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Implementing living labs in regulations: a case study of the realization of The Green Village

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Abstract

The European Union has set different targets to overcome the sustainability problems, but to reach these targets sustainable technologies are needed. To develop these sustainable technologies, living labs can be a valuable addition to the innovation process because at these sustainable technology living labs, sustainable technologies can be tested in a real life environment. However, the problem is that local regulations are blocking the realization of these sustainable technology living labs. First, because it is unclear what sustainable technology living labs are. Second, the regulations are not suitable to create a location with experimental technologies where visitors can interact with these technologies. Therefore the research question addressed in this research is: *To what extend do the regulations of the province and municipality have to change in order to realize sustainable technology living labs?* To analyze this problem, the path creation theory was used as a theoretical frame to guide the research. The Green Village, a sustainable technology living lab which has to be realized at the campus of the Technical University of Delft, was used in this research as a case study to find out what a sustainable technology living lab is and how regulations are influencing this realization process. The realization of the Green Village was analyzed with a qualitative case study research design, including a literature review and semi-structured expert interviews to collect data. From the results in this research can be concluded that a sustainable technology living lab is a continuously changing site where collaborating organizations can present, demonstrate and test their researched and future technologies in a real life environment. At this real life environment users can actively contribute to the innovation process of these technologies in order to accelerate the diffusion of sustainable technologies to create a sustainable future. The realization of this sustainable technology living lab is blocked by the Dutch regulations: land-use plan, national building decree and the building regulations. A specific regulation has to be designed, so that on a sustainable technology living lab location these three regulations are designed in such a way that it is possible to create a lab which fulfills the characteristics of a living lab.

Key words: sustainable technology living lab, path creation, realization process, blocking regulations, sustainable technologies, The Green Village

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1. Introduction

The European Union has set targets[1] for 2020 to overcome the sustainability problems (Eurostat, 2013). In order to achieve these targets, research for new technological solutions is needed. "Research can develop technical solutions to tackle environmental or societal challenges (e.g. technologies to reduce CO_2 emissions, to be more energy efficient, to replace scarce raw materials), but to be environmentally effective, technologies must be successfully commercialized." (Sabadie, 2014 p. 669). In order to successfully commercialize these sustainable technologies, a technological transition is needed wherein radical innovations and new technologies can be integrated in society (Rojey, 2009). Before new technologies can be integrated in society, testing and experimenting are of great importance to see how these technologies interact with the social system (Geels, 2002; Hekkert et al, 2007; Rogers, 2003; Tidd & Bessant, 2009). Therefore real life testing sites or 'living labs' are needed to test how these radical technologies interact with existing values in society (Nill & Kemp, 2009). A definition of a living lab is: "… a user-centric innovation milieu built on every-day practice and research, with an approach that facilitates user influence in open and distributed innovation processes engaging all relevant partners in real life contexts, aiming to create sustainable values." (Bergvall-Kåreborn et al, 2009 p.3). These real life experiments on a living lab also provide insights for the innovation process, such as insights in the economic and societal embedding of new technologies (Ballon et al, 2005). In order to create these insights for the innovation process of sustainable technologies, sustainable technology living labs are needed where actors can experiment with sustainable technologies. Examples of emerging sustainable technology living labs are 'The Green Village' in The Netherlands and 'HSB Living Lab' in Sweden (Climate-Kic, 2014).

Initiators of a sustainable technology living lab would like to construct a test facility where new and innovative technologies are realized in such a way that visitors can interact with these technologies (Feurstein et al, 2008). However for the realization of this living lab, the present local regulations (from the province and municipality) do create barriers. This regulatory problem is a result of the unclear characteristics of the sustainable technology living lab concept. Due to this lack of clearness, also in the scientific literature, local policy makers do not know how to deal with sustainable technology living labs in their regulations (Van Geenhuizen, 2013; Feurstein et al, 2008).

The aim of this research is to fill in the gap on the lack of clearness of the characteristics of sustainable technology living labs and the lack of clearness on how policy makers can deal with the realization of those living labs. With this research, recommendations can be created on how to overcome the regulatory barriers from the province and municipality in order to realize sustainable technology living labs. Therefore the research question is:

To what extend do the regulations of the province and municipality have to change in order to realize sustainable technology living labs?

Sub questions are used to identify the different aspects of the research question. The following sub questions are used to answer the research question:

1. *What are the characteristics of a sustainable technology living lab?*

[1] Compared to the 1990 levels: 20% more renewable energy sources, 20% CO2 emission reduced and 20% energy saved. Also the EU has to be resource efficient. (Eurostat, 2013)

The aim of this question is to discover what a sustainable technology living lab is. For this question information is needed on which activities actors would like to perform at a living lab, why living labs are needed for innovation and which conditions are required for innovation at a living lab. This question will address the lack of clearness on what the characteristics of a sustainable technology living lab are.

2. *To what extend do the present regulations influence the realization of sustainable technology living labs?*

With the answer of this question, knowledge will be acquired about how regulations affect the realization process of living labs. First, the most relevant regulations have to be identified, based on the characteristics of a living lab. The next step is to discover how these regulations influence the realization of a sustainable technology living lab. Based on this answer the stimulating and blocking regulations become clear.

3. *Which elements of the regulatory barriers can be improved in order to make the realization of sustainable technology living labs easier?*

The purpose of this question is to investigate which blocking elements can be changed in the regulations in order to make the realization of a sustainable technology living lab easier. With this answer it becomes clear which changes are needed in the regulations to guarantee safety and quality on the living lab, but still create an environment to experiment. This is the last step to answer the main research question.

The problem addressed in this research is analyzed with the path creation theory of Garud and Karnøe (2001), since this theory describes how a new and unknown artifact can be realized when the regulations are not supporting this artifact. This is also the case for sustainable technology living labs wherefore the regulations are not suitable so that living labs can be realized. To answer the addressed questions, a qualitative case study research design was used to investigate the problems of the realization of the Green Village in Delft. The Green Village is an emerging sustainable technology living lab, which will be constructed at the campus of the Technical University of Delft. The Green Village has to look like a real village with streets, buildings, infrastructure and public spaces like restaurants, event centers and offices within an area of 1.5 hectares (Van Wijk, 2013). The first data collection method of this case study was a literature review. However also semi-structured expert interviews were held with actors which are initiating the realization of the Green Village, or are participating in the realization process. With this research design, a description can be created on what the perspectives of different stakeholders are on the characteristics of the Green Village, and how it has to be realized.

Based on the results of this research, recommendations can be given on how the regulations have to change to stimulate the realization of a sustainable technology living lab. In this way experiments with new sustainable technologies can be performed in a real life situation and still the quality and safety of visitors can be guaranteed. This will provide advantages for the innovation process of socially needed radical innovations for a transition towards a sustainable society. In addition, this research also fills in the scientific gap in the literature on the lack of clearness of which characteristics sustainable technology living labs have and how policy makers can deal with those characteristics.

In chapter 2, the theoretical framework will be explained and integrated with concepts from what a sustainable technology living lab is, how the realization process works and how regulations can

influence this realization process. Chapter 3 comprises the methodology, with a detailed description on how the data is collected and treated to answer the research question. Also the quality of the research is addressed in this chapter. Chapter 4 portrays the results of the case study. The thesis will end with a discussion of the results and theory in chapter 5, and a conclusion in chapter 6 where an answer on the research question is given.

2. Theory

In this chapter, an overview is given of the theoretical background of the realization of sustainable technology living labs and how regulations influence this realization process. This theoretical background will result in concepts which will help to understand this process (Bryman, 2008). Section 2.1 portrays the path creation theory which explains how regulations influence the realization of a new artifact. Section 2.2 portrays the concepts of the path creation theory in combination with the concepts which describe the realization of a sustainable technology living lab.

2.1 Path creation

2.1.1 Path dependency

The path dependency theory of David (1985) and Arthur (1989) explains why it is difficult to introduce new construction concepts, such as sustainable technology living labs.

The path dependency theory describes how past events influence decisions of actors today (David, 1985; Arthur, 1989). In the past, choices were made to adopt a technology. Some technologies were adopted more often than other technologies, so therefore institutions were adapted to these preferred technologies (Arthur, 1989). Because more and more institutions were adapted to these technologies, for the next consumer there were more incentives to choose this technology (Arthur, 1989). These social influences are called relevance structures (Garud & Karnøe, 2001). A *relevance structure* is a coherent set of practices and meanings, but it also contains institutions, regulations and mutual understanding between actors (Heiskanen et al, 2011). These relevance structures are adapted to the most preferred technology. Due to this adaptation of relevance structures, new technological concepts must be in line with the present technologies. Therefore only incremental changes are easy to introduce and so it is difficult to introduce radically new concept (Garud & Karnøe, 2001). This stepwise, incremental development of technologies is called a path (David, 1985). Product developers are locked-in to these paths and therefore technological development is dependent on the previously developed path, i.e. path dependent (David, 1985). This lock-in can be explained as: actors are forced to act in one way due to the relevance structures and it is not possible to choose alternatives (Arthur, 1989). Therefore if initiators introduce a new concept, the relevance structures that are present create a resistance against this concept. These resistances are present because actors have to adopt new procedures and methods for a new concepts and also processes have to change, regulations have to be adapted and there are many unforeseen costs in changing the relevance structures (Häkkinen & Belloni, 2011).

This path dependency theory is also applicable to the realization problem of sustainable technology living labs. The present relevance structures prevent that the design of sustainable technology living labs cannot be radically different compared to the existing constructions. So to introduce a new construction concept, initiators have to change the present relevance structures. A theory that explains the process of breaking out of this lock-in in relevance structures, and to create new relevance structures for an innovative concept, is the path creation theory (Garud et al, 2010; Garud & Karnøe, 2001).

2.1.2 Path creation theory

The path creation theory explains the deviation from the existing relevance structures for a new artifact or concept. As Garud & Karnøe (2001) explain the path creation theory: it is possible to

create networks in order to gain momentum to mindfully deviate from the existing relevance structures (Garud & Karnøe, 2001; Heiskanen et al, 2011). This *mindful deviation* is the deviation from the present relevance structures that are not suitable to embed the new concept (Garud & Karnøe, 2001). So in order to realize sustainable technology living labs, mindful deviation is needed to change the relevance structure. The next section describes how initiators are able to create this mindful deviation.

2.1.3 Initiator actions

Initiators have to *mobilizing minds, creating agencies, forming alliances* and *lobbying,* in order to generate *momentum* to deviate from the present relevance structures into a new one (Heiskanen et al, 2011; Garud et al, 2010). The first step to initiate this deviation is by mobilizing minds. Mobilizing minds is creating a collective thought about a new concept among different actors (Garud & Karnøe, 2001; Meyer & Schubert, 2007). With mobilizing minds other actors become familiar with the new concept and therefore the resistance in their thoughts on the concept reduces. In this way, other actors will become enthusiastic for the new concept (Garud & Karnøe, 2001). By creating agencies, creating alliances and lobbying, the actors which agreed with the concept and which will try to make the concept a success are connected. There is a variety of actors that have to be involved, examples are internal actors at all levels of the company, but also external actors such as governments and stakeholders (Garud & Karnøe, 2001). When actors will get involved and also the 'embedded' actors in the relevance structure agree with the concept it is possible to generate momentum (Meyer & Schubert, 2007). This momentum is a result of actors changing their routines and regulations towards the concept and therefore it will be easier to realize it. Due to the momentum, the deviation from the existing relevance structures will start (Garud & Karnøe, 2001).

2.2 Path creation applied to realization of sustainable technology living labs

The path creation theory is used to describe the influence of regulations on the realization process of sustainable technology living labs. The path creation theory explains how a new concept can be realized regarding blocking regulations, so therefore first the characteristics of this new concept have to be identified in section 2.2.1. In section 2.2.2 the realization process of this sustainable technology living lab is explained. In section 2.2.3 a description of the influence of regulations on the realization process of this sustainable technology living lab is presented.

2.2.1 Characteristics of a sustainable technology living lab

The living lab concept was proposed as a solution by the European Union in 2006 to increase the economic activity in Europe (Dutilleul et al, 2010). A living lab is a real-world setting to experiment with new technologies and analyze how prototypes of these new technologies operate in a real-world environment (Lepik et al, 2010). At a living lab, actors such as users, entrepreneurs, researchers, students, government and other stakeholders are involved to create different innovations (Leminen et al, 2012). A living lab can be designed based on four different perspectives. First, a living lab can be designed by entrepreneurs as an extension of their R&D activities. Second, a living lab can be designed by the government to investigate social needs in society. The third type of a living lab is designed by knowledge institutes for promoting knowledge and develop new knowledge with other parties involved. The fourth type of a living lab can be designed by users to solve the users urgent problems (Leminen et al, 2012).

The comprehensive aspect of all types of living labs, is the *user involvement* in the innovation process (Lepik et al, 2010). An objective of a living lab is to investigate how users interact with new technologies, but also to make users familiar with new technologies (Liedtke et al, 2012). Users can give their opinion on the usage of the technology. These user opinions can be used as information for improving the technology (Liedtke et al, 2012; Leminen et al, 2012). For entrepreneurs a living lab can be an extension for their innovation process, because at a living lab information about the social embedding of their technology can be generated. In additions, living labs can also give insights in the *integration of the technology* in the larger technical system to investigate how their technology interacts with other technologies (Liedtke et al, 2012). Besides, entrepreneurs can show their innovation to other stakeholders, which have to implement or install the innovation (Leminen et al, 2012). For these stakeholders, a living lab is valuable to learn which new technologies are emerging and to learn from their stakeholder network how to deal with those new technologies (Liedtke et al, 2012). This *networking possibility* is another aspect of a living lab (Nyström et al, 2014). Stakeholders can also give input for the development of new technologies, and therefore the development becomes an interactive process at a living lab (Leminen et al, 2012). This learning and networking aspect of a living lab can make a living lab valuable for many actors (Quist & Tukker, 2013; Nyström et al, 2014).

The living lab concept can be used for different kinds of technologies. For example, living labs can play a role in the innovation process of sustainable technologies. Sustainable technologies are defined for this research as technologies which help to create sustainable development. Sustainable development is defined as "meeting the needs of the present without compromising the future generations' ability to meet their own needs" (WCED, 1987 p. 43). In order to create this sustainable development, radical technological changes are needed. Sustainable technologies can contribute to sustainable development if it is possible to dematerializes the production and consumption stages of a product and the technologies can decrease greenhouse gas emissions (Gaziulusoy et al, 2008). Another step to achieve sustainable development is by creating a sustainable energy supply. This sustainable energy supply limits air pollution, avoids climate change and limits the depletion of energy resources (Spalding-Fecher et al, 2005; Kaygusuz, 2001). The development of these sustainable technologies is a long-term, complex, radical and co-evolutionary process (Gaziulusoy et al, 2008). This development is long-term and radical because radically new technologies are needed than that are used nowadays. It is complex and co-evolutionary because sustainable technologies are interlinked with many technological systems and human interactions (Ibid.). A sustainable technology living lab can be a solution to these problems of new sustainable technologies, because on a living lab all actors which are relevant for the development of sustainable technologies are involved and innovations can be tested in systems (Nill & Kemp, 2009). In the following section, the realization process of sustainable technology living labs is described.

2.2.2 Realization of sustainable technology living labs

There are four phases to realize a construction, e.g. a sustainable technology living lab. These phases are: 1) planning, 2) design, 3) construction and 4) commissioning (Lee et al, 2012). In these different phases, different actors are present. These actors are, initiators, architects, contractors, local government, users, entrepreneurs, researchers, engineering experts and regulation experts (Rowlinson, 1988).

In the planning phase, the purpose of the construction has to be identified (Christensen, 2009). The initiators of the construction will hire an architect which will help with the realization process of the construction (Rowlinson, 1988). In this phase the 'basic characteristics' of the construction have to become clear (Rohracher, 2001). These characteristics are based on the use of the construction. In case of a sustainable technology living lab, entrepreneurs and researchers will give input and suggestions for experiments that have to be realized. The constructions will be designed in order to perform these experiments. In the planning phase, these aspects have to become clear (Lee et al, 2012). Different engineering experts and regulation experts will give advice where possible barriers are when these constructions have to be realized (Rowlinson, 1988; Christensen, 2009).

Based on the aspects identified in the planning phase, the construction characteristics have to become clear in the design phase (Rowlinson, 1988). In this design phase, the role of the initiator is more coordinating and creating involvement among actors is its main task. The architect will play the leading role in this phase and initiate negotiations, between different actors, on the design of the construction. Entrepreneurs and researchers will still give input for the construction design, e.g. technological knowledge about their experiments. The engineering experts will also give advice for possibilities on the technological aspect. The regulation experts will give advice about how this design have to be adapted regarding the regulations (Christensen, 2009). After the negotiations between the different actors, the final design has to become clear (Hajer & Zonneveld, 2010; Rohracher, 2001). This final design is the basic application for the local government to grant the permits for the construction (Christensen, 2009).

If the design is accepted by the authorities, the construction which is based on the design will be constructed. This construction will take place in the construction phase. In this construction phase, the design has to be converted into construction activities. An analysis has to be made about the need of human capital, different materials and site facilities during the construction (Chau et al, 2003). In this phase the contractor will play a leading role (Rowlinson, 1988). The engineering experts and the entrepreneurs will give technological input in the construction. They can deliver their technologies or give suggestions for how to construct these technologies (Lee et al, 2012). In this phase the regulation experts will still give some advice regarding the construction regulations. The government will evaluate if the contractors are following the regulations (Rowlinson, 1988). After the construction phase, the construction is ready to be used as a sustainable technology living lab.

The different actors which intervene in the realization and operation of a living lab, are presented in table 1. Also their contributions in the different phases are presented (Christensen, 2009; Quist & Tukker, 2013; Nyström et al, 2014; Oltander & Perez Vico, 2005; Garud & Karnøe, 2001). These contributions will be used to understand how a sustainable technology living lab will be realized, but also to see where the relevance structures influence this realization process. The influence of these relevance structures is explained in the next section.

Table 1: Contributions for the realization of a living lab based on (Christensen, 2009; Quist & Tukker, 2013; Nyström et al, 2014; Oltander & Perez Vico, 2005; Garud & Karnøe, 2001)

Actor / building phase	Planning	Design	Construction	Commissioning (living lab)
Local government		-Evaluating permit requests	-Evaluating construction activities	-Gaining knowledge about innovations -Guiding the innovation
Contractor			-Constructing the project	
Architects	-Advising	-Designing project		
Users/citizens				-Get familiar with innovations -Developing knowledge how users are involved with the innovations -Developing innovations
Entrepreneurs	- Proposing innovations -Joining network	-Input of technology information	-Delivering innovations/ technologies	-Entrepreneurial experimentation -Diffusing knowledge
Living lab initiators	-Initiating process -Formulating goals -Network formation	-Coordinate the process -Lobbying	-Finding contractors	-Coordinating activities -Promoting
Researchers	- Proposing experiments	- Knowledge input		-Developing knowledge -Diffusing knowledge
Engineering experts	-Advising	-Advising	-Constructing	
Regulation experts	-Advising	-Advising	-Advising	

2.2.3 Influence of relevance structure

The present relevance structures influence the realization of sustainable technology living labs. As explained in the introduction chapter, the focus of this research is on the influence of regulations on the realization of sustainable technology living labs. Therefore the governmental regulation, part of the relevance structure, are under investigation. These regulations set requirements for buildings designs (Garud & Karnøe, 2001).

Governments can use regulations to steer actor activity towards their policy goals (Häkkinen & Belloni, 2011). Köppel & Ürge-Vorsatz (2007) describe different regulations that governments can use to steer human action in relation with new technologies. These regulations can have different effects

on the realization of a sustainable technology living lab, e.g. they can be inducing or blocking. The definition of a blocking regulation is that the development of a sustainable technology living lab is hampered, i.e. the regulations are not designed to realize a sustainable technology living lab and this makes the realization difficult (Häkkinen & Belloni, 2011; Köppel & Ürge-Vorsatz, 2007). The result of blocking regulations can be that building projects are prohibited, costs increase due to delay or sets restrictions to building plans (Gyourko et al, 2008). The definition of inducing regulations is that they stimulate or accelerate the realization of a sustainable living lab, i.e. make the realization easier or make the realization process go faster (Häkkinen & Belloni, 2011).

The following regulations are relevant for the realization of sustainable technology living labs, because they influence the realization of constructions with sustainable technologies: appliance standards, building codes, procurement regulations, efficiency obligations & quotas, mandatory labeling program, capital subsidies/grants and tax incentives (Köppel & Ürge-Vorsatz, 2007 p. 10). Some other regulations which influence the realization of different constructions are: land-use plan (Louw et al, 2003; Häkkinen & Belloni, 2011) and the external appearance code of buildings (Judex, 2014). An explanation of these regulations is given in table 2. Some of these regulations are blocking because these are not suitable and not created to stimulate the realization process of sustainable technology living labs, and therefore makes realization difficult. An example of a blocking regulation of a sustainable technology living lab is the building code, because the radical new design of buildings of a sustainable technology living lab cannot meet the instructions of the code (Häkkinen & Belloni, 2011). Examples of inducing regulations can be subsidiaries for stimulating experimentation, tax incentives or governmental investments because this makes it easier to fund the project (Hörner & Samuelson, 2013; Häkkinen & Belloni, 2011).

Table 2: Regulations and definitions based on Köppel & Ürge-Vorsatz (2007 p. 10); Louw et al, 2003; Judex, 2014

Regulation	Definition
Appliance standards	The minimum efficiency level of different applications
Building codes	Sets the minimum standards for buildings
Procurement regulations	Defines minimum standards for procured products
Efficiency obligations & quotas	Quotas how the produced output has to look
Mandatory labeling program	Mandatory information provision for users on the performance of buildings
Capital subsidies/grants	Financial support
Tax incentives	Promote investments due to the tax regime
Land-use plan	The government decided what they want on a piece of ground
External appearance codes	The appearance of the buildings have to match the guidelines of the government

3. Method

In this chapter is described how an answer is given on the main research question and its sub questions. In section 3.1 the research design is described. Section 3.2 portrays the data collection methods. Section 3.3 contains the description on how the data was prepared. Section 3.4 contains the description on how the data was analyzed. Finally, section 3.5 describes the quality of the research.

3.1 Research design

For this research a case study research design was selected. A case study is a study of a phenomenon or a process as it develops within one case (Swanborn, 2010). Advantages of a case study are that phenomena can be studied in depth, in its own specific context and therefore, after the case study a thorough description and explanation of the phenomenon is a result (Ibid.). A disadvantage of a case study design is that the results are not generalizable to other cases (Kohn, 1997). Nevertheless the case study design was used for this research, because this research wanted to cover contextual conditions of The Green Village and its realization process (Baxter & Jack, 2008).

For this research the Green Village (GV) was used as a representative case for sustainable technology living labs, to analyze the realization process and characteristics of sustainable technology living labs. The GV is used as a case, because the GV is a sustainable technology living lab and therefore its realization process and the influence of regulation on the GV is similar to a sustainable technology living lab. As described in section 2.2.2, the realization process of a sustainable technology living lab consist of the realization of different projects and experiments. So to make this research more specific, the realization process of a single project at the GV was analyzed together with the regulations that influence this realization process. The project chosen for this thesis, was the realization of an experimental hydrogen fuel station. This hydrogen fuel station is now in the design phase and therefore in the highest state of realization at the GV. Therefore the design of this project is almost clear and the actors to realize this fuel station are already involved in the process and therefore easily accessible.

To perform the case study, an inductive qualitative research design was used. The inductive research design was used to generate theory (Bryman, 2008), which was for this research a description on how a new concept such as the GV can be realized regarding present regulations. Also a qualitative research design was useful to get data with a limited amount of respondents (Bryman, 2008). The required data for this research was data such as what the GV is, how do actors experience a living lab, how regulations are creating barriers for these living labs and how actors act regarding these barriers. To get this type of data, an inductive qualitative research design was the most suitable design (Bryman, 2008).

3.2 Data collection

Two methods were used to collect data for this research.

3.2.1 Literature review

The literature review was used to identify several aspects. First, literature was used to identify different characteristics of the GV. Second, the literature review was used to identify regulations that are of importance for the realization of the GV. Besides, literature was used to identify key actors and initiators of living labs in order to know which actors were relevant and who had to be interviewed.

This literature was found due to information of actors and initiators of the GV. This literature was[2]: 1) *Proeftuin The Green Village, operationeel programma kansen voor west 2 EFRO 2014-2020, project- en businessplan; 2) The Green Village Business Plan 2013; 3) Welcome to the Green Village* and 4) *different policy documents* (see appendix E for the used policy documents and regulations)

3.2.2 Expert interviews

The second data collection method was in-depth, semi-structured interviews with experts. Interviews are used in qualitative research to reflect on certain activities and phenomena (Roulston, 2012). A semi-structured approach was used, because with this approach the interview was guided by some basic questions and gave space to the interviewer to ask follow up questions (Bryman, 2008). To construct those interviews, information from the literature review and concepts from the theory section were used as sensitizing concepts. These sensitizing concepts gave a general sense of reference and guidance in approaching empirical instances (Blumer, 1954). Interview guides in semi-structured expert interviews were needed to guide the interview in the research topic, and to know for the interviewer which questions had to be answered by the respondent during the interview (Flick, 1998). The interview guide is presented in appendix A. This interview guide contains a general list with questions that were asked to all interviewees. For each specific interviewee, depending on the actor group, additional questions were asked. These additional questions are also described per actor in appendix A. Appendix A concludes with a table with the sensitizing concepts for which was searched for per question.

For this research the expert interview method was selected because experts were used in this study as representatives of a group of specific actors (Flick, 1998). The interviews were held with experts involved in the realization of the GV and experts involved in the realization of the fuel station. These experts had specific knowledge on a perspective of the researched problem. The problem addressed in this research, had to be analyzed from different perspectives, so therefore the expert interview is the most suitable method to get an overview of the different perspectives (Ibid.). The literature review indicated that the engineering experts are basically the same as entrepreneurs, so therefore this group is not included in the sample. Also the GV is an emerging living labs, so therefore there are no users available at this moment and so the user group was excluded from the sample. For each actor in table 1 in the theory section, two different experts were interviewed. One expert on the realization of the GV and one expert on the realization of the fuel station. However for the architect, only one expert was involved in the GV so therefore only this expert could be interviewed. So the sample of the research contains 13 expert interviews in total. According to Bryman (2008 p. 462) around the number of 12 interviews theoretical saturation could be reached. Which implies that no new information is generated. At the 13th interview, with Regulation expert 2, almost no new information was generated on the characteristics of a sustainable technology living lab and the realization process. Also no new regulations were mentioned which influence the realization process. So therefore can be concluded that with 13 interviews almost theoretical saturation was reached. A list of the interviewees and their function is described in appendix B. For privacy reasons the names and companies of the interviewees are not presented. Names and contact information can be provided on request and with permission of the respondent.

[2] Literature 1 and 2 are not published so therefore not freely accessible. Therefore these are not included in the reference list. These documents can be shown on request by the researcher.

The sampling method that was used to get access to the interviewees is the snowball sampling method. With the snowball sampling method, the researcher first starts with a small group of participants which are relevant for the research question and these participants propose other participants for the interviews (Bryman, 2012). With this method it is possible to get access to the high level experts in the field, from which the data can be collected (Flick, 1998). For this research, the initiators of the GV mentioned the participants for the actor groups that are described in table 1 and provide the contact information of these participants. All interviews were recorded by a recording device.

3.3 Data preparation

All obtained data resulted in texts. Section 3.3.1 portrays how the obtained literature was prepared for this research to analyze. Section 3.3.2 describes how the interviews were prepared. The interview data will result in a text which is treated in the same manner as the literature, as explained in section 3.3.1.

3.3.1 Literature review and coding process

The used literature was coded with an open coding strategy in order to identify relevant concepts. With this open coding strategy the data was analyzed line-by-line. Each line was analyzed in order to find key words or phrases that were related to the subject under investigation (Goulding, 2002). A code is a 'label' which was attached to the data. This label describes the meaning of a specific part of the data. With a code, the data was broken down in little pieces to conceptualize it (Flick, 1998). In this way, the data became more abstract. The codes, "[..]are formulated first as closely as possible to the text and later more and more abstractly. Categorizing in this procedure refers to the summary of such concepts into generic concepts and to the elaboration of the relations between concepts and generic concepts or categories and superior concepts" (Flick, 1998 p. 179). After the coding process, the codes were categorized in order to create different concepts, relevant for this research. A list of used codes and concepts is presented in appendix C. For this research, the subjects that were relevant and where codes linked to are the characteristics of sustainable technology living labs and the influence of regulations on the realization of these living labs. To have a sense on what was relevant, the concepts from the theory section were kept in mind as sensitizing concepts. The concepts that were found during the literature review were used to guide the interviews.

3.3.2 Expert interview

After the interviews, the recording was transcribed as soon as possible, because the interview was right after the interview fresh in mind. This makes the transcription process easier and the context and examples that the interviewee used were still clear for the interviewer. The recordings were exactly transcribed, word-by-word in order to include all available data. Also a complete transcription was needed in order to leave the researcher's interpretation out of the data collection (Flick, 1998). Thereafter the transcriptions were treated in the same way as the data from the literature was treated, as explained in 3.3.1. The transcriptions can be delivered on request by the researcher.

3.4 Data analysis

By using the concepts, found in the data, the different sub questions were answered.

3.4.1 Sub question 1: What are the characteristics of a sustainable technology living lab?

For answering this sub question, the concepts that were found in the data were used to make a description of the characteristics of a sustainable technology living lab. Also, the relations between the concepts helped to explain these living lab characteristics. A characteristic was for this research identified as a property or attribute that identifies a sustainable technology living lab.

3.4.2 Sub question 2: To what extend do the present regulations influence the realization of sustainable technology living labs?

In order to answer the second question, first the activities in the realization process were identified in order to know how the hydrogen fuel station had to be realized on a sustainable technology living lab. Thereafter the relevant regulations were identified by the literature review and expert interviews. Also was analyzed how these regulations influence the realization process of this fuel station. For this research, regulations could have a blocking or an inducing effect on the realization process of the fuel station on a sustainable technology living lab.

3.4.3 Sub question 3: Which elements of the regulatory barriers can be improved in order to make the realization of sustainable technology living labs easier?

With the barriers, identified at sub question 2, an investigation was made on which elements of these regulatory barriers have to change in order to make the realization process of the fuel station easier. For changing these regulations, the living lab characteristics have to be kept in mind because the fuel station operates at this living lab.

3.5 Quality of research

For evaluating this qualitative research, the following criteria were relevant (Baxter & Jack, 2008; Bryman, 2008; Riege, 2003).

Credibility implies how believable the findings are (Bryman, 2008). This also means or there are good conclusions drawn from the obtained results and that the case is understood correctly (Bryman 2008). The credibility was ensured in this research, because the transcripts of the interviews were sent to the interviewee in order to check or the respondent's answers were interpreted correctly. Also different experts from different actor groups were used to analyze the same problem. Due to the multiple insights of the different experts, a complete description could be created on the problems regarding the realization of sustainable technology living labs. In addition, literature was used to triangulate the data (Riege, 2003). During this research project, presentations were given to fellow students and scientists in order to verify the procedures and consistency of the research which is also important to ensure the credibility of the research (Flick, 1998).

Transferability implies whether the findings of the research apply to other contexts (Bryman, 2008). However, as stated by Kohn (1997), is it difficult to generalize the findings of case study research to other cases. A solution for this problem is that qualitative research can be generalized to a theory (Riege, 2003). Therefore a theory needs a good level of abstraction. A good level of abstraction is reached when the concepts in the theory are not only applicable to the GV, but are more general formulated and thus can be applied to other cases, e.g. other sustainable technology living labs (Bryman, 2012).

Dependability is focusing on the reliability or trustworthiness of this research (Bryman,2008). This implies that with the same data and procedures, the same findings and conclusions are made by other researchers. To ensure this, the process and procedures used in this research are described in detail. Also the complete transcriptions of the interviews were used in order to leave no information out of the research. Also, is described which actors were interviewed, how many actors were interviewed and also what the coding procedures were in order to ensure that the procedures are clear. To give more insights in the procedures, the used interview schemes and codes are included in the appendix in order to be sure that other researchers can perform the same research.

Confirmability is important to leave out the investigators own values of the research, i.e. that the research is conducted in an objective manner (Bryman, 2008). To ensure this, the transcripts of the data is available on request for other researchers to inspect them. Also memos were kept by the researcher during the research and included by the report to show how the thought process of the researcher was developing over time (Riege, 2003). In this way can be shown or the researcher has followed the right procedure and leave out his own values and interpretations. Two examples of memo's are included in appendix D.

4. Results

In this chapter, the results of the case study are described. Section 4.1 portrays the characteristics of the Green Village. Section 4.2 describes the influence of regulations on the realization of a hydrogen fuel station on the Green Village. Finally, section 4.3 describes how regulations have to change in order to realize this hydrogen fuel station.

4.1 Characteristics of The Green Village

The goal of the Green Village (GV) is to improve the innovation process of technologies in order to: 1) produce clean energy, 2) use waste as a resource, 3) produce clean water and 4) produce clean air (Van Wijk, 2013). There are two manners to reach the GV's goal. The first manner is by creating research programs and the second manner is to create a physical demonstration site. These two manners are described in section 4.1.1 and section 4.1.2 respectively. As Initiator 2 explains: "The Green Village is actually designed in two manners. The first manner is a physical location at the campus of the TU Delft. […]. It is possible to create a place to work and visit for researchers and companies to create, develop and apply new and innovative technologies. On the other hand, it is also a program with research activities next to the Green Village so that scientists and companies can collaborate."[3]

4.1.1 Research programs

Three concepts resulted from the coding process to describe the characteristics of the research programs of the GV. These concepts are *applied research*, *collaboration* and *projects.* In the following paragraphs, these concepts are explained in detail and it is explained how they are related.

Applied research

At the GV, applied research is initiated to create sustainable technologies. For these technologies, first fundamental research is performed by the TU Delft. This fundamental research is modified into applied research to be able to realize the technologies on the GV. The researchers from the TU Delft which perform this research are: scientists, students and PhD candidates. Different projects can be performed at the GV, such as a master thesis or PhD project because real life knowledge is available for the research. An example of research that is conducted at the TU in Delft is about the possibilities to use the car as a power plant. On the TU, Researcher 1 analyzes the technical possibilities of a hydrogen car, and he analyzes what happens if you use the car as a power plant. How the socio-technical system of this concept develops is researched by Researcher 2. However, the goal is to experiment with this car as power plant at the GV, and therefore applied research is needed in an early stage of the development. As Initiator 2 explains: "The Green Village forces you to think in a practical way about the innovations, because these innovations have to be realized. This thinking strengthens the applicability of the research and the development of technologies".

Collaboration

The GV is designed to show researched technologies in a real life setting. To create this real life setting, collaboration with external partners is needed because they add practical knowledge to the applied research. For the TU actors, this provides an opportunity to work on cases with real life data in connection with companies. As Researcher 2 explains: "In our project there is a user committee formed by 8 companies I think. Shell, Stedin and one of them is The Green Village. So in terms of the

[3] Quotations from interviews are literally translated from Dutch interview transcripts, except quotations of Researcher 2. This interview was already performed in English.

project. There is already a user committee where I interact with different actors and stakeholders. But sometimes the Green Village also organizes partner meetings." These partners are for example: small start-ups, large multinationals, entrepreneurs, trade associations and the government. However, these partners do not only collaborate with the TU researchers. The GV is also a platform of likeminded companies where they can collaborate and share knowledge. A result of this is that other research programs are initiated as well. On this platform, organizations can share knowledge on different aspects of sustainable technology research. Also due to this collaboration, companies are forced to leave their primary business and therefore innovation is stimulated. Entrepreneur 1 explains this action: "If there is a company that produces heat pumps, then it produces heat pumps. Because that is their primary business. I think, the Green Village is there for companies to leave their comfort zone. Especially, because I think that the needed technologies are a combination of different products and technologies. Therefore companies have to collaborate to create new products". Another incentive for this collaboration is the sharing of risk. At the GV, new and experimental technologies are researched and developed. In this stage of the technological development, the financial risks are high. The involvement of the university with subsidies is an incentive to experiment and to take (more) risks.

Projects

The research activities and collaboration result in projects that have to be realized at the GV demonstration site. These projects contain paradigm changing innovations for sustainable technologies. A paradigm changing innovation is an innovation that changes the ordinary knowledge, routines and technologies (Dosi, 1988). As Initiator 1 explains: "So, we already have 100 to 120 companies and organizations who collaborate with each other. We have a few paradigm changing system innovation processes started already. Therefore the research is also already started. We have installed a few PhD's and the next step is to realize this in real life". A list of projects that probably will be realized on the physical demonstration site of the GV is presented in appendix E.

4.1.2 Physical demonstration site

The physical demonstration site is the second way how the GV tries to reach its goal. Four concepts were found during the coding process of the data which describe the characteristics of the physical demonstration site. These concepts are: *dynamic environment*, *real life testing environment*, *demonstrate* and *user involvement.* These concepts are described in the following paragraphs in detail.

Dynamic environment

The physical demonstration site needs a dynamic character i.e. it has to be possible to continuously change the projects on the site. This dynamic character is needed because projects are created in the research programs and all projects have to be tested at this demonstration site. Therefore it has to be possible to replace the projects for newer projects. Also, the GV has to change the projects on a large scale in order to remain a village with new technologies since technologies age quickly. As Initiator 1 explains: "Well, you have to imagine that the Green Village is never finished. We want to continuously realize new technologies and test new systems. So you have created an environment, but it does not look the same every year. In addition, not every year the same will happen. However that is what we want. There is nothing worse than realize something of the future, but after 2 years it is not the future but the past. So therefore you have to change."

Real life testing environment

Testing technologies refers to finding out which characteristics technologies have and what the performance is of these technologies. On the GV, it is possible to test new technologies in a real life situation. In this real life situation, the technologies have to perform as if they are implemented in the present social and technical system. This situation is created due to the offices, shops, houses, streets and lightings etc. which are at the GV site. Also visitors from outside can visit the GV. These visitors are the customers and users of these future technologies. Due to these visitors, it is possible to experiment with a business case for future technologies. As Initiator 1 explains: "The people who work there can use the products and you can ask them about their opinion on these products. However you do not want to test only the user opinions, but also the business model which is behind the product. Is it profitable? Or can you think about other business cases and are consumer prepared to pay if you do it in another way. By creating this environment you can use new business models, ask about the opinion of users, test new business models and develop them faster".

Next to this, on the GV is it possible to test different technologies. For example, within the electricity system, all technologies are connected and they influence each other's performance. On the GV an environment is created where these new and technical systems can be realized and tested. In this way it is possible to test the performance of the system in a real life situation. For companies, the testing of these systems is also relevant for their innovation process, as explained by Contractor 1: "Here at the Green Village, we create a real life situation, where visitors are welcome and where people can use the facilities that there are. […] during a regular demonstration or pilot project, it is not possible to show the innovations in the large system. Often, the innovation is part of a large system, but with regular pilot projects it is not possible to show that. At the GV, this is possible." With these projects, the technologies are demonstrated to visitors. This demonstration is another concept that identifies the GV.

Demonstrate

At the GV, future technologies and systems are demonstrated to the visitors. They can see how the technologies operate, how the future technologies look like and how people probably live in the future. With the demonstration it is possible to create awareness by the visitors. Visitors can be educated why change is needed and how this change can be achieved, in order to stimulate the transition to a sustainable technology system. As Entrepreneur 1 explained: "And of course to involve visitors in the process like: it costs so many energy to do it as we always do. But if we change, we do this instead of this. And people can argue that they do not care if cables will change, but they also understand why we have to change."

Entrepreneurs also try with the demonstration possibility, to promote technologies to the visitors. When at the GV a technology will be demonstrated and used, it can change behavior of people who visited the GV. Like Entrepreneur 2 tries to achieve with a hydrogen fuel station: "This can be the starting point to make people near the Green Village enthusiast. To make them curious to drive on a hydrogen fuel. In this way it is possible to start the first hydrogen car fleet there."

Visitors and future users are not only involved at the GV to see the technologies. They are also able to participate in the innovation process of the demonstrated technologies.

User involvement

Within the GV, several communities are created where, besides companies and organizations, also visitors can participate. Inside these communities, actors think about innovations, give input for the development of innovations and give suggestions for improvement of products. Also when visitors are on the physical demonstration site, their activities are registered, e.g. the energy they consume, what they buy, how they use technologies etc. As Initiator 2 explains: "To register how they use the car, you can learn a lot from the data. That is one. Thereafter we will investigate with easy questionnaires, interviews and market research by asking people if they use our facilities."

Users are also invited to show and demonstrate their own sustainable solution and join the development of a sustainable future: "The Green Village must be a place and community for everyone, developed by everyone. From all over the world you can visit and experience the virtual Green Village. We want ideas from students, scientists, companies, organizations, artists, and especially from YOU, to develop the green future for everyone. Provide us with your ideas and thoughts and become a Green Villager, a Green Village club member or a Green Village innovator." (Van Wijk, 2013 p. 41).

4.1.3 Definition of the characteristics of the GV

When brining the info presented in sections 4.1.1 and 4.1.2, the GV can be defined as a *continuously changing site where collaborating organizations can present, demonstrate and test their researched future technologies in a real life environment where users can actively contribute to the innovation process of these technologies, in order to accelerate the diffusion of sustainable technologies to create a sustainable future.*

4.2 Influence of regulations on the realization of the hydrogen fuel station

Now the characteristics of the GV are clear, the influence of the regulations on the realization process of the GV has been analyzed. At the GV demonstration site, different projects have to be realized. Therefore section 4.2.1 portrays the realization process of a single project. The influence of regulations on this realization process is described in section 4.2.2.

4.2.1 Realization of a project

This section describes how a single project is realized on the GV site. As described in the methodology section, the realization of a hydrogen fuel station is used as a case. As found in the data, this fuel station is realized in 4 consecutive phases: 1) planning, 2) design, 3) construction and 4) commissioning.

Planning phase

In the planning phase, the realization process of the project is started. As described in the research programs section, these projects result from the research and collaboration in the research programs. The idea for creating a hydrogen fuel station is a consequence of the experimentation with hydrogen cars and next to this, researchers who want to investigate all stages of the hydrogen energy cycle, e.g. hydrogen production, refueling hydrogen cars and producing electricity with hydrogen cars. The relevance of creating a fuel station is explained by Researcher 1: "Well for our installation, we want to experiment in a self-created environment, because with an own installation, you can handle all measurements. […] It would be an ideal situation to test everything, but also to show the whole process. However especially, the measurements are the most important part."

However, this fuel station is not only realized for experimentation for researchers, but it has to be an open fuel station where others can refuel their hydrogen car too.

If the plan for the project is created, the location at the GV site has to become clear. Many projects have to be realized at the GV site. In order to organize this process, a master plan was created. However, due to the uncertainty which projects are realized the master plan is still flexible. The architect of the master plan will analyze how and where projects can be realized at the GV site. As Architect 1 explains: "Yes, actually that was our proposition to make it easier for the GV and make the process more flexible. We also had the goal to make the least amount of rules possible, and therefore we are involved at all moments during the process. The initiators are arguing with partners about what they will realize. If they have an idea, they will come to us and we analyze how their idea can be realized in our master plan. And we discuss how these ideas have to change in order to fit in the master plan." At this stage of the project realization, a location at the GV site can be proposed. The exact location is defined after the design phase when the characteristics of the project are clear.

Design phase

The design of the fuel station is based on the hydrogen demand at this station. To investigate this demand, a user profile is needed. A user profile refers to the quantity of users which will refuel their car at the station and how much hydrogen each car needs. As Entrepreneur 2 explains: "At first instance, you have to make an estimation what the demand for hydrogen is, and make an investigation which characteristics the fuel station needs. Therefore you have to ask, is this to test the car a few times, or is it an operational station. So the user profile is really important to determine. Besides, it is also important to investigate the refuel profile. The refuel profile is how many times the car is refueled. And how much time there is between two refuel moments." These investigations result in a program of demand. With this program of demand, a few alternative concepts of the fuel station will be created. These concepts include all technologies that are needed in order to fulfill the demands. Based on the financial feasibility of the alternative concepts, the final fuel station design is selected. Based on this final design, the exact location on the master plan can be determined. Also based on this design it is possible to request an environmental permit. This influence of the permit request is described in section 4.2.2. When the permit is granted, the design of the fuel station can be constructed.

Construction phase

When the needed permits are granted for the fuel station the construction process can start. As Regulation expert 1 describes this: "All organizations committed themselves to the project. Then you are ready to construct the project. However the construction process is actually a small part of the realization process." This project is constructed by the entrepreneurs and actors that will experiment with the fuel station. These actors have the technical and construction knowledge intern, to construct and engineer the fuel station. As Entrepreneur 2 describes: "Intern, we have a lot of experience and technical knowledge. We have knowledge how to develop such stations." And as Regulation Expert 1 explains: "We do the engineering internally. The preconditions become clear with the customers and other organizations. Then you can start the engineering process." If the construction process is finished, the project is ready for the commissioning phase.

Commissioning phase

The last phase of the realization process is the commissioning phase. In this phase it is possible to experiment with the project in a real life environment. As Initiator 2 explains: "For example, if you

look to the fuel station of the future. […] Here at the Green Village, we explain: we want to investigate the future to work real life on a futuristic fuel station. At this fuel station it is only possible to refuel with future fuels. At this station it is possible to create a platform for research and innovation." To explore the future, visitors are needed so that real life experiments can be performed with the fuel station. These visitors are able to refuel their car with hydrogen. It is also possible to check if the business case of a hydrogen fuel station is profitable, or how to change the business case to make it profitable. Every year, the project will be evaluated if it is still relevant and if the project include new technologies. If not, the project will be replaced by another project.

4.2.2 Influence of regulations

As argued in the introduction chapter, a problem for realizing projects at the GV is the influence of regulations. In this section is described which regulations influence the realization process of the hydrogen fuel station and how these regulations influence this process.

Environmental permit

Before the fuel station can be constructed, an environmental permit is needed from the municipality. After the design phase the municipality verifies if the construction design meets the quality requirements, as set by the government, to grant the environmental permit. These quality requirements deal with the environmental, health and safety effect of the construction on visitors. To grant the environmental permit, four evaluation frames are used to evaluate the construction. These frames are: 1) land-use plan, 2) national building decree, 3) building regulations and 4) the external appearance of buildings. In this section is described how these four frames influence the realization of the fuel station.

Land-use plan

The backbone of the environmental permit request is the land-use plan. In a land-use plan, for each specific location it is exactly described what is allowed to build on that specific location, what people are allowed to exploit on that location and which requirements are applied to that location. Evaluation criteria for the land-use plan are based on national guidelines and local policies. As Government 1 describes the land-use plan: "In a land-use plan, we evaluate all relevant laws and regulations. We also look if on that specific location, all conditions are fulfilled. We also check our own policies, because we also have our own policies as municipality." Because it is exactly described what is allowed on that location, it is difficult to realize different types of projects and new fuels there. This is needed because the GV will continuously renew their projects and implement different fuels and technologies at the fuel station.

If the requested permit does not fit with the land-use plan, the government cannot grant the permit. In order to get the permit granted, the land-use plan has to change, however this takes six to nine months. The present land-use plan of the GV location allows education and experimentation on that site. As Government 2 describes: "The land-use plan explains what we want on a specific location. The next 10 years. […] On the GV location, we want education and research. So it is possible to realize the research of the GV on the site." So it is allowed to realize the experimentation part of the fuel station according to the land-use plan. However with the fuel station, the actors will also sell hydrogen and experiment with economic activities at the fuel station. Only, these economic activities are not allowed according to the land-use plan. As Government 2 explains: "However, when there is a business plan attached to the construction, the experiment is finished. So the research is finished. [..] Yes, also a restaurant. Those things are excluded. Or you have to create a new land-use plan, or

arrange a permit to deviate from the land-use plan." So the land-use plan allows the realization of experimental projects. And if the fuel station was only an isolated experiment in a laboratory it was easier to realize. However, the fuel station has to be freely accessible. Therefore the national building decree is also of relevance for the environmental permit in order to ensure the safety of visitors and users of the fuel station.

National building decree

The national building decree contains regulations for the technical requirements of constructions. These requirements are created to ensure the safety, health, usability, energy savings and environment of the constructions (Rijksoverheid, 2015). The requirements that are used to evaluate the safety of a hydrogen fuel station are described in the PGS 35 (Dutch: programma richtlijn gevaarlijke stoffen/English: guidelines dangerous substances). In this PGS, there are technical norms for the components, such as ISO (International Standardization Organization) and ATEX (ATmosphères EXplosibles), and the internal distances between components is described. However this PGS 35 is still under construction and therefore not available. As Regulation expert 1 explains: "The PGS for hydrogen is not finished. That is a limitation, because you have to do a lot of research." Due to this, there are no regulations for the municipality to check or the hydrogen fuel station is safe. Therefore is not allowed to construct a hydrogen fuel station and besides that there are no regulations, the municipality has no clue about what the new technology is and therefore they also refuse the permit request. As Regulation expert 1 describes: "What also a limitation is, is that government has no clue what the technology is."

Building regulations

The building regulations are designed by the municipality to check buildings for immaterial aspects, such as parking lots, fire safety, the obligatory connection to public utilities and urban planning regulations (Gemeente Delft, 2007). In two ways, the building regulations hamper the realization of the fuel station. The first way is that the safety distance of hydrogen fuel stations is not described in the regulations. This safety distance is needed to insure if there is an accident on the fuel station, that there are no fatalities at other buildings. As Architect 1 explains: "There are no regulations designed for. No urban planning rules for many things that we propose to realize. So for example for the hydrogen fuel station, those regulations are not present in the urban planning regulations. So for many constructions you have rules. They explain the distance from the fuel station to dwellings. There are so many regulations to design a city, however for those constructions, those regulations are not available." So therefore, it is difficult to find a location where the project can be realized. The second way that the building regulations hamper the realization of the project is that there are many regulations set for buildings that are not relevant for temporary and experimental buildings. For example the obliged connection to all public utilities, e.g. water, electricity, sewage. Or the heights of buildings. If the building is temporary, experimental and has to fit inside all these regulations, it is difficult to realize these buildings.

External appearance of buildings

The last evaluation frame to grant the environmental permit, is the external appearance of buildings. This frame checks or the fuel station fits inside the landscape and is in line with the external appearance that the government wants in its city. However due to the temporary character of the project, which is five to ten years, this check is not applicable.

Influence of regulations

To conclude, the request of the environmental permit causes a problem for the realization of the fuel station. The land-use plan, national building decree and the building regulations all cause, in separate ways, that the environmental permit cannot be granted in order to construct the fuel station. This hampers the realization process of this hydrogen fuel station.

4.3 Improve the regulations

Concluding from the previous section, it became clear that the present regulations are not suitable to realize an innovative project at the GV. In this section is described how the hampering regulations have to change in order to realize the fuel station project at the GV site. Also an instrument of the government is described, in the last paragraph, which can be used to realize the proposed changes in the regulations. This instrument is the Crisis an recovery law.

Land-use plan change

The present land-use plan allows experimental activities at the GV location. However no economic activities, or projects with an exploitation plan are allowed at the GV location. Therefore it is not allowed to realize the hydrogen fuel station. Since this fuel station will be a 'fuel station of the future', the fuels have to be sold and a shop will be available at this station. To improve the realization process of this fuel station, the land-use plan has to change so that experimentation and economic exploitation of new technologies is allowed at the GV site. This land-use plan has to change in cooperation with the municipality. In addition, a more flexible land-use plan can be an advantage for the realization of the fuel station, because it is still not clear which fuels are added to the station to remain the fuel station of the future. Therefore no specific fuels and technologies which are allowed on the location have to be described in the land-use plan. So to make the realization process of the fuel station on the GV easier, the land use plan has to fit the definition of the characteristics of the GV: It must be possible to continuously realize different projects that can be demonstrated to visitors in a real life environment. And part of this real life demonstration and testing is also the experimentation with business cases.

National building decree change

The national building decree contains only regulations and norms that evaluate the safety of present fuels, such as gasoline, diesel, LPG etc. For these fuels, requirements are described which are socially accepted as 'safe'. However for hydrogen, these requirements are not described and therefore the permit is not granted. The first step to deviate from the existing norms is to do a risk analysis of the fuel station and create a well-documented technical portfolio (Drost, 2013). The second step is that on a location as the GV, the evaluation of the fuel station must not be based on the regulations for conventional fuel stations, but the evaluation has to consider if the hydrogen fuel station meets the safety requirements behind the regulations of these fuel stations. If the new fuel station meets these requirements, it is safe and can be realized. As Government 1 describes: "How can you arrange that you fulfill the conception, or the spirit of the law. There are several reasons why things are arranged as they are in the regulations. […] However there are more ways to reach the conception of the regulations, instead to fulfil literally to what is described in the regulations. What are the conceptions behind the regulations, and not what is literally described. And how can you fulfill differently this conception behind the regulations." Regarding this, to arrange the permit for the hydrogen fuel station, the safety requirements of the fuel station have to meet the safety conceptions behind the regulations of other fuel stations. In this way it is possible to guarantee the safety of the environment

and visitors on the hydrogen fuel station. For the hydrogen fuel station, key evaluation criteria have to be designed, in cooperation with the municipality, to evaluate or the fuel station can be considered as safe. The basis of these key criteria can be the permit request and studies behind a similar construction that is realized at another location. These criteria can be for example the safety distance between the fuel station and other projects, or to use only ATEX and ISO certified components. In order to evaluate the fuel station, an experienced and independent actor is needed which is familiar with the hydrogen fuel station technology. Contractor 1 explains that the evaluator has to be independent, because responsibilities have to be separated. If the GV realizes projects, then an independent evaluator has to evaluate or the design is safe. If the fuel station at the GV meet the designed key criteria, the fuel station can be considered as safe and the permit can be granted. Otherwise an iterative process with the evaluator is an option to get the design of the fuel station in line with the key criteria.

Building regulations change

As described, the building regulations hamper the realization process of the fuel station in two ways. The first way is that the safety distance of hydrogen fuel stations are not described. This distance ensures the safety of people near the fuel station and therefore it cannot be ignored. A quick manner to overcome this barrier is to analyze how this distance is calculated at similar projects or for comparable fuel stations. A long term manner is to calculate the distance with a Quantitative Risk Analyses (QRA).

The second way how the building regulations influence the realization of the fuel station is that many regulations are described, but the fuel station cannot meet these regulations because it is a temporary and experimental project. Since the fuel station cannot meet all the regulations, the permit is not granted. There are possibilities to dispense different building regulations (Gemeente Delft, 2007). Due to the experimentation and temporary character of the fuel station, not all regulations are relevant and the dispensation of these ‘redundant’ regulations makes the realization of the fuel station easier. Only the regulations that do not affect the safety of visitors have to be dispensed. The instructions for urban planning, except safety distances (Gemeente Delft, 2007 chapter 2, section 5) and the obliged connection to public utilities (Gemeente Delft, 2007 chapter 7, section 7) are examples of regulations that can be dispensed because they do not directly affect the safety of visitors. However there are also regulations which still have to be applicable to ensure the safety of visitors. These are the accessibility roads and entrances for emergency services (Gemeente Delft, 2007 article 2.5.3) and the instructions on fire safety equipment (Gemeente Delft, 2007 chapter 2, section 6). So with the municipality, agreements have to be created which regulations still have to be available and which regulations can be dispensed.

In table 3, on the next page, the regulations of the environmental permit are summarized and is explained how these have to change and which implications these changes have in order to make the realization of the hydrogen fuel station easier.

Table 3: How regulations have to change

Regulation	Elements to change	Improvements of regulations	Implications
Land-use plan	-Label of land-use plan, only experimentation allowed -Not flexible	-Economic, real life activities have to be allowed by land-use plan -Flexibility due to uncertainty	-Costs time, 6-9 months -Costs money -Involvement of municipality needed
National building decree	Norms in the decree are not described to realize hydrogen fuel stations	Evaluation of technologies not based on existing norms, but on quality criteria	-Evaluation criteria needed for example from other similar cases -Independent evaluation 'panel' needed -Cooperation of the municipality
Building regulations	Many guidelines not applicable to temporary and experimental constructions	Regulations have to be dispensed which do not affect safety	- In combination with the municipality, regulations have to be selected that can be dispensed. -Constructions can only be realized temporary

Crisis and Recovery Law

All changes in regulations which are proposed in the previous sections can be achieved with the Crisis and Recovery Law (Dutch: Crisis en Herstelwet). This law is introduced by the Dutch government to stimulate the construction sector, to create jobs and to stimulate sustainable technology experimentation (Rijksoverheid, 2010). This law makes it possible for innovative projects which are hampered by the present regulations to make the realization process easier (Ibid.), because it is possible to dispense different regulations and it allows to treat regulations differently (Crisis – en herstelwet, 2010, article 2.4). Also Government 2 underpins the value of the Crisis and Recovery Law: "I hope that they will use the Crisis and Recovery Law. Because many things are allowed then. You are also allowed to experiment. However first you have to sign up your project." This law can be relevant for the GV, because the GV contains innovative projects for developing sustainable solutions (Crisis – en herstelwet, 2010, article 2.4). So this law can be an opportunity for the initiators of the GV to overcome the regulatory barriers and to make the realization process easier.

5. Discussion

In this chapter this research is discussed. Section 5.1 discusses the results. Section 5.2 compares the results with theory. Section 5.3 discusses the limitations of the research.

5.1 Discussion of results

The first goal of this research was to give a definition of a sustainable technology living lab. The Green Village (GV) was used as a case study to create this definition. However, as described in section 4.1.1, the GV is initiated by the TU Delft and the influence of this university is a reason for organizations to participate in this living lab. In addition, different characteristics of a living lab, such as the input of fundamental research, are directly related to the influence of the TU Delft as well. Therefore, the characteristics of the GV are only applicable to a sustainable living lab with a knowledge institute as initiator. As described in section 2.2.1, Leminen et al (2012) divided living labs in four different categories. One of these categories was a living lab initiated by a knowledge institute. So therefore, the transferability of these living lab characteristics is limited to this category of living labs.

After the created definition of a sustainable technology living lab, the influence of regulations on the realization process was investigated. This research focused on the realization of an experimental hydrogen fuel station which has to be realized at the sustainable technology living lab. The realization process of the hydrogen fuel station consists of four consecutive phases, which are planning, design, construction and commissioning. As described in section 4.2.2, this realization process is hampered by regulations after the design phase, where the environmental permit has to be arranged. Three regulations have to change to realize the hydrogen fuel station. These regulations are: land-use plan, national building decree and building regulations. In this paragraph is discussed if these proposed changes in regulations are also applicable to other projects at the GV location. The proposed changes in the land-use plan also influence the development of other projects at the GV, because other projects also experiment with economical activities, such as a restaurant or the sale of electricity, as described by Initiator 1. Also because it is still unclear which projects will be realized at the GV, the proposed flexibility in the land-use plan is also needed. Changing the national building decree also makes the realization of other projects at the GV easier, because other projects all include innovative technologies. For all these innovative technologies regulations and guidelines are not described in the national building decree, as shown in the table in appendix E column 3. To get the technologies realized regarding the national building decree, all planned projects have to be evaluated on key evaluation criteria to ensure the safety of the technology. Examples of key criteria for the hydrogen fuel station are described in section 4.3.2. However for other technologies, different criteria could be applicable. An independent evaluator has to analyze if these technologies are safe, based on the information of the GV and key evaluation criteria of the municipality. The proposed change for the building regulations can also be applied to other projects of the GV, because all projects are temporary and are realized to demonstrate their functioning in a real life environment (Van Wijk, 2013). Therefore only regulations which ensure quality and safety of visitors still have to be applicable. This cooperation, evaluation and debate between different stakeholders, e.g. initiators and government, to realize innovative constructions is also recognized by Crawford and French (2008). Innovative constructions have to be evaluated on 'key criteria' which is related to the impact of the technology on the direct environment (Crawford & French, 2008). The transferability of the proposed changes in regulations is only applicable to sustainable technology living labs in the

Netherlands, because the investigated regulations are related to the Dutch planning system. This system differs from the planning system in other countries (Hajer & Zonneveld, 2010).

5.2 Comparison with theory and theoretical contribution

For this research, the path dependency and path creation theory were used to analyze the problem of regulations which hamper the realization of a sustainable technology living lab. These theories provided concepts to analyze the problem. To solve this problem, first the present relevance structure was identified which affects the realization of a sustainable technology living lab.

The present relevance structure that affects the realization of the sustainable technology living lab consists of regulations which are needed to get the environmental permit granted by the municipality. The environmental permit is needed in the Netherlands to construct buildings or projects. Therefore projects at the GV also need an environmental permit before initiators are allowed to realize them. To get the environmental permit granted, four evaluation frames are applicable. These frames are: land-use plan, national building decree, building regulations and the external appearance of buildings. These four frames are the regulations in the relevance structure that influences the realization of projects on a sustainable technology living lab. In order to realize a sustainable technology living lab, initiators have to deviate the relevance structure from the existing regulations to regulations that make the realization of a sustainable technology living lab easier.

The path creation theory describes that it is possible to deviate from the relevance structures by mobilizing minds, creating agencies, forming alliances and lobbying (Garud & Karnøe, 2001; Garud et al, 2010; Heiskanen et al 2011). Mobilizing minds is also relevant in the case of sustainable technology living labs, because initiators will realize technologies wherefore no regulations are available. Mobilizing minds is needed in order to create support of stakeholders and society in order to get accepted that projects are realized for which no clear safety guides are designed. As Regulation expert 2 describes: “Because there are no regulations, you have to develop an agreement system which has support from the stake holders. And also, it has to be socially acceptable that we will do it like this because there are no regulations.” Also with the government an alliance or agency is needed to make the realization easier, according to Entrepreneur 2: “If there is something new, there are no regulations available and the government does not know how to deal with those new technologies. That is finally also part of a test bench, that we have to create an alliance or agency with the government in order that it can be a test bench. That we have the possibilities to test new technologies. And of course you have to meet the regulations. You have to. But people have to be open minded to solve the problems during the realization process. They need to have an attitude like: we arrange it, unless…” Lobbying is seen by the government as one of the solutions to get the GV realized. As Government 1 describes: “The Crisis and Recovery law offers opportunities and possibilities to create things differently than we did before. However you have to put a lot of effort in it to realize it. You have to lobby to arrange it.” These examples show that the path creation theory is applicable to different solutions of the problem of realizing a sustainable technology living lab.

The theoretical contribution of this paper is that it filled in the gap which was addressed by Van Geenhuizen (2013) and Feurstein et al (2008). This gap was that the characteristics of a living lab are unclear and therefore it is difficult for other actors to deal with these living labs. In this research, a detailed description of a sustainable technology living lab is given with different characteristics, the

explanation of the characteristics and the connection between the characteristics. With these characteristics, more and in-depth insights are created on what a sustainable technology living lab is.

5.3 Limitations of the study

There are some limitations to this research. First, the investigated actors in this research were based on the defined actor groups in section 2.2.2. However the actor groups which were defined, are not comparable with the actor groups which are relevant for realizing a sustainable technology living lab. During the literature review it became already clear that the entrepreneur and the engineering expert are the same actor, because the entrepreneur who wants to experiment at the GV is part of a technical company that has engineering experience. Due to this similarity, the engineering experts were not included in the sample. Furthermore, it became clear that also the contractor has the same characteristics as the entrepreneur, because the contractor is a company that also wants to experiment with new constructions and possibilities at the GV. Due to this, the researched sample contains many entrepreneurs in comparison with other actors. Therefore the credibility of the research is lower than was proposed, because the focus in the sample is more on the entrepreneurial side than on other actors. Therefore the characteristics of the sustainable technology living lab are predominantly based on the perspectives of entrepreneurs.

Another actor that was not investigated is the user (visitor) of a sustainable technology living lab. Visitors were not included in this research, because the GV is an emerging sustainable technology living lab which is still under construction. Therefore there were no visitors that could be included in the sample. Including users in a sample can provide other characteristics and also other values for innovation of a sustainable technology living lab.

The goal of this research was to analyze how the regulations of the municipality and province have to change in order to realize sustainable technology living labs. However, the regulations of the province deemed not relevant in the case of the realization of the hydrogen fuel station. As Government 2 answered the following on the question if there are permits required from other governmental layers like the national government or province for the fuel station: “Not at this moment. […] But if you have more than 500 kg of hydrogen, or I do not know which amount exactly, than there are other governments relevant. Then I think, the ministry is responsible. But at this moment, only permits are needed from the municipality of Delft.” Since in this case, the regulations of the province seemed not relevant, the regulations of the province were not included in this research. For the local regulations, only the regulations of the municipality were included.

6. Conclusion

The aim of this research was to investigate how the regulations of the municipality and province have to change in order to realize sustainable technology living labs. With this investigation the following research question was answered: ***To what extend do the regulations of the province and municipality have to change in order to realize sustainable technology living labs?*** To answer this question, three sub questions were answered first.

The first sub question was: *What are the characteristics of a sustainable technology living lab?*
The definition of the GV is a definition of a sustainable technology living lab with a knowledge institute as initiator. Therefore the following definition of the characteristics of a sustainable technology living lab initiated by a knowledge institute can be generated: A sustainable technology living lab is a continuously changing site where collaborating organizations can present, demonstrate and test their researched and future technologies in a real life environment. At this real life environment users can actively contribute to the innovation process of these technologies in order to accelerate the diffusion of sustainable technologies to create a sustainable future.

The second sub question was: *To what extend do the present regulations influence the realization of sustainable technology living labs?*
The present regulations hamper the realization of a sustainable technology living lab. These regulations are not designed to realize new and innovative technologies on a location where it is possible that visitors interact with the technology. The regulations only contain safety norms for conventional technologies, because these norms are widely accepted. However the new and innovative technologies that have to be realized on the sustainable technology living lab location do not fit inside these norms and therefore the environmental permit cannot be granted. Blocking regulations which are part of the environmental permit are: land-use plan, national building decree and building regulations.

The third sub question was: *Which elements of the regulatory barriers can be improved in order to make the realization of sustainable technology living labs easier?*
To make the realization of sustainable technology living labs easier the land-use plan, national building decree and building regulations have to change. The land-use plan has to be designed more flexible in such a way that economic activities are allowed on the living lab location. Currently it is not allowed to sell produced hydrogen on the fuel station. However the real life characteristic of a living lab is to experiment with technologies and sell the product which is part of it. This land-use plan can change with the cooperation of the municipality which has to design and approve the new land-use plan. Furthermore, the national building decree has to evaluate technologies in a different manner. The technologies have to be evaluated on key evaluation criteria from the government. These criteria are needed to check the safety of technologies. Examples of these key criteria are: the safety distance to other projects, the chances that an installation might explode or the certification of components. An independent evaluator has to check if the technologies are in line with these key criteria. To conclude, several building regulations have to be dispensed in order to realize projects in a sustainable technology living lab. In cooperation with the municipality, the initiators have to evaluate which regulations can be dispensed because they do not affect the safety of visitors. Regulations that can be dispensed are instructions for urban planning and the obliged connection to the public utilities.

With these answers combined, the answer on the main research question can be given: ***To what extend do the regulations of the province and municipality have to change in order to realize sustainable technology living labs?***

In order to realize a sustainable technology living lab, a regulation has to be designed in such a way that on the location where a sustainable technology living lab is realized different regulations are applicable than on other locations. This difference is needed, because the projects that are realized at the sustainable technology lab location are in an experimental phase, which differs from technologies that are realized in conventional constructions. This new regulation has to allow that the land-use plan, national building decree and the building regulations have to be different at this sustainable technology living lab location. First, the land-use plan has to allow besides experimental activities also economic activities so that the real life characteristics of the sustainable technology living lab can be met. For this real life characteristic, experimenting with business cases and selling products is needed. Also this land-use plan has to be more flexible described. Second, the innovative technologies that can be realized must not be evaluated following the exact description of technologies in the national building decree. A special building decree with safety norms and key criteria is needed in order to evaluate the safety of the technologies, because new technologies cannot be evaluated regarding the present regulations. These key criteria can be safety distance to other projects and the certification of components. And thirdly, together with the municipality have to be analyzed which regulations in the building regulations are still relevant for evaluating constructions at a sustainable technology living lab. In this manner, redundant regulations can be dispensed. These regulations are for example the urban planning regulations and the obliged connection to the public utilities. With the special regulation for sustainable living lab locations, the realization process of a sustainable technology living lab is easier, but still the safety of visitors is taken into account.

This research provided guidelines for different stakeholders to realize sustainable technology living labs. Especially for policy makers, guidelines are described about which regulatory barriers have to be reduced and how policy makers can achieve this to make the realization process of sustainable technology living labs easier. With these sustainable technology living labs, the innovation process can be improved of the needed sustainable technologies to overcome the sustainability problems which the world faces.

The conclusion of this research created several possibilities for further research. The data that was used was based on the Green Village, a living lab initiated by a knowledge institute. To get a complete understanding of a sustainable technology living lab, the definition of the characteristics of a sustainable technology living lab can be researched within other categories of living labs as described by Leminen et al (2012). With these further investigations, the understanding of a sustainable technology living lab can be improved to create a more general description of a sustainable living lab. To analyze the influence of regulations on the realization process in other countries, for each specific country new research is needed, because regulations differ between countries. Another possibility for further research can be to improve the sample of researched actors Based on the actor groups created in this research, a better representative sample can be made during further research due to a better composition of the actor groups. This will give other insights, or a deeper understanding of the problem. Also users can be included next time.

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This master thesis is the final work of my master program Innovation Sciences at Utrecht University. I started this program, because I think we have to create sustainable technologies in order to overcome the sustainability problems that the world faces. With the knowledge I obtained during this master program about innovations, I hope that I can help to improve the innovation processes of sustainable technologies in order to create a transition towards a sustainable energy supply.

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Appendix A: Interview schedule

What is The Green Village:

- Can you give a description of The Green Village?
- Which actors are all involved at The Green Village?
- Do you think that The Green Village is important for your innovations?
- Why would you experiment on The Green Village?
- What has to be possible at The Green Village to have added value to your innovations?
- Which information can you obtain on The Green Village, do you expect?
- For developing this information, is there no other location possible?
- What is all possible on The Green Village if the project is finished?

How to realize the Green Village:

- What activities are needed to realize The Green Village?
- Which phases can you distinguish from start till end?
- Which actors are therefore needed?
- Which role can you play in the realization of The Green Village?
- How do the realization of The Green Village differ from other projects?
- On what do you advice The Green Village in the realization?

How do regulations influence the realization:

Regulations during realization
- Which regulations influence the realization of The Green Village?
- Can you mention a few regulations?
- Are there regulations that makes the realization process of the Green Village easier?
- Are there some actions from the government that makes the realization of The Green Village easier?
- Which regulations hampers the realization process?
- How are these regulations hampering the process?
- Are there possibilities to deviate from the hampering regulations?

Regulations during commissioning phase:
- Which regulations are of influence on the experimentation with technologies?
- Which regulations makes the experimentation with technologies easier?
- Which regulations hampers the experimentation with technologies?

Solutions:
- Is it possible to design The Green Village differently to get away with the regulations?
- Is it possible to realize a project such as The Green Village easier?
- How could you change the regulations to make the realization of The Green Village easier?

ACTOR SPECIFIC QUESTIONS
– Needs to be integrated in the interview guide before doing the interview with the actor-

Contractor
- How do you realize ordinary construction projects?
- Which phases are applicable to such projects?
- How do the realiation of The Green Village differ from other projects?
- How do you see those differences in the realization process?

Architects
- How do you try to design The Green Village by taking into account the hampering regulations?
- Is it possible to design The Green Village differently due to the present regulations?

Entrepreneur
- Can you give suggestions how The Green Village have to be realized, regarding your innovations?
- How important is the netwerk possibility on The Green Village?

Initiator
- What is your goal by realizing The Green Village?
- What is your role when the realization process of The Green Village is finished?

Experimenters
- Do you have relevant knowledge, which is needed for designing experiments on The Green Village?

Regulation experts
- Which regulations are of influence on the realization of buildings?
- Why are these regulations designed?

Government
- Which role can the government play for finding solutions?

Table 4: Interview questions and keywords wherefore is searched with the questions

Question	Direction of answer	Keywords
What is The Green Village:		
- Can you give a description of The Green Village?	characteristics of TGV	experimentation; open; networking; users; lab
- Which actors are all involved at The Green Village?	Different actors	Name different actors (table 1)
- Do you think that The Green Village is important for your innovations?	value of TGV	innovation process; product development; actor input
- Why would you experiment on The Green Village?	value of TGV	differences of information; experimental environment; networking
- What has to be possible at The Green Village to have added value to your innovations?	characteristics of TGV	inducing regulations; different information sources
- Which information can you obtain on The Green Village, do you expect?	value of TGV	user information; system information; stakeholder input
- For developing this information, is there no other location possible?	value of TGV	innovative environment; unique possibility
- What is all possible on The Green Village if the project is finished?	Value of TGV	Experimentation; demonstration; networking
How to realize the Green Village:		
- **What activities are needed to realize The Green Village?**	Realization activities	Different activities (table 1)
- Which phases can you distinguish from start till end?	realization phases	different phases (table 1)
- Which actors are therefore needed?	different actors	name different actors (table 1)
- Which role can you play in the realization of The Green Village?	actor role/activity	explain their activities (table 1)
- How do the realization of The Green Village differ from other projects?	differences between other projects	comparisons between activities in projects
- On what do you advice The Green Village in the realization?	actor role/activity	explain actor role (table 1)

Influence of regulations		
Regulations during realization		
- Which regulations influence the realization of The Green Village?	Identify regulations	different regulations (table 2)
- Can you mention a few regulations?	Identify regulations	different regulations (table 2)
- Are there regulations that makes the realization process of the Green Village easier?	Identify regulations for TGV	different regulations (table 2)
- Are there some actions from the government that makes the realization of The Green Village easier?	Identify governmental actions	different regulations (table 2)
- Which regulations hampers the realization process?	Identify blocking regulations	regulations hamper realisation
- How are these regulations hampering the process?	Identify blocking regulations	regulations hamper realisation
- Are there possibilities to deviate from the hampering regulations?	Solutions for blocking regulations	suggestions for change
Regulations during commissioning phase		
- Which regulations are of influence on the experimentation with technologies?	Regulations for experimentation on lab	different regulations (table 2)
- Which regulations makes the experimentation with technologies easier?	Stimulating regulations on living lab	regulations stimulate experimentation
- Which regulations hampers the experimentation with technologies?	Blocking regulations on lab	regulations hamper experimentation
Solutions		
- Is it possible to design The Green Village differently to get away with the regulations?	Present solutions	suggestions on design for long-term solutions
- Is it possible to realize a project such as The Green Village easier?	Future solutions	general suggestions for long-term solutions
- How could you change the regulations to make the realization of The Green Village easier?	Future solutions	suggestions for regulations on long-term solutions
ACTOR SPECIFIC QUESTIONS		
Contractor		
- How do you realize ordinary construction projects?	Description of realization process	identify construction activities (table 1)
- Which phases are applicable to such projects?	Identify phases	identify construction

		phases (table 1)
- How do the realiation of The Green Village differ from other projects?	Identify differences	comparisons with other projects
- How do you see those differences in the realization process?	Description of differences	examples of differences
Architects		
- How do you try to design The Green Village by taking into account the hampering regulations?	Description of design process	explanation of design changes
- Is it possible to design The Green Village differently due to the present regulations?	Insights in design regarding regulations	solutions for short term design problems
Entrepreneur specific		
- Can you give suggestions how The Green Village have to be realized, regarding your innovations?	Entrepreneur activity on TGV	explanation on how they influence realisation
- How important is the netwerk possibility on The Green Village?	Identify important activities	Information on other stakeholders
Initiator specific		
- What is your goal by realizing The Green Village?	Identify realisation reasons	specify their goals
- What is your role when the realization process of The Green Village is finished?	Identify initiator role	specify their role
Experimenters		
- Do you have relevant knowledge, which is needed for designing experiments on The Green Village?	Realisation activity	identify their role in realization process on knowledge
Regulation experts specific		
- Which regulations are of influence on the realization of buildings?	Identify construction regulations	description of regulations (table 2)
- Why are these regulations designed?	Identify reason for regulations	reasons for why regulations are developed
Government		
- Which role can the government play for finding solutions?	Identify governmental actions	Description of governmental possibilities to help the realization

Appendix B: List of interviewees

Table 5: Interviewees and their function

Interviewee	Function
Initiator 1	Main initiator of the Green Village
Initiator 2	Initiator of the Green Village and contact for the hydrogen fuel station
Entrepreneur 1	Involved to experiment with sustainable buildings at the Green Village
Entrepreneur 2	Involved to experiment and exploit the hydrogen fuel station at the Green Village
Regulation expert 1	Expert in regulations of fuel station with gasses. Part of the same company as entrepreneur 2
Regulation expert 2	Advices the Green Village on regulation problems.
Contractor 1	Have to realize the innovative infrastructure on the Green Village
Contractor 2	Have to realize the innovative infrastructure on the Green Village
Researcher 1	PhD student on analyzing technical possibilities of the Car as Powerplant
Researcher 2	PhD student for the societal effect of the Car as Power Plant project
Government 1	Policy advisor environment and spatial planning
Government 2	Environmental permit evaluator
Architect	Designed the master plan for the Green Village and evaluates or single projects fit inside the master plan

Appendix C: List of concepts and codes

Table 6: Concepts and codes characteristics of living lab

Concept	Codes
Research	Social relevant knowledge; scientific research, research topics; science; visualize research; real world data creation
Collaboration	Platform; connecting companies; companies and organizations; spreading risks; exposure; likeminded companies; combine knowledge; out comfort zone; deliver possibilities; actor interaction; information on innovations; knowledge sharing
Projects	System changes; new technologies; infrastructure; do not work properly; sustainability; future standards
Test environment	Pilot projects; test bench; experiment; functioning of technology; freedom for experimentation; application of technologies
Demonstration	Show innovations; public site; living lab; demonstration of research; working of the future; exposure for technologies; tangible technologies; small variants; show whole systems; convince visitors
Real life	Real working; practical application; safe; everybody understands; external visitors; work and visit place; realize projects; not only test; business case; practical thinking; revenues for users
Dynamic	Never finished; continuously changing; newer technologies; temporary village
Users involved	Users have to see technologies; awareness creation; feedback; participate in innovation; shop; measure user activities; reactions of users; attract visitors
Goal	Accelerate innovation; achieve goals; sustainable innovations; sustainable society; greening economy; innovative region

In this appendix, only the concepts of the description of a sustainable technology living lab are presented. A complete spread sheet of the other concepts and all other codes can be provided on request.

Appendix D: Memo's

In this appendix, 2 examples of memo's are included that were used during the research

Date: 21 April 2015 After interviewing contractor 2

It seems that the contractors I interviewed are the same as entrepreneurs. This actor is involved at the Green Village as a construction company. However this contractor also wants to experiment with its new and constructed technologies. Also compared with the answers of Entrepreneur 2, who explains that they will construct the fuel station, it seems that there is no clear distinction possible between the actors contractor and entrepreneur. With the earlier findings that the engineering experts and entrepreneurs are also the same, the conclusion can be made that the entrepreneur that will experiment on the Green Village also constructs and install its experiment or technology. With this in mind, the sample that was created to investigate the problems around the realization of a sustainable technology living lab is not representative, which was preferred.

Date 22 April 2015 After interviewing governmental actor 2

It seems very difficult to realize the Green Village. To get the environmental permit, the construction have to fit inside the national building decree. However it is impossible at this stage to get the construction to fit in the decree. There are no norms for evaluating the technologies, and therefore the permit cannot be granted. So the government will not grant the permit. However there seems to be a solution. There is a law, the crisis and recovery law. With this law it is possible that some regulations are not relevant anymore. However, the governmental actor doubts or the mayor and councilors will give the Green Village carte blanche to create everything they want without asking for a permit. It is on a urban location, with many people living there. And because it is open and everybody can enter the location, probably the municipality do not want that there will happen anything risky. So it will be difficult to use this opportunity.

Appendix E: Innovations and conflicting regulations GV

In table 7 some proposed projects that have to be realized on The Green Village. These projects are described in column 1. In column 2 the newness or innovation of the projects is described. In the 3th column, the conflicting regulations or norms are described. The references are in this table mentioned with a number. Under the table the references are described. The innovations in this table are derived from the booklets: *Welcome to the Green Village* and *The Green Village Business Plan 2013.* Also some innovations are derived from the interviews. Also the newness is created by information from the interviews and booklets.

Table 7: Innovations and conflicting regulations on The Green Village

Innovation	Newness	Conflicting regulation
Public DC electricity grid	More efficient than AC grid due to: - less conversion moments - uses less copper - no electromagnetic radiation	- Electricity law, DC electricity not allowed on the grid, only AC [1] - Metrologiewet, no measurement equipment available which is required for public grid [2]
DC electricity in buildings	Appliances operate on DC electricity, therefore no converter needed from AC to DC. This saves energy losses due to conversion	NEN 1010, no guidelines for DC network in buildings [3]
Produce and distribute own drinking water	Possibilities to produce drinking water from: - Rain - Hydrogen electricity production - Greywater	"Drinkwaterwet", not allowed to produce own drinking water [4]
Separated human waste streams	More efficient recycling system	Permission needed from municipality and purification companies if they will treat different organic waste separately [5]
Placement of all infrastructure in ducts	Easier and cheaper for: - Replacement - Maintenance	Different NEN norms; guidelines that all cables and tubes must have a minimal distance [6]
Storage of hydrogen cars in buildings	Cars on hydrogen are: - More energy efficient - Can be used to produce electricity	NPR 7910-1 Not allowed to store hydrogen in a closed space [7]
Local production of hydrogen near buildings	Because hydrogen is needed for research, it is more efficient to produce it local	Quality demand for external safety – a minimum distance required between production and buildings [8]
Local hydrogen gas station	When hydrogen cars will be used, then also hydrogen gas stations are needed	- NPR 8099:2010 safety distance [9] - Environmental permit
Building lighting with integrated LED	Shorten the distance between light source and light use increase efficiency	NEN – EN 12464-1 whole spaces have to be lightened, not only objects [10]
Public lighting without lampposts	By integrating LED, lighting of the public space can be more energy efficient	NPR 13201-1 public lighting has also a social function, therefore larger lamps needed [11]

Constantly changing village	The village has to change over time in order to keep the technologies in the village up-to-date	To constantly change the village, the permit procedure takes a lot of time due to many permits
Economic activity on GV site	Testing of business case in combination with testing the technology	Land-use plan, not allowed to perform economic activity on education site.
Hydrogen fuel station	Able to refuel the car	PGS 35 is still under construction
Realizing own innovative utility infrastructure	Experiment with new possibilities in infrastructure	The building regulations obliged that all constructions have to be connected to the public utilities.

List of used regulations in this table, in this list are only regulations described which are not described in the thesis:

[1] Elektriciteitswet, (1998, 2 July). Online available: http://wetten.nl/BWBR0009755/Opschrift/geldigheidsdatum_12-06-2015 <12-6-2015>
[2] Metrologiewet, (2006, 2 February). Online available: http://wetten.overheid.nl/BWBR0019517/geldigheidsdatum_12-06-2015 <12-6-2015>
[3] Groenewege, R., Smeets, H., Leenders, C., Koolmees, N., (2008). Elektrische veiligheid – laagspanning. Online available: http://www.arbokennisnet.nl/images/dynamic/dossiers/elektrische_veiligheid/d_elektrische%20veiligheid_laagspanning.pdf <12-6-2015>
[4] Drinkwaterwet, (2009, 18 July). http://wetten.overheid.nl/BWBR0026338/geldigheidsdatum_12-06-2015 <12-6-2015>
[5] Gemeente Delft, (2012). Gemeentelijk riolerings plan Delft 2012-2015. Online avaliable: http://ris.delft.nl/document.php?m=1&fileid=66723&f=c327f3b734d5628fd1d4e1a061c38cc6&attachment=0&c=9365 <6-3-2015>
[6] Stedin, (n.d.). Kabels en leidingen – criteria voor aanleg en beheer. Online available: https://www.stedin.net/zakelijk/~/media/files/stedin/richtlijnen/stedin-richtlijnen-kabels-en-leidingen.pdf <6-3-2015>
[7] IAB Ingenieurs. (2009). Wijziging NPR 7910. Online available: http://www.iab-atex.nl/wijziging_npr_7910.htm <12-6-2015>
[8] Brandweer Amsterdam-Amstelland, (n.d.). Handreiking voor optreden tijdens incidenten met waterstoftoepassingen. Online available: http://brandweerkennisnet.nl/publish/pages/18874/veiligheidsprocedure_waterstof_1_0.pdf <6-3-2015>
[9] Agentschap NL, (2010). NPR 8099 – waterstoftankstations. Online available: https://www.infomil.nl/publish/pages/75269/presentaties_npr_waterstoftankstations_samengevoegd_ppt.pdf <6-3-2015>
[10] Agentschap NL, (2010). Standaard programma van eisen verlichting. Online available: http://www.rvo.nl/sites/default/files/bijlagen/Programma_van_eisen_definitieve_versie_12-01-2010.pdf <12-6-2015>
[11] Gemeente Heusden, (2005). Beleidsplan openbare verlichting. Online available: http://decentrale.regelgeving.overheid.nl/cvdr/images/Heusden/i23980.pdf <12-6-2015>