Master Thesis

Standardization used as a tactic by institutional entrepreneurs

The case of the hydrogen mobility industry in the Netherlands

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Abstract

A fundamental transition in the mobility industry has still failed to materialize as sustainable technologies face difficulties that are related to the institutional setting or the lack of this setting. Institutional entrepreneurs use standardization as one of their tactics to achieve institutional change for hydrogen-based technologies. While standardization improves the innovation development process, it can also shift competitive advantage of actors when they either fail to perceive the new way of competing or are unable to respond to the new developments. The following research questions are answered: ***"How do actors in the hydrogen mobility industry of the Netherlands operate in the standardization process of the hydrogen and fuel cell technology and how does this influence the hydrogen technology innovation development process?"*** This research used the Dutch hydrogen mobility industry as case study, because actors of this industry are actively engaged with the standardization of safety regulations of a hydrogen filling station, namely PGS 35. Furthermore, this research applies a case study research design to inductively identify the relevant actors' motivations, strategies, reasoning and interpretations in the standardization process of PGS 35. Based on data retrieved from twelve semi-structured interviews, a system process analysis is employed to determine indicators. This research demonstrated that entrepreneurs participated for various reasons and three main identified concepts were found: *knowledge diffusion*, *compatibility* and *proprietary technology.* In the first two concepts both private and public participants had mainly corresponding actions and goals regarding improving the innovation development process and gaining competitive advantage. However, a contradiction is found in the concept of proprietary technology as private actors strive for flexibility in technological solutions and public actors aim for a variety reduction to simplify licensing applications for hydrogen filling stations. The conflicting motivations were solved as performance-based requirements were established to ensure flexibility and design-based technical solutions have been written down as examples to advice licensing authorities. Policy makers should "measure" the interests of the participant on the basis of the desired functionality by these participants. Doing so, conflicting motivations and goals can be identified and solved during the standardization process. This will likely reduce the lead time of the standard process. Future research could focus on the effect of the five other tactics on the standardization process as activities were identified which relate to these tactics.

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Giovanni van Eijk

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1. Introduction

Transport has a central place in our economy and society, because mobility is essential for both the national and international markets and for the quality of life of citizens as they like to make use of their freedom to travel (European Commission, 2011). However, the European transport has a downside. It depends for 96% of its energy needs on oil and oil products, which has led to a significant increase in greenhouse gas (GHG) emissions (European Commission, 2010). The European Union has developed a roadmap towards a competitive and resource-efficient transport system to reduce the GHG emissions and the oil dependency. All the goals of this roadmap will eventually contribute to a 60% cut in transport emissions by 2050 (European Commission, 2011). New sustainable technologies for vehicles and infrastructure are needed to lower these transport emissions as current vehicles make use of fossil fuel technologies which are responsible for these emissions.

Although new and more efficient technologies have emerged, a fundamental transition has still failed to materialize (European Commission, 2011; Farla et al., 2012). Industries have become locked into fossil fuel-based energy systems by the process of technological and institutional co-evolution which is induced by path-dependent increasing returns to scale. This lock-in hinders the development and diffusion of carbon-saving or sustainable technologies despite their apparent environmental and economic advantages (Unruh, 2000). The same applies to the transition from a carbon-based energy system to a hydrogen-based economy. Among other things, socioeconomic barriers block the implementation of hydrogen and fuel cells as clean energy technologies of the future (Edwards et al., 2008). Sustainable technologies, like the hydrogen fuel cell technology, face difficulties that are related to the institutional setting or the lack of this setting. In the case of the hydrogen mobility industry[1], the public has a negative attitude towards hydrogen systems in general and vehicles with fuel cells in particular as alternative and clean energy technology (Hoen & Koetse, 2012; Sharaf & Orhan, 2014). One of the reasons is a lack of internationally-accepted codes and standards for safety in the design, installation, operation, maintenance, and handling of hydrogen equipment as hydrogen is a highly flammable gas (Sharaf & Orhan, 2014). Currently there are 14 ISO standards which are relevant for the hydrogen mobility industry and almost half of these standards were developed and implemented in the last four years (ISO, 2015a, 2015b). A notable degree of activities takes place in the standardization process of hydrogen technologies as new ISO standards are currently planned or under development (ISO, 2015a). According to Klein Woolthuis et al. (2013) the process of standardization creates opportunities for the industry and eventually will result in changes of the established institutions.

In this research institutions are defined as the (unwritten) rules of the game, such as norms that lead to routine like behavior (Jepperson, 1991) or rationalized myths (Meyer & Rowan, 1977). A distinction can be made between soft/informal institutions which are socially embedded institutions and hard/formal institutions which are rules, laws, policies and regulations (Edquist & Johnson, 1997; Johnson & Gregersen, 1995; Klein Woolthuis et al., 2005; North, 1990; Pacheco et al., 2010). Both types of institutions can enable or constrain the development of sustainable technologies in the mobility sector and are therefore examined. These institutions influence actors' behavior. However the same actors/entrepreneurs are also capable of influencing, and possibly changing, institutions (Battilana et al., 2009). The current institutions hamper sustainable innovations and institutional change is required. Institutional change is the process of de-institutionalization of existing institutions, and the theorization and institutionalization of new more

[1] The hydrogen mobility industry is defined as all relevant industrial, innovation and other economic activities which are dealing with hydrogen technology and fuel cells in the mobility sector.

suitable institutions (Greenwood et al., 2002). To reach this required modification, institutional entrepreneurs can initiate and/or accelerate institutional change by creating new or transforming existing institutions (DiMaggio, 1988; Leca et al., 2008). Within the body of literature of institutional entrepreneurship, institutional entrepreneurs are conceptualized as influential (groups of) individuals or organizations and incumbents that challenge old, and initiate new, institutions (Dacin et al., 2002; Fligstein, 1997; Garud & Karnøe, 2003; Kishna, 2015). These institutional entrepreneurs employ standardization to influence both formal and informal institutions to create a more favorable institutional context (Klein Woolthuis et al., 2013)

A market that requires an infrastructure-related system, like the mobility sector, is known for its monopolistic or oligopolistic character (Arrow, 1962). These types of market structures hamper innovation, which eventually increases costs for society (Arrow, 1962). Standardization can be used as an important mechanism to overcome this problem (Egyedi & Spirco, 2011). Multiple and different types of actors are involved in the process of standardization and thus the views of all interested organizations are taken into account which results in partial abolition of the monopolistic or oligopolistic character (Egyedi & Spirco, 2011; ISO, 2016). Institutional entrepreneurs can use standardization as one of their tactics in order to achieve institutional change (Bansal, 2005; Hart, 1995; Klein Woolthuis et al., 2013). Standardization is all about creating stability which seems to be in contrast with innovation, since innovation is all about changing the current state (Schumpeter, 1942). So it can be argued that innovation and standardization prove challenging to reconcile (Blind, 2009). However, prior research proves that it is not a contrast by definition. Standardization can be used as a catalyst for innovation (Blind, 2009; Temple, 2005). In addition, effectively influencing or setting standards, for instance, in the form of certification or norms and being the first mover can create a competitive advantage for firms or entrepreneurs and thereby hold a temporary monopoly (Boiral, 2007; Penrose, 1995; Porter, 1980, 1985). The findings of Klein Woolthuis et al. (2013) showed that the process of setting standards to gain and maintain a competitive margin is used by institutional entrepreneurs in an existing market. The authors also demonstrated that being the first to create an industrial norm, with certificates to substantiate adherence to the norm, is used as a mechanism for institutional change.

Previous literature showed that standardization is used as a mechanism for institutional change and has two clear effects, namely improving the innovation development process as a catalyst for innovation and gaining a strategic and competitive advantage for the firm. However there is a contradiction, because developments in the innovation development process can shift competitive advantage of actors when they either fail to perceive the new way of competing or are unwilling or unable to respond to the new developments (Porter, 1998). So stimulating the innovation development process can possibly lead to a loss of competitive advantage and this eventually affects the decision process of institutional entrepreneurs. This research will examine the motivations and strategies of institutional entrepreneurs who are involved with standardization in the hydrogen mobility industry. The hydrogen mobility industry is used as case study, because it is found that actors of this industry are currently engaged with standardizing the necessary technologies. The research area is delimited to the Netherlands, since it is one of the most active actors in the European Union (FCHJU, 2014). The research questions are as follows:

How do actors in the hydrogen mobility industry of the Netherlands operate in the standardization process of the hydrogen and fuel cell technology and how does this influence the hydrogen technology innovation development process?

This research contributes to the existing literature on institutional entrepreneurship and its relation to standardization as a tactic to overcome institutional difficulties with the ultimate goal of improving the innovation development process; it provides a better understanding of the use of standardization in acquiring institutional change. This research presumed that actors have two targets to strive for in the standardization process: 1) attaining solution(s) for difficulties in the hydrogen technology innovation development process and 2) gaining a competitive advantage for the organization that they represent. This research has elucidated how these two goals are played out by the actors involved in the standardization process and whether these two goals precluded one another or strengthened one another.

According to the Dutch Ministry of Infrastructure and the Environment, the cooperation between the various kinds of companies, organizations and entrepreneurs in the hydrogen mobility industry, have led to problems on agreements. An example of a problem on an agreement is the quality of hydrogen which can be used as fuel. Automotive manufacturers demand varying purities to be used in their vehicles. Based on the outcomes of this research, the Dutch Ministry of Infrastructure and the Environment has a better understanding of the goals and strategies of the actors in the standardization process. With these insights they can advise on how to solve these types of problems and improve the development of the technology which can lead to an improved implementation of hydrogen technology in the mobility sector. This research is conducted in collaboration with the Ministry of Infrastructure and the Environment, which has an active role in the network of the hydrogen mobility industry of the Netherlands. They are in contact with actors from every segment in the hydrogen technology innovation development process. The remainder of this research is structured as follows. Section two covers the theoretical section, section three and four covers the methodology and operationalization, section five covers the results, section six covers the analysis and section seven ends with a conclusion and discussion.

2. Theory

In this section the relevant theoretical background and the related concepts are explained which are used in this research. Firstly, the literature of institutional entrepreneurship is used to explore the concept of institutional entrepreneurship and the relevant activities. Secondly, the literature of standardization is reviewed to determine the types of standards that are typically seen in the standardization process. Finally, this section ends with an overview of the current state-of-the-art advancements of the hydrogen mobility industry to give an insight in the most important developments and their relation to the standardization process.

2.1 Institutional entrepreneurship

There are two largely divergent streams of thought that describe institutional entrepreneurship: sociology-based institutional theory and economics-based institutional economics (Pacheco et al., 2010). Pacheco et al. (2010) suggest that while institutional economics focuses mostly on the origin and outcomes of institutional entrepreneurship, the sociology-based institutional theory perspective is more concerned with the process and mechanisms that drive such change. The goal of this research is to get a better understanding of standardization as a mechanism and therefore this research focusses on sociology-based institutional theory.

The literature on sociology-based institutional theory focusses on explaining social behavior with respect to specific contextual forces and treats institutions as socially constructed rule systems or norms that produce routine-like behavior (Jepperson, 1991; Kishna, 2015). Within this literature strand, institutions are seen as taken-for-granted social rules that stabilize and pattern behavior (Kishna, 2015; Meyer & Rowan, 1977; Oliver, 1991; Scott, 2008a). Institutions comprise of three elements: regulative, normative and cultural-cognitive elements (Scott, 2008a, 2008b). Regulative elements emphasize rule-setting, monitoring and sanctioning activities. The prescriptive, evaluative, and sanctioning dimension of social life are covered by the normative elements (Scott, 2008b: 54). At last, cultural-cognitive elements underline the shared conceptions that constitute the nature of social reality and the frames through which meaning is made (Scott, 2008b: 57). Furthermore, institutions cause behaviors to be patterned and reproduced and lead to specific ways of doing, accepting and thinking in various social groups (Garud & Karnøe, 2003).

However, institutions are not uniformly taken-for-granted and are therefore continuously challenged and contested. This causes new institutions to be created and existing institutions to be changed over time (Dacin et al., 2002). Legitimacy is obtained by means of changing institutions, i.e. building a perception that the new technology is appropriate or acceptable (Dacin et al., 2007; Seo & Creed, 2002; Thornton & Ocasio, 2005). This is essential for the hydrogen fuel cell technology because of the lack of acceptance by the public (Hoen & Koetse, 2012; Sharaf & Orhan, 2014). Institutional change can be driven by institutional entrepreneurs who are (organized) actors who recognize the need for new institutions to satisfy their interests, while simultaneously being influenced by the currently existing institutions (DiMaggio, 1988; Garud et al., 2007; Garud et al., 2002; Greenwood & Suddaby, 2006; Maguire et al., 2004). Furthermore, institutional entrepreneurs can affect new ideas, build coalitions and engage in political action with the goal to create a new path for development (Klein Woolthuis et al., 2013). Actors who function as institutional entrepreneurs conceptualize new institutional arrangements and undertake actions to realize this new institutional setup (DiMaggio, 1988; Greenwood & Suddaby, 2006; Kishna, 2015; Maguire et al., 2004). Two main conditions have to be fulfilled for actors to be regarded as institutional entrepreneurs: 1) actors must initiate changes that break with the institutionalized template for organizing in the context under study, and 2) actors must actively participate in the implementation of these changes by mobilizing resources (Battilana et al., 2009; Kishna, 2015).

As argued in literature on institutional entrepreneurship, collaborations between different organizations, private as well as public, have been recognized as a potential route for institutional change as collaborations can trigger the establishment of shared visions and frames, can build up trust and legitimacy for a group of organizations, can lead to reduced, shared risks, and shared resources (Gray, 1989; Lawrence et al., 2002; Phillips et al., 2000; Trist, 1983). In such manner, collaborations potentially give organizations the ability to overcome power, size, and resource limitations needed to change the institutional setting or standard (Lawrence et al., 2002).

It can be concluded that institutional entrepreneurs, e.g. participating in a collaboration, make use of their resources and capabilities to create new or change existing institutions (Battilana et al., 2009; Garud et al., 2007; Kishna, 2015; Maguire et al., 2004). However, the actions of the institutional entrepreneurs can differ in the degree of intentionality as they can be aware or unaware of the effect of their actions regarding institutional change (Kishna, 2015). The prime condition to classify the actors in the mobility industry as institutional entrepreneurs is that their actions, whether intentionally or unintentionally, contribute to the change that breaks with the current institutionalized technological standard. Furthermore, these change-oriented actions do not have to be successful in order to characterize these actors as institutional entrepreneurs (Kishna, 2015).

Institutional entrepreneurs can apply six different types of actions or tactics to achieve the desired institutional change: framing, theorization and professionalization, collective action, lobbying, negotiation and standardization (Klein Woolthuis et al., 2013; Pacheco et al., 2010). Using the tactic of *framing*, institutional entrepreneurs can depict their preferred institutional arrangement as appealing to the widest possible audience. This tactic ties back to the goal of creating legitimacy for new forms and practices by closely integrating new ideas and processes with commonly accepted narratives (Pacheco et al., 2010). *Theorization and professionalization* is the practice of developing abstract categories into chains of cause as well as effect and is used to create support for their "right" solution (Klein Woolthuis et al., 2013; Pacheco et al., 2010). Institutional entrepreneurs make use of *collective action* to bring the interests of different groups together, for example by providing common meaning or identities, and sketching a pervasive vision on a common development path (Fligstein, 1997; Klein Woolthuis et al., 2013). Institutional entrepreneurs collaborate with other actors, such as local authorities, to influence formal institutions. *Lobbying or political tactics* can be employed to bring forward the vision and interests of the collective group as an institutional entrepreneur acts as an organizer, and expression of a collective group and is the spark that moves that group toward (collective) action (Klein Woolthuis et al., 2013; Pacheco et al., 2010). An institutional entrepreneur can also *negotiate* with other actors, because it is important to establish contractual forms, property rights and financial arrangements in realizing new ventures. By negotiating with actors new formal institutional arrangements and incentive schemes can be altered (Klein Woolthuis, 2010). At last, the sixth tactic, standardization, is found by Klein Woolthuis et al. (2013). Through alteration of formal institutions with certificates and standards, a competitive edge is created and field change potentially initiated by institutional entrepreneurs, resulting in other organizations adapting to the initiated change.

2.2 Standardization

As described above, institutional entrepreneurs can use the process of standardization to achieve institutional change. Standards can help to spread new practices or technologies in an organizational field (Boiral, 2007), but also to create a competitive advantage in terms of first mover advantage (Klein Woolthuis et al., 2013). A standard can be defined as a construct that results from reasoned, collective choice and enables agreement on solutions of recurrent problems (Tassey, 2000). Complementary to this definition, an industry standard is defined as a set of specifications to which all elements of processes, formats, products and procedures should conform under its jurisdiction (Tassey, 2000). In the academic literature, various taxonomies are postulated for standards. In this research the economic function, the creation-process and the formulation of a standard are chosen as starting point for typologies. These typologies are described in the following paragraphs.

Firstly, standards can fulfil four different economic functions in a technology-based economy as seen in Table 1 (Tassey, 2000). Standards can be specified to an acceptable product or service performance along one or more dimensions such as functional levels, performance variation, service lifetime, efficiency, safety, and environmental impact. A minimum level of *performance or quality* often provides the point of departure for competition in an industry (Tassey, 2000). Standardization processes assist in evaluating scientific and engineering *information* in the form of publications, electronic data bases, terminology, and test and measurement methods for describing, quantifying, and evaluating product attributes. In technologically advanced industries, like the hydrogen mobility industry, a range of measurement and test method standards provide information which reduce transaction costs between actors (Tassey, 2000). Standards specify properties which a product must have in order to work physically or functionally with complementary products within a product or service system. *Compatibility or interoperability* is typically manifested in the form of a standardized interface between components of a larger technological system (Tassey, 2000). Compatibility can be divided in three types: physical compatibility, communication compatibility and compatibility by convention (Farrell & Solaner, 1986). At last, a standard can *limit* a product to a certain range or number of characteristics such as size or quality levels, but also limits data formats and combined physical and functional attributes (Tassey, 2000).

Table 1: Economic roles of standards in a technology-based economy (Tassey, 2000)

Function	Definition
Quality/reliability	Specification of acceptable product or service performance
Information	Provision of measurement and test methods
Compatibility/interoperability	Specification of properties that a product must have in order to work physically or functionally with complementary products
Variety reduction	Limitations of a product to a certain range or number of characteristics such as size or quality levels.

Secondly, standards can be divided based on their position in the creation-process of a standard, especially on the organizations which enforce the standard (David & Greenstein, 1990; Hanseth et al., 1996). A summary is given in Table 2. The first standard, *de jure*, is set by governments from outside the related industry and directed at companies. This is a form of governmental regulation. If actors in an industry agree on a standard by themselves, then it is a *formal* standard. When it is developed through an association a *de facto* standard is enforced by an influential company. In the case of agreement between companies to use a certain method and/or technology, but without establishing a formal standard, this is seen as an informal way to create a de facto standard. However, the line of demarcation is in practice less clear.

Table 2: The creation-process of standards (David & Greenstein, 1990; Hanseth et al., 1996)

Type of standard	Locus
De jure standards	Governments (e.g. ISO, ASCII)
Formal standards	Standardization committees (e.g. CEN, IEC)
De facto standards (Informal)	Private companies (e.g. MP3, HTML)

Finally, there is the formulation of standards. There are two main types of formulation: performance-based standards and design-based standards (Blind, 2009; Egyedi & Spirco, 2011; Tassey, 2000). This is shown in table 3. *Performance-based* standards are formulated in such a way to meet a certain achievement, e.g. a required set of actions or specific output. In contrary, the *design-based* standards capture the exact layout and materials used.

Table 3: Types of formulations (Blind, 2009; Egyedi & Spirco, 2011; Tassey, 2000)

Type of standard	Elaboration
Performance-based standards	Fixed achievements
Design-based standards	Fixed design and material used

2.3 The hydrogen mobility industry

A functional fuel cell was developed as early as the 1800s (Sharaf & Orhan, 2014). In the next two centuries many other milestones were reached and in the early 2000s the technology was developed to an early commercialization of fuel cells (see table 4) (Sharaf & Orhan, 2014). These developments have eventually led to the first commercial hydrogen fuel cell vehicle (HFCV). However, the developments stagnated for several reasons. Fuel cells are relatively expensive per kWh, have a low durability, an immature hydrogen infrastructure network and the lack of internationally-accepted codes and standards for hydrogen systems in general and fuel cells in particular (Sharaf & Orhan, 2014). Despite the costs and low durability of fuel cells, Toyota launched the world's first commercially available fuel cell vehicle the "Mirai" powered by the Toyota Fuel Cell System (Hasegawa et al., 2016). Automotive company Toyota has improved the technological drawbacks of the vehicle; however, the infrastructure is still immature.

Table 4: Development milestones in the history of fuel cells (Sharaf & Orhan, 2014).

Year(s)	Milestone
1839	W.R. Grove and C.F. Schönbein separately demonstrate the principals of a hydrogen fuel cell
1889	L. Mond and C. Langer develop porous electrodes, identify carbon monoxide poisoning, and generate hydrogen from coal
1893	F.W. Ostwald describes the functions of different components and explains the fundamental electrochemistry of fuel cells
1896	W.W. Jacques builds the first fuel cell with a practical application
1933-1959	F.T. Bacon develops AFC technology
1937-1939	E. Baur and H. Preis develop SOFC technology
1950	Teflon is used with platinum/acid and carbon/alkaline fuel cells
1955-1958	T. Grubb and L. Niedrach develop PEMFC technology at General Electric
1958-1961	G.H.J. Broers and J.A.A. Ketelaar develop MCFC technology
1960	NASA uses AFC technology based on Bacon0s work in its Apollo space program
1961	G.V. Elmore and H.A. Tanner experiment with and develop PAFC technology

1962-1966	The PEMFC developed by General Electric is used in NASA0s Gemini space program
1968	DuPont introduces Nafion
1992	Jet Propulsion Laboratory develops DMFC technology
1990s	Worldwide extensive research on all fuel cell types with a focus on PEMFCs
2000s	Early commercialization of fuel cells

Overview of the current (international) standards

There is a lack of internationally-accepted codes and standard in the hydrogen mobility industry, because there are just a few ISO standards for hydrogen technologies which are applicable for the hydrogen mobility industry. Most of the standards are primarily focused on the required infrastructure for the hydrogen mobility industry (ISO, 2015a, 2015b) . Table 5 gives an overview of all the current international standards which are relevant for the hydrogen mobility industry, in this case hydrogen technologies and fuel cells.

Table 5: A chronological overview of all relevant ISO standards for the hydrogen mobility industry (ISO, 2015a, 2015b)

ISO code	Content	Published on
ISO 16110-1:2007	Hydrogen generators using fuel processing technologies -- Part 1: Safety	2007-03-09
ISO 22734-1:2008	Hydrogen generators using water electrolysis process -- Part 1: Industrial and commercial applications	2008-07-01
ISO/TR 11954:2008	Fuel cell road vehicles -- Maximum speed measurement	2008-10-09
ISO/TS 15869:2009	Gaseous hydrogen and hydrogen blends -- Land vehicle fuel tanks	2009-02-01
ISO 6469-1:2009	Electrically propelled road vehicles -- Safety specifications -- Part 1: On-board rechargeable energy storage system (RESS)	2009-09-14
ISO 6469-2:2009	Electrically propelled road vehicles -- Safety specifications -- Part 2: Vehicle operational safety means and protection against failures	2009-09-14
ISO 16110-2:2010	Hydrogen generators using fuel processing technologies -- Part 2: Test methods for performance	2010-02-05
ISO 22734-2:2011	Hydrogen generators using water electrolysis process -- Part 2: Residential applications	2011-11-15
ISO/TR 8713:2012	Electrically propelled road vehicles -- Vocabulary	2012-04-25
ISO 14687-2:2012	Hydrogen fuel -- Product specification -- Part 2: Proton exchange membrane (PEM) fuel cell applications for road vehicles	2012-11-30
ISO 17268:2012 / ISO/AWI 17268	Gaseous hydrogen land vehicle refueling connection devices	2012-12-01
ISO 23273:2013	Fuel cell road vehicles -- Safety specifications -- Protection against hydrogen hazards for vehicles fueled with compressed hydrogen	2013-06-03
ISO 23828:2013	Fuel cell road vehicles -- Energy consumption measurement -- Vehicles fueled with compressed hydrogen	2013-11-15
ISO/TR 15916:2015	Basic considerations for the safety of hydrogen systems	2015-12-15

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The most recent ISO standard, which is still under development, is the ISO 19880, which describes the requirements for a hydrogen fueling station. It consists of seven parts, namely general requirements, dispensers, valves, compressors, hoses, fittings, hydrogen quality control (see table 7)(ISO, 2015a).

Table 6: Parts of the ISO 19880 standard (ISO, 2015a)

ISO Code	Content
ISO/DTR 19880-1	Gaseous hydrogen -- Fueling stations -- Part 1: General requirements
ISO/CD 19880-2	Gaseous hydrogen -- Fueling stations -- Part 2: Dispensers
ISO/CD 19880-3	Gaseous hydrogen -- Fueling stations -- Part 3: Valves
ISO/AWI 19880-4	Gaseous hydrogen -- Fueling stations -- Part 4: Compressors
ISO/AWI 19880-5	Gaseous hydrogen -- Fueling stations -- Part 5: Hoses
ISO/AWI 19880-6	Gaseous hydrogen -- Fueling stations -- Part 6: Fittings
ISO/AWI 19880-8	Gaseous hydrogen -- Fueling stations -- Part 8: Hydrogen quality control

The ISO standards are the most important standards since they apply worldwide. As can be seen almost half of these standards are developed and implemented in the last four years and new important standards are still under development. ISO standards are developed according to the principles of industry-wide, voluntary consensus, so that the views of all interested organizations are taken into account (ISO, 2016). This means that the hydrogen mobility industry is actively developing standards to improve the innovation development process of hydrogen technologies. Countries in Western Europe, e.g. United Kingdom and the Netherlands, have their own national standards, and these are mainly related to the ISO standards. In 2015, Dutch actors in the hydrogen mobility industry have developed Publicatiereeks Gevaarlijke Stoffen (PGS) 35 which is similar to ISO 19880. PGS provides guidance for companies who produce, transport, store or use hazardous substances and for authorities responsible for granting licenses and monitoring these companies (PGS, 2015). PGS 35 is focused on safety measures of hydrogen fueling installations which deliver hydrogen to road vehicles. Since the (inter)national hydrogen mobility industry is currently standardizing the hydrogen filling station, PGS 35 is chosen as standard for this research as the research area is delimited to the Netherlands.

3. Method

This section describes the research method of this research and first explains the research design used. This is followed by an elaboration on the method of data collection and data analysis.

3.1 Research design

The aim of this research was to find a better understanding of the use of standardization by institutional entrepreneurs as a mechanism for obtaining institutional change. A qualitative approach can be used to understand people's interpretation of subjects (Bryman, 2012). Thus a qualitative approach was chosen, because the aim of this research was to understand the relevant actors' motivations, strategies, reasoning, and interpretations to use standardization as a tactic to initiate institutional change in the hydrogen mobility industry. For this research PGS 35 is chosen as a case study, because a variety of entrepreneurs of different disciplines were involved in the standardization process (PGS, 2015) and allowed to get a better understanding of the tactic's circumstances.

This research used all the aforementioned theoretical concepts in an inductive manner as a guideline to extract a better understanding of the use of standardization. In this research contextual understanding was of importance and as determined in the theory section the relevant concepts have no clear indicators and can vary among different institutional entrepreneurs. Consequently, the measurements of the concepts in this study should be developed from the results and therefore the data collection was of an explorative nature to understand the perception of actors. The method of data collection is further explained in the next section.

3.2 Data collection

The PGS 35 document contains an annex with the composition of the participants who have participated in PGS 35. A team of 20 members from different organizations participated in the development of PGS 35 (PGS, 2015). Three hydrogen producers, three infrastructure related actors, three governmental actors and three industry associations' actors of the team were selected and interviewed about the standardization process of PGS 35. An overview of the interviewed participants is presented in *Appendix A*. Based on this selection and diversity a broad understanding of the different interests and strategies used is obtained until a saturation of relevant data was achieved. The data was collected through the use of recorded semi-structured interviews. This type of interviewing was chosen, because of the explorative nature of this research and the advantages that this type of interview provides in this context. In semi-structured interviews the interviewer follows a script to a certain extent, where all interview questions are asked in a similar manner from interviewee to interviewee. In addition, this interview structure gave the possibility to gain in-depth information as much as possible from the interviewee by asking more (context)-specific questions for further clarification. Therefore these types of interviews are flexible and provide the space to ask for more specific and relevant questions to maximize information gathering (Bryman, 2012). This was useful, because the aforementioned theoretical concepts were used as a guideline in the interview and the contextual understanding was of importance in this research. Furthermore, the interviewer was able to ask follow-up questions in this setting as a reaction to what were seen as significant replies (Bryman, 2012). Being able to react and differ from the pre-constructed interview script to gather new insights fitted the need to identify indicators for the theoretical concepts. The interview script (see appendix B) was piloted and pre-tested[2] to ensure that the interview questions generate appropriate data

[2] In appendix A an overview is given of the interviewees in this research. One of the participants is marked with: (pilot) as this interview was used as the pilot interview.

(Bryman, 2012). Additionally, secondary public sources are used to support participants' statements and to explain technical concepts of hydrogen filling stations.

3.3 Case study interviews

The interviews were aimed at gathering insights provided by the questioned actors regarding the given concepts in the aforementioned theory section. Qualitative research often uses purposive sampling to select their units of observation (Bryman, 2012). Purposive sampling is a form of non-probability sampling, where the sample cases are picked in a strategic way to be relevant. The research problem has been specified to actors who are involved with the construction of PGS 35 in the hydrogen mobility industry of the Netherlands, to ensure feasibility of conducting this research. Alexander Hablé, program manager at the Ministry of Infrastructure and the Environment, has cooperated in contacting the relevant actors who were involved with the construction of PGS 35. In general, there were four different stakeholders involved in the hydrogen mobility industry: hydrogen producers, local and national government, infrastructure related organizations, and research organizations and industry associations (H2 Mobility, 2016; NWBA, 2016).

3.4 Data analysis

This research transcribed the recorded interviews for analyzing. These transcriptions are made publicly available for those interested. All data were coded, based on the theoretical categories developed in the theory section, while leaving room for open coding, using "in vivo" labels. NVivo qualitative data analysis software is used as supportive tool in this coding process. To ensure that the coding process is conducted in a structured way, the concepts introduced in the theory section are used as sensitizing concepts to guide the interview questions and coding process. Sensitizing concepts were introduced by Blumer (1954). They lack clear definition in terms of attributes or fixed benchmarks. In the context of this research, sensitizing concepts 'give a general sense of reference and guidance in approaching empirical instances' (Blumer, 1954:7). In this line of reasoning, sensitizing concepts are used in this study as guidance in such a way that they give a general sense of what to look for (Bryman, 2012). In the data was sought how the following sensitizing concepts played a role in the realization of PGS 35: "*Role in standardization process*", "*Economic function of standard*", "*Creation-process of standard*", "*Type of formulation*" and "*Goal of the standard*".

There were two main phases of coding: initial coding and selective coding (Charmaz, 2006). The first phase is an open-minded process and resulted in coding every relevant line of text with the first initial impression of the data (Bryman, 2012; Charmaz, 2006). In this way, representative quotes (RQ) are formulated (Gioia et al., 2013). First order codes (FO) are derived out of these representative quotes collected from the interviewees. These first order codes, informant centric codes, do not contain any interpretations by the researchers and are therefore a literal restated reflection of the quotes (Gioia et al., 2013). Furthermore, when the quote's context is not immediately apparent, this context is attached to the representative quotes between brackets. In the next phase, selective coding, the revealing codes are highlighted. New codes may be generated by combining the first order codes (Bryman, 2012; Charmaz, 2006). These second order codes (SO), researcher centric codes, contain narrative interpretations by the researchers (Gioia et al., 2013). At this point, second order codes are derived from the identified representative quotes. An example of this study's data analysis process can be seen in figure 1.

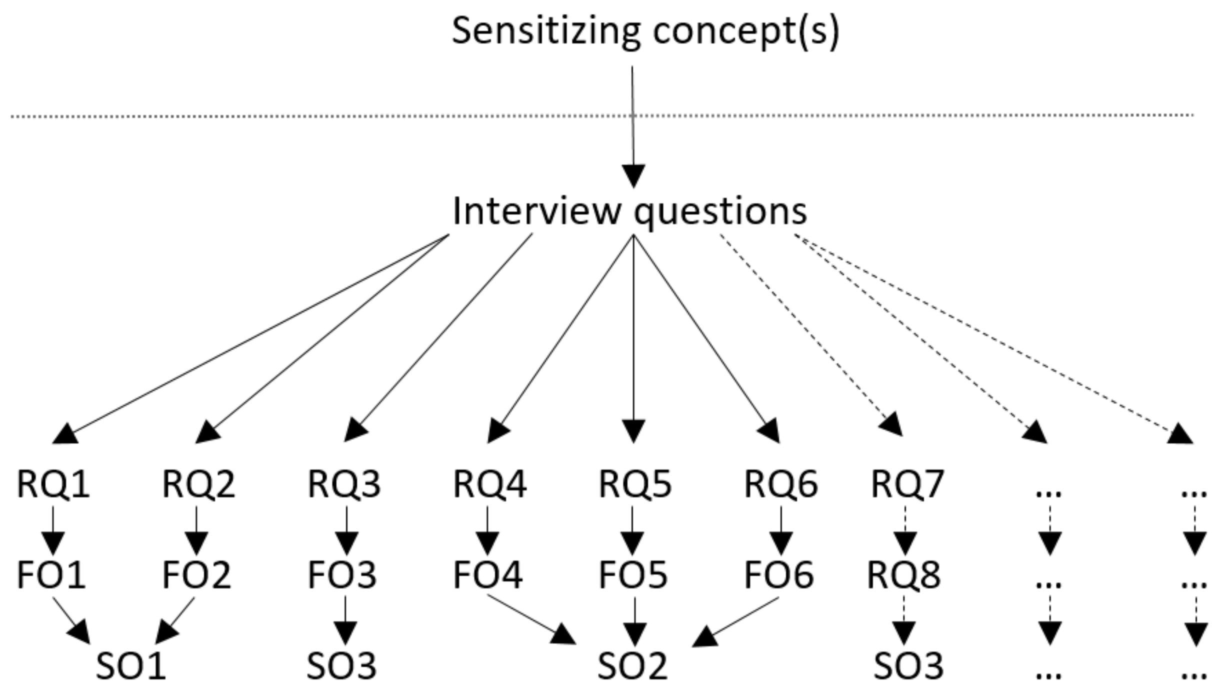

Figure 1: Coding tree (RQ= Representative quote, FO= First Order code, SO= Second Order code)

The created second order codes are processed via a systemic analysis. All the second order codes are evaluated and compared for matching purposes and motivations in order to find overlapping topics in the data. Thereafter, the second order codes are assessed for the impact they have on the two effects of standardization: Improvement of the innovation development process and gaining competitive advantage. An example of the coding structure is presented in Appendix C.

Throughout the process of coding, there was a constant comparison between codes/codes and codes/theoretical concepts, to increase the validity and inter code reliability of the created indicators (Bryman, 2012). Since constant comparison is used to ensure that after each round of coding and analysis (Strauss & Corbin, 1990), new meanings and relationships are compared to verify and deepen the analysis. Because this research used a case study methodology, the generalizability of the results is limited. To limit the risk of arriving at incorrect conclusions, this research verified and corrected the case description of PGS 35 with the aid of the interviewees where possible (Saunders et al., 2009).

4. Operationalization

The next section explains on which theoretical concepts (see figure 2) the interview questions (see appendix B) were based. Then followed by the operationalization of theoretical concepts regarding institutional entrepreneurship and the effects of the standardization process.

4.1 Motivation of actors in the standardization process

In this research the innovation development process is defined as all the relevant activities of the thought process for the development of a new technology from the idea stage through to market launch and beyond (Cooper & Edgett, 1999). Competitive advantage is defined as the ability of a company to deliver the same benefits as competitors at a lower cost or deliver benefits that exceed those of competing products. So, a competitive advantage enables the firm to create superior value for its customers and superior profits for itself. (Porter, 1998). Literature describes that standardization of technologies has positive relations with the innovation development process and competitive advantage. Questions were aimed at the influence of the type of negotiated standard on the innovation development process and/or competitive advantage which depends on the goal of the concerned actor. Follow-up questions were focused on the motivations of choice. As mentioned in the introduction, both goals can be stimulated by the process of standardization, however the relation between those two can create friction and affects the motivations or strategies of institutional entrepreneurs. Questions were focused on the induced changes of the standardization process. Follow-up questions were directed on the influence of the interrelation on the motivation of the interviewee. Answers of the interviewees were used to determine the effect of this interrelationship.

4.2 Standards negotiated in the standardization process

As described in the theory section standards have different functions and are formulated in a particular way. The interviews started with questions which determined the function and type of the standard which are co-developed by the interviewee. Based on the answers of the interviewee the perception of the actor can be determined. These formed the basis to ask follow-up questions for the motivations of actors in the standardization process and the relations between the type of standards, improving the innovation development process and gaining competitive advantage.

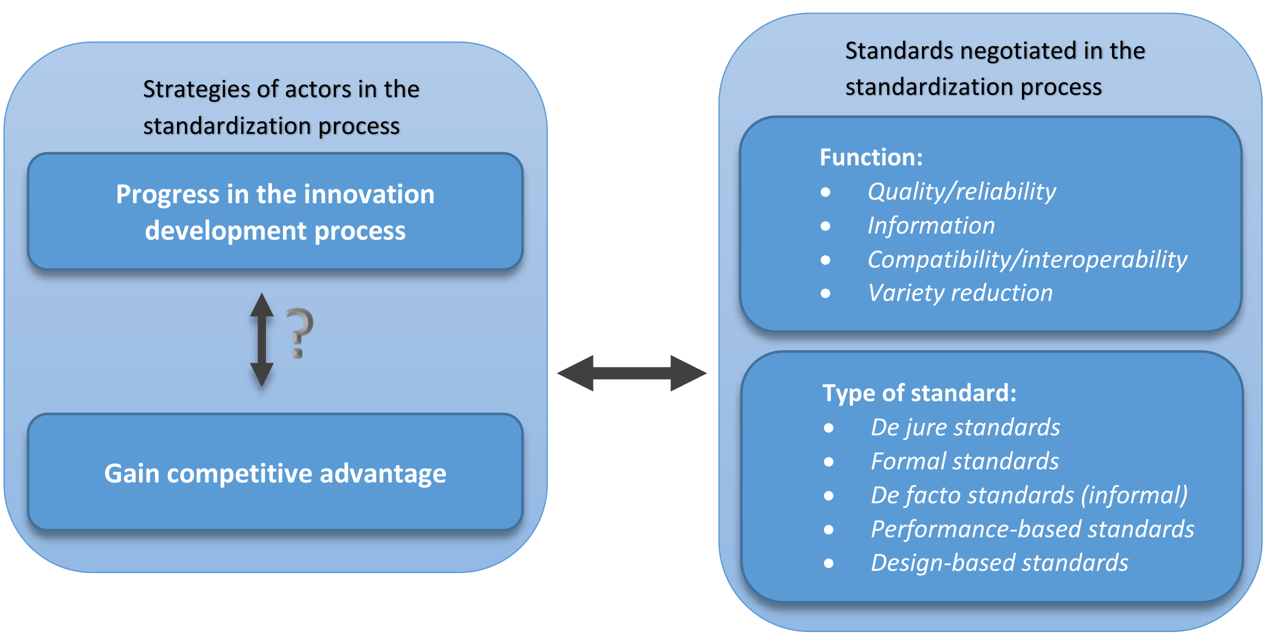

Figure 2: The relationship between negotiated standards and the motivation of actors in the standardization process.

5. Results

In this section the collected data is structured along the characteristics of the negotiated standard, as described in the operationalization. This is an overview of all the motivations in the standardization process of PGS 35 in the Netherlands, based on twelve interviews with stakeholders (see Appendix A). Statements of the interviewees are incorporated in this section and marked with a number which corresponds with the overview in Appendix A. These interviews were done in the period between 10 May 2016 and 16 June 2016.

First the involvement and motivation of actors in the standardization process are elaborated to function as a starting point. This is followed up by the results of actor's actions upon the type of standard, which include the creation-process and formulation of the standard, and the related motivations are described. Thereafter the results related to the function of the standard are given.

5.1 Involvement of actors in the standardization process

A governmental actor has fulfilled his role as principal for the standardization process and has used previous experiences with other standards to improve the process and the standard itself. He has experienced with PGS 33[3] that municipalities did not fully acknowledge the standard and hindered the realization of LNG fuel stations. "*A representative of a private organization wanted to realize five LNG fuel stations and the representative said: I had to explain at five different competent authorities what we were going to do to get a certificate.*"(#8). All five municipalities declined to grant a certificate of no objection which you have to get before applying for a license. The governmental actor thought that complying with PGS 33 would be sufficient to acquire a certificate and later on the license. However, he noticed from this example that PGS 33 was not always well known by the relevant official in that specific municipality and that the standard was ignored by this official. Another reason for his involvement is the reorganization of the local environmental services which initiated a loss of knowledge, because regional environmental services with less officials were formed in order to centralize the assessments of environmental applications, e.g. certificate of no objection for a LNG fuel station in that specific region. For that reason, the governmental organization has controlled the development of PGS 35 and promoted the involvement of regional environmental services. According to the governmental actor, it was not useful to stimulate the hydrogen mobility technology and have immediate problems with licensing applications, since local authorities do not understand how to handle such applications.

The governmental actor was complemented by a different governmental organization to act as a facilitator between all the involved parties. "*We have a continuing focus on standardization processes, because it is our core business."(#*9). The governmental organization is involved and has experience with the development of national standards, European standards, ISO standards and other types of international standards. For that reason, the governmental actor tried to centralize himself in national, and international networks and one of the activities was to facilitate the development of PGS 35. His goal was to allow experts to join the discussion and to review the agreements on usefulness as he compared it with international developments on the same subject. From his perspective the hydrogen mobility industry can only become successful if it is addressed on a large (international) scale. In addition, the Ministry of Infrastructure and the Environment stimulates the Dutch hydrogen mobility industry and one of the stimuli was to financially support the facilitator in order to develop and internationally promote PGS 35.

[3] This is a standard that was designed for LNG fuel stations (PGS, 2013).

Two private actors and one public actor were asked by the facilitator to join the team to contribute to the standardization process. An infrastructure actor's motivation was initiated when he got informed about the goal of the standard. "*My organization is developing a technique to compress hydrogen in a completely different way than the current technologies.*"(#4). Compressor efficiency has a large impact on the costs of compression, storage, and dispensing of the hydrogen filling station (Parks et al., 2014). Therefore, he wanted to prevent exclusion of his technology by regulations that only allow the current technologies as his technology works different from the current compression technologies. For that reason, his goal was to develop regulations which describe the degree of safety and to a lesser extent how these have to be reached.

Another actor from an infrastructure related organization belongs to the technical and operations team of the firm that tries to participate and affect in all relevant ISO, European and national committees. The participant mentioned that the facilitator did invite them to join the process. The aim of the actor's team is to influence the standardization processes of these committees in order to: "…*end up with regulations which allow safe consistent and affordable operations for our sites.*"(#6) For that reason they bring information of their sites into the standardization processes. For example, their company basic construction setup that was used as company standard for hydrogen filling stations which are built in Germany.

A representative of an industry association was also asked by the facilitator to bring in expertise as the representative was involved in the construction of a hydrogen filling station in Arnhem, acting from both licensing and enforcement of the municipality. While participating in the licensing and enforcement of the local hydrogen filling station he found shortcomings in the field of standards regarding guaranteeing public safety. The involved parties in Arnhem have used standards with some safety aspects and discovered that the standards used did not fully cover all the (public) safety aspects of the hydrogen filling station. "*My role was to create a document which can be used by the governmental authorities regarding licensing and enforcement*."(#12)

A participant from a hydrogen producing firm would like to carry out future projects in the field of the hydrogen filling network in the Netherlands. This actor has no publicly accessible hydrogen filling stations in the Netherlands, however he is aware that the licensing process does not work optimally, because there are no clear safety regulations for hydrogen filling stations. He and a colleague of him have already participated in a similar standard, the NPR 8099. This is a Dutch Practice Guideline for hydrogen filling stations and has no formal legal status. Therefore, he got involved in the standardization process, since he understood that a formal legal document is needed to properly carry out the future projects.

A governmental actor working at a local environmental service was involved as an external safety consultant and acknowledged that local authorities do not precisely know how to judge a license application of a hydrogen filling station. As he mentioned: "*If you do not know what the critical safety problem areas [of a hydrogen filling station] are… this makes it impossible to develop appropriate measures*."(#7). The standardization process was in his opinion an optimal way to tackle this problem, because public parties were in consultation with the private parties. Also because, along the process the public parties got relevant information and knowledge about the (constructional) processes of a hydrogen filling station. Based on this information exchange municipalities and local environment services are able to assess an application.

Three actors from the private industry got involved in the process, since they already own and exploit hydrogen filling stations within and outside the Netherlands and thus the standardization process was of influence on their market. One of the hydrogen producers mentioned: “*Our core business activities take place in the United States of America and our goal is to expand our activities worldwide.”*(#2). Their core business is in the United States of America and thus the technologies developed by his organization had to comply with the American standard. Since his goal is to expand to the Netherlands, these techniques must match with the Dutch regulations: “*The safety requirements for a high-pressure tank are different in the United States of America from the ones in Europe.*”(#2). Therefore, he had tried to fit the American safety requirements with those of the safety standard in the Netherlands. This gave his organization the opportunity to improve the construction efficiency of hydrogen filling stations in the Netherlands in order to sell their hydrogen in the Netherlands.

A representative of an industry association was an advocate of the existing fossil fuel infrastructure. His goal was to act on all (existing) station operators’ behalf so it is fair and easy for these operators to start and operate a hydrogen dispensing installation. Doing so he has used the experiences from the distribution of his own fossil fuel stations. Another industry association actor’s organization tests and certifies all the components of alternative fuels, including those from hydrogen technologies. He was mainly concerned with hydrogen vehicles and the receptacle nozzle[4] of the hydrogen filling stations and also participates in study groups of ISO and North-American standardization committees. Therefore, his contribution was to make constant comparisons between the standardization process and other hydrogen standardization processes: *“…to make sure there is no hiatus between what I find in all the other study groups on hydrogen.”*(#11).

Figure 3: The nozzle of hydrogen filling stations which is standardized on design-based requirements (SAE, 2010)*. On the left side the 350 bar nozzle and on the right side the 700 bar nozzle* (WEH, 2016)

At last, two infrastructure actors were involved in order to create optimal market conditions for their hydrogen filling stations. One of the infrastructure actors stated that their core business is based on another alternative fuel, namely CNG. During the deployment of their CNG infrastructure in the Netherlands, he noticed that clear and well-defined regulations are needed in order to avoid hindrance in the deployment. Out of his experience he noticed that there were differences in safety requirements by various municipalities. The local officials did not uniformly agree on how to build and operate a CNG station which is publicly safe. His organization expended their core business to more alternative fuels, including hydrogen. Therefore, he has participated in the standardization process in order to deploy a nationwide

[4] The connector between the hydrogen vehicle and the hydrogen filling station which is standardized by the Society of Automotive Engineers (SAE) in J2601 (see figure 3) (SAE, 2010).

accepted standardized hydrogen filling station. He added: "*…so we do not have to implement adjustments to our concept, because a local official does not consider it safe enough to guarantee public safety."*(#5)

5.2 Type of standard

Creation-process of the standard

The creation-process of the standard is about which organization enforces the standard. An infrastructure actor stated that: "*The standard was drafted by businesses, government, fire departments, environmental services, licensing authorities and enforcers."*(#5). The government (Ministry of Infrastructure and the Environment) gave a facilitator who is a representative of the standardization committee, NEN, instructions to develop PGS 35 partly because of European Union climate targets. The directive Clean Power for Transport which forces Member States to actively support renewable energies and alternative fuels (European Commission, 2015) was an important stimulus for the government, according to actor 9. Simultaneously, an offer came from the private industry to standardize safety issues for the hydrogen filling infrastructure, since they had started building the first publicly accessible hydrogen filling stations.

A hydrogen producer mentioned: "*Together with the municipality of Arnhem and a private organization, we had built a publicly accessible hydrogen filling station … it was a collaborative project*" (#2). The hydrogen filling station was built while taking into account international regulations and NPR 8099. All the concerned parties discovered the lack of a national standard and thus a collective request from both private and public parties was made for standardization.

A participant from a hydrogen producing company claimed that without a safety standard the hydrogen filling stations would remain unique projects in a protected environment and it would not transpose well to an urban environment. According to the hydrogen producer, Dutch municipalities need a reference document, like PGS 35, in order to properly deal with the licensing process. They have no experience and knowledge of such a station and in the end they have to authorize building and distributing of a publicly accessible hydrogen filling station in their municipality. An example of this lack of experience is the licensing process and the building of the hydrogen filling station in Rhoon, the Netherlands. Since there was no PGS 35 at that time the local official of the municipality and the private firm concerned had to improvise with the licensing process. "*We have gone through the licensing process as if we were building and distributing a chemical plant.*" (#1). So the municipality had used safety regulations for a different type establishment in order to continue with the licensing process.

One of the governmental actors acknowledged that there is a common interest in the public and private parties for this standard. "*…from all the directions there was a call to establish this document.*" (#12). He argued that this type of collaboration with both private and public actors also provides a self-correcting effect, because specific claims by stakeholders can be evaluated for truthfulness, since a variety of organizations is involved. As a result, the standard is not based on one specific organization that gave the information on how to make the hydrogen filling station publicly safe. Other organizations are able to interfere with these claims and it is more likely to result in the most desired outcome in terms of safety regulations. This was seen as advantageous for the aim of the Ministry of Infrastructure and the Environment.

Formulation of the standard

A standard can be formulated based on performance-based and design-based elements or a combination of both. In this standardization process, public as well as private actors have mainly designed the standard on the basis of performance-based elements with some design-based elements. There is a common agreement that the aim of PGS 35 was to provide performance oriented clarity among all interested parties.

A hydrogen producer stated: " *[It is] performance-based, because safety conditions mainly have to do with performance of components, leakages rates, and so on.*" A participant from an infrastructure related company said that pressurized components of the hydrogen filling station have to comply with the Pressure Equipment Directive (PED) of the European Union. "*The Pressure Equipment Directive covers a very broad range of products such as vessels, pressurized storage containers, heat exchangers, steam generators, boilers, industrial piping, safety devices and pressure accessories.*" (European Commission, 2016). This entails that pressure assembly or equipment placed and/or put into service on the EU market must meet drafted essential requirements. Meanwhile the PED does not indicate how these essential requirements must be met and thus leaving flexibility to manufacturers as regards technical solutions to be adopted (European Commission, 2016). According to the hydrogen producer 80% of the PGS 35 had to comply with the PED and this directive gives flexibility in constructions of hydrogen filling stations.

Some public and private actors insisted on formulating design-based elements in order to support the performance-based elements and these serve as examples for the licensing process. A governmental actor mentioned: "*…use a hose which is safe to use. You can do this by indicating in an annex or an additional chapter with examples on how you can achieve that."*(#9). Another governmental actor gave a specific example to ensure external safety: "*If the station has a roof, it has to be designed in such a way that the hydrogen can flow away. For example, a roof which runs obliquely upwards.*"(#7). Furthermore, PGS 35 is formulated with an equivalence clause which means "..*you should use what is prescribed in the standard, unless you can prove that your way or technology is at least as good."* (#6). Therefore, PGS 35 is formulated by the actors to contain both elements: "*it is somewhere between design and performance based, but is more directed to performance-based elements."* (#9).

5.3 Function of the standard

In order to reach the (personal) goals of the institutional entrepreneurs they can strive for a specific functionality of the standard. Participants strived for the functionality quality/reliability, information, compatibility or variety reduction.

Quality/reliability

The goal of two public actors and a private actor was to guarantee public safety. A governmental actor mentioned that a constant high level of quality and reliability of hydrogen filling stations is important for the industry. He said: "*As an operator, you do not want that such an installation explodes which will result in being seen as the bad guy in society.*"(#8). The quality of the components used must meet a certain (safety) level to make the hydrogen filling station reliable and safe for public use. A governmental actor complemented that the process of standardization will make the hydrogen fillings station more reliable, since early warning systems are obligatory to implement in the station. However, the quality of hydrogen is not taken into account, because the quality of hydrogen has no effect on this. In order to reach the functionality of quality and reliability the two public actors have focused on making PGS 35 as a reference document for public as well as private organizations to provide clarity and to avoid unnecessary potential troubles regarding the quality and reliability of hydrogen filling stations.

According to the private participant, an infrastructure actor, guaranteeing public safety is top priority to establish the hydrogen mobility infrastructure. By eliminating uncertainty among governments and consumers the development of the market will be less hindered which eventually results in an improved market success of his technology. Additionally, he tried to protect his technology from excluding regulations prescribed by PGS 35: "*…I tried to prevent that there were regulations which were purely focused on existing technologies*" (#4). For that reason, his goal was to write down the performance requirements of the components and focus less on the design-based elements which can only be described by using currently available technologies.

In contrast to the above actors, a participant of a hydrogen producing company stated that the focus of the PGS 35 was not to provide quality of hydrogen filling stations, because components which are under pressure must already comply with the PED. "*There is a PED applicable in the Netherlands and all kinds of aspects [of a hydrogen filling station] regarding safety requirements are already treated.*" (#2).

Information

A hydrogen producer's goal of PGS 35 was mainly to provide useful information for the hydrogen mobility industry contributing to the reference document for private as well as public organizations, because the existing hydrogen filling stations are built on poorly designed regulations and agreements. In addition, he tried to fit his company constructional standards of a hydrogen filling station which originate from the USA with PGS 35 regulations. These company's constructional standards were at the time suited to the American governmental standards. This also applies to some other participants of PGS 35 as they originate from Germany and France. Together with the other participants they have delivered information regarding constructional standards of their hydrogen filling station for the reference document. Differences in constructional standards were solved in an informal way by sharing design-based elements: "*We have a 3 meters tall blowpipe and the competitor said they have one of 5 meters, the optimal will lie somewhere in the middle*" (#2). These design margins have been included in PGS 35 and this was considered as a stimulus as there were no strict design-based regulations included which could be detrimental to his company.

Other hydrogen producers as well as industry association actors acknowledged that the PGS 35 describes broad outlines, performance-based requirements that must be met. A hydrogen producer complied with by stating that his goal was to make the document long lasting, because there is a certain expectation of the development of the technology. Too specific and obligatory (design) details and regulations will hamper the innovation process, since it leaves no leeway for new technologies/developments.

All hydrogen producers were motivated to contribute to the standardization process with information as one participant from a hydrogen producing company mentioned: "*…if you know an aspect about a specific gas and your competitor gets a major accident because he didn't know that specific aspect."* (#1). Since this must be avoided at all times, private organizations try to protect the upcoming market from accidents and so they claim that safety information of this technology has no commercial benefit. An infrastructure actor added that outcomes of firm's studies and projects were considered as sufficient to be used as "true" information for PGS 35.

An industry association actor's goal was to prevent actor's differences in interpretation of a safe hydrogen filling station. He saw PGS 35 as an opportunity to make an informative manual for both public and private actors and eliminate these differences of interpretations and added: "*… and you will also prevent aspects to be overlooked…*"(#11). He also claimed that it would create an improved investment climate, because it provides clarity for investors as private actors know how to comply with safety regulations with new potential hydrogen fuel stations, reducing risk.

Compatibility

One of the hydrogen producers wants to build a hydrogen filling station in the near future and for that reason his contribution was to make all future hydrogen filling stations compatible with the current consumer familiarizations, including safety of the station. "*If one tanks petrol or diesel, [filling a hydrogen car] has to be comparable.*"(#1). The payment system must be designed in such a way that the right filling point is released as there are two filling pressures, namely 350 and 700 bar. Just as gasoline and diesel vehicles are only suitable for one of the two fuels, a hydrogen vehicle is suitable for a maximum filling pressure. The payment system should release the filling point with the right pressure as the consumers selected this while starting the transaction.

In addition, an infrastructure actor main goal was to align the whole hydrogen filling infrastructure on the supply side. As he said: "*[the standard] is all about compatibility, the receptacle nozzle, pressure levels and temperature levels all need to be identical…*"(#5). This eventually creates a better market and closes out bunglers in order to protect the (new) market, since the compatibility of the technology went wrong several times in his core business, CNG. Consumers discovered the newly available fuel and tried to fuel their LPG suitable vehicles, however the nozzle of a CNG filling point is different from the LPG filling point. At some point adapters were available at websites, which made it possible to fuel a LPG suitable vehicle with CNG fuel. This has resulted in dangerous situations, because a LPG tank has a maximum filling pressure of 50 bar and a CNG tank is filled up to a pressure of 250 bar. The standardized hydrogen receptacle nozzle is included in PGS 35 to avoid this kind of situation, because the receptacle nozzle communicates with the hydrogen vehicle with the help of infrared technology. Due to the infrared technology it excludes adapters to be used. To strengthen this, he aims for parity with other (European) countries and thus he actively promotes the standard on a European level which is supported by the government: "*…with the help of the ministry we can bring the PGS at an international level*" (#8).

A governmental actor's goal was to optimize the reference document PGS 35 to his most desired outcome. So he agreed with the infrastructure actor on the fact that all hydrogen filling stations should fit with all hydrogen vehicles and this must be regulated with the standard. Another governmental actor agreed that communication systems should be included to guarantee public safety and this was his personal goal.

A hydrogen producer's intention was to fit the firm's technology with the current legislation as he saw PGS 35 as a manner to incorporate his technology in the described state-of-the-art technology in the standard. Since PGS 35 is provided with examples of technological components that match with the safety regulations, licensing authorities and enforcers make use of these examples and thus future hydrogen filling stations with his technology are more likely to be approved by these local authorities. This will contribute to a more efficient and effective licensing process and improves the compatibility of his technology with the safety regulations, which is beneficial for his market position.

Variety reduction

A governmental actor has strived for unification of technologies to prevent public debates about the technologies used for a hydrogen filling station. According to him, this provides clarity among all interested parties in the market. So a reduction in the variety of technologies is needed to reach his goal. Another governmental actor stated: "*In the end you try to give everyone some sort of comfort*" (#8) and improve the technological development of the hydrogen filling station in the Netherlands. In order to reach his goal selected technologies are prescribed in the standard which results in a reduction of variety in technologies.

However private parties tried to prevent variety reduction. As described in the quality/reliability paragraph an infrastructure actor tried to prevent that his technology would be excluded by safety regulations of the standard and thus this infrastructure actor focused his contribution on preventing the occurrence of a variety reduction due to the standard. A hydrogen producer added: "*At the moment it is precompetitive work.*"(#3). His organization must be able to develop the (new) technologies within the limits of the safety regulations. If the market starts to grow, then they are able to implement new technologies for hydrogen filling stations and for that reason he tried to prevent a variety reduction of technologies.

6. Analysis

The analysis in this chapter uses a systemic analysis as described in the method section. The goals and motivations from the involved actors in the result section are structured and linked with each other and revealed the dynamics of the standardization process.

6.1 Identified indicators

During the systemic process analysis, the motivations and strategies of all the interviewees were compared with each other and resulted in overlapping topics (see appendix E). Motivations and strategies were focused on *licensing procedures*, *guaranteeing public safety* and *information sharing*. For example, public and private actors experienced problems with licensing procedures to guarantee public safety and directed their motivations and strategies to solve this problem. Furthermore, participants were concerned with the compatibility of the hydrogen filling station on different levels. Participants, were involved to incorporate hydrogen filling dispenser in *fossil fuel* stations. Other participants focused their activities on the *compatibility with related technologies*. At last, overlapping motivations and strategies were found on the topic of *fitting proprietary technology*, *flexibility of the standard* and a difference in motivation between *public and private* participants. The motivations and strategies were focused on formulating the standard to such an extent that it incorporates all (new) technologies for hydrogen filling stations.

In appendix D the table with the systemic process analysis can be found and the identified indicators are structured within a mind map in Appendix E. The mind map is used as a simplified overview and to structure the analysis section. The paragraph 6.2 starts with the initial motivation to participate in the standardization process. The following paragraphs show the analysis of the overlapping topics and their relation to the two main outcomes of the standardization process. The identified concepts guide the final conclusions of this research.

6.2 Participating in the standardization process

PGS 35 is formulated by both public and private participants as both of them preferred such a reference document due to the uniformity of regulations that is important in the context of granting licenses. Also due to the footing and transparency they provided as regards granting licenses for the construction of a hydrogen filling station (PGS, 2015). The initial motivations and reasons for the involvement of the public and private actors differ as some were immediately involved and others were later on asked to join the standardization process. Public actors could get increasingly involved in the upcoming market, because more private organizations expand their market activities in the Netherlands. One was motivated to join the process since he experienced that with a similar standard its practical influences, problems regarding licensing of an alternative fuel station, were not optimal, and therefore lost a portion of the value. Based on these experiences he tried to optimize PGS 35 in order to eliminate these practical issues. A public participant was involved as it is his core business to facilitate in formulating standards and is actively involved with other standardization processes of hydrogen technologies on multiple levels, like ISO. It could be the case that a public participant is mainly involved with safety regulations of hydrogen fuel cell vehicles in different standardization processes. While making constant comparisons with the safety regulations of the hydrogen filling stations and other standards during the standardization process. Doing so, future difficulties can be avoided and may result in an improved implementation of the standard. A private participant, in this case an entrepreneur from an infrastructure related company, was motivated since he or she is part of a team which participates in different standardization processes and directs these processes in such a way it will protect their current market position and activities. This showed that the motivations of institutional entrepreneurs to participate can result to an influence on the innovation development process or the competitive advantage of the company. It also showed that private organizations are less focused on improving the innovation development process with respect to public organizations as can be seen in the motivations and goals of the participants and the overview in appendix D.

6.3 Overall agreement on type of standard

All participants explained that PGS is developed and led by a representative of a standardization committee with the cooperation of both public and private organizations. It can be concluded that PGS 35 is a formal standard. In addition, all participants stated that PGS 35 is formulated with both performance-based elements and design-based elements. The performance-based elements formed the basis for the obligatory safety regulations. The design-based elements are used as possible examples that fit the safety regulations. There was no inconsistency found in the motivations and strategies of the institutional entrepreneurs on the type of standard.

However, a variety of motivations and goals revealed that actors had different type of desired functionalities. Some motivations and strategies were found in more than one function and this is elaborated in the rest of this section

6.4 Knowledge diffusion

Licensing procedures

A public participant experienced licensing difficulties with PGS 33 which is made for a similar alternative fuel. Municipalities have difficulty with the technological understanding which leads to difficulties in dealing with a license application for this technology. Therefore, he promoted the involvement of local environmental services in the process to improve the usability of the document resulting in a better understood reference document for licensing authorities in comparison with PGS 33. An industry associate participant was involved with a licensing application for a hydrogen filling station and acknowledged the lack of indistinctness about the technology. This is supported by a private participant as he was aware of lacking a standardization document for licensing authorities and he claimed that there is need for this to stimulate the licensing procedure. His involvement to establish the standard was mainly to assure the development future hydrogen fillings station by the company.

The core business of participant from an infrastructure related company originates from another alternative fuel, namely CNG. This participant experienced hindrance with the deployment of the CNG infrastructure, because municipalities individually demanded specific safety requirements. So clear and nationwide accepted regulations for licensing authorizations should avoid similar hindrance and gives the opportunity to expand the business with hydrogen filling stations across the Netherlands.

The standardization process of PGS 35 is seen as the solution to tackle the problem of indistinctness of the technology and alignment of safety requirements, since private and public parties were in consultation with each other. According to a public participant the availability of unified information about safety regulations which are accepted nationwide will likely improve the investment climate in the Netherlands. As can be seen the actions of the institutional entrepreneurs have led up to an improvement of the innovation development process, because the standard will likely remove the indistinctness of the technology and improve the acceptance of using hydrogen in public areas. Private participants will likely benefit from an accelerated licensing procedure and this could improve the investment climate in the Netherlands.

Public safety

The common goal of public and private participants is to guarantee public safety with a reference document with standardized safety regulations. A representative of an industry associate has previous experiences with licensing and enforcement of a hydrogen filling station. Along these activities shortcomings were found in the field of standards regarding public safety requirements. By making a reference document which is suitable for licensing and enforcement authorities these public parties are able to guarantee public safety of this new technology.

According to an infrastructure participant guaranteeing public safety is also essential to establish an upcoming industry, since there is uncertainty among governments and consumers. So his strategy was to focus PGS 35 on the functionality of quality and reliability, because a hydrogen filling station will be safe to be used if a high quality of components is demanded to use in such a filling station. A public participant, in this case an industry associate, claimed that information is needed to prevent interpretation differences between licensing authorities. A PGS document is therefore a useful concept to act as an informative manual for all parties and it also ensures that safety aspects are not forgotten in the licensing process. Thus he strived for an informative functionality of the standard. A private participant's goal was to deliver useful information to the reference document, because the current hydrogen filling stations are built on poorly designed regulations and agreements as there was indistinctness (at municipalities) on ideal construction methods of hydrogen filling station in order to ensure public safety. Thus this hydrogen producer also strived for an informative functionality of the standard. In contrast to a governmental actor who tried to guarantee public safety by including a communication system between station and vehicle which is a focus on the functionality of compatibility. The guarantee of public safety is reached with different standards functionalities and all contributed to the innovation development process as there were no goals to improve the competitive advantage.

Information sharing

The shared information is found to have no commercial value and it is shared to protect the market from accidents by inexperienced organizations or individuals. Ensuring a high level of quality and reliability of hydrogen filling stations is important for the industry, according to a governmental actor. By ensuring this level of quality, reputational damage by accidents in the Dutch market, which can harm the development of the technology, can be prevented. That is why the public participant directed the standardization process towards the functionality of quality and reliability. This could improve the innovation development process as reputational damage is likely to hinder the development of the technology by a lack of (public) acceptance.

Concept of knowledge diffusion

Both parties are proportionally equal motivated with the above topics in terms of found motivations and strategies. Of all the identified topics, the participants addressed most of the strategies and motivations to these topics in the standardization process (see appendix D). All topics are related to the diffusion of knowledge within the mobility industry. Participants experienced difficulties with licensing procedures, because local authorities do lack in knowledge of the technology used. The standard is needed to spread knowledge to include those local authorities. Complementary on this, knowledge diffusion is needed to ensure publicly safe hydrogen filling stations. To achieve this, everyone should have access to the document that contains the safety conditions of (prescribed) constructions. The information shared between the participants of the standardization process has no commercial value, because the risk of construction failures is too high and can lead to reputational damage to the hydrogen mobility industry. It can be said that all the motivations and strategies are directed to improve the innovation development process. Gaining competitive advantage had no influence on the motivations and strategies of the participants, since the shared knowledge had no commercial value. As a result of the knowledge diffusion licensing applications take relatively less time, because of the availability of knowledge required to assess the applications. The private participants have gained an advantage; however, it is not clear whether they have gained a competitive advantage. After all, all private organizations will experience an accelerated licensing application and thus an accelerated realization. No friction was observed between the two possible outcomes of the standardization process.

6.5 Compatibility

Compatibility with fossil fuels

A representative of the fossil fuel infrastructure industry association who is also active by himself in this market and acted on behalf of these type of fuel station operators. His goal was to make it possible to easily join the hydrogen-based market with existing fuel stations. An infrastructure actor continued with the expectation of future hydrogen filling stations of his company and these should match with current habits/standards of consumers including guarantee of public safety. According to this participant matching customers' familiarization will lead to a better adoption of the hydrogen technology. Both motivations and strategies have influenced the innovation development process, because the fossil fuel market gets involved in the hydrogen mobility industry and current users of fossil fuel vehicles are relatively better able to use the new technology. The fossil fuel market has the largest market share at the moment, thus acceptation and integration by them will more likely result in an increase of interest in the hydrogen technology. Also, both participants will benefit from this compatibility as it could lead to an expansion of income by integrating a hydrogen filling station into a fossil fuel station. But also an increase of potential customers since hydrogen filling stations are practically operated in the same way as ordinary fossil fuel stations.

Compatibility with related technologies

There was a public interest to optimize the reference document by improving the compatibility with related and dependent technology, since hydrogen filling stations depend on hydrogen fuel cell vehicles and thus these hydrogen-based technologies should fit. The goal of an industry associate was matching the safety regulations for the hydrogen filling station with those of the hydrogen fuel cell vehicles with a special focus on integrating the standardized receptacle nozzles. To reach his goal he got involved in standardization processes on both national and international level in order to prevent a hiatus in regulations between the hydrogen filling station and the hydrogen fuel cell vehicle. Furthermore, there was a private interest in the unification of the technology on the supply side of the market, because, as stated in the paragraph *information sharing*, bunglers are unwanted as they could harm the market by using the technology in the wrong way. To strengthen the unification and compatibility, PGS 35 is actively promoted by an infrastructure participant on a European level, since unwanted activities should also be excluded in other European countries to protect the image of the market and technology. All the motivations and strategies were focused on improving the innovation development process, since an optimized compatibility with related technologies is likely to prevent reputational damage.

Concept of compatibility

Both parties are proportionally equal motivated with the above topics in terms of found motivations and strategies. Of all the identified topics, the participants addressed least of the strategies and motivations to these topics in the standardization process (see appendix D). Both topics are related to the compatibility of the hydrogen filling station in the current society and mobility market. Motivations and strategies were focused on compatibility with the current fuel standard, fossil fuels. Both in terms of integration of a filling installation into an existing fossil fuel gas station and matching the ease of use of a hydrogen filling station as consumers are now accustomed with gas stations. In addition, the standardized hydrogen filling station have to be compatible with related technologies such as the hydrogen fuel cell vehicles. It can be said that if the new technology is compatible with the existing technology then private organizations of the established market can gain a competitive advantage. The established market has already experience with offering fuels to the market and will benefit from an integration of the hydrogen filling installation. These fossil fuel operators will gain a competitive advantage compared to organizations that only deal with the hydrogen technology. Compatibility with related technologies has only influence on the innovation development process. Private organizations which develop and implement hydrogen filling stations will not retrieve a competitive advantage, because all filling stations have this advantage of compatibility. Also here, no friction was observed between the two possible outcomes of the standardization process, because the information used was extracted from other industries, markets and standardization processes.

6.6 Proprietary technology

Fitting proprietary technology

Hydrogen producers tried to fit their proprietary technology to the safety regulations of PGS 35. One of the hydrogen producers has already exploited hydrogen filling stations all over the world and his goal was to match the company's' constructional standard with the safety standard in the Netherlands. This gives the private participant the opportunity to continue building hydrogen filling station with almost the same company standards and sell their produced hydrogen in the Netherlands. So information was derived from company's' constructional standards while simultaneously matching these standards with the safety regulations of PGS 35. Another hydrogen producer stated that fitting the technology used by his company with current Dutch legislation is beneficial for his company. The reason for that is that PGS 35 is supplied with design-based examples to support the essential performance regulations and their companies' constructional standards are included as an example. All these actions of the private participants are in favor of gaining competitive advantage, because licensing authorities recognize and authorize the proposed technology in the licensing application.

Flexibility

Hydrogen producers agreed upon the fact that the regulations are mainly formulated as performance based requirements and leaves flexibility to a manufacturer as regards to technical solutions. These margins are considered as a stimulus to contribute to the standard by the private participants. Since these performance based requirements resulted in flexibility of using a variety of technological solutions, it also made PGS 35 a long tenable document for evolving technology. This is because it creates room for future technologies, since there are no obligatory design-based requirements to meet the safety regulations. Another private participant, an actor from an infrastructure related company, had the goal to protect his technique, because it completely differs from the current technological standard by the other private participants. The formulation of the standard was of importance to prevent exclusion of the technology by the standard. Participants from hydrogen producing firms used the strategy of informational functionality and tried to contribute to the innovation development process, since the information provided for the standard leaves flexibility to current and future technologies. Whereas the infrastructure actor who used quality as function for the standard to protect his technology from exclusion ensured that PGS 35 was focused on quality requirements to reach flexibility. So he had a firm focused goal instead of contributing to the innovation development process.

Public vs. private

Nevertheless, the public and private interests do not always correspond and this was the case in the variety reduction of technologies. A governmental participant claimed that unification of technological solutions is needed to prevent (public) debates about these technologies and will create clarity among all interested parties. Another governmental participant complemented this with that comfort and clarity for involved actors is needed to improve the development of the infrastructure as prescribed technologies are included in the reference document for licensing authorities.

This is in contrast with the private parties as they focused on preventing the occurrence of variety reduction since this could exclude newly developed technologies from being implemented in the industry. For example, an infrastructure actor protected his technology from exclusion, since it is not yet on the market, by creating flexibility in the use of technological solutions. A private participant, in this case a participant from a hydrogen producing company, claimed that the hydrogen mobility industry recently started to grow and this will bring new firms with (new) technological solutions to the market. A variety reduction induced by the safety standard will leave no room for future technologies. The hydrogen producer acknowledged that his company is developing new technologies and thus a variety reduction will be disadvantageous for his company.

The public parties tried to improve the innovation development process, because a variety reduction could bring more clarity to licensing authorities as there is a limited number of technological solutions which can be used for a hydrogen filling station. However, the private parties claimed that it is detrimental to the innovation development process when (new) firms would not have the opportunity to develop new technological and improved solutions for hydrogen filling stations.

Concept of proprietary technology

Private parties are proportionally more motivated with the above topics in terms of found motivations and strategies (see appendix D). All topics are related to proprietary technology, because the motivations and strategies involved the technology used by the participants. First, the motivations and strategies were focused on matching their proprietary technology with the drafted standard, PGS 35. Consequently, the private participants have the possibility to directly implement their technology in hydrogen filling station which have completed the licensing process. This is because the developed technology matches immediately with the required regulations in the field of guaranteeing public safety. Second, motivations and strategies were also focused on achieving flexibility of the technology used, because some participants were still developing proprietary technologies. Through the formulation of obligatory performance-based elements flexibility of technology used is achieved. Public parties were in favor of unification of the technology used in hydrogen filling station to simplify the licensing process, while private parties focused on flexibility to protect the proprietary technologies.

Friction was observed between the two possible outcomes of the standardization process, because the private participants had to partially reveal the proprietary technology. Based on test results of their proprietary technologies they had to reveal it is safe to use and guarantees public safety. Private participants had the possibility to share design-based elements and compared this with each other to formulate a range of approved design-based elements to act as examples. Local authorities make use of these examples of design-based elements to assess the licensing application. So the private organizations gained a competitive advantage, since the design-based elements of their hydrogen filling station match with those in the standard and thus their licensing application will likely proceed faster. By also revealing design-based elements private participants lose at the same time their competitive advantage, because new entrants know how to build a hydrogen filling station in terms of performance-based and design-based elements. The private participants improved the innovation-development process, because new entrants are relatively more able to build a hydrogen filling station due to the availability of both performance-based and design-based elements in the standard. The technology is more likely widely available and relatively faster deployed due to improved and accelerated licensing procedures.

7. Conclusion & discussion

This research aimed to examine the motivations and strategies of institutional entrepreneurs who are involved with a standardization process in the hydrogen mobility industry. New technologies, like the hydrogen fuel cell technology, face difficulties that are related to the institutional setting or the lack of this setting. Institutions could enable and constrain the development of sustainable technologies in the mobility sector. Since the current institutions hamper the hydrogen-based technologies, institutional change is required. Thus to reach this required modification, institutional entrepreneurs can initiate and/or accelerate institutional change by creating new or transforming existing institutions. However, a contradiction emerged, because developments in the innovation development process can shift competitive advantage of actors when they either fail to perceive the new way of competing or are unable to respond to the new developments. Therefore, the focus was on the contradiction between attaining solutions for difficulties in the hydrogen technology innovation development process and gaining a competitive advantage for the organization that they represent. The chosen method was to perform a case study and to hold in-depth interviews with stakeholders involved in the standardization process of PGS 35. The aim of this case study was to answer the following research question:

How do actors in the hydrogen mobility industry of the Netherlands operate in the standardization process of the hydrogen and fuel cell technology and how does this influence the hydrogen technology innovation development process?

How do they operate in the standardization process?

Both public and private actors in the standardization process of PGS 35 encountered problems with the licensing process of publicly accessible hydrogen filling stations. Since there was insufficient information about the new technology and it had no clear safety regulations, local municipalities and private organizations had to improvise in order to complete the licensing process of the first publicly accessible hydrogen filling station in the Netherlands. Similar alternative fuels experienced the same issues and these experiences were used to improve the reference document itself and thereby also the licensing process. To improve the value of the standard, participants are actively promoting PGS 35 to a European level to create a better connection between the Netherlands and the rest of Europe.

Private actors' strategies were mainly focused on protecting and stimulating the development of their own technologies and market positions, because the standardization process could also exclude them from participating in the market by specific safety regulations. Compatibility and flexibility were a key element for the private actors in this process as they tried to fit the technology with the current legislations, related and dependent technologies and consumer's familiarizations.

To conclude three main concepts where found that covers all the motivations and strategies of the participants in the standardization process of PGS 35, namely knowledge diffusion, compatibility and proprietary technology. With regard the first two concepts both private and public participants had mainly corresponding motivations and goals regarding improving the innovation development process. Some participants did strive for gaining competitive advantage, but there was no friction observed in these concepts. On the other hand, a contradiction was found in the concept of proprietary technology as private actors strive for flexibility in technological solutions and public actors aim for a variety reduction to simply licensing applications for hydrogen filling stations. Despite the contradiction, the informal interaction between the participants in combination with the flexibility of the established safety regulations provided low friction in the consideration between the overall development of the technology and maintaining /gaining a competitive advantage from the standard. This research revealed that if there is a private majority focused on a concept than friction in possible outcomes occurs and this needs to be solved to finalize the standardization process. The solution in this case was margins in construction possibilities in performance and design-based elements of the standard. In the case of an equal distribution of motivations and strategies at a concept no friction occurs and the standardization process experiences therefore no complications.

How does this influence the hydrogen technology innovation development process?
As a result of this cooperation between public and private actors the standard has ensured that there is clarity between all parties regarding information diffusion on the technology itself and the minimal safety measures which are needed to guarantee public safety.

Due to this clarification, the participants expect that there will be an increased acceptance of the new technology across the Netherlands and eventually throughout Europe. Private actors would be subject to an improved investment climate for the implementation of their own products. In addition, the range of construction possibilities gives the private participants a competitive advantage, because local authorities are more likely to approve the proposed hydrogen filling station as they fully match with the construction possibilities. The wide range of construction possibilities also provides a relatively eased entry to the market, since the standard provides information about the required performances of a hydrogen filling station with possible constructional designs. Thus it improves the innovation development process, since technology is more likely widely available and relatively faster deployed due to improved and accelerated licensing procedures.

To conclude the standardization process of PGS 35 will likely lead to an improved technology innovation development process given all parties are better off after the standardization. The likelihood of an increased acceptance can be deduced from influencing current institutions and the creation of new institutions by the institutional entrepreneurs.

7.1 Limitations of the research

First, this research examined one specific standardization process to understand the dynamics regarding the motivations and strategies of institutional entrepreneurs who use standardization to overcome institutional change. The generalizability of this research is not particularly high, since the found motivations and strategies are applicable to standards which have a clear focus on safety regulations. However, within the possibilities of this research it resulted in in-depth understanding of the underlying reasons for the chosen actions of the institutional entrepreneurs.

Not all participants of the PGS 35 were interviewed in this research. The uninvited participants are mainly public actors and these could have given more insights on the used motivations and strategies of public parties. However, all private parties were interviewed and in some way balanced with the same amount of public related participants. Throughout the process of data collection, a saturation of information was noticed by the researcher and this was the reason to stop the data collection.

Furthermore, the safety aspect of hydrogen-based technologies had a major influence on the standardization process of this case study. It can be said that every motivation or strategy is in some manner influenced by the dangers of using hydrogen as it is a highly flammable gas. The effect of this important aspect played a significant role in this case study. Such an influencing aspect does not appear in any standardization process and therefor lowers the generalizability of this research. However, the safety issue can be linked to the lack of acceptance as mentioned in the introduction section and it was to be expected that this would play a role in this research.

Another limitation is the dividing line between hydrogen producing companies and infrastructure related companies as both types of organizations are increasingly involved with each other's industry. From the interviews it can be concluded that their involvement in the hydrogen mobility industry lead to an expansion of their business activities. An example is the change of business activities of hydrogen producing companies. In order to increasingly sell their produced hydrogen, these organizations have developed hydrogen filling stations around the globe. By means of building and exploiting these hydrogen filling stations the hydrogen producing firms try to increase selling their produced hydrogen to a new type of costumer. This likely to happen with infrastructure related companies, since there are techniques to produce on-site hydrogen with the aid of, for example electricity of renewable energy sources. It is not clear what the effects are on the standardization process, since there are changing interests at stake. Further research could focus on the effect of changing interests of private organizations along a standardization process.

7.2 Theoretical implications

Secondary activities of institutional entrepreneurs are found and these are related to the five other tactics which can be used to overcome institutional as institutional entrepreneurs also showed activities which are related to these tactics. For example, some participants actively lobbied on a European level on behalf of the standard and the hydrogen mobility industry. This showed that tactics are possibly combined to change the institutions and might have an effect on the motivation and strategy used by institutional entrepreneurs when using standardization as a tactic. Future research could focus on the influence of the five other tactics on the process of standardization.

Fuglsang and Sørensen (2011) showed that innovation in reality could happen as small step 'bricolage'. In other words, a do-it-yourself problem-solving activity taking place in daily work situations. It is one of the three main processes of innovations observed in literature. The other two are management-initiated innovation and management-mediated innovation and all three processes are weakly connected to each other (Fuglsang & Sørensen, 2011). This case study showed that bricolage is not possible, because users are not able to experiment with the technology as 'bunglers' are also unwanted by the private participants. The hydrogen filling stations have to comply with the safety regulations of the standard in order to maintain their license. These activities could change the construction and usage of the hydrogen filling station and therefore do not match anymore with the required safety regulations. Thus problem-solving activities in daily work situations are likely prevented. This matches with the findings of Fuglsang and Sørensen, the three processes of innovation are weakly connected due to the outcome of the standardization process. Future research could focus improving the connection between the three processes of innovation in the case of standardizing a technology.

Finally, the motivation and activities of the participants of PGS 35 showed a different degree of intentionality, because some entrepreneurs were fully focused on achieving (inter)national acceptance of the hydrogen-based technologies. However, some entrepreneurs contributed as they were invited to join the standardization process and only complied with the invitation to share information and expertise. Based on the outcomes of this case study the degree of intentionality and the self-interest of the institutional entrepreneur in the standardization process are likely related. Future research is needed to confirm this observed relationship.

7.3 Policy implications

Implications for governmental bodies as well as private companies arise from this study. The interests of the different organizations or entrepreneurs play a significant role in the standardization process as it influences all the actions and motivations of these entrepreneurs. Thus, a certain degree of “balance” of interests, or in the case of PGS 35 the *flexibility of technological solutions*, should provide a solution to safeguard the interest of each participant. This “balance” or flexibility affects the lead time of the standardization process as participants of PGS 35 acknowledged that it took less time to establish PGS 35 compared to other standardization documents of PGS.

A facilitator or principal of the standardization committee can enhance the standardization process by “measuring” the interests of the participant on the basis of the desired functionality by these participants. Doing so, it is possible to create an overview of all the desired motivations and goals and conflicting motivations and goals can be identified. These conflicts can be included and solved in order to come to a consensus as this is demonstrated in PGS 35 by drawing up design-based examples in a predominantly performance-based standard. A reduction of lead time can be achieved, since the participants arrive more quickly to a general consensus.

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Appendix A: Overview of the involved actors

Table 7: An overview of the involved actors in this research

Assigned number	Actor	Description
#1	Hydrogen producer 1 (Pilot)	Representative of Air Liquide Benelux Industrial
#2	Hydrogen producer 2	Representative of Air Products Nederland B.V.
#3	Hydrogen producer 3	Representative of Linde Gas Benelux
#4	Infrastructure related actor 1	Representative of HyET
#5	Infrastructure related actor 2	Representative of Pitpoint
#6	Infrastructure related actor 3	Representative of Shell Global Solutions International
#7	Governmental actor 1	Representative of DCMR Milieudienst Rijnmond/IPO
#8	Governmental actor 2	Representative of Ministry of Infrastructure and the Environment
#9	Governmental actor 3	Representative of NEN
#10	Industry associate and other 1	Representative of BOVAG / SWING Fuel Stations BV
#11	Industry associate and other 2	Representative of KIWA Nederland BV
#12	Industry associate and other 3	Representative of VNG/ Omgevingsdienst Regio Arnhem

Appendix B: Interview scheme

Interview questions

Hello my name is Giovanni van Eijk and I am a master student Innovation Sciences at Utrecht University. First I would like to ask you if I can record this interview for my research [*answer interviewee*]. My research focuses on standardization of hydrogen technologies. Actors in the hydrogen mobility industry, like you, are involved with the standardization process for different reasons. This diversification of reasons makes the process more difficult to establish. The goal of this interview is to map out the involvement and motivations of actors in the standardization process. The ultimate goal of the research is to better understand the standardization process and maybe even make that process more efficient.

(The main questions are marked with a number [*1,2,3…*] and possible sub questions are marked with a letter [*a,b,c…*].)

Negotiated standard and motivation

Role of the actor in the development process of the negotiated standard

1. What was/is your role in the process of the [name of the standard] standard and why?
    a. How does this comply with your own vision?
    b. How does this comply with the vision of your organization?
    c. How does this comply with the vision on the collaboration with other organizations?

Function of the standard

From literature perspective a standard has a certain type of economic function, namely: quality/reliability, information, compatibility/interoperability or variety reduction.

2. If I am right the [*name of standard*] standard has [type of function] function, correct?
3. What is the reason for the choice of this function and why?
    a. How does this comply with your vision?
    b. How does this comply with the vision of your organization?
    c. How does this comply with the vision on the collaboration with other organizations?

Type of standard

Standards can be divided based on the creation-process of a standard, namely from governmental perspective (de jure standard), standardization committees (formal standards) or private organizations (informal standard).

4. What type is this standard?
5. What is the reason for the choice of this type and why?
    a. How does this comply with your vision?
    b. How does this comply with the vision of your organization?
    c. How does this comply with the vision on the collaboration with other organizations?

There are also two types of formulation of standards, namely performance-based and design-based.

6. If I am right the [*name of standard*] standard is [type of formulation], correct?
    a. How does this comply with your vision?
    b. How does this comply with the vision of your organization?
    c. How does this comply with the vision on the collaboration with other organizations?

Goal of the standard and collaboration

7. What is the intention and goal of the standard?
    a. How does this relate to improving the innovation development process and/or gaining competitive advantage?
    b. To what extent did this influence the intention or goal of the standard?
    c. Are/were there specific desired or induced consequences of the standard?
    d. To what extent did this influence the intended goal?

Appendix C: Example data analysis

Table 8: An example of the data analysis

<table>
<tr><th>Type of quote</th><th colspan="4">Example</th></tr>
<tr><td>Representative quote 1</td><td colspan="4">“As towards what I do in Shell, I and a couple of colleagues from the technical team and from the operation team from Germany we spread ourselves around the relevant ISO, European and national committees.”</td></tr>
<tr><td>Representative quote 2</td><td colspan="4">“We want to end up with regulations which allows safe consistent and affordable operations of our sites. So fit for purpose must be safe and has to be good operations, but we do not need to be gold-plated. That is how we see our role.”</td></tr>
<tr><td></td><td colspan="4"></td></tr>
<tr><td>First order code 1</td><td colspan="4">…actor from an infrastructure related organization belongs to the technical and operation team of the firm who try to participate and affect in relevant ISO, European and national committees.</td></tr>
<tr><td>First order code 2</td><td colspan="4">The aim of the team is to influence the standardization processes of these committees in order to: “end up with regulations which allow safe consistent and affordable operations of our sites.”(#6)</td></tr>
<tr><td></td><td colspan="4"></td></tr>
<tr><td>Second order code</td><td colspan="4">Part of a team which operates in several standardization processes on national and international level. The aim is influencing the regulations into a favorable environment for their hydrogen filling stations.</td></tr>
<tr><td></td><td><u>Improvement innovation development process</u></td><td></td><td><u>Gaining competitive advantage</u></td><td>•</td></tr>
</table>

Appendix D: Systemic analysis

Table 9: Overview of the systemic analysis of the gathered data

Initial motivation	Innovation process	Competitive advantage	Type of actor
Experience with PGS 33 which is made for a similar like alternative fuel. Licensing authorities have troubles with technological understanding and dealing with license application for this technology. Thus a higher involvement of local environmental service in the process to improve the usability of the document.	•		Governmental
Core business is facilitating standardization processes; Involvement on national and international level, like ISO. Agreement match with the international developments	•		Governmental
Protecting technique as it is completely different from the current technological standard. Formulation of the standard was of importance to prevent exclusion of the technology by the standard.	•	•	Infrastructure
Part of a team which operates in several standardization processes on national and international level. The aim is influencing the regulations into a favorable environment for their hydrogen filling stations. (Example of influence: delivering basic diagram of a hydrogen filling station.)		•	Infrastructure
Previous experience with licensing and enforcement of a hydrogen filling station. Found shortcomings in the field of standards regarding public safety. Making the document suitable for governmental authorities regarding licensing and enforcement.	•		Industry association
Awareness of lacking a standardization document and need for this to proceed in the licensing application. Involvement to establish the standard for future hydrogen fillings station by the company	•	•	Hydrogen producer
Experience with licensing application for a hydrogen filling station and acknowledge the lack of indistinctness about the technology. PGS 35 seen as the solution to tackle this problem as private and public parties were in consultation with each other.	•		Industry association

Already own and exploit hydrogen filling station all over the world and the goal was to match the company's constructional standard with the safety standard in the Netherlands. Opportunity to continue building hydrogen filling station with almost the same company standards and dispose their produced hydrogen in the Netherlands.		•	Hydrogen producer
Matching the safety regulations of the hydrogen filling station with those of the hydrogen fuel cell vehicles with a special focus on the standardized receptacle nozzle; involved in the standardization process on both national and international level in order to prevent a hiatus in regulations between.	•		Industry association
Representative who is also active by himself in the existing fossil fuel infrastructure and acted upon behalf of these fuel station operators. His goal was to make it possible to easily join the market with existing fuel stations.	•	•	Industry association
Core business in another alternative fuel, namely CNG, experienced hindrance with the deployment of the infrastructure as municipalities individually demanded specific safety requirements. So clear and defined regulations for licensing authorizations to avoid this hindrance and expand the business with hydrogen filling station across the Netherlands.	•	•	Infrastructure
Quality			
A high level of quality and reliability of hydrogen filling station are important for the industry. Preventing reputational damage by accidents in the Dutch market which can harm the development of the technology	•		Governmental
Guarantee public safety with a reference document with standardized safety regulations	•		Governmental and infrastructure
Guarantee public safety is essential to establish upcoming industry as there is uncertainty among governments and consumers.	•		Infrastructure
Protecting own proprietary technology by only insisting on performance requirements of components as (his) technology differs completely from the current used technologies.	•	•	Infrastructure
Information			
Deliver useful information to the reference document, because the current hydrogen filling station are built on poorly design regulations	•		Hydrogen producer

and agreements as there was indistinctness (at municipalities) on ideal construction methods of hydrogen filling station which ensure a high level of safety.			
Information in the standard derived from company constructional standards while simultaneously matching these standards with the safety regulations of PGS 35.	•	•	Hydrogen producer
The regulations are mainly formulated as performance based requirements and leaves flexibility to manufacturer as regards to technical solutions. These margins are considered as a stimulus to contribute to the standard.	•		Hydrogen producer
These performance based requirements, which leaves margins in using various of technological solutions make it a long tenable document for evolving technology.	•		Hydrogen producer
As it creates a leeway for future technologies since there are also no obligatory design-based requirements.	•		Hydrogen producer
Safety information disclosure between the participants to protect the market from (unnecessary) accidents which can harm the upcoming market by reputational damage.	•		Hydrogen producer
Information needed to prevent interpretation differences between municipalities. PGS 35 is a useful concept to act as an informative manual for all parties and it also ensures that safety aspects are not forgotten in the licensing process.	•		Industry associate
The availability of information about safety regulations which are nationwide accepted will more likely improve the investment climate in the Netherlands.	•		Industry associate
Compatibility			
Future hydrogen filling stations are expected and these stations should match with current habits/standards of consumers including guarantee of public safety. New customers' familiarization will lead to a better adoption of the technology.		•	Infrastructure
Technological unification on supply side of the market as bunglers are unwanted and could harm the market by using the technology in the wrong way. This could lead to reputational damage for the industry.	•		Infrastructure

To strengthen the unification and compatibility PGS 35 is actively promoted on a European level, since unwanted activities should also be excluded in other European countries to protect the image of the market and technology.	•		Infrastructure
Public interest to optimize the reference document by improving the compatibility with related and dependent technology as hydrogen filling stations depend on hydrogen fuel cell vehicle and thus these should fit.	•		Governmental
In order to guarantee public safety a communication system between station and vehicle should be included to ensure this.	•		Governmental
Fitting the technology used by his company with current legislation, since PGS 35 is supplied with design-based examples to support the essential performance regulations.		•	Hydrogen producer
Variation reduction			
Unification of technology used is needed to prevent (public) debates about the technology used and will create clarity among all interested parties.	•		Governmental
Comfort and clarity for involved actors is needed to improve the development of the infrastructure as prescribed technologies are included in the reference document for licensing authorities.	•		Governmental
Focused on preventing the occurrence of variety reduction since this could exclude newly developed technologies from implemented in the industry. For that reason, the participant protects his technology from exclusion as it is not yet on the market.		•	Infrastructure
The hydrogen mobility industry starts to grow and this will bring new firms with (new) technological solutions to the market. A variety reduction caused by the standard will leave no leeway for future technologies. The hydrogen producer is developing new technologies and this will be disadvantageous for his company.	•	•	Hydrogen producer

Table 10: Overview of the impact of the systemic analysis

Overview of outcomes		A	B	C
Private	Hydrogen producer	5	3	2
	Infrastructure	4	3	3
Public	Governmental	8	0	0
	Industry associate	5	1	0

Assessment for the impact on the two effects of standardization: ***A** is impact on innovation development process*, ***B** is impact on both outcomes and **C** is impact on gaining competitive advantage.*

Table 11: Overview of motivations per found topic

Overview of motivations per topic	Public	Private
Licensing procedures	3	2
Guaranteeing public safety	4	3
Information sharing	1	1
Compatibility with fossil fuels	1	1
Compatibility with related technologies	2	2
Fitting proprietary technology	0	2
Flexibility	0	3
Public vs. private	2	2

Appendix E: Mind map identified overlapping topics