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The influence of technology development stages on the drivers of coopetition in the Dutch Green Hydrogen sector

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Executive Summary

To accelerate the energy transition collaboration with competitors is necessary. The simultaneous activity of collaboration and competition is termed “coopetition”. Literature on coopetition shows that this type of collaboration can improve innovativeness of organizations by knowledge sharing and competitive tensions. By researching the drivers of coopetition on innovative technologies focused on green hydrogen across different technology development stages, understanding on the role of coopetition for innovations is increased. The technology development stages consist of the development of an innovation from an idea towards maturity.

For this qualitative research 23 interviews were conducted covering 10 different coopetitive clusters. The sample was found by snowballing technique and data collection stopped when the data was saturated. The results show that the sustainability context of the study influences the collaboration as there is a desire to be a front runner and as reputational benefits are expected by coopeting companies. Furthermore, the results show that the technology development stage influences and can explain the drivers for coopetition, the coopetition structure, governance mechanisms, size of companies and intensities of coopetition. The technology stages explain the results by the different stage functions and characteristics. As the technology stage influences the drivers of coopetition and characteristics of coopetition it is important for both policy makers and management to take them into account. Policy makers can use this understanding to stimulate specific coopetition configurations to accelerate the development of innovations. This research provides insights to the importance of specific coopetition types for developing innovations. Hence, management can use this knowledge to indicate the need for, but also evaluate, coopetitive strategies.

Introduction

To prevent irreversible environmental impact on the planet, acceleration of sustainable development (SD) is urgent (IPCC, 2018; Field, Barros, Dokken, Mach, & Mastrandrea, 2014; Rockström et al., 2009). Sustainable development implies that current activities do not impact future generations (Brundtland, 1987). Hence, 'business as usual' is inconceivable and unprecedented transitions are necessary (Mead, 2018; Reficco et al., 2018). However, in many industries the sustainability transition is hampered by barriers such as sunk costs, high risks and lock-ins which slow down SD (Konnola et al., 2006; Reficco et al., 2018). Investments in sustainable activities are often deemed unattractive for businesses and - if executed - (large) firms usually operate independently which is ineffective for accelerating SD (Galbreath, 2014; Nidumolu et al., 2014). As the size of sustainability problems (e.g. climate change or resource depletion) is beyond individual capabilities (Nidumolu et al., 2014), collaboration strategies with important stakeholders such as the government, customers and competitors are frequently mentioned for tackling the barriers of SD (Bengtsson & Raza-Ullah, 2016; Bouncken et al., 2015; Dorn et al., 2016). Especially collaboration with competitors could have large potential for accomplishing sustainability transitions as research indicates that these strategies are necessary for dealing with dynamic markets, and as industries face similar sustainability issues (Christ et al., 2017; Limoubpratum et al., 2015).

The term 'coopetition' is a neologism of collaboration and competition. It was coined in 1913 as a paradox strategy that could be fruitful for gaining both competitive and collaborative benefits and that could increase the total market value instead of competing for the same value (Giovanni B. Dagnino & Rocco, 2009; Minà & Dagnino, 2016; Rusko, 2012). Over the years coopetition became an established concept in management research (Brandenburger & Nalebuff, 1995) and different types of coopetition are identified (Bengtsson & Raza-Ullah, 2016; Bouncken et al., 2015; Dorn et al., 2016). An important distinction is made between horizontal coopetition (collaboration on the same level with direct competitors), and vertical coopetition (up- and downstream in the value chain). Furthermore, coopetition types can be distinguished regarding the number of actors involved such as dyadic and multiple relationships. Coopetition is found on different levels such as the inter-firm, the intra-firm, the network and the individual level.

Bengtsson & Raza-Ullah (2016) concluded that these types of coopetition are different and therefor need to be specified in research.

Previous research focused on the drivers, processes and outcomes of coopetition. It is found that different drivers can stimulate the emergence of coopetition such as short product life cycles, uncertain and instable markets, partner relationships and internal vulnerability (Bengtsson & Raza-Ullah, 2016; Dorn et al., 2016; Gnyawali & Park, 2011; Ritala, 2012). Moreover, coopetition is found to be driven by the need to reduce costs, the familiarity with market actors, the need to find new markets and by pressure from stakeholders (Gnyawali et al., 2006; Lechner & Dowling, 2003). Coopetition can also be risky as the process is complex and management has to deal with internal and external tensions, decreased flexibility, interdependencies and the threat of opportunism (Levy et al., 2003) which could seriously harm innovation (Quintana-García & Benavides-Velasco, 2004), competitive advantage (Afuah, 2000) and relationships (Zerbini & Castaldo, 2007) and makes formal governance structures necessary (Bengtsson & Raza-Ullah, 2016; Bouncken et al., 2015; Dorn et al., 2016). Conversely, coopetition can improve various outcomes such as knowledge sharing and creation, financial and innovation performance and quality of the relationships between the actors by e.g. sharing costs, R&D and creating economies of scales (Bengtsson & Kock, 2014; Bengtsson & Raza-Ullah, 2016; Bouncken et al., 2015; Dorn et al., 2016; Gnyawali & Park, 2011; Luo, 2007b; Ritala et al., 2016).

Within the field of coopetition research, little distinction exists between the different types of coopetition which results in contradictive research outcomes (Vanyushyn et al., 2018). Most management research aims to explain the outcomes, processes and drivers of coopetition on innovations while only focusing on horizontal dyadic coopetition among large firms in technology markets (Bengtsson & Raza-Ullah, 2016). Comparison and distinction among cases of coopetition is missing. More specifically, there is a research gap with regards to describing the influence of innovation characteristics and for different types of coopetition such as horizontal and vertical coopetition or dyadic and multiple coopetition (Bengtsson & Raza-Ullah, 2016). This study addresses this gap by examining the impact of various development stages on coopetition drivers in the green hydrogen sector. This results in the following research question:

How do coopetition drivers differ for various development stages of green hydrogen technologies and why?

The focus on specific drivers of coopetition in the context of sustainability is relevant for literature, policy makers, business and society broadly. Drivers are a fundamental aspect for understanding the phenomenon of coopetition and thus for understanding the different types of coopetition (Christ et al., 2017). Furthermore, as current studies have focused on single technology context types and context influences coopetition (Bengtsson & Raza-Ullah, 2016), it is vital to analyze different contexts to understand *how* context influences coopetition, which is as of yet unclear. Hence, this study indicates the influence of different technology development stages and the innovation context on coopetition.

Among others, Field et al (2014) indicate an increasing need for a variety of collaboration strategies in the context of sustainability to accelerate sustainable innovations (He, Miao, Wong, & Lee, 2018; Yami & Nemeh, 2014). By indicating different coopetition drivers for different types of coopetition in different innovation contexts, this study provide tools to policy makers for shaping and stimulating specific types of coopetition in a sustainability context. This study could enable firms to make better decisions by increasing their understanding on their own and partner drivers. Furthermore, by assessing drivers of coopetition across different technology stages, this study provides insight to the different coopetition benefits and risks related to a particular technology context. Furthermore, this research is relevant to society as it investigates the drivers of coopetition in the context of sustainability, which provides insights in the means to increase or decrease coopetition for the development of sustainable innovations for SD.

Chapter 2: literature framework

2.1 Defining Coopetition in a sustainability context

The hybrid activity of coopetition has been defined as “a strategic and dynamic process in which economic actors jointly create value through cooperative interaction, while they simultaneously compete to capture part of that value.”(Bouncken, Gast, Kraus, & Bogers, 2015, p.591). And as “a paradoxical relationship between two or more actors simultaneously involved in cooperative and competitive interactions, regardless of whether their relationship is horizontal or vertical.” (Bengtsson & Kock, 2014, p182). As there are different types of coopetition which can take place on different levels and between a different amount of actors (e.g. intra, inter-firm, network, dyadic, multiple) there is not one clear phenomenon which causes conceptual ambiguity and makes a single definition unrealistic (Bouncken et al., 2015). However, in the definitions found on coopetition the mutual activity of competition and collaboration between the same actors is central (Bouncken et al., 2015). This central interaction remains when defining coopetition in a sustainability context.

Sustainability is often defined as meeting the needs of the present without compromising the needs of the future (Gauthier, 2017; Brundtland, 1987). In order to achieve this, new corporate strategies are developed for sustainability which focuses on the triple bottom line (Gauthier, 2017). While coopetition literature merely includes economic benefits of coopetition, coopetition related to sustainability focusses on overall win-win benefits of economic, social and environmental performance (Christ et al., 2017; Gauthier, 2017). For this, all cases of coopetition focusing on sustainable innovations will be concerned with trade-offs between the three dimensions and focusses on reaching the best strategy to deal with those trade-offs (Christ et al., 2017). In this thesis, coopetition in a sustainability context implies the coopetition for developing a sustainable innovation that replaces the dominant technology.

The single definition of coopetition in relation to sustainability is “Sustainability-related bi-lateral coopetition aims to achieve superior economic and environmental performance for individual companies through the development of win–win solutions via cooperation between two competing companies horizontally at the same stage of production and/or vertically through the supply chain with companies competing and collaborating at different upstream and downstream stages” (Christ et al., 2017, p. 1032). In this research a broader definition will be used as different types of coopetition are included such as coopetition among different numbers of actors. Furthermore, the definition provided by Christ et al. (2017) does not include the social dimension and assumes that there is superior performance on the triple bottom line while most studies show that business have trade-offs on these three elements. Hence this thesis proposes a broader and more flexible definition which states that coopetition in the context of sustainability is the mutual activity of competition and collaboration between actors horizontally at the same stage of production or vertically through the supply chain to achieve win-win solutions for high economic, social and environmental performance.

2.2 Technology development stages

This paper touches briefly upon the Innovation System (IS) approach to provide characteristics of innovation development stages and indicate their influence on coopetition drivers (Hekkert, Suurs, Negro, Kuhlmann, & Smits, 2007). The IS approach is a socio-technical perspective that assumes that innovations diffuse by both collective and individual interactions across industries, governments and social institutions (Hekkert et al., 2007; Markard, Hekkert, & Jacobsson, 2015). According to IS literature, an innovation develops across similar trajectories in different stages as it is influenced by incumbent technology designs and their innovation systems (Hekkert, Suurs, Negro, Kuhlmann, & Smits, 2007; Kemp, 1994). Across these stages, 7 IS functions (F) are recognized (Hekkert et al., 2007). These are entrepreneurial activities (F1: innovative commercial experiments), knowledge development (F2: R&D activities), knowledge diffusion (F3: through networks), guidance of the search (F4: selection process for convergence), market formation (F5: niche market), resource mobilization (F6: financial, material & human), and the creation of legitimacy (F7: political lobby) (Hekkert et al., 2007; Suurs et al., 2010).

Hekkert, de Boer and Eveleens (2011) propose a framework including 5 different technology development stages. The stages indicate the development of the technology and ranges from pre-development, development, take-off, acceleration to a stabilization stage (Hekkert, de Boer, & Eveleens, 2011). The different technology development stages have different technological characteristics, different key functions, include a different degree of structuration, and different interactions between collectives and individuals, these are the technological innovation systems (Bento & Wilson, 2016). Bento and Wilson (2016) use a different categorization of stage functions than presented by Hekkert et al. (2007), both categorizations of functions are shown below in table 1.

The technology in the pre-development stage exists of various ideas and concepts, in the development stage it consists of a selection of different prototypes, in the take-off stage the technology has a dominant design, in the acceleration stage the technology is a standardised product that is ready for mass production, and in the stabilization stage there is a stable and diffused market of a standardized, dominant technology (Bento & Wilson, 2016). The IS of the first stage has a key function of knowledge development (Hekkert & Negro, 2009), knowledge creation and experimentation, the interactions are via R&D networks and informal institutions and there is no or little structuration (Bento & Wilson, 2016). The IS of the second stage has a key function of knowledge creation, focuses on diverse networks, technology-specific institutions, and some structuration (Bento & Wilson, 2016). The IS of the third stage has a key function of resource mobilization and gaining legitimacy for the dominant technology design, focuses on different networks, technology-specific institutions, and medium to high structuration (Bento & Wilson, 2016). The IS of the fourth and fifth stage have all IS functions as key functions (Bento & Wilson, 2016), focuses on established industry networks, include stable formal and informal institutions and high structuration (Bento & Wilson, 2016). For an overview see table 1.

Table 1

Overview of technology development stages

Characteristics of technology development stages	**Stage 1: Pre-development**	**Stage 2: Development**	**Stage 3: Take-off**	**Stage 4 & 5: acceleration and stabilisation**
Technological characteristics	Various ideas and concepts	Selection of prototypes	Dominant design	Standardized, stable and accepted design
Key function	Entrepreneurial experimentation (F1), Knowledge creation (F2), knowledge development (F3), Direction of search (F4)	Entrepreneurial experimentation (F1), Knowledge creation (F2), Direction of search (F4), Market formation (F5)	Market Formation (F5), Resource mobilization (F6), gaining legitimacy (F7)	All functions (F1, F2, F3, F4, F5, F6, F7)
Interactions	Informal institutions, little structuration	Diverse networks, technology-specific institutions	Different networks, technology-specific institutions	Established industry networks, stable formal and informal institutions
Structuration	Low	Medium structuration	Medium-high	High structuration

Source: Bento & Wilson, 2016, p.99, adapted by author based on Hekkert & Negro, 2009

2.3 Structure of coopetition

The structure of coopetition is often related by literature to the coopetition goal (Yami & Nemeh, 2014) and hence related to technological development stages. As the coopetition structure is assumed to be related to the technological development stages, and hereby to coopetition drivers, an overview of structures is provided in this paper.

In this research four structures of coopetition will be distinguished based on the categorization of Yami and Nemeh (2014), these are horizontal dyadic, horizontal multiple, vertical dyadic and vertical multiple coopetition (table 2). A clear distinction is made in literature between horizontal and vertical coopetition because of the different purposes. Horizontal coopetition involves collaboration between direct competitors on the same stage in the value chain and is found to be beneficial as close competitors have the closest complementary resources (Bengtsson & Raza-Ullah, 2016, p. 29; Chetty & Wilson, 2003; Schiavone & Simoni, 2011). Vertical coopetition involves collaboration between competitors up and downstream in the value chain while they compete in a stage above or below in the value chain (Yami & Nemeh, 2014). This can exist when partners decide to launch products or services in the market of their partner (Bengtsson & Raza-Ullah, 2016) or when they already compete on one level and decide to collaborate on another (Dorn et al., 2016). Vertical coopetition has proven to be useful for the development of markets throughout the value chain (Luo, 2007a).

Secondly, a clear distinction is made between dyadic and multiple partnerships. An important disparity found between these two types of coopetition are the dynamics in the relationship. It is found that for coopetition with multiple actors (>2) the configuration and reconfiguration of the cluster is critical and the level of trust in each other is widely distributed (Ritala, 2012). When the consortium is larger, partner characteristics as trust are often less important and wide and radical innovation objectives, public funding, institutional support and interoperability between technologies are important (Schiavone & Simoni, 2011; Yami & Nemeh, 2014). On the contrary, for dyadic coopetition, the configuration is static, the level of social capital is high, and often there is a clear vision on the collaboration involving incremental innovation and high value creation (Yami & Nemeh, 2014, p. 252).

It is expected that the first technological development stage will drive vertical multiple coopetition as the whole value chain will need to be composed to develop a non-existing market and as coopetition for radical innovations are found to be only beneficial in an early stage of the industry (Bouncken et al., 2018; Chetty & Wilson, 2003; Yami & Nemeh, 2014). In the second stage, a similar patterns is expected, however, as there is a need for more specific product development towards a dominant design, smaller consortia like dyadic are assumed. In their research, Song, Cheon and Pire (2015) show that increasing competition in the market can drive horizontal multiple coopetition as there is a need to expand the market. Multiple horizontal clusters are expected in the third stage as competition on a dominant product design increases, as there is a need to improve product performance, and attain institutional support for legitimacy and market development (Levy et al., 2003; Schiavone & Simoni, 2011; Song et al., 2015; Yami & Nemeh, 2014). Considering the stable conditions, a high interdependence and reliance on trust and governance structures are expected in the fourth and fifth stages. Hence, horizontal dyadic clusters are expected.

Table 2

Expected coopetition structures per technological development stage

Tech. dev. Stage	Pre-development stage	Development stage	Take-off stage	Acceleration and stable stages
Coopetition cluster structure	Vertical Multiple	Vertical Dyadic	Horizontal Multiple	Horizontal Dyadic

Source: based on Yami & Nemeh, 2014

2.4 Drivers of coopetition

Before firms coopete with each other, different reasons for coopeting need to be present which are the drivers of coopetition. Drivers are seen as that what motivates firms to engage in coopetition partnerships (Gnyawali & Park, 2011) or to collaborate with firms (Burgers et al., 1998; Gnyawali & Park, 2011). Dorn et al. (2016) define drivers as the antecedents that "reflect the specific conditions under which coopetition is likely to occur" (p.487). Bengtsson & Raza-Ullah (2016) take the concept of drivers broader by stating that drivers are what pushes and pulls collaboration and competition, underlining that the lack of drivers is what hampers coopetition.

Different drivers of coopetition have been found on different levels and in different research settings. Most is known about the drivers of inter-firm dyadic coopetition of MNCs, large firms and SMEs in a technology context (Dorn et al., 2016; Gnyawali & Park, 2009, 2011). But some research has been conducted on other structures of coopetition in other contexts, such as vertical and multiple (Chetty & Wilson, 2003) and e.g. in the tourism sector (Della Corte & Aria, 2016; Kylänen & Rusko, 2011). Though recognized as important, research on different aspects of coopetition remain scarce (Dorn et al., 2016). Two important literature reviews on coopetition indicate that the drivers can be divided in three themes, being the external drivers, the partner specific drivers and the internal drivers (Bengtsson & Raza-Ullah, 2016; Dorn et al., 2016). As most literature focusses on horizontal dyadic coopetition in a technology context, it is assumed that the drivers which are currently indicated in literature are based on this type of coopetition. As can be seen in table 3, comparing the drivers from different literature reviews with a case study on this type of coopetition confirms this assumption (Gnyawali & Park, 2011). Nevertheless, these literature frameworks on drivers will be used as the foundation for this paper as literature on different types of coopetition is scarce. Table 4 and 5 at the end of this chapter show the drivers used in this study and the expected drivers across different technology development respectively. In chapter 6, empirical data is used to confirm or reject these theoretical assumptions.

Table 3

Overview literature on drivers

Bengtsson & Raza-Ullah, 2016, p. 33	**Dorn et al., 2016, p. 448**	**Gnyawali & Park, 2011, p. 658**
Internal drivers Internal goals Capability Prospective strategies Perceived vulnerability	**Individual factor of firm** Need for knowledge and resource acquisition Self-perception of the firm	Firm strategies and aspirations
External drivers Industrial characteristics Technological demands Influential stakeholders	**Market conditions** Specific industry settings High degree of change and competition Early or late industry life-cycle stages Regulatory bodies enforcing/prohibiting competition	Industry and technological challenges & opportunities
Relational drivers Partner characteristics Relationship characteristics	**Dyadic factors between potential partner firms** Compatible resource endowment Presence of trust Extant ties of potential partner firms	Superior and relevant partner resources & capabilities

2.4.1 Internal drivers

Internally firms can be actively and reactively driven to coopete (Gnyawali & Park, 2009, 2011). Firms actively engage in coopetition in order to improve their position by pursuing their goals such as increasing bargaining power and improving (sustained) competitive advantage (Barney et al., 2016; Gnyawali & Park, 2009; Min et al., 2005). Firms with ambitious goals relative to the market have prospective strategies to constantly scan the environment in order to find opportunities to enhance their knowledge, bargaining power or capabilities (Bengtsson & Raza-Ullah, 2016; Gnyawali & Park, 2009, p. 319). Furthermore, firms reactively engage in coopetition in order to defend their position and reduce their perceived strategic vulnerability (Gnyawali & Park, 2009, 2011). Strategic vulnerability can be perceived because of decreasing profitability or reputation. Perceived vulnerability can be caused by external factors such as new competitors, a new and unfamiliar market or because of superior (Gnyawali & Park, 2009). Perceived vulnerability can be caused internally when targets are not met or when resources are perceived to be lacking (Gnyawali & Park, 2009).

It is expected that the sustainability context will impact the firm aspirations and perceived vulnerability as trade-offs need to be made and as different strategies will be needed for achieving these goals including more collaboration (Christ et al., 2017). Furthermore, the ambition of goals and potential of reputation benefits can be higher as of the sustainability context (Limoubpratum et al., 2015; Volschenk et al., 2016). The perceived vulnerability is expected to be high as the problem of sustainability is large and cannot be solved by a single actor, as firms are working on new technologies in an unfamiliar market with different dynamics, as new competitors are expected to enter the market for sustainability and as internal capabilities and resources are expected to be scarce in the new market.

It is expected that the IS influences internal drivers as organizations in earlier stages will coopete more as a reaction of lacking resources and changes in the environment (Gnyawali & Park, 2009). Hence, vulnerability is expected to be a stronger driver in the first stage. On the other hand, organization that are pro-actively driven coopete to learn, to increase bargaining power and to increase competitiveness (Gnyawali & Park, 2009). These goals seem to be stronger drivers when a dominant technology is chosen and needs improvement, legitimacy and a growing market. Hence, organizations in later stages are expected to react pro-actively and thus are driven by stronger aspirations.

2.4.2. External drivers

External drivers are the drivers in the contextual and transactional environment of the firm including influence from the industry and stakeholders (Bengtsson & Raza-Ullah, 2016).

Important aspects of the industry that drive coopetition are the stage of the industry lifecycle, the technological demands and the degree of change and competition within the industry (Bengtsson & Raza-Ullah, 2016; Dorn et al., 2016). The configuration of the industry lifecycle drives coopetition. At the early stage of the industry, coopetition can be driven by the growth level (Luo, 2004), the uncertainty in the market (Ritala, 2012), and the concentration of actors (Gnyawali et al., 2006; Lechner & Dowling, 2003). Secondly, coopetition is driven by aspects of a high technological demand such as short product life cycles (Quintana-García & Benavides-Velasco, 2004), convergence of technologies, increasing R&D costs (Gnyawali & Park, 2009, 2011) high technological uncertainty and increased complexity of the technology (Afuah, 2000; Burgers et al., 1998). Thirdly, market characteristics such as increasing competitiveness and market shifts are found to drive coopetition as these external demands increase the need to share risks and resources among firms to keep up with the dynamic market (Shee, VanGramberg, & Foley, 2011; Dorn et al., 2016 from Padula & Dagnino, 2007).

It is expected that the sustainability context will influence the industry drivers by high technological demand for eco-innovation and a growing and shifting market (He et al., 2018). It is expected that the IS influences industry drivers as different development stages pose different technological demands, different market characteristics and a need to develop and react to different formal and informal institutions (Bento & Wilson, 2016). As an earlier technological development stage involves technological ambiguity, a high need for R&D, a turbulent market and little competition on the technology, it is expected that industry characteristics are a stronger driver of coopetition in earlier technology development stages.

Besides these industry drivers, action of stakeholders such as increased governmental intervention and customers demand, drive firms to collaborate with competitors. Increased governmental intervention is found to stimulate coopetition by imposing incentives, policies or reforms (Bengtsson and Raza-Ullah, 2016 from Barretta, 2008; Mascia, Di Vincenzo, & Cicchetti, 2012). Luo (2004) describes that increased governmental intervention can also hamper coopetition by e.g. antitrust regulation. Furthermore, literature has indicated that increased demand from influential customers can stimulate coopetition (Levy et al., 2003).

It is expected that the sustainability context will increase the pressure from stakeholder drivers. High governmental intervention is expected because of international and national sustainability goals. Furthermore, high customer demand is expected as customers drive the greening of business practices (Beamon, 2008, found in; Limoubpratum et al., 2015) like via product stewardship where customers force firms to take responsibility over the whole supply chain (Sundarakani et al., 2010). As technologies in more developed technology stages have the function of gaining legitimacy they can be pressured by consumers for improving product performance (Levy et al., 2003).

2.4.3 Partner specific drivers

Partner specific drivers include characteristics of the partner and the relationship that promote coopetition strategies to emerge. The usefulness of the partner resources and capabilities is an important driver for coopetition. These are resources and capabilities which are superior, complement firm resources and which contribute to the organizational objectives (Bengtsson & Raza-Ullah, 2016). Furthermore, goal alignment drives coopetition as firms need to find each other by creating mutual benefits (Luo et al., 2008). The state of the relationship is also a driver for coopetition. This state is determined by trust potentially built over time and is important as it indicates the commitment of the partner and risk of opportunistic behavior (Dorn et al., 2016). Furthermore, the possibility to increase market power is an important motivation for collaboration (Bengtsson & Raza-Ullah, 2016; Dorn et al., 2016; Gnyawali & Park, 2011).

The usefulness of resources and capabilities is expected to be moderate high in a sustainability context as diverse resources and capabilities are needed for SD (Nidumolu et al., 2014). The goal alignment is expected to be high in the sustainability context as industries face mutual unsustainable practices and as trade-offs will need to be made (Christ et al., 2017; Reficco et al., 2018). It is expected that the IS influences partner specific drivers as there is a dependence on external partner resource for experimentation in the first and second technological development stage (Nieto & Santamaría, 2007). Hence, the usefulness of partner resources is expected to be a strong partner driver in the first stages. Furthermore, in the later stages where the technology is more developed and where horizontal collaborations are expected, a collective goal and trust are expected to drive the firms share similar and competitive resources (Ann Peng et al., 2018; Ritala & Hurmelinna-Laukkanen, 2013; Yami & Nemeh, 2014). The importance of goal alignment is highlighted as an important driver for incremental improvements in more developed technologies and was found in the case of Samsung and Sony as they had the collective goal to produce LCD

TV's in order to keep up with the dynamic market (Gnyawali & Park, 2011). Moreover, as trust is found to be important in dyadic clusters it is also expected to be important in the second stage (Yami & Nemeh, 2014).

Table 4

Drivers of coopetition

Internal Drivers	External Drivers	Partner Drivers
Aspirations of the firm • Ambition goals • Prospective strategies	Industry Characteristics • Industry Lifecycle • Technological Demand • Market characteristics	Partner characteristics • Usefulness partner resources & capabilities • Goal alignment
Perceived vulnerability • External • Internal	Stakeholders • Governmental intervention • Consumer Demand	Relationship • Trust • Market power

Table 5
A literature derived hypothesis of coopetition drivers per technology development stage

Drivers	Pre-development stage	Development stage	Take-off stage	Acceleration and stabilization stages
Internal Drivers	Perceived vulnerability	Perceived vulnerability	Aspirations of the firm	Aspirations of the firm
External Drivers	Industry Characteristics	Industry Characteristics	Stakeholders	Stakeholders
Partner Drivers	Usefulness partner resources & capabilities	Usefulness partner resources & capabilities , trust	Goal alignment, trust	Goal alignment, trust

Chapter 3: Methodology

3.1 Research design

A multiple case study was conducted as the theory on coopetition is unexplored, complex and still in construction. Additionally, the context of the phenomena is important for identifying the different drivers (Ann Peng et al., 2018; Gnyawali & Park, 2011; Yami & Nemeh, 2014). Furthermore, the study used existing literature on drivers in order to compose a framework on the drivers of different types of coopetition in a sustainability context. The study was explorative, and confirmed or rejected drivers of the framework proposed in table 5. No additional drivers were found. The empirical context, case selection, methods for data collection and analysis are described below.

3.2 Empirical context

For this thesis, different cases were selected from the Dutch green hydrogen industry. The development of green hydrogen in the Netherlands was interesting for identifying drivers of different types of coopetition in a sustainability context for three reasons. First, the hydrogen industry is diverse. The dominant technology black hydrogen is developed, and this market is mature. However, the technology of green hydrogen cannot compete with the dominant technology as it is financially unattractive. Secondly, as green hydrogen is still financially unattractive, the development of green hydrogen is mainly driven by environmental and partly social objectives. Thirdly, coopetition was expected in the Dutch green hydrogen industry as the green hydrogen industry fits the characteristics of external drivers including an early stage of the lifecycle and as the Netherlands recognized the high potential of the North of the Netherlands for the development of green hydrogen, resulting in increased governmental intervention (Bengtsson & Raza-Ullah, 2016; Dorn et al., 2016). Furthermore, different types of coopetition were expected as this thesis includes different cases from the green hydrogen industry including projects in different markets with different market characteristics and different technological characteristics.

3.3 Case selection

In case studies, the case should be informative and representative for the phenomenon studied and therefor chosen strategically instead of randomly (Swanborn, 2010, p.52). To strategically select the cases, the first step was indicating all collaboration initiatives around the development of green hydrogen in the Netherlands. This was done by asking key actors (e.g. chairman roundtable Hydrogen, members of the energy coalition and organizational spokespersons on Hydrogen initiatives) who are familiar with the Dutch green hydrogen market and by desk research (e.g. documents 'who is who Hydrogen and Fuel Cells in the Netherlands', 'Overzicht waterstofinitiatieven' and websites such as 'www.waterstofnet.eu'). Secondly, all collaboration initiatives were mapped on different factors such as type of coopetition, stage of coopetition (starting/completed), actors within the partnership, size of the organizations, market segment of the organization and place of actors in the value chain of green hydrogen. Based on these factors the informativeness and representativeness of the cases were indicated and a diverse case selection was made. In total 23 organizations part of 10 clusters were interviewed. Of these 2 of the ten clusters were removed from the sample as it was unclear whether the cluster involved a coopetitive relationship. In total 8 clusters were included in the sample (table 6).

Table 6 includes the indication of organization size (Small is <500 employees, large is >500 employees), the market segment, the value chain position, the type of cluster and the cluster number. The value chain position differs between the production of green hydrogen, the transport of green hydrogen and the usage or, facilitating the usage of green hydrogen. As cluster 9 includes a combination of transport and facilitating the usage of green hydrogen, they are indicated to operate in both parts of the value chain. As firm specific factors are indicated to influence drivers for sustainable innovations (He et al., 2018), these are included in the data analysis.

Table 6
Data sample

Company #	Size	Market Segment	Value chain	Type Cluster	Cluster #
C1	S	Mobility	Usage	D-V	2
C2	L	Mobility	Usage	D-V/M-H	2; 5
C3	L	Mobility	Usage	M-H	5
C4	S	Mobility	Usage	M-H/DH	1; 5
C5	S	Mobility	Usage	D-H	1
C6	L	Energy	Production	D-H	4; 8
C7	S	Mobility	Production & Usage	MV	10
C23	S	Mobility	Usage	MH	6
C8	S	Mobility	Usage	MH	6
C9	S	Mobility	Usage	MH	6
C10	L	Energy	Production	MV	8
C11	L	Energy	Transport	MV	7; 8
C12	L	Chemical	Usage	MV	7; 8
C13	L	Chemical	Production	MV	7
C14	L	Energy	Production	DV	3
C15	S	Chemical	Transport	DV	3
C16	L	Heating	Transport & usage	MM	9
C17	L	Heating	Transport & usage	MM	9
C18	L	Heating	Transport & usage	MM	9
C19	L	Heating	Transport & usage	MM	9
C20	L	Heating	Transport & usage	MM	9
C21	S	Heating	Transport & usage	MM	9
C22	L	Heating	Transport & usage	MM	9

Specification abbreviations: Size S=small (<500 employees), L= large (>500 employees).
Type cluster D=dyadic, M=multiple, V=vertical, H=horizontal

3.3 Data collection

To analyze the drivers of different types of coopetition in the hydrogen market, qualitative data was gathered by conducting semi-structured interviews and quantitative data was collected in parallel by adding a survey on a 5 point Likert scale to the interview guide. By combining these two data sources, the perceived importance and influence of each driver could be analyzed and compared qualitatively and quantitively. The qualitative data explained the influence of the driver and sometimes rejected quantitative results, and the quantitative value of each driver indicated the relative importance. Eventually, this research relied mostly on the qualitative data.

First, interviews were used to explore and describe motivations for coopetition on developing green hydrogen in the Netherlands. Interviewees were selected per case. In case of a project the project manager of each firm was interviewed, in case of larger consortiums the chairman of the consortium and majority of spokespersons of the participating organizations were interviewed. The selection of respondents depended on relevancy and accessibility of clusters active in the green hydrogen industry and stopped when data was saturated. The interviews were semi-structured, when possible conducted face-to-face and took around 60 minutes. The interview guide (Appendix B) consists of questions which were derived from literature (Appendix A). Secondly, a quantitative 5 point Likert scale was added to the interview guide to indicate the importance of each literature derived driver (table 4). Some respondents requested to receive the interview guide before the interview. In these cases the first part of the interview guide was sent but the second part including the Likert scale on literature derived drivers was not send to prevent bias in the first part of the interview.

3.4 Data Analysis

All interviews were transcribed and together with the documents were analyzed by NVivo. This analysis consisted out of two steps. First, each coopetition case was analyzed in-depth to identify which drivers contributed to the specific coopetition partnership. This was done by using the codes derived from literature as stated in Appendix C. No new codes were found. Secondly, the results of the different cases were compared to find patterns across the cases and to allocate drivers and intensities of the drivers to the types of coopetition. Possible influence of the context of sustainability was not specifically measured but is discussed in the results section.

Chapter 4 : the sustainability context - green hydrogen

The sustainability context of this research implies the sustainable production of hydrogen in the Netherlands. This chapter first discusses the existing dominant technology, which is black hydrogen. Second, it discusses the sustainable alternative, which is green hydrogen. Third, to provide context on the IS and the projects in the sample, this chapter discusses the current activities in the green hydrogen market.

4.1 Hydrogen

Hydrogen (H) is a chemical element. It is the lightest existing gas and does not occur as a sole atom in nature. Instead, the atom need to be derived from other molecules such as H2O and CH4. Currently, hydrogen is an important feedstock for different industries, e.g. for the production of ammonia (NH3 (aq)), and methanol (CH3OH) (CE Delft, 2018). There is increasing interest in sustainable production of hydrogen as it reduces CO2 emissions of industry and, as it can be a scalable energy carrier which enables increasing the production of renewable energy as the surplus of renewable energy production can be stored by converting the surplus into hydrogen and storing, for example, in salt caverns. Differences in the energy supply and demand can then be matched.

Currently, the total consumption of hydrogen is estimated in the Netherlands to be 0,8 million ton per year (CE Delft, 2018). It is estimated that 80% of this hydrogen is produced in the Netherlands by Steam Methane Reforming (SMR) and 20% is a byproduct of the chemical industry (CE Delft, 2018). SMR is an endothermic process in which high temperature steam (700-1000 ℃) is used on a methane source to react with the carbon monoxide; CH4 + 2 H2O → CO2 + 4 H2. As can be seen in the equation, the outcome is carbon dioxide (CO2) and hydrogen (H2). In the Netherlands the resource for SMR is natural gas (CH4). The byproduct of this process, CO2, is in the Netherlands around 12,5 Million tons (CE Delft). As of the CO2 intensive production of hydrogen via SMR, this type of hydrogen production is named ‘black hydrogen’.

More sustainable production methods of hydrogen imply the production of ‘blue hydrogen’ and ‘green hydrogen’. The production method of blue hydrogen is similar to black hydrogen, however, the produced carbon is captured and stored (CCS). In order to effectively use CCS, large investments for the development of CCS need to be made. The production method of green hydrogen is based on the splitting of water with electrolysis by using renewable power. $2H_2O$ →

$2H_2 + O_2$. Hereby no greenhouse gas (GHG) emissions are produced. In general there are three electrochemical methods for water electrolysis. These are Alkaline, Polymer Electrolysis Membrane (PEM) and Solide Oxide electrolysis. Of these three methods, alkaline electrolysis is the dominant technology as it is relatively cheap, has a higher durability and higher purity of gas. The technology of water electrolysis was invented around two centuries ago, however, as the technology is, compared to SMR, expensive, uncertain, inefficient and has a low durability, the share of hydrogen production via water electrolysis remains low (Rashid et al., 2015). Due to pressing national and regional GHG goals, increased attention is raised to the production of large scale blue and green hydrogen. Blue hydrogen is seen as a feasible short-term alternative and green hydrogen as the long term solution. By stimulating the development of blue hydrogen, a risk of creating a technological lock-in exists where green hydrogen is not able to compete. In this case, unsustainable production methods using fossil fuels will remain. Hence, this thesis sees green hydrogen as the sustainable solution.

4.2. Green Hydrogen

The value chain of green hydrogen consists of three dominant parts, the production, the transportation and the consumption of green hydrogen (fig. 1). Different markets are being developed on the consumption or downstream part of the value chain. Three markets are addressed in this thesis which are the consumption of hydrogen by: the industry, the mobility market and the heating market. The three parts in the value chain and the three markets face different characteristics and innovation states which can influence the emergence of coopetition. The three dominant parts in the value chain are elaborated below.

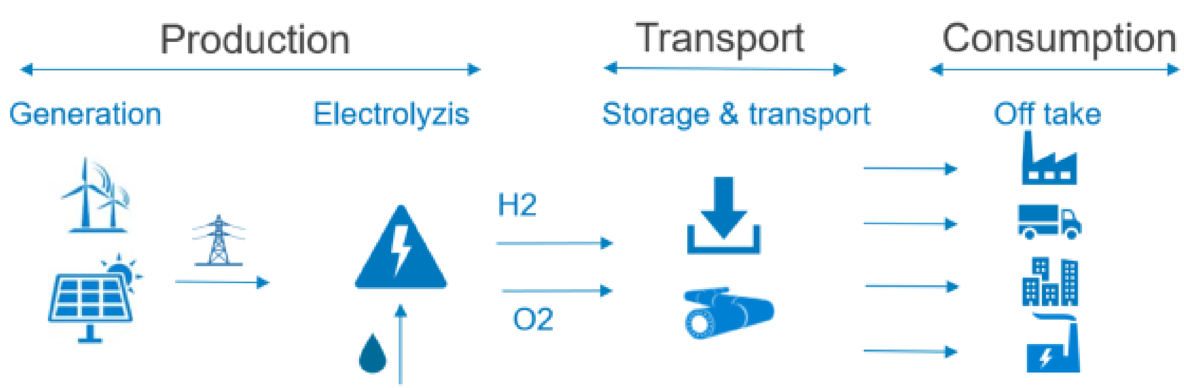


Figure 1: The value chain of green hydrogen

4.2.1 Production of green hydrogen

In the Netherlands production and commercial sale of green hydrogen does not exist. Currently, different research institutions and organizations invest in pilot projects on the generation of green hydrogen. These researches focus on improving the scalability and efficiency of green hydrogen generation. It is concluded that green hydrogen should be produced on a large scale to reduce costs and meet the possible demand. Hence, organizations study the feasibility of large scale generation of green hydrogen. Different subsidies from the EU and Dutch government are being developed for green hydrogen production. Some subsidy schemes are finished and already permitted. An increasing amount of subsidies for bridging the financial gap of the production of green hydrogen are expected.

4.2.2 Transport of green hydrogen

Different possibilities of the transport of green hydrogen exists. The Netherlands has a national gas infrastructure which is owned by one public company. Future national plans include the elimination of natural gas transport which implies that this infrastructure will become obsolete. By retrofitting the current gas infrastructure, green hydrogen can be transported through the Netherlands. A national green hydrogen infrastructure will reduce transport costs and increase accessibility of the green hydrogen. The Dutch public company is currently executing different pilot projects on retrofitting of the gas infrastructure. Besides a national infrastructure, different construction companies are developing regional and local infrastructure for hydrogen. Furthermore, transport of hydrogen by freight exists. However, when transporting large volumes of green hydrogen, the transport via freight will be inefficient due to the large density of H2. Hence, the Netherlands focusses on transporting hydrogen via a retrofitted gas infrastructure. In other countries, R&D focusses on the transport of hydrogen by different types of mobility. For example, via ships (Japan & Australia) and via trucks Currently, research and development is invested in optimizing these transport possibilities.

4.2.3 Consumption of green hydrogen

Three potential markets for hydrogen are indicated in this thesis: the industrial market, the mobility market and the heating market. The industry is the largest consumer of black hydrogen in the Netherlands. Consequently the industry is the largest potential market for green hydrogen on the short term. Currently, no green hydrogen is consumed in the industry as green hydrogen is not able to compete with black hydrogen. However, some industries are exploring the possibilities.

Different players are active with hydrogen in the Dutch mobility market. Currently, the Netherlands has five hydrogen gas stations (not all public) and around 188 hydrogen cars (*Hoeveel waterstofauto's zijn er in Nederland?*, 2019). Thirteen hydrogen gas stations are planned and financed with subsidies, mainly from the EU (*Forse uitbreiding van aantal waterstoftankstations in Nederland*, n.d.). The current hydrogen car producers are Hyundai and Kia. Hyundai and Kia currently invest in the development of larger freight vehicles. Besides the development of cars and trucks, hydrogen trains (currently a pilot in the North of the Netherlands), hydrogen ships and smaller hydrogen projects as garbage trucks (Groningen) and forklifts are being developed. The projects in the mobility market are not 100% operating on green hydrogen, however, this is the long term goal. The consumption of green hydrogen for heating in buildings is currently explored by a pilot project in the Netherlands. The project is in collaboration with the local government and received national subsidies for the project. Besides this, no (pilot) projects of green hydrogen for heating buildings are present.

Chapter 5: results

This chapter states the results of this thesis. The clusters are discussed per technological development stage. In each sub paragraph, the different cluster characteristics are briefly discussed as the clusters differ on the project, the size of actors in the cluster, the relation within the cluster, the sizes of the companies in the cluster, the structure of collaboration and the position in the value chain (table 7, next page). Furthermore, per cluster it is discussed where and how there is competition, why they collaborate or, what barriers are, and why they collaborate with the specific partner(s).

5.1 Pre-development stage

Cluster 1 is categorized in the pre-development stage as no prototypes or pilots exist of the product the cluster is developing.

The project of *cluster 1* involves the development of a hydrogen infrastructure for the heating of buildings. The size of the cluster is around 20 partners, of which seven are included in the sample. Apart from company 21, all companies are large. Company 20 coordinates the cluster. The cluster is structured in working groups which each focusses on a sub part of the sustainable innovation. As stated by company 20, the collaboration used to be dynamic and loosely structured around a project plan (including in-kind contribution per organization) and actors used to join and leave. As there were some complaints of free-riders, the collaboration became a fixed group of committed actors (C19). Later, the project was assigned a subsidy for which a legal agreement was signed (C20).

The position of the project in the value chain differs between transport and usage. For usage, they operate in the heating market. Different direct competitors collaborate on developing parts of the sustainable innovation which results in a mixed structure including 8 horizontal coopetitive relationships and some horizontal relationships. Furthermore, company 21 assumes some competition with company 22, while company 22 does not assume competition with company 21.

As indicated, the organizations all operate in the same sector and includes engineering consultancy offices, construction organizations and developers of gas infrastructure. As the actors operate in the same sector, there is competition on projects (C16; C18; C20), on customers (C17; C19) and on the development of new technologies (C21; C22). Though different organizations

Table 7

Overview of the different clusters and their characteristics

	Tech. dev. Stage	Project	Size cluster	Size companies	Structure of collab-oration	Position value chain	Relation
1	Pre-development	Develop hydrogen heating infrastructure buildings	~20	~19 large, 1 small	In kind contribution/ project plan	Consumption, heating	Horizontal & vertical
2	Development	Develop hydrogen production	3	Small & 2 large	LOI	Production & consumption industry	Vertical
3	Development	Large scale production & consumption	4	Large	LOI	Production & consumption industry	Vertical
4	Development	Develop hydrogen generators	3	Small	LOI	Consumption, mobility	Horizontal
5	Development	Large scale production	2	Large	LOI	Production	Vertical
6	Take-off	Create network hydrogen gas stations (NL)	2	Small	Individual investment, no clear governance	Consumption, mobility	Horizontal
7	Take-off	Create network hydrogen gas stations (Benelux) & lobby	3	One small, two large	Grand agreement & platform	Consumption, mobility	Horizontal
8	Take-off	Improve gas station reliability	2	Small & large	contractually and project-based	Consumption, mobility	Vertical

are close competitors, it is stated by C16 and C19 that there is no fierce competition. The organizations are large and operate in diverse markets hence they do not depend on specific projects also, the organizations often have slightly different focus areas and capabilities (C19). Furthermore, collaboration on a project with competing organizations is common in the sector (C16) and many competitors have joint ventures (C19). According to C21, the project of cluster 1 is one where organizations with similar techniques stand together and strengthen each other. Though different actors are clear competitors, competition is perceived to be low.

The organizations participate in this cluster because they want to be aware, and want to be part, of innovations in the gas sector (C18; C20). Different actors indicate that they want to be a frontrunner in the energy transition and that they want to add green hydrogen to their extensive portfolio of technologies for the energy transition (C16; C17; C19; C22). C19 states that all participating organizations are frontrunners and all benefit from the project by using it as a first reference project. C22 states that the mission of the firm is to find a green and affordable gas solution and that the company also engages because of a positive impact on their image. C17 states that they believe that the time is right to grow with the green hydrogen market and strengthen their position of being a frontrunner in the energy transition. The organizations are aware of the changing energy landscape and want to be innovative to be able to adapt to the changing environment (C22).

The interviewees indicate different barriers, or, motivations to collaborate in the cluster. First, the project that they are working on is new and innovative. Therefor, the organizations indicate to miss the knowledge to meet possible requests (C18; C19). Furthermore, they need to discover and invent different technological characteristics that they have not faced before (C16; C17; C19). Third, regulation for applying green hydrogen in the gas infrastructure needs to be created and adapted (C19). Moreover, it is indicated that the technology needs to be developed and improved and the technological readiness level needs to rise (C17; C19; C22). Another motivation for the collaboration is the creation of an equal level playing field (C22). C20 indicates that potential customers did not want to invest in green hydrogen because of the lack of competition in the market. Hence, individual actions are not moving the supply chain. C21 states that they collaborate as they have a strong, non-monopolistic vision in regard of the energy transition. C19 and C22 conclude that they collaborate as there are high risks to the investments, but also high potential. Hence, the risks are better beared together.

Most companies indicate that they collaborate specificly with these (competing) partners as they have strong complementing resources. It is highlighted that no single organization in the hydrogen market has the expertise or knowledge to do everything (C18; C19). Especially as the project is a ‘system solution’ (C22). As the organizations operate in the same sector they ‘speak the same language’ and are well aware of each complementing capabilities (C19). This makes it easier to divide the work, and to indicate where to add value (C16; C19).

5.1.1 Drivers Pre-development stage

As only one cluster is categorized in the pre-development stage, there is no comparisson. The actors indicate to participate as they have the internal ambition,a goal to be a frontrunner in the energy transition and foresee reputational benefits, which indicates prospective strategies. Furthermore, it is indicated that the internal knowledge of actors is lacking for the innovation, which indicates internal vulnerability. The motivations to collaborate as of the presence of high and a changing environment indicates external vulnerability.

As the organizations collaborate on an entirely new product, they face an IS system that is not suitable for their product in the sense of lacking regulation, lacking competition and lacking technology. The collaboration is driven by these three external factors as they together shape regulation, as they foster competition, and as they experiment on the technology by developing the innovation in a large cluster. Furthermore, it is indicated that the companies collaborate to keep up with the energy transition. Hence, the external drivers are technological demand and market characteristics such as a high degree of market change and a low degree of competition. Moreover, a low degree of governmental intervention is present and seems to drive coopetition.

It is indicated that the partners collaborate with these specific organizations as they are frontrunners with strong complementing resources. This is important as it is indicated that the actors miss the knowledge to develop the innovation alone. Furthermore, it is indicated that the project involves high risks but also high potential. Hence, partner drivers are usefulness of partner resources & capabilities, goal alignment and an increase in market power.

5.2 Development Stage

Cluster 2, 3, 4 and 5 are categorized in the technological development stage as prototypes exist but no commercial sale of the products is present. Cluster 2, 3 and 5 focus on the production of green hydrogen. Cluster 4 focusses on green hydrogen generators.

The project of c*luster 2* involves the production of green hydrogen on a former gas production site. The cluster exists of two main companies of which C14 is a large company and C15 is a small company. The companies collaborate as part of a larger collaboration in which they explore different ways to make the energy production more sustainable, for this they signed a LOI. The project is located at the production part in the value chain. Company 14 operates in the energy market on the production side of the value chain. Company 15 operates in the chemical market in the transport side of the value chain. Company 14 is a supplier of company 15 and a large company while company 15 is defined as a small company. The coopetition relationship is hence vertical.

Besides being a supplier of C15, C14 operates in similar markets as C15. Hence, C14 recognizes C15 as a competitor. But, as shown by the following statement, C14 does not interpret C15 to be a competitor on the particular project. 'See, if you see competitors then I think about the competitors of today. Those are just the other companies in the energy sector. […] That is […] company 15. But on this, I don't see them as competitors' (C14).

The two companies participate in this cluster because they perceive a changing energy landscape and a changing energy demand. C14 mentions that, as a consequence of the ambitious Dutch off shore wind production targets, more renewable energy will be produced and part of that has to be stored. Hence, C14 anticipates on this development by participating in a project on capturing and carrying energy via green hydrogen. C15 states to participate in this project as they want to anticipate on the future energy demand of their current customers.

Company 14 indicates that in sum, they collaborate as the business ecosystem is underdeveloped and as there is a need for developing the whole value chain. First, there is no single actor who is able to execute current activities in the green hydrogen on its own, as it covers different sectors and value chain integration is needed (C14). Second, there is a lack of a viable business model (C14). Third, as there is a lack of regulation (C14). And fourth, as there is a lack of competition (C14). C15 states that the underdeveloped technology, the lack of off takers and the high development and operational costs are important barriers to overcome with the collaboration.

The project of c*luster 3* focusses on the development of the whole green hydrogen value chain. The cluster includes four companies (C6, C10, C11 & C12). All four companies are included in the sample, of which C6 at time of data collection was still in negotiation. This negotiation did not succeed, however, as the data was collected earlier, C6 is included in the sample. All four companies are large and the the organizations are working on a feasibility study. Here mutual investments are made in R&D. The collaboration is governed by a LOI. The project involves actors across the value chain, however, the short-term aim is on production of green hydrogen. The organizations are divided across the value chain and the cluster includes an organization that produces renewable energy, an organization that can produce green hydrogen on a large scale, an organization that can transport green hydrogen and an organization that can consume green hydrogen on a large scale. The cluster actors have a supplier-consumer relationship and operate in different parts of the value chain, hence the coopetition relationship is vertical.

There is competition in the cluster as C6 and C10 are direct competitors who operate in similar markets. C10 and C11 have similar capabilities, but do not operate in similar markets. C11 and C12 are both engaged in a competing project of cluster 3, and hence competition exists between the projects. However, as there is currently no developed market, competition is perceived by the actors to be low. Furthermore, C10 and C11 indicate that collaboration with competitiors is common in their industry.

The organizations indicate to collaborate because they want to contribute to the development of, and position themselves in, the green hydrogen economy without operating on all facets of the value chain (C6, C12. C10 indicates that their goal is to anticipate on the increasing renewable energy production by investing in green hydrogen as an energy carrier as this will be, according to C10, a more affordable alternative to full elektrification. C11 collaborates in the to ensure their license to operate as a gas company, which requires adaptation to the energy transition. C12 indicates that they collaborate in the project as it is their goal to produce (more) sustainable products and with this anticipate on future demand.

The organizations indicate that collaboration is a requirement to achieve their goals and to stimulate the development of a green hydrogen market. First, it is important as there is a need for the development of competition in the market to create a functional market (C10, C11). Second, there is a need to invest in large scale green hydrogen production to suppress costs and to ensure that the market develops, however, this requires large investments and the development and reliability of other parts in the value chain such as the transport and off take of the large scale green hydrogen (C10, C11, C12). Third, C12 indicates that they simply do not have the capabilities to succeed such a project as the value chain for large scale green hydrogen is too complex. Hence, these specific actors collaborate because of their complementary assets and capabilities, and, due to reduce risks (C6, C10, C11, C12).

The project of *cluster 4* involves the development of a hydrogen infrastructure for ships and companies in their areas. An aspect of this project is to reduce CO2 emissions of ships by replacing current fuel driven generators with green hydrogen driven generators. The cluster exists out of three seaports (C8, C9, C23). All organizations are small. The organizations collaborate by collectively researching the implementation of hydrogen generators. The collaboration is governed by a LOI that operate in the mobility market and usage segment of the hydrogen value chain. C8, C9 and C23 are small companies and coopete horizontally.

There is competition among the three seaports as they operate in a similar market. The competition between the seaports is on attracting firms to settle in their area (C9). Hence, the seaports focus on increasing attractiveness of their area. However, the organizations have a focus on different market segments, have a different vision on operating a specific type of area, and are partly governmental owned (C9). Competition is perceived to be low on the cluster project (C9).

The companies collaborate to reduce their environmental impact on surrounding areas, increase attractiveness to customers and to achieve their climate goals (C8, C9, C23). According to C8 it is in the interests of all Dutch seaports and the realization of their climate goals to accelerate the green hydrogen transition. C9 states that the development of green hydrogen is the only possibility to decrease pollution of the industry in their area. The seaports are faced with similar climate goals, which they cannot achieve by themselves (C8). The organizations indicate that they overcome barriers with this project by sharing the large investment costs (C8). The companies indicate to collaborate with these specific partners as there is history of collaboration and a good relationship (C23). Furthermore, the three seaports have to deal with the same Dutch sustainability goals for seaports and face similar challenges on decreasing pollution in their areas (C9), hence they have a mutual urgency to act.

The project of *cluster 5* involves the production of large scale green hydrogen. The cluster size is two (C6 and Cx). Cx is not included in the sample and is a main shareholder of C6. The cluster have signed a LOI for collectively researching the feasibility of the project (C6). The position of the project in the value chain is in the production of hydrogen. In the collaboration, C6 is a supplier of Cx, hence the companies coopete vertically.

Company C6 and Cx are direct competitors in different markets as they produce and sell the similar products (C6). Furthermore, due to their capabilities, they have the possibility to enter each others markets in area's where they are not yet competing which can increase tension. Competition is perceived to be low on the particular project as both organization have different goals (C6). The companies collaborate as they want to gain knowledge on a developing market (C6). However, the organizations do not have each other capabilities and not the desire on the short term to develop those capabilities as they involve very different processes (C6). Hence, the complementarity of the capabilities and assets is a clear motivation for their colaboration (C6). Furthermore, the organizations work together as there is a history and trust between the companies (C6).

5.2.1 Drivers Development stage

It is significant that all four clusters in the development stage collaborate on an investment project. Furthermore it is significant that three of the four clusters compete vertically to develop a larger value chain for the production of green hydrogen.

Cluster 2, 3, 4 and 5 indicate to collaborate to keep up with the energy transition and because of the high risks and costs involved in the project. This indicates that the organizations face some external vulnerability due to a changing environment. Furthermore, cluster 3 and 5 indicate that they collaborate to gain knowledge on the green hydrogen market without developing all necessesary activities. Moreover, the desire to develop knowledge on the green hydrogen market can both indicate an ambition to be a frontrunner in the energy transition, thus a prospective stategy, as internal vulnerability of having a lack of knowledge.

Cluster 2, 3 and 4 emphasize to collaborate as the market is underdeveloped, which is detrimental as there e.g. is a lack of regulation, lack of competition, high risks and lack of off takers. Moreover, cluster 2, 3 and 5 indicate to collaborate in the cluster to anticipate on or, benefit, from future energy demand. This indicates that the clusters are driven by market characteristics being a high degree of change (risks) and a low degree of competition. Furthermore, it indicates a lack of governmental intervention as a driver and, consumer demand as a driver.

All four clusters indicate that the projects require different capabilities. Hence, complementarity of assets and capabilities is a strong driver. Cluster 4 collaborates as the organizations have aligned goals. Cluster 4 and 5 mention that the history with, and trust in, the partner(s) is an important driver to collaborate with the specific partner(s). Furthermore, as cluster 2, 3 and 5 indicate to also collaborate to anticipate on and benefit of future energy demand, this indicates that an increase of market power drives their collaboration.

5.3 Take-off stage

Cluster 6, 7 and 8 involve technologies that are commercially available but not sold on a large scale, hence their projects are categorized in the take-off stage. Cluster 6 and 7 both have projects at the end of the value chain and exists out of companies in the mobility market with similar goals.

The project of *cluster 6* involves the development of a network of hydrogen gas stations in the North of the Netherlands. The cluster size is three (C4, C5 & C11). Both C4 and C5 are small companies, C11 is a large company. The project was initiated in 2017. No clear governance mechanism was indicated. However, the project of cluster 6 is not finalized and currently there is no progress. The project is at the consumption part of the value chain in the mobility segment. C4 and C5 collaborate horizontally, C11 collaborates vertically.

C4 and C5 compete directly on consumers as they sell similar products, furthermore there is competition on subsidies as they pursue similar goals and apply for similar subsidies (C5). The organizations collaborate to construct a hydrogen gas station network in the Netherlands to accelerate the transition and to increase the amount of consumers (C4, C5). It is realized that a green hydrogen gas infrastructure is neccesary to increase consumer demand but it is too expensive and risky to develop a network alone (C4). Furthermore, as both organizations are small, it can be perceived that they do not have the resources to develop a network on their own. By collaborating they have a stronger proposition (C4). The organizations collaborate as they both have the interest and ability to realize a green hydrogen gas infrastructure in the specific region (C5). C11 facilitated the project and the development of a green hydrogen gas infrastructure in the region. However, according to C4 the project stagnated as the small company could not meet the high standards of C11 and as internal processes of C11 were slow and bureaucratic.

The project of *cluster 7* involves the development of of a hydrogen infrastructure in the Benelux and on policy advise via the Dutch hydrogen platform. The cluster consists of three organizations (C2, C3, C4). C2 and C3 are large companies, C4 is a small company. The cluster collaborate in two different settings with different goals. First, the organizations of cluster 7 collaborate via the hydrogen platform to inform the government on the development of hydrogen in mobility. Second, the cluster collaborated on an European subsidy scheme to create a network of hydrogen stations in the Benelux. Collaboration with different competing organizations was a requirement for this subsidy (C2). The first collaboration is structured and governed by participation on the hydrogen platform where more actors are involved and non-confidential information is discussed (C3). The second collaboration is firmly structured and governed by a grand agreement of the European subsidy (C2). The projects are at the consumption part of the value chain in the mobility segment. The three companies operate in the same market and coopete horizontally on two projects.

C2, C3 and C4 operate gas stations and hence compete on market position and customers. C2 and C3 are large organizations that operate on a global scale in multiple markets. C4 is a smaller company that only operates in the Dutch gas station market. C4 is a dealer station that retails fuels of C2. As C2 and C3 are main, multi-market, competitors they perceive competition to be fierce. C3 states that there is no competition in the green hydrogen market, as there is not really a market to compete in. However, C2 states that competition is present and there is no room for mutual investments: '[Invest] with company 3, really the horizontal competition? No way' (C2). C3 states that it is important to take into account that "we [C3] can only collaborate in this country because there isn't a market yet and we [C3] are constantly aware that the moment that there becomes a question of a market being existent, we have to change our way of working". C3 explains that the relationship with C2 has changed over time as, at the start of the collaboration activities, C2 was a start-up. Furthermore, the relation changes as at the start of the collaboration (2011 - 2013) the market of hydrogen in mobility was completely non-existent, currently it is stated to be existent but very, very small and hence tension has increased (C3).

It is indicated that the organizations collaborate in the hydrogen platform to share non-confidential information, to discuss vision & scenarios of the hydrogen industry and to send a message to the government (C3; C4). The sharing of non-confidential information is emphasized by both C3 and C4 as regulations on sharing market sensitive information are strict. The collaboration on the hydrogen platform is important as hydrogen developments are facing high costs, a need to develop specific regulations and a need to create demand (C2; C3).

The organizations collaborate in the subsidy request as they want to grow the hydrogen network in the Netherlands and generate a critical mass for the hydrogen market, without excessive risks (C2, C3). This collaboration was a subsidy requirement, however, the main argument for the collaboration is the stronger commercial proposition of a network of hydrogen gas stations compared to single stations (C3, C4). This is important as there is a lack of hydrogen demand. By collaborating, the organizations hope to generate a critical mass for the hydrogen market, without excessive risks, to stimulate e.g. the import and use of hydrogen vehicles (C3, C4). C2 states that they collaborate with these competing organizations as the market is very small and needs to grow, hence, there is a need for similar capabilities to build similar gas stations.

The project of *cluster 8* involves the construction of hydrogen gas stations. The cluster size is two (C1 & C2). Company 1 is a small company while company 2 is a large company. The collaboration is contractually and project-based (C1). The companies work together on a longer period, however, this collaboration is non-exclusive and new contracts are signed per project (C1). The position in the value chain is on the usage of hydrogen in the mobility market. Company 1 provides technology for the construction of hydrogen gas stations to company 2. Hence, the coopetition is vertical.

First, the companies did not compete as there was only a supplier-buyer relationship. However, company 1 indicates that competition in the market has become more intense; '[Right now] it [the market] is too far in development, there was more [collaboration] in the bubble between 2000-2010 but not now. And that is because everyone sees opportunities and protects themselves'.

Competitive tension between these two parties increased when company 1 started to enter the market of company 2. For this, their collaborative relationship shifted and became coopetitive. ‘Sometimes [it is the question] are you our competitor or our supplier? And, do you want to collaborate? But, you also supply to our competitors?’ (C2).

The companies collaborate because they offer different complementary technologies within the value chain. Furthermore, C1 indicates to colllaborate with C2 to increase future work demand as C2 is larger and more likely to expand projects internationally. The projects in the hydrogen gas stations are indicated to be costly investments, together the companies can bear the costs and assign to subsidies (C1). C1 also indicate to have collaborated with C2 as collaboration was a requirement for a subsidy request.

5.3.1 Drivers Take-off stage

Cluster 6 and 7 both indicate to collaborate to develop a stronger network of hydrogen gas stations to increase the critical mass and reduce excessive costs and risks. Furthermore, both clusters collaborate to improve their commercial proposition. Cluster 7 collaborates to create and operate qualitative and reliable hydrogen gas stations, hence they also collaborate to create a stronger commercial proposition. This shows mainly the internal driver of prospective strategies. Furthermore, it indicates an external driver being the consumer demand. Another external driver indicated is high governmental intervention. This as it is significant that all three clusters in the take-off stage mention subsidy requests as an important factor for their collaboration. As stated by the clusters, the subsidies they can apply to often require collaborative structures. Furthermore, it is significant that all three clusters operate in the mobility segment in the consumer part of the value chain. This indicates the influence of the external driver of a similar industry lifecycle. Furthermore, all clusters indicate to collaborate with the specific partner(s) because of complementary resources. Finally, the clusters indicate to collaborate with the partner drivers to improve their commercial proposition and with this, their market power.

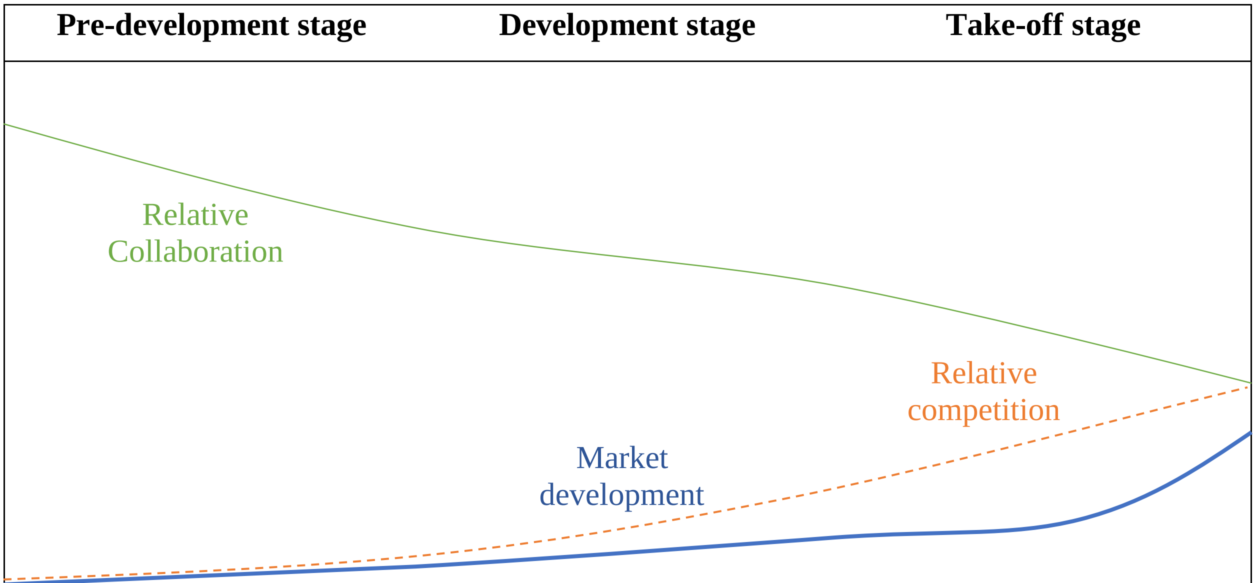
Chapter 6: Discussion

This paper explored the influence of technology development stages on the drivers of coopetition characteristics in a sustainability context. The findings indicate that different coopetition characteristics are influenced and can be explained by an innovation its technology stage. The data obtained in this research cover the first three technology development stages. The results indicated a relation between the technological development stage, the structure of coopetition and the coopetition drivers. Other findings emerged from the data showing a relation between the technology development stage and the governance mechanisms, the firm size and the intensity of coopetition. The findings are summarized in table 8 and figure 2 and discussed in the paragraphs below.

Table 8

An empirical indication of coopetition drivers per technology development stage

Drivers	**Pre-development stage**	**Development stage**	**Take-off stage**
Internal Drivers	Prospective strategy Ambition goals External vulnerability Internal vulnerability	Prospective strategy Ambition goals External vulnerability Internal vulnerability	Prospective strategy
External Drivers	Technological demand Market characteristics	Market characteristics Lack of gov. demand Lack of consumer demand	Governmental intervention Consumer demand
Partner Drivers	Divers Complementary resources Goal alignment Increase market power	Complementary resources Goal alignment Trust Increase market power	Complementary resources Increase market power



Loose governance	Medium governance	Tight governance
Large actors involved	Mixed size actors	Mixed size actors

Figure 2: *Overview of empirically derrived patterns across stages*
Definition lines in the figure: Green thin line=collaboration pattern, orange dotted line=intensity competition pattern, blue thick line=market development

6.1 Sustainability context

The sustainability context might have influenced coopetition across the different stages, especially the drivers for coopetition in the first stage. In cluster 1, different organizations indicated to have strong internal drivers to collaborate on the development of a green innovation. In these cases, organizations indicated to have ambitious goals to participate and form the energy transition by being first movers. With this, the sustainability context might increase internal firm and intrinsic employee motivation (Limoubpratum et al., 2015). Different organizations of cluster 1 indicated that reputation effects of participation in this cluster was an important aspect of the internal motivation. The influence on reputational benefits for driving coopetition in a sustainability context is supported by current literature stating that the creation of socio-environmental value, with the aim to create economic value, can catalyze the engagement into coopetition (Limoubpratum et al., 2015; Volschenk et al., 2016). Some trade-offs on social, environmental and financial aspects were stated across the coopetition clusters and are assumed to influence internal motivations and expected risks from long term environmental pressures, nevertheless no clear finding on the influence of trade-offs was indicated and the financial aspect of the innovation seemed to dominate the trade-off.

6.2 Structure of coopetition

The cluster operating in the first technology development stage had a mixed structure and consisted of multiple actors. In the second stage, three of the four clusters had a vertical structure and the clusters on average consisted of three actors. In the third stage, two of the three clusters where horizontal and consisted of two actors. These results partly align with the expectations derived from literature (table 2). A mixed multiple structure in the first stage align with the vertical multiple assumption derived from literature as it confirms the need to involve diverse actors to develop a non-existing market and radical innovations (Bouncken et al., 2018; Chetty & Wilson, 2003; Yami & Nemeh, 2014). In the second stage mainly vertical triads are found instead of the assumed vertical dyads. Though including a third actor in a cluster has important implications, the assumption that the second stage involves smaller consortia than in the first stage to develop a specific product towards a dominant design can be confirmed. The vertical value chain collaboration can be explained as organizations operate with suppliers in the first stages as few standards exists and as the risks around the products are larger (Tether, 2002) and as vertical collaboration is essential for product innovations as it e.g. reduces lead times and hence fit the first two development stages (Nieto & Santamaría, 2007).

The finding of mainly dyadic horizontal clusters in the third development stage did not align with the assumptions based on literature (table 2). Multiple clusters were expected as of increased competition, an need to improve product performance and to increase institutional support (Levy et al., 2003; Schiavone & Simoni, 2011; Yami & Nemeh, 2014). The results can not be explained by literature however, they might be explained by the small sample, fewer actors in the third stage in relation to the sustainability context or as the actors perceived competition to be too high.

6.3 Drivers

As shown in table 8, this study indicates different drivers per technology development stage. The paragraphs below discuss the indicated internal, external and partner drivers in relation to the hypothesized drivers in table 5, chapter 2.

6.3.1 Internal Drivers

As stated in chapter 2, literature indicates that firms are internally driven to coopete because of their aspirations and because of perceived vulnerability. Where aspirations are indicated to be a pro-active internal driver, perceived vulnerability is indicated to be a re-active interal driver (Gnyawali & Park, 2009). The findings provide concrete insight to the literature derrived expectations shown in table 5. Foremost, it indicates that in all three technological developments stages firms are driven by aspirations. However, when the technology is less developed, organizations are driven by ambition while in later stages, when firms have a concrete outlook of the technology, firms are driven by prospective strategies. Furthermore, the data confirms the expectation that organizations are driven by perceived vulnerability.

Across all three stages, companies were mainly frontrunners and interviewees indicated prospective strategies as an antecedent for coopetition. The pro-active attitude of the companies across all stages can be explained by the sustainability context. Furthermore, in the first and second stage, ambition of goals, external and internal vulnerability were indicated to be drivers for coopetition. The ambition of goals in these stages can be explained by the simultaneously indicated internal vulnerability. The internal reactive driver of vulnerability indicates the presence of large external threats (Gnyawali & Park, 2009). This would indicate that organizations operating in an earlier technology development stage feel more threatened, uncertain and challenged than an organization operating in a later technology development stage. This might be explained by the uncertainty of the future of the innovation the different clusters across the stages are working on. While in the first stage, the future of the innovation is unsure and other innovations are likely to evolve, the clusters in the third stage work with a proven concept in a growing market, promising value creation (Luo, 2007b). Furthermore, as the organizations in earlier technology stages work on more pioneering activities, they will have developed less resources and capabilities to deal with these pioneering activities. Hence, more ambition is required.

6.3.2 External Drivers

As stated in chapter 2, literature indicates that firms are externally driven to coopete because of industry characteristics and stakeholders. The results confirm a stark contrast between the two types of external drivers across the three stages (table 5 and 7). In stage 1 and 2, the external drivers include industry characteristics and rather a lack of institutions posed by stakeholders while in the third stage projects are driven by stakeholders. The differences between the stages can be explained by the maturity of the innovation. In the first two stages, the technology is less mature and less certain. The degree of change in the market is high due to technological changes entering the industry (Lynn & Akgün, 1998) and for this the costs and risks of R&D are high (Gnyawali & Park, 2011). Literature adds that the introduction of new products and technologies, operating by different type of actors in the energy industry, can drive coopetition as industry entry barriers are reduced, competitive advantages are less sustainable, and as firms have less control on their future (Dai, 2008 derrived from Bengtssons & Raza-Ullah, 2016, Burgers). With this, the results are aligned with literature as they show how uncertainty and instability, as a results of industry characteristics, are strong coopetition drivers (Bengtsson & Raza-Ullah, 2016; Burgers et al., 1998; Giovanni Battista Dagnino & Padula, 2002; Ritala, 2012).

Stage 3 is driven by stakeholders. According to literature, this makes sense as the clusters focus on markets that are already established and as they focus on technological convergence, hence they need to create industry structure, legitimacy, integrate networks to set industry standards and norms, and create a critical mass for the product to actually take-off (Ritala, miotti; gnyawali 2009; Mione, 2008). Furthermore, the organizations operating in the third stage focus on moving towards a common direction to have greater influence on the dominant innovation of the new market (Ritala & Hurmelinna-Laukkanen, 2013). This strategy of the close horizontal competitors is found effective for growing a market and for rising entry barriers, as the close competitors are assumed to have extensive horizontal coverage and hence reach a critical mass sooner (Ritala, 2012). Finally, the requirement of collaboration with competitiors of different subsidy schemes in the third stage, contributes to previous results of Mariani (2007) indicating a different way of how governments 'force' coopetition.

6.3.3 Partner Drivers

As stated in chapter 2, literature indicates that firms are driven to coopete with particular organizations due to partner characteristics and relationship characteristics. The results add insight to the partner drivers expected in table 5 as besides in the first and second stage, partner resources and capabilities appear to be a main partner driver for coopetition. Furthermore, goal alignment unexpectedly appeared to be a driver in the first two development stages instead of the third stage. Finally, the results indicate that trust was mainly important in de the second development stage and.that an increase in market power was a driver for coopetition in all three technology development stages (table 8).

The results strongly indicate that all clusters collaborate because of a need of complementary resources, however, the type of required complementary resources differed per stage. In the first stage a need for combining more diverse resources was found, while in the third development stage there was a need to share risks and costs involved. In the second stage, a combination of both type of complementary resources was found. Both results can be explained by literature. First, literature assuming a resource-based perspective underlines the importance of complementary resources as a main driver of inter-firm cooperation (Miotti & Sachwald, 2003; Tether, 2002). It is stated that there are two reasons for a firm to collaborate with other firms on an innovation, either they do not possess all the resources needed and hence desires diverse resources and an improvement for innovation capabilities to realise more radical innovations, or, the firms focus on incremental innovations and want to reduce risks and/or costs and hence want to pool similar resources, have a common understanding and rapid knowledge absorbtion (Miotti & Sachwald, 2003; Nieto & Santamaría, 2007; Ritala & Hurmelinna-Laukkanen, 2013; Tether, 2002). The findings reflect the need for different type of complementary resources for the different technology development stages. In the first stage, there is a need for idea/concept generation and inventing a product that is both new to the firm as to the market. In the second stage, there is a need to develop a first succesful commercial product by incremental innovations. While in the third stage, some incremental innovations might be needed but the focus is on succesfully implementing and marketing an innovation.

In both the first and second stage, goal alignment was indicated to be a partner driver while in the third stage goal alignment was not indicated to be an important driver. In their literature review, Dorn et al. (2016) found that goal alignment is important to prevent problems and achieve shared value, furthermore, they found that goals tend to be stronger aligned in “dense and less centralized networks” (P. 497). In the coopetitive relation between Sony and Samsung, goal alignment was an important driver for mutual investments under time-pressure and with a lack of resources (Gnyawali & Park, 2011). The difference between the partner driver of goal alignment across the first two stages and the third stage might be explained by the mutual investments and interdependence in the first two development stages, where actors are more dependent on their partners. In the third stage, organizations collaborate to strengthen their current position, however, the actors do not depend on the partner their resources. Instead they depend on other external stakeholders (governments & consumers).

Only in stage two, trust is indicated to be a driver for coopetition. The importance in this specific stage is assumed to be related to the large mutual investments in specific assets in the second stage. This finding is aligned with literature which state that reciprocal investments in asset specifity and uncertainty increase the need for inter-organizational trust (Poppo et al., 2008). Furthermore, trust increases success of a collaboration and contributes to overcoming conflicts (Ding et al., 2012; Dorn et al., 2016). Hence, collaborations facing larger mutual investments might attach a greater value to trust into their partners.

In all stages an increase of market power is found to be a partner driver. Literature states that market power is important for firms to develop and orchestrate networks (Bengtsson & Raza-Ullah, 2016; Vapola et al., 2008). Which is mainly found to be relevant in the case of cluster 1. Furthermore, literature states that companies collaborate to create a shared vision (Negro, Hekkert, & Smits, 2008), for standardization (Bergek et al., 2008) and to change legislation (Kemp & Loorbach, 2003). Cluster 6 and 7 of stage three show this as they have created a shared vision to have a stronger bargaining power towards the government, indicating the need for more financial support and, adapt legislation.

6.4 Governance mechanism

The research findings indicate different strictness of governance mechanisms across the clusters operating in the three different clusters. The differences on the strictness of governance mechanisms seem to be related to the structure of the technological development stage stated in table 1. The looser governance structure in the first stage can be explained as radical innovations are easier to protect compared to the more incremental innovation in the third stage due to imitability and number of competitors knowledgeable of the technology in the market (Ritala & Hurmelinna-Laukkanen, 2013). Furthermore, the lack of any governance system and later implementation of a governance system in the first cluster is explained by Ritala et al. (2013) by the occurance of ‘friendly’ collaborations working on risky, radical innovations and the later notion to install appropriability mechanisms once the radical innovation appears able to create value. It is indicated by literature that most organizations collaborating on innovations do not form formal arrangements (Tether, 2002).

6.5 Size

The data indicated a dominance of large organizations in the first stage while in the second and third stage more of a mix between the size of actors was observed. This might be explained by the need of guidance, entrepreneurial activities, knowledge development and knowledge diffusion in the first stage (Suurs et al., 2010). Though smaller organizations are often more entrepreneurial as a whole, larger organizations have more resources and are able to spend a relative small amount of resources to more risky activities (Tether, 2002). Furthermore, having a large resource base, a large network, a good reputation and alliance skills makes it easier to enable and guide other large organizations and diffuse knowledge more quickly (Nieto & Santamaría, 2007; Tether, 2002). Moreover, as small organizations might fear power assymetries and dominance from larger firms, they might prefer to stay out of a collaborations including 'giants' (Tether, 2002) As it is very rare for small firms to become central in a network they will benefit less from knowledge flows (Bengtsson & Raza-Ullah, 2016). Furthermore, organizations involved in the more innovative projects and concept creation of the first stage are often the organizations that invest heavily in R&D activities, these are the organizations that are able to have an R&D facility (Miotti & Sachwald, 2003). Thus, to obtain resources in a larger collaboration, one should have resources to share which in general are larger firms (Miotti & Sachwald, 2003).

6.6 Intensity of coopetition

The research results indicated that the instensity of collaboration and competition differed across the three technology development stages. All clusters operating in the third technology indicated higher competition and lower collaboration compared to the previous two development stages. Furthermore, different clusters operating in the third technology development stage indicated that they collaborated more intensely before. Literature provide different explanations for the changing degree of collaboration and competition across the development stages.

First, coopetition across the development stages might made the partners closer competitors (Perks & Easton, 2000). This seems to be the case with cluster 8 where a supplier after a while entered the same market as its partner. Furthermore, it might be, that when the product transforms from a concept into a concrete scalable product less collaboration is possible as competitors deal with anti-trust legislation (Ritala & Hurmelinna-Laukkanen, 2013). This seems to be the case with cluster 7, where two of the three organizations emphasized that they are not allowed to discuss market sensitive information. Another explanation is provided by Ritala et al. (2013) who state that tensions between two competing partners increase as there is a common knowledge base and as the value-creation potential of the innovation is higher, this restricts knowledge sharing as the risk of opportunism increases. All organizations in stage 3 operated in the same part of the hydrogen value chain, in the same market and except for one company, all in the same business. This underlines a common knowledge base and value-creation potential.

Furthermore, the different degrees of innovation across the three stages influences the competitive tensions as radical innovations are created by external resources and incremental innovations are mainly build upon internal knowledge (Ritala & Hurmelinna-Laukkanen, 2013). As a result, the collaboration on incremental innovations involve a larger risk of firm specific knowledge spill-overs. A last factor that might influence the intensity of competitive tension within coopetition is the proximity to the customers. Bengtsson and Kock (2000) found that competitive tension is found to be higher when collaborating on activities closer to the customer. The three clusters that operated in the third stage all operated in the last part of the hydrogen value chain, close to the final hydrogen consumer. These increased tensions and risks correspond with the increased governance mechanisms described above.

Though competitive tensions were described and clearly indicated to be more intense in particular clusters, no interviewee recognized direct competition on the project. Interestingly, some clusters indicated that even when collaborating with ‘the fiercest’ firm competitors no competition was present. This implies that in these clusters one company department treats the ‘partner’ different than another. This shows how coopetition results in role conflicts between companies (Bengtsson & Raza-Ullah, 2016). The way a company deals with these tensions refer to their strategy to deal with this tension. Different coopetition strategies are found across the different stages to deal with these conflicts. In the first stage, one organization clearly coordinates the cluster which indicates a third part mediation strategy. The coordination of coopetitive tensions in a network by one actor often induces more tensions (Bengtsson & Raza-Ullah, 2016). Hence, it is assumed that this strategy is only possible in the first stage due to the relatively limited tensions present in this stage. In the second stage there seems to be an integration strategy (Bengtsson & Raza-Ullah, 2016), integrating both the activities by mutual investments and integrating the competitive and collaborative tensions. In the third stage different firms appear to use a structural strategy to deal with the coopetitive tension whereas they separate the competitive and collaborative tensions in time and space (Bengtsson & Kock, 2000; Bengtsson & Raza-Ullah, 2016)

Chapter 7: Conclusion

This study adressed the question '*How do coopetition drivers differ for various development stages of green hydrogen technologies and why?'*. The results of this study indicate that coopetition drivers differ across different development stages of technology in a sustainability context. Furthermore, the data showed that the structure of clusters, governance mechanisms, size of the companies and intensities of coopetition differed across technology development stages. These differences can be explained by the technology stages and the characteristics of innovations across the development stages. In the pre-development stage a focus on a variety of new concepts and a more radical innovation requires diverse resources and capabilities. As the value generation of the innovation is uncertain, large organizations which have the resources and profit from reputational benefits invest. Furthermore, as the innovation is uncertain and far from competitive, and as there is a need for mainly external resources, competition is low and collaboration is high. Conversely, in the take-off stage, the dominant innovation is developed and creating a favorable institutional environment, legitimacy for the innovation and scaling up similar products are the main aims. Hence, in the take-off stage there is a need for similar internal resources and capabilities. Coopetition with similar competitors by bringing internal resources on a nearly competitive product increases the intensity of competition and reduces the intensity of collaboration in the coopetition (Figure 2). Especially as the product is close to customers. The rigidity of the governance structure differs between the needed appropriability regime across the different development stages and the readiness of the innovation.

7.1 Theoretical implications

This study addressed the lack of focus on the context in coopetition research by comparing coopetition across different technology development stages in a sustainability context and by addressing different structures of coopetition. This study indicates the influence of technology development stages on coopetition in a sustainability context. By comparing eight coopeting clusters, it increased understanding on different motivations for, and outcomes of, coopetition. It showed that three different technological development stages implicated different coopetition structures and drivers. Furthermore, the study showed that coopetition across three technology development stages involved different governance mechanisms, different size of companies, and different intensities of collaboration and competition. With this it provides evidence for the influence of technology development stages on different characteristics of coopetition. Furthermore, it shows there is an ever-lasting ambiguity when trying to define the concept of coopetition universally. Instead, the concept of coopetition should be placed and defined in specific contexts.

Furthermore, this study shows the influence of the research context on coopetition characteristics. In this study, the sustainability context influenced the clusters by possible reputation advantages, the emphasis of framing the collaboration for social and environmental goals, the awareness of the necessity of collaborations to overcome sustainability challenges and firm and employee motivation. In this, the research results contribute to the field of coopetition research by adding insights on an innovation in the sustainability context. Furthermore, this study contributes to coopetition literature by showing that different research contexts influence coopetition research results.

7.2 Practical implications

This study has different implications for practice. First, it contributes to the understanding of policy makers on the different technology development stage characteristics and demands for certain coopetitive collaborations. With this, it provides directions on how policy makers can stimulate specific configurations of certain coopetitive clusters considering the technology development stage. Secondly, it contributes to the understanding of management on the influence technological development stages and the different coopetition demands. With this, management could adapt the configuration of coopetition clusters to the technology development stages and functions. Furthermore, this study increases understanding on the different coopetition benefits and risks as this is related to the technology needs and the intensity of collaboration and competition in the stages. Management might make better decisions on different coopetition strategies by better understanding their own and competitor motivations to collaborate. Thirdly, this study contributes to society by providing insights in the needs and means of stimulating the right form of coopetition for catalyzing sustainable innovations, and hence for accelerating SD.

7.3 Limitations

Different limitations were present in this study. Firstly, despite the snowballing technique, the final cluster sample is small. Whether this cluster is relatively small is unclear as it is unknown how many coopetitive clusters work on this innovation. Second, despite the effort to involve different interviewees per cluster, some cluster characteristics remained difficult to assess as different interviewees shared different and sometimes conflicting information on specific cluster characteristics. These ambiguities make some data difficult to analyze. This might be prevented by a larger sample and by including multiple interviewees per company.

A variety in coopetition intensity, forms and goals among the clusters makes it difficult to compare the data. Different cluster sizes and vertical or horizontal relations are assumed to influence the data. Furthermore, as most actors denied competition, even when dealing with their fiercest competitors, it was difficult for an outsider to assess the presence and intensity of competition. Qualitative and quantitative data was triangulated. By combining an interview and a Likert-scale survey both detail-rich data and numerical data were collected. However, due to the limited sample size it was difficult to compare the numerical data. Hence, the numerical data provides information on the priorities of an individual rather than those of a set or group of individuals (e.g. a coopetition cluster). Furthermore, as data indicated the influence of technology development stages as the study progressed, this iteratively changed the focus of the research. However, the methodology did not change iteratively with the research aim. Though an iterative methodology would have been ideal for this research, important implications are made based on the gathered data.

7.4 Future research

This explorative case study shows that technology development stages influence coopetition in clusters. Further research on the relation between technology development stages and coopetition characteristics is needed to better understand and generalize the findings. Specifically research that includes different contexts and industries, uses different research methods, includes more than three technological development stages, and focuses on specific types of coopetition (e.g. vertical, horizontal, multiple, dyadic) is valuable. As the context influences the coopetition characteristics, the large amount of coopetition research within the technology industry is assumed to bias current coopetition literature. Hence, research is required that compares coopetition across different industries and across different types of innovation, e.g. social innovation.

Furthermore, this study included technological innovations in a sustainability context. Although influence of this context on the drivers of coopetition is indicated, more research is needed to understand how the sustainability context influences coopetition. In this research, interviewees clearly indicated a lack of competition with actors while working with competitors on a new innovation. More in-depth research is desired on measuring and understanding the intensity of coopetition with competitors in time and geographically.

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Appendix

A. Operationalization

The operationalization explains the measurement of the drivers of coopetition and the type of coopetition. The indicators, topics and descriptions are derived from the literature stated in chapter two.

Table 9

Operationalization drivers of coopetition

Dimension	**Indicator**	**Topic**	**Description**
External Drivers	Industry Characteristics	Industry Lifecycle	Are drivers of early lifecycle found such as a high growth level, high market uncertainty and instability. Or drivers of mature market such as a concentrated and regulated market, high needs of efficiency and effectiveness by e.g. economies of scale or optimization of distribution channels
		Technological Demand	Are drivers of a high technological demand found like short product life cycles, convergence of technologies, increasing R&D costs, high technological uncertainty and increased complexity of the technology
		Market Characteristics	Increased competitiveness is indicated by 1.competitive rivalry, 2. Bargaining power of suppliers, 3.bargaining power of customers, 4.threats of new entrants, 5. Threat of substitute products or services. Degree to which the market is shifting is indicated by changes of the abovementioned five market characteristics.

	Stakeholders	Governmental Intervention	Are regulations imposed, policies made, reforms and incentives or other institutional support or public funding present for the sustainable market.
		Consumer Demand	Do consumers show products stewardship and demand sustainable products and supply chains for the specific market
Partner Drivers	Partner	Usefulness partner resources & capabilities	Do the partnering firms have superior resources in relation to the industry and/or does the firm show a dependence on the partner their superior resources. Does the firms indicate to have different or unique resources. Does the firm indicate that the partner resources are complementing to their resources
		Goal alignment	Do the firms have a similar vision and ambition in respect of climate change (measured by e.g. comparison environmental targets, comparison vision from annual report, description scenarios, similar arguments for engaging in coopetition related to long term goals). Do the firm show that mutual benefits can be derived from pursuing the coopetition goals
	Relationship	Trust	Do the firms show to have a certain trust in their partners by e.g. mentioning experience with the partner firm, past successes, stable performance of partner firm
		Market power	Does the firm describe the partner market power by e.g. mentioning high bargaining power in different aspects of the market, increasing of total market power in towards

			other stakeholders (e.g. governmental regulation, suppliers) by collaboration
Internal Drivers	Aspirations of the firm	Ambition of goals	The level of ambition in the sustainability context is indicated by the sustainability goals of the firm in relation to the sustainability goals of the industry (environmental, societal, financial). E.g. what percentage of CO_2 reduction is set or what percentage of profits is invested in projects for enhancing sustainable development
		Prospective strategies	Does the firm show to have prospecting strategies by indicating that they want to be a key player or market leader, does the firm indicate to search for opportunities to enhance knowledge, bargaining power and/or capabilities
	Perceived vulnerability	External	Does the firm indicate that it perceives to be vulnerable because of external sources like new competitors entering the market or because the firm operates in a new market on pioneering technologies
		Internal	Does the firm indicate that it perceives to be vulnerable because of internal sources like poor performance as own targets are not met and because missing knowledge, resources and capabilities

Table 10

Operationalization types of coopetition

Dimension	**Indicator**	**Topic/description**
Role of coopetition	Vertical	Does the firm collaborate up and downstream in the value chain while competing with the same partner on another level in the value chain.
	Horizontal	Does the firm collaborate with (direct) competitors on the same stage in the value chain.
Size of coopetition	Dyadic	Do two actors compete and simultaneously collaborate
	Multiple	Do more than two actors compete and collaborate simultaneously

B. Interview guide

Introduction

- Thanking for participation in the research and underlining relevance of participation by the specific person
- Introducing myself, study and purpose of the research
- Define coopetition and types of coopetition
- Communicate confidentiality and ask permission for mentioning position, firm name and for recording the interview

General questions (indication type of coopetition)

1. Could you elaborate on the collaboration with partner(s) x?
    - Why did it start?
    - When did it start?
    - What is the current phase? (starting phase, finalizing, finalized)
    - Whom is participating?
2. Could you elaborate on the competition with partner(s) x?
    a. Compete vertically?
    b. Compete horizontally?

External drivers

3. How is/was the firm decision to coopete with firm(s) x influenced by characteristics of the industry?
    a. E.g.: high growth level, market uncertainty, market instability, increasing R&D costs, high uncertainty on technologies in the market, high complexity of technologies in the market or increased competitiveness in the market and market shifts

4. How is/was the decision of firm x to collaborate with competitors influenced by stakeholders (such as the government and consumers)?

    a. E.g. governmental intervention: regulations imposed, policies made, reforms and incentives or other institutional support or public funding present for the sustainable market

    b. E.g. do consumers show products stewardship and demand sustainable products and supply chains for the specific market

Partner specific drivers

5. Why was it decided to specifically collaborate with partner(s) x (and not with another partner)?

    a. E.g. usefulness partner resources and capabilities because superior, uniqueness or complementing

    b. E.g. aligned goals as similar vision, ambition and mutual benefits

6. How did/does the state of the relationship with firm x influence the decision to collaborate?

    a. E.g. past collaborations/projects, reputation of firm x, trust

7. How did the market power of firm x influence the decision to collaborate with firm x?

    a. E.g. increased individual and shared bargaining power

Internal drivers

8. How would you describe the sustainability aspirations of the firm in relation to the industry?

  a. E.g. is firm ambitious, key player with relatively high goals or rather waiting from the sideline

  b. E.g. is the firm proactively scanning the environment for opportunities to increase knowledge, resources and capabilities

9. What vulnerabilities are recognized for operating in the green hydrogen industry?

a. E.g. competitors entering the market and capabilities because the firm operates in a new market on pioneering technologies

b. E.g. poor performance as internal targets are not met or a lack of knowledge, resources

Intensity of drivers

10. Which factors for implementing coopetition strategies discussed before would you indicate to be the strongest reasons for engaging in this specific coopetitive partnership?
11. How would you order the beforementioned arguments for engaging in this specific coopetitive partnership from very important to not important?

C. Codebook interviews & documents

The codebook document and interview analysis explains the concepts used to code the documents and interviews in a reliable manner.

Table 11

Codebook and Documents – External Drivers

External Drivers	**Code**	**Description**
Industry Characteristics	Industry Lifecycle	Industry lifecycle includes statements on high Growth level, market uncertainty, market instability, the degree of concentration of actors and regulation in the market and the need of increasing effectiveness and efficiencies
	Technological Demand	Technological demand includes statements on product lifecycles, convergence of technologies, amounts of and increasing or decreasing R&D costs, degree of technology uncertainty and technological complexity in the market
	Market Characteristics	Includes statements and changes of market characteristics being 1. competitive rivalry, 2. Bargaining power of suppliers, 3. bargaining power of customers, 4. threats of new entrants, 5. Threat of substitute products or services.
Stakeholders	Governmental Intervention	Includes aspects on imposed regulation, policies, reforms or incentives/institutional support, public funding for green hydrogen
	Consumer Demand	Includes the presence of demands for product stewardship by demanding sustainable products, demanding that those who make, sells or buy a product takes responsibility for minimizing environmental impact through the whole supply chains for the specific market

Table 12

Codebook Interviews and Documents – Partner Drivers

Partner Drivers	**Code**	**Description**
Partner	Usefulness partner resources & capabilities	This code indicates statement on the partner resources and includes statements on them being superior in relation to the industry, being depending on the partner resources, them being unique resources, and the complementarity of resources
	Goal alignment	This code includes statements on the similarity of vision and ambition in respect of climate change and on mutual benefits for different partners
Relationship	Trust	This code indicates whether the partnering firms have a history together, have had successes with collaboration, expect stable and reliable performance of partner
	Market power	Include statements on the market power, bargaining power

Table 13

Codebook Interviews and Documents – Internal Drivers

Internal Drivers	**Code**	**Description**
Aspirations of the firm	Ambition of goals	This code includes statements on the ambition of the sustainability goals of the firm in relation to the sustainability goals of the industry by mentioning environmental, societal, financial benefits or improvements and by e.g. stating what percentage of CO_2 reduction is set or what percentage of profits is invested in projects for enhancing sustainable development
	Prospective strategies	Includes statements on the attitude and proactiveness of the firm in relation to the market e.g. statements on being a key player or

		market leader, and on searching for opportunities to enhance knowledge, bargaining power and/or capabilities
Perceived vulnerability	External	Indications on the perception to be vulnerable like new competitors entering the market or because the firm operates in a new market on pioneering technologies
	Internal	Indicates the perception of vulnerability of the firm like poor performance as own targets are not met and because missing knowledge, resources and capabilities

Table 14

Codebook Interviews and Documents – Type of coopetition

Dimension	**Indicator**	**description**
Role of coopetition	Vertical	Indicates collaborative activities between competitors up and downstream (supplier-consumer) in the value chain while competitive activities on another level in the value chain. Can be indicated by either recent introduction of product in partner market or of partner in firm their market or by the existence of competition on one stage and the decision to collaborate in a value chain stage before or after.
	Horizontal	Indicates collaborative activities between (direct) competitors on the same stage in the value chain.
Size of coopetition	Dyadic	Indicates competitive and collaborative activities between two partners
	Multiple	Indicates competitive and collaborative activities between more than two partners