does not give RJF an advantage over fossil based jet fuels: *"The airlines do not commit certain prices. If the airlines committed to paying 5 dollars per gallon that would gave some way towards that encouraging investments. But they do not, often the airlines just say we are going to pay the market price, that is not pretty attractive."* (Interview 16)

Another barrier is that some organizations who might be interested in taking off RJF are not allowed to do so, one example is the United States Navy being a substantial investor in the development of RJF with different grants and support mechanisms. However they are not allowed to sign off-takes from upcoming technologies: *"But the government has been unable to sign any contract or even provide a letter of intent. A lot of that has got to do with the acquisition law. You can compete in those fuel off-takes if you are up and running. But if your facility is being built and has not proven any supply this regulation does absolutely nothing for you."* (Expert)

Oil industry

The economic feasibility of current projects is under a lot of pressure due to the low oil price. RJF compete directly with fossil sources, so in order for RJF projects to become successful a higher oil price will make it easier to compete. It is however discussed that investors might remain hesitant to invest even if the oil price comes up due to the uncertainty and chance of a falling oil price in the future: *"Even if oil prices were to go back up to where they were, investors will still be anti about investing, because they know it can fall again."* (Expert)

Besides the price of oil, the strong position of these oil-incumbents results in strong lobby groups. *"The petroleum lobby is constantly against alternative sources and alternative feedstocks."* (Expert). Such lobby has in previous research been indicated as a barrier for investments to flow into new technologies (Teppo & Wustenhagen, 2006; Ulmanen et al., 2009).

Price volatility

Price volatility can be seen as an opportunity, although at this point the low oil price puts pressure on the RJF development: *"I think one of the key barriers of any of the biofuels or any liquid fuel market is the volatility in oil pricing. Which provides external investors with almost no comfort on what returns they are going to generate."* (Public Investor). Airlines indicate the price volatility of oil as a reason to invest or sign off-take agreements with biofuel producers, because although the price might be high, RJF takes away uncertainties on security of supply: "*We always will have oil, but oil will become more expensive to explore and also to get kind of security of feedstock if you have more alternatives. So I think we might not have 100% biojet but if they're just several amounts there is a bit more flexibility."*(Strategic Investor).

Competition

Besides the oil price there is another potential hazard on the financial side of RJF. Competition is a two sided barrier. On the one hand there is competition for feedstock. As indicated, biomass is scarce so competition on the feedstock strengthen this scarcity even more: *"If you look at the producer of feedstock, e.g. a farmer, the business case for biofuels is not even a very interesting one. If you look at biomaterials, and you convert your agricultural waste streams into bulk chemicals, not even fine chemicals. You can make so much more money per hectare than if you would transfer it to fuels, so there is no incentive at all to substitute fuels."* (Private Investor)

On the other hand, RJF faces competition with renewable diesel and other products which could be produced with biofuel facilities: *"You could go out and buy, a jet A1 (RJF) right now with either Fischer-Tropsch or HEFA and unfortunately if you are looking at maximizing production of jet fuels on either of those pathways then your overall process yield is actually lower than if you would be looking to maximize diesel production."* (Expert)

History of biofuels and the lack of successful projects

First generation biofuels, and more recently KiOR had to cope with numerous set-backs and investors lost a substantial amount of their investments on these facilities. For these investors a clear negative influence on their decision making process is indicated: *"Yes absolutely, massive negative influence due to past failures. You also see it in waste gasification technologies there are a lot of investors who will not touch it because they have lost money in the past and once burned, twice shy. They just will not go near it at all, no matter how proven it is they just say no."* (Public Investor)

In the same light investors are influenced by successful projects. Once the first few facilities are online, financing becomes much easier and will influence the decision makers at the investor side (Solecki et al., 2011). Currently there is a lack of such projects creating a barrier for investors: *"Yes commercial successes are needed, everyone has heard the stories there has been the hype. The initial kind of hype died down, now we need a couple of these companies, the Red Rocks, or other companies to get commercial, to show that they can actually generate cash."* (Private Investor)

Technology scale-up

Another current barrier is the failure to prove the scale-up of the technologies. The technologies are often proven to be working on a small pilot or demonstration scale as shown by the technological pathways in the structural analysis. However on larger scale it seems that new problems arise, as one of the former large projects of advanced biofuels KiOR stated: *"The optimization projects and upgrades are targeted at improving throughput, yield and overall process efficiency and reliability. In terms of throughput, we have experienced issues with structural design bottlenecks and reliability that have limited the amount of wood that we can introduce to our BFCC system. These issues have caused the Columbus facility to run significantly below its nameplate capacity."* (Lane, 2015e). Both the yields, efficiency and reliability had issues as well, eventually resulting in the bankruptcy of KiOR.

Quality of partners and team

One of the factors influencing investments, often not taken into account is the quality of partners (e.g. technology providers). Investors indicate this as a vital point, to gain confidence in the project. As this factor changes from project to project, it cannot be stated as a barrier or opportunity. Therefore this factor is included as a general criterion. Red Rock works as an exemplary project where the investors praise the amount and quality of partners: *"They (Red Rock) did a tremendous job in terms of bringing partners to the table, very early. So they have got some announced partnerships with the US department of defence. They got off-take agreements announced with fed-ex and southwest (airlines). And they have a supply-agreement with a timber supplier and technology providers for various technologies. They did a very good job in putting together a project where a lot of the components are defined contractually and the economics are fairly defined contractually. Which is extremely unusual for a start-up in a project of this type. And made us as an investor confident to invest."* (Private Investor)

Besides the partners, the team of the project or company to invest in is important as well. This is already indicated by Feeney et al., in 1999 and confirmed in this thesis by the investor of Red Rock: *"What is really interesting about the project is that they have got a great operating team in the leadership. The CEO and CFO have financed, constructed and operated many bio-fuels plans, so they have got a lot of experience in this area, which is great."* (Private Investor)

4.3.2 Overview

In Figure 13, an overview is provided of the barriers and opportunities regarding investments in RJF, the barriers are indicated on the left, while the opportunities are on the right. In the centre, the general criterion to stimulate investments is provided. It should be noted that factors could move from a barrier towards opportunities if conditions change. As an example, if oil prices come back up this can turn into an opportunity for future RJF investors.

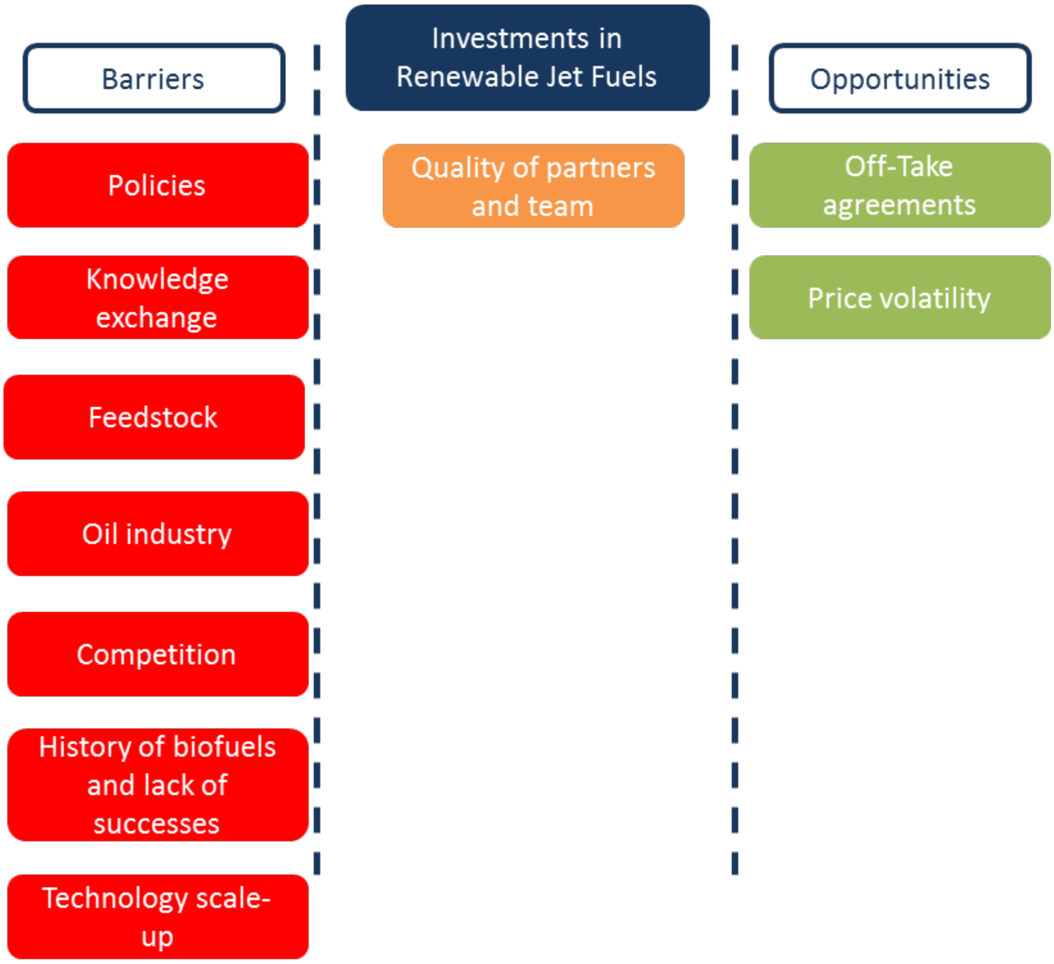

Figure 13. Overview of barriers and opportunities

5 Discussion

This discussion consists of three parts, the first part states the theoretical implications of this thesis. This is followed by the implications for society that can be derived from this thesis. In the final part the limitations are discussed and recommendations for future research are provided.

5.1 Theoretical implications

This thesis has three major theoretical implications. At first, this thesis contributes to the body of literature regarding the factors influencing investment decision making. This thesis confirms the classical investment theories about the importance of economic risk-management, such as financial returns and feedstock securities (Arrow & Lind, 1970; Ehrlich et al., 1994; Fenn et al., 1996). Additionally, this thesis showed the importance of non-economic factors and their influence on the investors decision making process. One important and well established insight in the investment decision making process, is the existence of bounded rationality (Feeney et al., 1999; Simon, 1955). Investors, in this thesis, confirmed that they often could not obtain enough objective information, which negatively influenced their investment decision making process. This thesis showed that this lack of objective information resulted in investors to be relying heavily on their own interpretation which is influenced by their own experience, the opinion of external advisors and lobby groups. This also contributes to the findings of Masini and Menichetti (2013), showing the influence of low confidence of the investor and its external advisors on their decision to not invest in a technology. This factor might also explain the (lack of) investments in other renewable technologies that compete with strong incumbents and strong lobby groups. Therewith this thesis also confirmed the research conducted by Wüstenhagen and Menichetti (2012), who stated that the perception of risk and return is as important and should be taken into account equally as actual risk and return.

Additional to the perception that influence investors' decision making process, there is the theory about path dependency in venture capital investments. Teppo & Wustenhagen (2006) showed the difficulty of attracting private funding into the emerging renewable energy sector. Investors will invest more easily in sectors they know and have affinity with, than in new emerging ones, despite similar risks and return opportunities. Pinkse and van den Buuse (2012) went a step further and concluded that investors see better risk-return options on their previous path they invested in than in the less familiar territory of renewable energies. In this thesis these findings are extended with a negative experience in a previous path. In the RJF sector private investors seem to see worse risk-return options due to their losses in their previous path: first generation biofuels.

This thesis further contributes to the theory of Technological Innovation Systems. The TIS is often used to analyse a technology in general or to describe a technological transition (Bergek et al., 2008; Hekkert et al., 2011; Negro et al., 2012; Suurs & Hekkert, 2009a). In this thesis, the TIS is used to find factors influencing the performance of one part of the system, investments. By analysing the TIS, a broad range of influencing factors could be analysed systematically, which still makes it a relevant framework to use. Furthermore, this thesis showed that focusing on one part of the system can result in more specific societal implications and recommendations for policymakers, providing a possible solution to the often heard criticism in TIS literature that recommendations and implications remain too generic (Bening et al., 2015). There has been criticism that contextual factors are hard to incorporate in the TIS analyses as well (Markard et al., 2015; Markard & Truffer, 2008). By focusing on one part of the TIS and including complementary literature on the topic of investors lead to the possibility to incorporate such external factors more easily in the TIS. Including this context and creating more specific recommendation, by focusing on one part of the TIS, could therefore be applied in other cases as well.

5.2 Societal implications

This thesis showed that there is a need for clear guidance of the RJF technologies. As there is a wide diversity of technologies, the scare financial resources are split inefficiently across the numerous technological pathways. Therefore, policy makers should focus on setting the right circumstances to enable the best technologies to develop. Two policy actions are important to enable this. The first is the need for stable policy, as explained in numerous previous studies (Masini & Menichetti, 2010; Suurs & Hekkert, 2009a; Wood, 2012). Exemplary for the current unstable policy situation is that 3 out of 5 NER300 projects are ceased due to uncertainties about future policy. The second policy action should enable a fair competition with road biofuels. Road biofuels are currently incentivised while RJF is left out of these policies, as a consequence RJF is not incentivised compared to road biofuels. Creating a level playing field for the different biofuel technologies and their market opportunities is therefore key, to enable the best technology to develop.

Another societal implication is the discussion about availability of resources in early growth stages (Mason & Harrison, 2001; Nicholson, 2000; Queen, 2002). The results of this thesis showed that both experts and investors state there is widespread availability of cash in the market, looking for a place to be invested in. However, the private investors state that risks in projects are too high, and project owners are not able to convince investors that their projects have manageable risks. An interesting insight from this thesis is the involvement of strategic investors in the advanced biofuel projects, partly solving this lack of private investments. Contrary to what one would expect from theory, strategic investors take up the role of private investors bridging the 'valley of death' and taking the high risks to reach their own strategic goals (Bürer & Wüstenhagen, 2009; Wüstenhagen & Menichetti, 2012). Policy makers could use this knowledge to create policy to stimulate this involvement of strategic investors.

In order to attract the private investors and take away their perception of high risks in advanced biofuel projects it is necessary to learn from the United States situation. Demonstration facilities are longer stimulated by governmental policies in order to get the technology through the valley of death and lower risks. This has a two-sided affect as it enables investors to get genuine experience with a technology before they have to take high risks. Scaling up too fast outside the safety of research institutes, as has happened with the meanwhile bankrupt KiOR project, could prejudice investors against the whole advanced biofuels area.

A last societal implication is about the lack of knowledge exchange. Project owners could and should actively inform investors, instead of assuming the investors know the market dynamics. Investors often do not have the specific knowledge about technologies and should therefore be better informed, showing the issue addressed by Mason & Stark (2004) that project owners are not stating the right information in their business plans. However, investors will not trust the information from the project owners right away, as the project owners have a clear personal interest in attracting the investors' money. This also addresses the problem of the consultants, in between investors and project owners, as they are keen on keeping both groups unaware of the opposite side, to leave them dependent of their own consultancy information. To solve this knowledge exchange issue, the TIS analysis shows the importance of independent knowledge networks. Policy makers should create more knowledge networks such as the IEA Bioenergy platform (2015), to show the progress of the RJF sector. This also helps policy makers to educate themselves to keep up to date about the technological possibilities and objectively analyse the potential of RJF. This would help policy makers to justify investments in RJF over other technologies that could decarbonise industries.

5.3 Limitations and future research

This thesis has several limitations which reveal a number of topics for future research, these are discussed in the following. The database of projects was created during this thesis by analysing the advanced biofuel projects in the United States and European Union. This sample is deemed representative for the market due to the majority of projects going on in both these areas. However, due to the history of first generation biofuels currently plants in e.g. the South American region are retrofitted for advanced biofuel purposes. Therefore, including a wider regional focus might result in other drivers for investment, missed in this thesis. Retrofitting a plant could for example be very interesting for the current owner of the plant and could thus result in a strong opportunity for strategic investors. Additionally, the projects are analysed by extending the database created by IEA Bioenergy (2015), with additional projects and investor involvement. It should be kept in mind that these projects provide a representative overview at the current moment in time. However, due to the infancy of the sector, projects can disappear and involvement of a specific investor group can change quickly due to changed policies or market dynamics. Therefore when interpreting the results the timeframe of the projects and the moment of writing of this thesis should be closely kept in mind.

Furthermore, due to the infancy of the sector, it would be interesting to see whether the barriers indicated in this thesis were indeed of importance on the industry after the industry has developed towards a commercial success or failure. Therefore a future study looking in hind-sight to the industry, using for example, a history event analysis, a common used method in innovation system research, would contribute to the results of this thesis (Hekkert et al., 2007; Suurs & Hekkert, 2009a, 2009b).

Another limitation within this thesis is the distinction and focus on three 'investor groups'. This distinction is based on previous literature, and due to the limited information the investors were willing to provide this broad distinction was necessary. If a more in depth description of financial options (e.g. a distinction between, grants and debt finance) is used, other more specific barriers might come to light. Furthermore this thesis remains to be mainly descriptive. As the results are qualitatively assessed, it would be very interesting to use these findings in a quantitative research and see whether the barriers and opportunities hold. Due to the hesitancy of investors to talk about their investment criteria, an anonymous survey could provide such insights.

This thesis focusses on investors and experts from the advanced biofuel sector. This led to the result that policy action is needed on numerous market failures. However, conducting a similar TIS analysis and putting e.g. policy makers central, could result in very different results. With such additional research, the different influencing factors important for other actors in the sector can be found. Additional research to the sector from different perspectives could therewith help to build a comprehensive overview of the sector.

6 Conclusion

By creating a database of 56 advanced biofuel projects and interviewing 21 stakeholders in the advanced biofuel sector, this thesis answered the following question: *What is the current state of investments in the advanced biofuel sector and what are opportunities and barriers for investors to invest in the Renewable Jet Fuel sector?*

Three sub-questions were used to find an answer on this question. The first showed the large involvement of strategic investors in advanced biofuels projects. Private investors, on the other hand, seem to be hesitant to invest. As expected from the literature, public investors are involved intensively to support the technology in its early stage of development. The second sub-question elaborated on the state of the Technological Innovation System. The TIS showed that the functions resource mobilisation, guidance of the search and knowledge exchange are not fulfilled and hamper the construction of the TIS. The function market formation is a well fulfilled function in the TIS. This is also the function in which RJF distinguishes itself from road biofuels, due to the limited decarbonisation options in the aviation sector. The other functions of the TIS were neutrally fulfilled with both positive and negative aspects. The final sub-question listed the opportunities and barriers to invest in RJF. The analysis showed that: current policies, knowledge exchange, feedstock, oil price, competition on feedstock and production capacity, history of failed biofuel projects and problems with scaling-up facilities are current barriers. The willingness and need of the aviation industry to become sustainable becomes visible in the form of off-take agreements and is, together with the price volatility of conventional oil, the biggest opportunity for current investors.

This thesis has two major implications on theory. The thesis focused on one part of the TIS, investment, resulting in the ability to include more contextual factors and propose more specific policy recommendation. Furthermore, the thesis found that previous investments and lack of knowledge have a negative influence on the investments in RJF, therewith building upon the academic literature regarding non-economic factors influencing the investment decision making process. For policy makers this thesis suggests that a stable policy is needed, which enables a level playing field for different biofuel technologies to develop. Also specific policy is needed to support different investor groups; in the case of RJF strategic investors should be supported for taking the high risks, which private investors are not willing to take. Furthermore, an independent knowledge network should be created to educate both investors and policy makers themselves about the progress of RJF and overcome the biased information from project owners or intermediaries.

Future research should verify the results when the sector is fully developed. Furthermore, focusing on one specific part of the TIS analyses provided interesting and rich insights into the factors influencing this actor group. Therefore, this should be repeated on a different actor group within RJF as well as on other industries.

7 References

Abengoa. (2013). *Abengoa inaugurates its first demonstration plant using Waste-to-Biofuels (W2B) technology*.

Abengoa. (2014). *Abengoa celebrates grand opening of its first commercial-scale next generation biofuels plant*.

Abengoa Bioenergy. (2011). Abengoa Bioenergy Partnerships. Retrieved July 11, 2015, from http://www.abengoabioenergy.com/web/en/acerca_de/colaboraciones/

Abengoa Solar Inc. (2013). Form F-1 Abengoa. Retrieved July 10, 2015, from http://www.sec.gov/Archives/edgar/data/1161785/000104746913009517/a2216882zf-1.htm

ABLC Next. (2015). ABLC What is next for the advanced bioeconomy. Retrieved October 26, 2015, from http://advancedbiofuelssummit.com/

Alberici, S., Spottle, M., & Toop, G. (2014). *Assessment of sustainability standards for biojet fuel Final report Assessment of sustainability standards for biojet fuel*. *Ecofys*.

AliphaJet Inc. (2012). AliphaJet joins ABFA, begins biojet commercial scale-up program. Retrieved July 2, 2015, from http://www.biodieselmagazine.com/articles/8573/aliphajet-joins-abfa-begins-biojet-commercial-scale-up-program

AltAir Fuels. (2015). AltAir Fuels partners. Retrieved July 10, 2015, from http://altairfuels.com/our-partners/

Aquatic Energy. (2015). *Aquatic Energy converting algae to food and fuel Overview*.

Arrow, K., & Lind, R. (1970). Uncertainty and the Evaluation of Public Investment Decisions. *American Economic Review*, *60*(3), 364–378.

Bastasch, M. (2015). The Ethanol mandate harms air quality, "leads to increased mortality." Retrieved October 3, 2015, from http://dailycaller.com/2015/07/23/scientist-the-ethanol-mandate-harms-air-quality-leads-to-increased-mortality/?utm_source=dlvr.it&utm_medium=twitter

Bauen, A., Howes, J., Bertuccioli, L., & Chudziak, C. (2009). *Review of the potential for biofuels in aviation*. *E4tech*. London.

Bauhaus Luftfahrt. (2015). Bauhaus Luftfahrt Neuwe Wege. Retrieved October 2, 2015, from http://www.bauhaus-luftfahrt.net/

Bening, C. R., Blum, N. U., & Schmidt, T. S. (2015). The need to increase the policy relevance of the functional approach to Technological Innovation Systems (TIS). *Elsevier*, *16*, 73–75.

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., & Rickne, A. (2008). Analyzing the functional dynamics of technological innovation systems: A scheme of analysis. *Research Policy*, *37*(3), 407–429.

Berndes, G., Hansson, J., Egeskog, A., & Johnsson, F. (2010). Strategies for 2nd generation biofuels in EU – Co-firing to stimulate feedstock supply development and process integration to improve energy efficiency and economic competitiveness. *Biomass and Bioenergy*, *34*(2), 227–236.

Beta Renewables. (2013a). Beta Renewables Project Alpha. Retrieved July 8, 2015, from http://www.betarenewables.com/projects/3/alpha

Beta Renewables. (2013b). Crescentino in Figures. Retrieved June 15, 2015, from http://www.betarenewables.com/crescentino/project

Beta Renewables. (2014). Biochemtex and Beta Renewables signed a contract with energochemica SE for the construction of a 2nd generation ethanol plant in the Slovak Republic. Retrieved June 16, 2015, from http://www.betarenewables.com/press-release-detail/3/biochemtex-and-beta-renewables-signed-a-contract-with-energochemica-se-for-the-construction-of-a-2nd-generation-ethanol-plant-in-the-slovak-republic

Biofuels international expo & conference. (2015). Biofuels International Conference. Retrieved October 26, 2015, from http://biofuels-news.com/conference/

BioGasol. (2015). Biogasol is a leading supplier of advanced sugar extration systems. Retrieved June 16, 2015, from http://www.biogasol.com/

Bioliq. (2014). What is Bioliq? Retrieved August 10, 2015, from http://www.bioliq.de/english/24.php

Borregaard. (2015). The world's leading biorefinery. Retrieved August 11, 2015, from http://www.borregaard.com/content/view/full/10231

Brown, T., & Brown, R. (2013). A review of cellulosic biofuel commercial-scale projects in the United States. *Biofuels, Bioproducts and Biorefining*, *7*(3), 235–245.

Bryman, A. (2012). *Social Research Methods*. *Social Research Methods*. Oxford university press.

Bürer, & Wüstenhagen. (2009). Which renewable energy policy is a venture capitalist's best friend? Empirical evidence from a survey of international cleantech investors. *Energy Policy*, *37*(12), 4997–5006.

Business Wire. (2015). Investment from Flagship Ventures brings red rock biofuels closer to construction of its first commercial biofuel refinery. Retrieved July 2, 2015, from http://www.businesswire.com/news/home/20150317005218/en/Investment-Flagship-Ventures-Brings-Red-Rock-Biofuels#.VZvJ1_lVi1j

Butamax. (2015). Butamax Advanced Biofuels. Retrieved June 16, 2015, from http://www.butamax.com/biofuel-company.aspx

Buzzell, R. (1966). Competitive behavior and product life cycles. *New Ideas for Successful Marketing*, 46–68.

CAAFI. (2010). Fuel Readiness level. Retrieved July 5, 2015, from http://www.caafi.org/information/fuelreadinesstools.html

Carlsson, B., & Stankiewicz, R. (1991). On the nature, function and composition of technological systems. *Evolutionary Economics*, 93–118.

Chempolis. (2015). Chempolis. Retrieved August 11, 2015, from http://www.chempolis.com/solutions/biofuel-industry/

Cheng, J. J., & Timilsina, G. R. (2011). Status and barriers of advanced biofuel technologies: A review. *Renewable Energy*, *36*(12), 3541–3549.

Christensen, C. (2013). *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail*. Harvard Business Review Press. Retrieved from https://books.google.com/books?hl=nl&lr=&id=3JnBAgAAQBAJ&pgis=1

Cobalt. (2015). Cobalt commercialization. Retrieved July 2, 2015, from http://www.cobalttech.com/commercialization.html

Cool Planet. (2014). Cool Planet First Commercial Facility. Retrieved July 2, 2015, from http://www.coolplanet.com/products-technology/first-commercial-facility

Culverwill, W. (2015). Boston firm backs Lakeview ' s $ 200M biomass plan. *Portland Business Journal*, *1*(1), 2–3.

Diamon Green Diesel. (2012). Diamon green Diesel. Retrieved from http://www.diamondgreendiesel.com/Pages/default.aspx

District Energy. (2013). Fortum to start supplying bio-oil to a local energy company. Retrieved August 10, 2015, from http://www.districtenergy.org/blog/2013/10/15/fortum-to-start-supplying-bio-oil-to-a-local-energy-company/

Dow, J., Ribeiro, S., Econometrica, S., & Jan, N. (1992). Uncertainty aversion, risk aversion, and the optimal choice of portfolio. *Econometrica*, *60*(1), 197–204.

DuPont. (2013). *DuPont cellulosic ethanol: commercializing advanced renewable fuel in Iowa*.

DuPont. (2015). The DuPont Cellulosic Ethanol Facility in Nevada, Iowa: Leading the way for commercialization. Retrieved July 10, 2015, from http://www.dupont.com/products-and-services/industrial-biotechnology/advanced-biofuels/cellulosic-ethanol/nevada-iowa-cellulosic-ethanol-plant.html

E2 Environmental Entrepreneurs. (2014). *Advanced Biofuel Market Report*.

EBTP. (2015). Biofuels for air transport. Retrieved June 22, 2015, from http://www.biofuelstp.eu/aviation-biofuels.html

Ehrlich, S., De Noble, A., Moore, T., & Weaver, R. (1994). After the cash arrives: A comparative study of venture capital and private investor involvement in entrepreneurial firms. *Journal of Business Venturing*, *9*, 67–82.

Emerald Biofuels. (2015). Emeral Biofuels Projects. Retrieved July 3, 2015, from https://emeraldonellc-public.sharepoint.com/projects

ENI. (2014a). *ENI refining & marketing; the Venice Biorefinery*.

ENI. (2014b). *Green Refinery : reinventing petroleum refineries*.

EPA. (2015). Program overview for renewable fuel standard program. Retrieved October 1, 2015, from http://www2.epa.gov/renewable-fuel-standard-program/program-overview-renewable-fuel-standard-program

Erickson, B. (2015). Why is EPA proposing to continue delaying the arrival of advanced biofuels. Retrieved October 1, 2015, from http://www.biofuelsdigest.com/bdigest/2015/07/07/why-is-epa-proposing-to-continue-delaying-the-arrival-of-advanced-biofuels/

EUDP. (2014). *Inbicon and Terranol collaboration demonstrates a fast , high yielding process for 2G bioethanol production*.

European Biofuels Technology Platform. (2015). R&D&D Funding and Projects. Retrieved October 1, 2015, from http://www.biofuelstp.eu/funding.html#discont

European Commission. (2014). Horizon 2020. Retrieved October 1, 2015, from http://ec.europa.eu/programmes/horizon2020/en/what-horizon-2020

Fagerberg, J., Mowery, D. C., & Nelson, R. R. (2006). *The Oxford Handbook of Innovation*. *The Oxford Handbook of Innovation*. Oxford Handbooks Online.

Feeney, L., Haines, G. H., & Riding, A. L. (1999). Private investors' investment criteria: Insights from qualitative data. *Venture Capital*, *1*(2), 121–145.

Fenn, G., Liang, N., & Prowse, S. (1996). The Economics of the Private Equity Market. *Board of the Governors of the Federal Reserve System*, (December 1995), 1–69.

Fortum. (2015). Bio-Oil. Retrieved August 10, 2015, from http://www.fortum.com/en/products-and-services/biooil/pages/default.aspx

Foxon, T. J., Gross, R., Chase, A., Howes, J., Arnall, A., & Anderson, D. (2005). UK innovation systems for new and renewable energy technologies: drivers, barriers and systems failures. *Energy Policy*, *33*(16), 2123–2137.

Fuglie, K., Heisey, P., King, J., & Pray, C. (2011). *Research Investments and Market Structure in the Food Processing , Agricultural Input , and Biofuel Industries Worldwide Visit Our Website To Learn More !*

Fulcrum Bioenergy. (2015). Fulcrum Bioenergy Partners. Retrieved July 2, 2015, from http://fulcrum-bioenergy.com/partners/

Futurol. (2012). Project Futurol. Retrieved June 15, 2015, from http://www.projet-futurol.com/Le-Projet_a21.html

Gas Technology Institute. (2015). Making green gasoline in an integrated biorefinery. Retrieved July 2, 2015, from http://www.gastechnology.org/Solutions/Pages/Making-green-gasoline.aspx

Gegg, P., Budd, L., & Ison, S. (2015). Stakeholder Views of the Factors Affecting the Commercialization of Aviation Biofuels in Europe. *International Journal of Sustainable*

Transportation, *9*(8), 542–550. Retrieved from http://www.tandfonline.com/doi/abs/10.1080/15568318.2013.825824

Greasoline. (2015). Greasoline. Retrieved August 4, 2015, from http://www.greasoline.com/

Green Car Congress. (2012). Progress toward commercializing the GTI IH2 thermochemical process for drop-in hydrocarbon fuels. Retrieved July 2, 2015, from http://www.greencarcongress.com/2012/08/gtiih2-20120821.html

Green Star Products. (2015). Green Star products, Inc. Outlook for 2015. Retrieved from http://www.gspi.com/c.htm

Grubb, M. (2005). Technology innovation and climate change policy: An overview of issues and options. *KEIO Economic Studies*, *41*(2), 103–132.

Hamelinck, B. C., Cuijpers, M., Spoettle, M., & Bos, A. Van Den. (2013). *Biofuels for Aviation*.

Harrington, K. (2015). Alt-Air's bio-jet fuel to power United's planes this summer. Retrieved July 10, 2015, from http://www.aiche.org/chenected/2015/07/alt-airs-bio-jet-fuel-power-uniteds-planes-summer

Hekkert, M. P., Negro, S., Heimeriks, G., & Harmsen, R. (2011). Technological Innovation System Analysis. Faculty of Geosciences. Retrieved from http://www.innovation-system.net/wp-content/uploads/2013/03/UU_02rapport_Technological_Innovation_System_Analysis.pdf

Hekkert, M. P., & Negro, S. O. (2009). Functions of innovation systems as a framework to understand sustainable technological change: Empirical evidence for earlier claims. *Technological Forecasting and Social Change*, *76*(4), 584–594.

Hekkert, Suurs, Negro, Kuhlmann, S., & Smits, R. E. H. M. (2007). Functions of innovation systems: A new approach for analysing technological change. *Technological Forecasting and Social Change*, *74*(4), 413–432.

Hellmann, T., & Thiele, V. (2014). Friends or foes? The interrelationship between angel and venture capital markets. *Journal of Financial Economics*, *115*(3), 639–653.

IATA. (2014). *International Air Transport Association 2014 Report on Alternative Fuels, Effecrtive December 2014*.

IEA Bioenergy. (2015). Commercializing 1st and 2nd generation liquid biofuels from biomass. Retrieved August 10, 2015, from http://demoplants.bioenergy2020.eu/projects/mapindex

INEOS Bio. (2011). *Indian river bioenergy center*.

Iowa Energy Center. (2014). *Becon Facility*.

Jacobsson, S., & Bergek, A. (2004). Transforming the energy sector: the evolution of technological systems in renewable energy technology. *Industrial and Corporate Change*, *13*(5), 815–849.

Jacobsson, S., & Johnson, A. (2000). The diffusion of renewable energy technology: An analytical framework and key issues for research. *Energy Policy*, *28*, 625–640.

Janssen, R., Rutz, D., Mergner, R., & Janssen, R. (2013). Production facilities for second-generation biofuels in the USA and the EU – current status and future perspectives. *Biofuels Bioproduct & Biorefining*, *7*, 647–665.

Jessen, H. (2014). Fiberight still working at MSW plant in Iowa. *Biomass Magazine*. Retrieved from http://fiberight.com/fiberight-still-working-at-msw-plant-in-iowa/

Karlsruhe Institute of Technology. (2013). First Gasoline Produced by KIT. Retrieved August 10, 2015, from https://www.kit.edu/kit/english/pi_2013_13992.php

Kleer, R. (2010). Government R&D subsidies as a signal for private investors. *Research Policy*, *39*(10), 1361–1374.

Klepper, S. (1996). Entry , Exit , Growth , and Innovation over the Product Life Cycle. *The American Economic Review*, *86*(3), 562–583.

Klette, T. J., Møen, J., & Griliches, Z. (2000). Do subsidies to commercial R&D reduce market failures? Microeconometric evaluation studies. *Research Policy*, *29*(4-5), 471–495.

KLM. (2012). Grote KLM-Klanten kiezen voor biofuel. Retrieved October 20, 2015, from https://klmtakescare.com/nl/content/grote-klm-klanten-kiezen-voor-biofuel

Lane, J. (2012). Paradigm BioAviation announces $120M aviation biofuels project in Illinois. Retrieved August 10, 2015, from http://www.biofuelsdigest.com/bdigest/2012/12/20/paradigm-bioaviation-announces-120m-aviation-biofuels-project-in-illinois/

Lane, J. (2014a). Empyro breaks ground on biomass pyrolysis oil production plant in the Netherlands. Retrieved August 11, 2015, from http://www.biofuelsdigest.com/bdigest/2014/05/27/empyro-breaks-ground-on-biomass-pyrolysis-oil-production-plant-in-the-netherlands/

Lane, J. (2014b). Inside the US Navy's cost-competitive military biofuels program. Retrieved July 2, 2015, from http://www.biofuelsdigest.com/bdigest/2014/09/21/inside-the-us-navys-new-cost-competitive-military-biofuels-program/

Lane, J. (2014c). Solazyme and the year of living dangerously. Retrieved July 10, 2015, from http://www.biofuelsdigest.com/bdigest/2014/03/03/solazyme-and-the-year-of-living-dangerously/

Lane, J. (2014d). US Navy, DOE, USDA award $210M for 3 biorefineries and mil-spec fuels. Retrieved July 3, 2015, from http://www.biofuelsdigest.com/bdigest/2014/09/19/breaking-news-us-navy-doe-usda-award-210m-for-3-biorefineries-and-mil-spec-fuels/

Lane, J. (2015a). Amyris, Total to commercialize renewable, low-carbon jet fuel technology; Total takes 75% stake in JV. Retrieved July 20, 2015, from http://www.biofuelsdigest.com/bdigest/2015/06/30/amyris-total-to-commercialize-renewable-low-carbon-jet-fuel-technology/

Lane, J. (2015b). BP's exit from cellulosic ethanol: the assets, the auction, the process, the timing, the skinny. Retrieved July 20, 2015, from http://www.biofuelsdigest.com/bdigest/2015/01/18/bps-exit-from-cellulosic-ethanol-the-assets-the-auction-the-process-the-timing-the-skinny/

Lane, J. (2015c). FedEx, Southwest Airlines combine to buy entire jet fuel output of Red Rock biorefinery, through 2024. Retrieved July 21, 2015, from http://www.biofuelsdigest.com/bdigest/2015/07/21/fedex-southwest-airlines-combine-to-buy-entire-jet-fuel-output-of-red-rock-biorefinery-through-2024/

Lane, J. (2015d). Industry's withering critique of EPA's Renewable Fuel Standard proposals for 2014, 2015, 2016: The Digested version. Retrieved August 3, 2015, from http://www.biofuelsdigest.com/bdigest/2015/07/29/industrys-withering-critique-of-epas-renewable-fuel-standard-proposals-for-2014-2015-2016-the-digested-version/

Lane, J. (2015e). KiOR announces $347M loss for 2013: "We have substantial doubts about our ability to continue as a going concern." Retrieved October 14, 2015, from http://www.biofuelsdigest.com/bdigest/2014/03/17/kior-announces-347m-loss-for-2013-we-have-substantial-doubts-about-our-ability-to-continue-as-a-going-concern/

Lane, J. (2015f). The airlines: who's doing what in aviation biofuels? Retrieved October 27, 2015, from http://www.biofuelsdigest.com/bdigest/2015/10/19/the-airlines-whos-doing-what-in-aviation-biofuels/

Lane, J. (2015g). The Pyromaniax, Class of 2015: The Top 10 Pyrolysis projects in renewable fuels. Retrieved August 11, 2015, from http://www.biofuelsdigest.com/bdigest/2015/08/03/the-pyromaniax-class-of-2015-the-top-10-pyrolysis-projects-in-renewable-fuels/

Lane, J. (2015h). United Airlines invests $30M in Fulcrum BioEnergy; inks $1.5B+ in aviation biofuels contracts. Retrieved June 30, 2015, from http://www.biofuelsdigest.com/bdigest/2015/06/30/united-airlines-invests-30m-in-fulcrum-bioenergy-inks-1-5b-in-aviation-biofuels-contracts/

Lane, J. (2015i). What is UOP? The renewable story revealed. Retrieved July 27, 2015, from http://www.biofuelsdigest.com/bdigest/2015/07/27/whats-uop-at-uop-the-renewables-story-revealed/

Lane, J. (2015j). Why such a struggle to advance renewable fuels? The games people play. Retrieved October 2, 2015, from http://www.biofuelsdigest.com/bdigest/2015/07/03/why-such-a-struggle-to-advance-renewable-fuels-the-non-cooperative-games-people-play/

Lanzatech. (2015). LanzaTech. Retrieved July 10, 2015, from http://www.lanzatech.com/company/investors/

Lee, D., Lim, L., & Owen, B. (2013). *Bridging the Aviation CO 2 Emissions Gap Report Principal investigators included*. Manchester Metropolitan University.

Lemer, J. (1996). *The government as venture capitalist: The long-run impact of the SBIR program. National bureau of economic research*.

Macias, J. (2011). Form S-1 Fulcrum BioEnergy, Inc. Retrieved July 2, 2015, from https://www.sec.gov/Archives/edgar/data/1434441/000119312511254422/d234433ds1.htm

Markard, J., Hekkert, M., & Jacobsson, S. (2015). The technological innovation systems framework: Response to six criticisms. *Environmental Innovation and Societal Transitions*, *16*, 76–86.

Markard, J., & Truffer, B. (2008). Technological innovation systems and the multi-level perspective: Towards an integrated framework. *Research Policy*, *37*(4), 596–615.

Masini, A., & Menichetti, E. (2010). The impact of behavioural factors in the renewable energy investment decision making process: Conceptual framework and empirical findings. *Energy Policy*, *40*(1), 28–38.

Masini, A., & Menichetti, E. (2013). Investment decisions in the renewable energy sector: An analysis of non-financial drivers. *Technological Forecasting and Social Change*, *80*(3), 510–524.

Mason, C., & Harrison, R. (2001). "Investment Readiness": A Critique of Government Proposals to Increase the Demand for Venture Capital. *Regional Studies*, *35*(7), 663–668.

Mason, C., & Stark, M. (2004). What do Investors Look for in a Business Plan?: A Comparison of the Investment Criteria of Bankers, Venture Capitalists and Business Angels. *International Small Business Journal*, *22*(3), 227–248.

Mason, & Harrison. (2002). Barriers to investment in the informal venture capital sector. *Entrepreneurship & Regional Development*, *14*(3), 271–287.

Mawhood, R., Cobas, A., Slade, R., & Final, S. (2014). *Establishing a European renewable jet fuel supply chain: the technoeconomic potential of biomass conversion technologies*. *RENJET Climate KIC*.

Mazzucato, M. (2011). *The entrepreneurial state: Debunking public vs. private sector myths* (1st ed.). Anthem Press.

NABC&E. (2015). National Advanced Biofuels Conference & Expo. Retrieved October 26, 2015, from http://www.advancedbiofuelsconference.com/ema/DisplayPage.aspx?pageId=Home

Negro, S. O., Alkemade, F., & Hekkert, M. P. (2012). Why does renewable energy diffuse so slowly? A review of innovation system problems. *Renewable and Sustainable Energy Reviews*, *16*(6), 3836–3846.

Neste Oil. (2015). Innovation that fuels the future. Retrieved August 11, 2015, from https://www.neste.com/en

Nicholson, M. (2000). Scotland survey: angels venture further afield. *Financial Times*.

NREL. (2009). Biochemical Conversion Projects. Retrieved July 3, 2015, from http://www.nrel.gov/biomass/proj_biochemical_conversion.html

O'Reilly, C. ., & Tushman, M. L. (2004). The ambidextrous organization. *Harvard Business Review*, 4–9.

Peter Haug. (2015). Founding Angel Activities. Retrieved August 4, 2015, from http://www.peterhaug.de/experience/founding-angel-activities/

Pinkse, J., & van den Buuse, D. (2012). The development and commercialization of solar PV technology in the oil industry. *Energy Policy*, *40*(1), 11–20.

POET DSM. (2014). Project Liberty. Retrieved July 25, 2015, from http://poet-dsm.com/liberty

Preem. (2014). Preem invests SEK 300 Million in new biofuel capacity. Retrieved August 10, 2015, from https://www.preem.se/en/in-english/investors/corral/results-and-reporting/2014/preem-invests-sek-300-million-in-new-biofuel-capacity/

Proctor, C. (2015). Biofuel from new $ 200M Southern Oregon plant destined for FedEx jet engines. *Portland Business Journal*, 1.

Queen, M. (2002). Government policy to stimulate equity finance and investor readiness. *Venture Capital*, *4*(1), 1–5.

Ragwitz, M., & Miola, A. (2005). Evidence from RD&D spending for renewable energy sources in the EU. *Elsevier*, *30*(11), 1635–1647.

Rajagopal, D., Sexton, S., Hochman, G., & Zilberman, D. (2009). Recent Developments in Renewable Technologies: R&D Investment in Advanced Biofuels. *Annual Review of Resource Economics*, *1*(1), 621–644.

Renew. (2008). Renew sustainable energy systems for transport. Retrieved August 15, 2015, from http://www.renew-fuel.com/home.php

Research Triangle Institute. (2015). *Biomass Conversion Equipment/Test Systems*.

Rink, D. R., & Swan, J. E. (1979). Product life cycle research: A literature review. *Journal of Business Research*, *7*(3), 219–242.

Roberts, D. G. (2013). *Progress and Barriers in Renewable Investment*.

Rogers, M. (1962). *Diffusion of Innovations*. Simon and Schuster.

Sapp, M. (2014). Emeral Biofuels to use UOP's renewable diesel process for DOD contract. Retrieved July 3, 2015, from http://www.biofuelsdigest.com/bdigest/2014/10/01/emerald-biofuels-to-use-uops-renewable-diesel-process-for-dod-contract/

Saunders, M., Lewis, P., & Thornhill, A. (2011). *Research Methods For Business Students* (5th ed.). Pearson Education India.

Schumpeter, J. (1934). *The theory of economic development: an inquiry into profits, capital, credit, interest, and the business cycle* (Vol. 55). Transaction publishers.

Scottish Bioenergy. (2012). Scottish Bioenergy. Retrieved June 16, 2015, from http://www.scottishbioenergy.com/

Shell. (2015). Shell and advanced biofuels. Retrieved August 15, 2015, from http://www.shell.com/global/environment-society/environment/climate-change/biofuels-alternative-energies-transport/biofuels/advanced-biofuels.html

Simon, H. A. (1955). A Behavioral Model of Rational Choice. *The Quarterly Journal of Economics*, *69*(1), 99–118.

Sims, R. E. H., Mabee, W., Saddler, J. N., & Taylor, M. (2010). An overview of second generation biofuel technologies. *Bioresource Technology*, *101*(6), 1570–80.

SkyNRG. (2015). Technology Section. Retrieved August 10, 2015, from http://skynrg.com/technology-section/

Solecki, M., Richey, D., & Epstein, B. (2011). *Advanced Biofuel Market Report 2011*. *Environmental Entrepreneurs*.

Solena Fuels. (2014). GreenSky London project taking off. Retrieved August 4, 2015, from http://www.solenafuels.com/index.php/projects/greensky-london

Solena Fuels. (2015). Solena Fuels. Retrieved August 10, 2015, from http://www.solenafuels.com/index.php/about-us

SP Biofuels. (2014). SP Biofuels. Retrieved July 10, 2015, from http://www.sp.se/en/centres/spbiofuels/sidor/default.aspx

St1 Biofuels Oy. (2014). Cellunolix ethanol plant to be built in Finland. Retrieved August 11, 2015, from http://www.st1biofuels.com/company/news/cellunolix-ethanol-plant-to-be-built-in-finland

Steeper Energy. (2015). Pilot Plan Steeper Energy. Retrieved August 4, 2015, from http://steeperenergy.com/projects/pilot-plant

Sunliquid. (2014). Cellulosic Ethanol from agricultural residues - think ahead, think sunliquid. Retrieved June 15, 2015, from https://www.clariant.com/en/Business-Units/New-Businesses/Biotech-and-Biobased-Chemicals/Sunliquid

Suurs, R. a. a., & Hekkert, M. P. (2009a). Competition between first and second generation technologies: Lessons from the formation of a biofuels innovation system in the Netherlands. *Energy*, *34*(5), 669–679.

Suurs, R. a. a., & Hekkert, M. P. (2009b). Cumulative causation in the formation of a technological innovation system: The case of biofuels in the Netherlands. *Technological Forecasting and Social Change*, *76*(8), 1003–1020.

Teppo, T. K., & Wustenhagen, R. (2006). Do Venture Capitalists Really Invest in Good Industries? Risk-Return Perceptions and Path Dependence in the Emerging European Energy Vc Market. *International Journal of Technology Management*, *34*(2), 63–87.

Total. (2015). BioTfuel a project to produce biofuels via thermochemical conversion. Retrieved August 10, 2015, from http://www.total.com/en/energies-expertise/renewable-energies/biomass/strategic-partnerships/biotfuel-project-produce-biofuels-thermochemical-conversion

Tyson Foods. (2014). Renewable Energy Group agrees to acquire Tyson Foods' half ownership of dynamic fuels. Retrieved July 3, 2015, from http://ir.tyson.com/investor-relations/news-releases/news-releases-details/2014/Renewable-Energy-Group-Agrees-to-Acquire-Tyson-Foods-Half-Ownership-of-Dynamic-Fuels/default.aspx

Ulmanen, J. H., Verbong, G. P. J., & Raven, R. P. J. M. (2009). Biofuel developments in Sweden and the Netherlands. *Renewable and Sustainable Energy Reviews*, *13*(6-7), 1406–1417.

UPM Biofuels. (2015). Investment in the world's first biorefinery producing wood-based diesel. Retrieved August 10, 2015, from http://www.upmbiofuels.com/biofuel-production/biorefinery/Pages/Default.aspx

Utterback, J. M., & Abernathy, W. J. (1975). A dynamic model of process and product innovation. *Omega*, *3*(6), 639–656.

Van De Ven, H. (1993). The development of an infrastructure for entrepreneurship. *Journal of Business Venturing*, *8*(3), 211–230.

Viguie, J.-C., Ullrich, N., Porot, P., Bournay, L., Hecquet, M., & Rousseau, J. (2013). BioTfueL Project: Targeting the Development of Second-Generation Biodiesel and Biojet Fuels. *Oil & Gas Science and Technology-Revue D Ifp Energies Nouvelles*, *68*(5), 935–946.

Virent. (2015). Virent Partners. Retrieved July 3, 2015, from http://www.virent.com/partners/

Winskel, M., McLeod, A., Wallace, R., & Williams, R. (2006). Energy policy and institutional context: marine energy innovation systems. *Science and Public Policy*, *33*(5), 365–376.

Winters, P. (2013). *The Current Status of Cellulosic Biofuel Commercialization*.

Wood, A. (2012). *Literature Review of Industrial Policy Options for Renewable Energy*.

Wüstenhagen, R., & Menichetti, E. (2012). Strategic choices for renewable energy investment: Conceptual framework and opportunities for further research. *Energy Policy*, *40*(1), 1–10.

Yin, R. K. (2009). *Case Study Research: Design and Methods. Essential guide to qualitative methods in organizational research*.

Zeachem. (2015). Zeachem Investors. Retrieved July 3, 2015, from http://www.zeachem.com/investors/

Appendix A – List of projects

Table 6. List and information of EU Projects

Name	Start-up	Country	Purpose	Status	Public	Private	Strategic	Stage of development	Source
Fortum	2013	Finland	Demonstration	Operational	Yes		Yes	Development	(District Energy, 2013; Fortum, 2015)
UPM	2015	Finland	Commercial	Operational			Yes	Development	(UPM Biofuels, 2015)
Preem Petroleum	2010	Sweden	Commercial	Operational			Yes	Development	(Preem, 2014)
Steeper Energy	2013	Denmark	Pilot	Operational	Yes			Pre-Development	(Steeper Energy, 2015)
Solena, Greensky	2017	UK	Commercial	Planned		Yes	Yes	Development	(Solena Fuels, 2014, 2015)
Total, BioTFuel collaboration	2012	France	Pilot	Operational	Yes		Yes	Pre-Development	(Total, 2015)
Greasoline GmbH	2011	Germany	Pilot	Operational			Yes	Pre-Development	(Greasoline, 2015; Peter Haug, 2015)
Karlsruhe Institute of Technology, Bioliq	2014	Germany	Pilot	Operational	Yes		Yes	Pre-Development	(Heisey et al., 2011; Karlsruhe Institute of Technology, 2013)
ENI	2014	Italy	Commercial	Operational			Yes	Development	(ENI, 2014a, 2014b)
Vienna University	2005	Austria	Pilot	Operational	Yes			Pre-Development	(Renew, 2008)
Tubitak	2015	Turkey	Demonstration	Planned	Yes			Development	(IEA Bioenergy, 2015)
Neste Oil	2011	Netherlands	Commercial	Operational			Yes	Development	(Neste Oil, 2015)
ST1	2016	Finland	Commercial	Planned	Yes		Yes	Development	(St1 Biofuels Oy, 2014)
Chempolis Ltd.	2008	Finland	Demonstration	Operational			Yes	Development	(Chempolis, 2015)
SP/EPAP	2004	Sweden	Demonstration	Operational	Yes			Development	(SP Biofuels, 2014)
Borregaard AS	2012	Norway	Commercial	Operational		Yes	Yes	Development	(Borregaard, 2015)
BioGasol	2008	Denmark	Pilot	Operational	Yes	Yes		Pre-Development	(BioGasol, 2015)
Inbicon	2009	Denmark	Demonstration	Operational			Yes	Development	(EUDP, 2014)
Maajberg Energy Concept Consortium	2017	Denmark	Commercial	Planned	Yes	Yes	Yes	Development	(IEA Bioenergy, 2015)
Butamax Advanced Biofuels LLC	2010	United Kingdom	Demonstration	Operational			Yes	Development	(Butamax, 2015)
Scottish Bioenergy	2009	United Kingdom	Pilot	Operational			Yes	Pre-Development	(Scottish Bioenergy, 2012)
Procethol 2G	2011	France	Pilot	Operational	Yes	Yes	Yes	Pre-Development	(Futurol, 2012)

Sunliquid, Clariant	2012	Germany	Demonstration	Operational	Yes		Yes	Development	(Sunliquid, 2014)
Abengoa Salamanca	2013	Spain	Demonstration	Operational	Yes		Yes	Development	(Abengoa, 2013)
Abengoa Sevilla	2016	Spain	Planned	Planned				Development	(IEA Bioenergy, 2015)
Beta Renewables	2012	Italy	Pilot	Operational			Yes	Pre-Development	(Beta Renewables, 2013a)
Beta Renewables (IBP)	2012	Italy	Commercial	Opperational			Yes	Development	(Beta Renewables, 2013b)
Beta Renewable (Slovak Republic)	2017	Slovak Republic	Commercial	Planned			Yes	Take-Off	(Beta Renewables, 2014)
Empyro	2015	Netherlands	Commercial	Operational	Yes		Yes	Development	(Lane, 2014a)

Table 7. List and information of US projects

Name	Start-up	Country	Purpose	Status	Public	Private	Strategic	Stage of development	Source
Aliphajet Inc.	2015	USA	Pilot	Planned	Yes		Yes	Pre-Development	(AliphaJet Inc., 2012)
Fulcrum Bioenergy, Sierra Biofuels Plant,	2017	USA	Commercial	Planned	Yes	Yes	Yes	Take-Off	(Fulcrum Bioenergy, 2015; Lane, 2015h; Macias, 2011)
Red Rock Biofuels	2017	USA	Commercial	Planned	Yes	Yes		Take-Off	(Business Wire, 2015; Lane, 2015c)
Green Star Products	2012	USA	Pilot	Operational			Yes	Pre-Development	(Green Star Products, 2015)
Cool Planet; Project genesis	2016	USA	Commercial	Planned	Yes			Deveolpment	(Cool Planet, 2014)
Aquatic Energy	2011	USA	Pilot	Operational	Yes		Yes	Pre-Development	(Aquatic Energy, 2015)
REG Geismar (former dynamic fuels)	2010	USA	Commercial	Operational			Yes	Development	(Tyson Foods, 2014)
Diamond Green Diesel	2014	USA	Commercial	Operational			Yes	Development	(Diamon Green Diesel, 2012)
Virent inc.	2009	USA	Demonstration	Operational	Yes	Yes	Yes	Development	(Virent, 2015)
GTI Gas Technology Institute	2012	USA	Pilot	Operational	Yes		Yes	Pre-Development	(Gas Technology Institute, 2015; Green Car Congress, 2012)
Research Triangle Institute	2015	USA	Pilot	Planned	Yes		Yes	Pre-Development	(Research Triangle Institute, 2015)

Emerald	2017	USA	Commercial	Planned	Yes			Development	(Emerald Biofuels, 2015; Sapp, 2014)
ZeaChem Demonstration	2011	USA	Demonstration	Operational		Yes	Yes	Development	(Zeachem, 2015)
Cobalt	2011	USA	Demonstration	Operational	Yes	Yes		Pre-Development	(Cobalt, 2015)h
National Renewable Energy Laboratory	2011	USA	Pilot	Operational	Yes		Yes	Pre-Development	(NREL, 2009)
Beta Renewables Alpha	2016	USA	Commercial	Planned	Yes		Yes	Development	(Beta Renewables, 2013a)
Abengoa	2014	USA	Commercial	Operational	Yes	Yes	Yes	Development	(Abengoa Bioenergy, 2011)
POET	2008	USA	Pilot	Operational			Yes	Pre-Development	(IEA Bioenergy, 2015)
POET-DSM	2014	USA	Commercial	Operational			Yes	Development	(POET DSM, 2014)
Iowa State University	2009	USA	Pilot	Operational	Yes			Pre-Development	(Iowa Energy Center, 2014)
Dupont	2015	USA	Commercial	Planned	Yes		Yes	Deveolopment	(DuPont, 2013, 2015)
Fiberight LLC	2015	USA	Commercial	Planned	Yes	Yes		Development	(Jessen, 2014)
Solazyme	2014	USA	Commercial	Operational		Yes	Yes	Development	(Lane, 2014c)
Ineos Bio	2013	USA	Commercial	Operational	Yes		Yes	Development	(IEA Bioenergy, 2015)
Lanzatech	2014	USA	Pilot	Operational		Yes		Pre-Development	(Lanzatech, 2015)
Dupont Cellulosic Ethanol Demo plant	2010	USA	Demonstration	Operational	Yes		Yes	Development	(DuPont, 2013, 2015)
AltAir	2015	USA	Commercial	Planned	Yes		Yes	Take-Off	(AltAir Fuels, 2015)

Appendix B – Identification factors to analyse functions

F1: Entrepreneurial Experimentation

- Number of new entrants, including diversifying established firms
- Number of different types of applications
- The breadth of technologies used and the character of the complementary technologies employed

F2: Knowledge development and diffusion

- Bibliometrics (citations, volume of publications, orientation)
- Number, size and orientation of R&D projects
- Number of professors
- Number of patents
- Learning curves

F3: Knowledge exchange

- Knowledge exchange between science and industry
- Knowledge exchange between users and industry
- Knowledge exchange across geographical borders

F4: Guidance of the search

- Beliefs in growth potential
- Incentives from factor/product prices, e.g. taxes and prices in the energy sector
- The extent of regulatory pressures, e.g. regulations on minimum level of adoption ("green" electricity certificates, etc.) and tax regimes
- The articulation of interest by leading customers

F5: Formation of markets

- Phase of market (nursing, bridging, mature)
- Who are the customer groups
- What are the standards in market or other market pull stimuli

F6: Mobilisation of resources

- Rising volume of capital
- Increasing volume of seed and venture capital
- Changing volume and quality of human resources (e.g. number of university degrees)
- Changes in complementary assets

F7: Counteracting resistance to change

- Is there alignment between the TIS and current legislation and the value base in industry/society
- How legitimacy influences demand, legislation and firm behaviour
- What (or who) influences legitimacy, and how

Appendix C – Interview questions

This list of interview questions is based on previous literature (Bergek et al., 2008; Hekkert et al., 2011; Masini & Menichetti, 2010, 2013; Mason & Harrison, 2001, 2002; Queen, 2002; Roberts, 2013; Wüstenhagen & Menichetti, 2012). The list is used as a guideline, depending on the interviewee and the answers provided the questions are adjusted to get the most interesting in-depth answers.

Introduction

- Thanks for cooperating, is it alright if I record this interview for my own records
- My names is Oskar Meijerink, a student working on RENJET (explain)
- What are your (company's) key activities?
- What is your role within this?

Question for all interviewees involved in RJF

- Jet fuel
- What is your opinion on bio fuels in general?
- What about RJF?

Feedstock

- What feedstocks do you consider to be most promising?
- Why these? is there any problem considering these feedstocks?
- Do you think costs / availability as a key-problem in the feedstock production?
- What do you think is important to overcome these issues?

Conversion Technologies

- What conversion technologies you think are most suitable for the production of bio jet fuels? Which other might be promising?
- Do you recognize any barriers or opportunities in the market to block or enhance commercialisation?
- What do you think of repurposing production facilities

Getting funded

- For projects like you are working on now, how did you receive funding?
- Is there a person in your company solely working on getting funds?
- Why focus on (grants etc, and not venture capital e.g.)?

Interviews with key-actors (based functional analysis)

- Considering this development curve (show and explain), in which phase you would say, RJF is in?
- Explain the 7 functions and TIS, with the following questions I try to find whether these functions are well developed in the TIS.

F1: Entrepreneurial experimentation (Actors from structural analysis)

- Are these the most relevant actors?
- Are there sufficient industrial actors in the innovation system? Do the industrial actors innovate sufficiently?
- Do the industrial actors focus sufficiently on large scale production?
- Does the experimentation and production by entrepreneurs form a barrier for the Innovation System to move to the next phase?

F2: Knowledge development

- Is the amount of knowledge development sufficient for the development of the innovation system?
- Is the quality of knowledge development sufficient for the development of the innovation system?
- Does the type of knowledge developed fit with the knowledge needs within the innovation system
- Does the quality and/or quantity of knowledge development form a barrier for the TIS to move to the next

F3: Knowledge exchange

- Is there enough knowledge exchange between science and industry?
- Is there enough knowledge exchange between users and industry?
- Is there sufficient knowledge exchange across geographical borders?
- Are there problematic parts of the innovation system in terms of knowledge exchange?
- Is knowledge exchange forming a barrier for the IS to move to the next phase?

F4: Guidance of the search

- Is there a clear vision on how the industry and market should develop?
- In terms of growth
- In terms of technological design
- What are the expectations regarding the technological field? -
- Are there clear policy goals regarding this technological field? - Are these goals regarded as reliable?
- Are the visions and expectations of actors involved sufficiently aligned to reduce uncertainties?
- Does this (lack of) shared vision block the development of the TIS?

F5: Formation of markets

- What is the current status of demand for biojet in the EU and globally?
- Is the current and expected future market size sufficient?
- Does market size form a barrier for the development of the innovation system?

F6: Mobilization of resources

- Are there sufficient human resources?
- If not, does that form a barrier?

- Are there sufficient financial resources?
- If not, does that form a barrier?
- Are there expected physical resource constraints that may hamper technology diffusion?
- Is the physical infrastructure developed well enough to support the diffusion of technology?

F7: Counteracting resistance to change

- What is the average length of a project?
- Is there a lot of resistance towards the new technology, the set up of projects/permit procedure?
- If yes, does it form a barrier

Investors

- Considering investments in the biojet industry, what is your feel about the distribution of investor types?
- Public, Private, Strategic
- What is not available but needed in your opinion
- Why not any other, not mentioned.
- Why do you think these are underperforming

Selection criteria

- On what criteria do you base investments?

Financial

- Economic, is it risk and possible returns?
- Are you considering investing in high risk proof-of-concept projects?
- Why not? Do you think it is the role of others to get the technology to the next level, interesting for VC, and Angels?
- Debt Structure (maturity, covenants, cash traps)

Social, psychological

- How large, if any, is the role of the team you are investing in?
- Should the CEO of a firm you would invest in be technically or marketwise be the better one
- Is there a social reason to invest, or based on facts only?
- Have you invested in similar projects in the past?
- Does the result of these investments affect your investment decision on current projects?

Policy

- Do you think policy could stimulate investments?
- What policy instruments could help?
- Do you consider tax incentives as a good policy instrument?
- Do you rather have a push or pull strategy of government?
- Push in the way of capital investments

- Pull to stimulate and create right market conditions
- Should government even influence in the market?

Market
- Feedstock uncertainties
- Do you think the market is important before investing?

Technology
- Do you have experts analysing technologies?
- Do you have certain risk levels when above you would not invest in it?
- Is the risk based on technology?
- Do you consider other parties proving good technology trustworthy?
- Operations Risks

Sponsors partners management (political, quality of partners and senior management)

Attributes of owners and attributes of business

Appendix D – Investor activity

Figure 14 shows the activity of each investor type in the different phases. It is possible that one project is funded by e.g. both public and strategic money, therefore the sum of the three investor types is higher than the total amount of projects investigated in each phase. Example: the pre-development phase consist of 19 projects however, in 13 of these projects public funding is involved, 4 times private funding and 12 times strategic funding is involved.

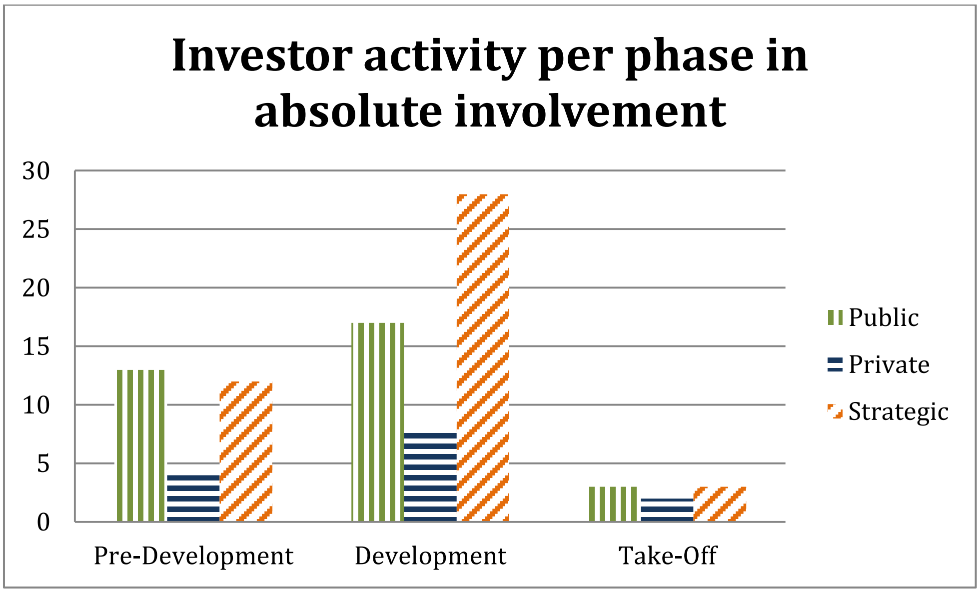

Figure 14. Investor activity per phase of development

Figure 15 shows, the same data in percentages. Taking the pre-development phase as an example again: in 68% of the cases public investors were involved, 21% private investment involvement and 63% percent strategic investments,

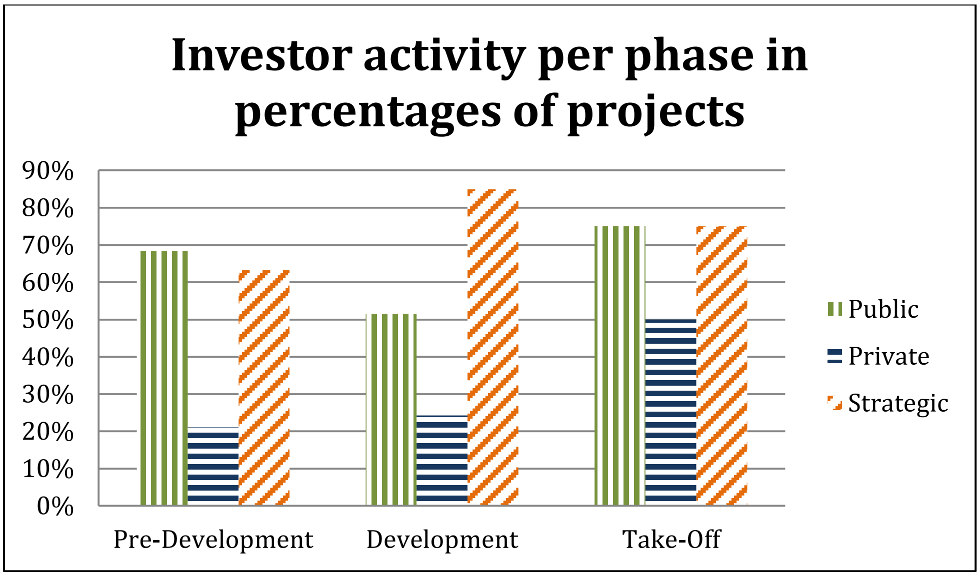

Figure 15. Investor activity for each phase of development