Renewal of De Drachtsterweg

How renewal can be used to push for energy neutral infrastructure

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Abstract

The Netherlands increasingly faces a challenge for renewal in infrastructure. From a Large Transport Systems Perspective (LTS) this issues a change, co-evolution, in congruence between sociotechnical actors. These sociotechnical actors have to change, but the main research question focusses on how they change towards a sustainability centered, in particular energy neutral, planning practice for infrastructure.

Firstly, it is necessary to know how the sociotechnical regimes from the Large Transport Systems Perspective (LTS) change. The Multilevel Perspective (MLP) is used to explain what drives these systemic changes. Secondly, an understanding of what the regime should change towards, in order to be energy neutral, is needed. Sustainable Innovation Policy (SI-policy) provides the basis for this new sociotechnical regime that works towards energy neutral infrastructure.

The Drachtsterweg in Leeuwarden is used as a case study, because involved government agencies and private parties pushed for an energy neutral renewal project.

Based on the results of this case study, the aging of infrastructure leading to renewal can be used to realize energy neutral infrastructure, so long as governments make energy neutral an integral part of renewal projects, learn to work with uncertainty and market parties get the room to innovate.

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Chapter 1 Introduction

1.1 Relevance

"I am old, not obsolete", were the words Arnold Schwarzenegger's terminator used to describe that even though he had aged as a machine, he could still be functional. No matter how advanced he was in 1984, he was struggling in the 2015 movie. This point very much relates to what, among others, Tongur & Engwall (2017, p. 84) say about technology: "As existing assets age, technological and market development at the landscape level can make institutionalized technologies obsolete."
Willems et al (2016) identify a problem for policy makers in the years to come: Dutch infrastructure systems have components that show symptoms of ageing and policy makers need to develop policies that adequately address these problems. Basic maintenance is no longer sufficient, because structures have become either structurally or functionally inadequate. Replacement and renewal of existing infrastructure has become important to consider for planners. Transport systems have transitioned from a phase of maturity to renewal.
Infrastructure in western countries, such as the Netherlands, are highly complex systems, with typical examples being waterways, railway systems and highways. Systems have developed to a mature state, meaning they are highly evolved and reluctant to change (Willems et al, 2016). Phase changes have implications for the interrelations between social and technical components (Bolton & Foxon, 2015). For one, it is important to think of ways to keep systems performance up to a minimum structural standard. Secondly, new infrastructure should be developed in such a way that it deals with uncertainties of the future.
It is clear that systems are important and that they face a challenge in terms of a need for renewal. According to minister van Nieuwhuizen (Rijksoverheid, 2018) society relies on these systems. Malfunction or structural deficiency causes negative side effects, such as economic damage or increased travel time. Infrastructure also has to be more energy efficient, which is phrased as "the ambition to make networks energy neutral (Rijksoverheid, 2018, p2)."

The renewal of "de Drachtsterweg" in the city of Leeuwarden is interesting to look at. Over the course of the past years, the former bridge has been replaced for an aqueduct. This report aims to explore the policy measures behind the project and to what extent the congruence between the sociotechnical linkages in the project changed in relation to the old situation, particularly for energy. The project is part of the "Leeuwarden vrijbaan"-program, which consists of Rijkswaterstaat, the province of Friesland and the municipality of Leeuwarden. This program features dozens of other projects, such as "de haak om Leeuwarden" and was initially designed to improve accessibility throughout the city. What makes Drachtsterweg of particular interest is that over time sustainability became one of the key points that policy makers wanted to address for the aqueduct (Gemeente Leeuwarden, 2014; Rijksoverheid, 2018; RoyalHaskoningDHV, 2017).

1.2 Research problem

Infrastructure has become old and it consequentially faces becoming structurally inadequate or becoming unable to function to the standard of changing societal demands. This makes redeveloping, in relation to future uncertainties, important in renewal projects (Tongur &Engwall, 2017; Willems et al.,2016).
The focus in this report will be towards improving understanding sustainability in renewal projects in the Netherlands. More specifically, the aim is to improve understanding of making projects energy neutral. Van Wee and Annema (2013), as well as national planning agencies (Rijksoverheid, 2012;

2018), identify energy use as one of the major environmental problems for the upcoming decades. All arguments considered, society benefits from new reliable, sustainable and functional infrastructure, while science benefits from a better understanding of institutional changes that lead to congruence between policy and technique for infrastructure renewal and energy sustainability.

The aim of this report is to discover how renewal projects can contribute to the increase of sustainable infrastructure and how improve implementation of energy neutrality in future projects. Based on Geels (2007) it is difficult to make a transition from one phase to the other, due to momentum in technological trajectories. External circumstance and/or technological niches can break this momentum and overcome stability (Van de Poel, 2000; Tongur & Engwall, 2017). Scarce energy sources are an external circumstance that lead to energy shortages. Although society is reliant on energy, trajectory and embedded regimes often lead to carbon-lock in (Foxon, 2007; Geels, 2007). Change should be seen as an opportunity, and a necessity, to overcome carbon-lock in and to create more energy efficient transport systems.
In order to make changes to the existing regime, first a theoretical understanding is needed of what regimes are. The Large Transport Systems perspective (LTS) is used for explaining regimes. Changing or innovating these regimes is explained with the Multilevel Perspective model (MLP). Overall, the focus is directed towards including sustainability, more specifically energy usage, in this process of regime shift.
Based on the created theoretical frame a number of actors can be identified that issue a need for renewal of "de Drachtsterweg": depleting energy sources, increased traffic numbers and the technical aging of infrastructure. These needs translate to clear goals: the need for energy neutral systems and a needed increase in traffic capacity. Here the sustainable innovation policy (SI) is added, to provide the basis for analyzing how the regime should change in order to address these energy challenges. This SI- framework provides the basis for this empirical question and explains how these actors have been applied to this case in planning practice.
The research focuses on one case in particular. This final question serves as a means to connect the findings of the theoretical and the empirical question: have externalities and innovations lead to regime changes and how has this been applied to "de Drachtsterweg"? The insights provide a basis for future renewal projects: integrating energy neutrality in renewal projects.

Summarizing, the research problem is that structural and functional aging led to a need for renewal, energy neutral infrastructure and institutional change. These needs led to the following main question: **How can the need for renewal in infrastructure help stimulate energy neutral transport systems?** In order to answer the main question, three secondary questions will be answered:
-How are sociotechnical regime changes made in large transport systems?
-What institutional processes, from the Large Transport Systems perspective, Multilevel Perspective and sustainable innovation policies, led to improved energy neutrality on "de Drachtsterweg"?
-How can the insights from "de Drachtsterweg" be used to improve energy neutrality in future renewal projects?

Chapter 2 Theoretical framework

2.1 Literature search strategy

According to Healey and Healey (chp 2, 2010) literature search strategies are needed to build a framework. Willems et al (2016) was used as a starting point that provided a keyconcept: the LTS model. The reference list, also from other used articles, was used to find new search terms. Ultimately, a framework was built based on four key concepts: LTS, sociotechnical innovation, MLP and SI. All other introduced concepts fit within this framework.
To account for quality, the framework was built from more than 10 different peer reviewed articles. Also, all articles older than 2000 have been backed, or expanded on, with more recent sources.

2.2 Large Transport Systems Perspective (LTS)

The LTS approaches the development of infrastructure as a sociotechnical system. It explains systems as a combination of social and technical actors, rather than as a strictly technical system. It identifies four phases of development for transport infrastructure: establishment, expansion, maturity and renewal. These phases each feature different social and technological needs. The degree to which these actors match, or mismatch, is known as congruence. In order for a system to function, there is a minimum degree of congruence needed between the social and the technical components. Each phase requires its own unique congruence between technical and social actors (Willems et al, 2016), also described by Geels (2007) as sociotechnical linkages.
Willems at al. (2016) identifies a problem related to infrastructure systems in the Netherlands. The year 2010 is marked as the transition from a phase of maturity to one of renewal. Existing infrastructure requires reparations and redevelopment to fit to the needs associated with future uncertainties. Policies should consider longer time horizons and higher scale integrated policies that consider objects in the network and in regional context, rather than in isolation. Incidentally, there is a need for sociotechnical linkages and congruence to co-evolve as systems transgress to new phases, because otherwise there is a risk of potential mismatch. This creates a challenge: changing the congruence of sociotechnical systems to fit the new phase of renewal.
Infrastructure already shows a high state of development, meaning these systems are mature or have already surpassed maturity. An associated effect is that systems and sociotechnical linkages show less radical changes. Mature systems build momentum and have a tendency to stabilize in maturity, because they follow technological trajectories (Geels, 2007). These trajectories develop cumulatively, or shift to new trajectories.
Sociotechnical regime was created as a concept that describes patterns of cognitive routine, a way of thinking, in planning practices (Nelson & Winter, 1982). Regimes consist of a system of shared rules and perceptions that communities of engineers share. Rip and Kemp (1998) expanded this concept to a way of problem defining that is embedded in institutions. Geels (2004) expanded this concept to a broader set of social groups, such as private parties and policy-makers. Chapter 2.2 explained what sociotechnical regimes are. Chapters 2.3 and 2.4 explain how these regimes change.

2.3 Sociotechnical innovation as a non-linear process

Innovations of technique and changes to policies and regimes do not occur linear, such as proposed in traditional economic theories, based on a traditional economic argument. This traditional way of thinking describes two types of policy measures: innovation policies and environmental policies that each deal with deal with different market failures. However, system innovation should be seen as the interaction of sociotechnical actors within a dynamic, non-linear, context of uncertainty (Foxon &

Pearson, 2007). Franzeskaki and Loorbach (2010) identify four characteristics for innovation: complex with interrelated elements, analysis based on long time-horizon, non-linear developments and factors of uncertainty related to long-term changes.
Based on the implications of the LTS model sociotechnical actors have to co-evolve. However, treating this process as a linear and stable development can in fact lead to a process of carbon lock-in, due to the tendency for momentum (Foxon & Pearson, 2007; Geels, 2007). Rather than assuming these changes will occur, an understanding of elements that facilitate change is needed.

2.4 Multilevel Perspective (MLP)

Van Wee & Annema (2013) provide a theoretical understanding of system innovations theory. It encompasses a description for all the relations between sociotechnical actors and their value to society. Innovation is the development of technique and knowledge. Hoogma et al (2002) distinguish two categories of innovation: contributing to regime optimization and contributing to regime-shifts, but this research focusses on the regime-shifts. Geels (2002) explains regime-shift from a multilevel perspective.

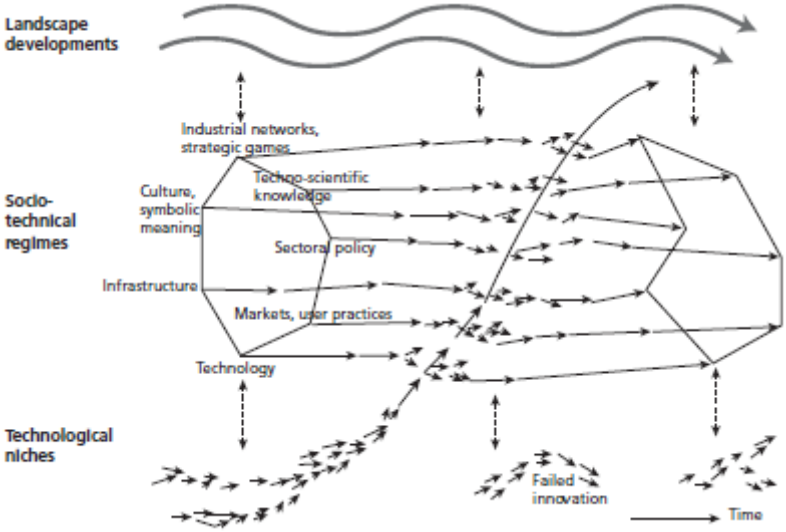

Image 1: Multilevel model of system innovation. *Source: Geels 2002*

The MLP perspective (**Image 1)** consists of sociotechnical-regimes and it changes under influence of technological niches and landscape development.
The technological niches consist of the invention of all new techniques. Due to effects of momentum and trajectories, innovation happens on the outside of the regime. Innovation therefore counts as external to the regime, rather than internal. When these inventions successfully penetrate sociotechnical regimes they become part of the regime, although inventions often fail (Geels, 2002).
Sociotechnical landscape consists of factors that are external to the sociotechnical regime. It is important to consider, because the regime often cannot make changes to these deep structural trends, but some external factors, like environmental impacts, are directly caused by the transport systems. Technology and technological innovations affect the externalities of transport. One of the challenges, related to effects on the environment, is energy usage (Geels, 2005; Van Wee & Annema, 2013). Developments can be tangible, such as the built environment, or non-tangible, such as impact of environmental issues. They can develop fast or slow. Relevant external circumstances are energy dependency, increased traffic and embeddedness in society (Van Wee & Annema, 2013; Rijksoverheid, 2018).

Overcoming stability is difficult, because changes follow established paths and occur only gradually (Bolton and Foxon, 2015). According to Geels (2007) sociotechnical changes can be made by altering these trajectories, or under pressure from external circumstance. Van de Poel (2000) adds that regime and landscape always affect transition, whereas niche innovations are not necessarily present by definition. To overcome stability, Tongur and Engwall (2017) argue that the landscape can create a window of opportunity. This is a destabilizing effect on the existing regime, but it does not necessarily result in change, but rather offers that chance (Kingdon & Thurber, 1984). Technological niches offer radical innovations a protected environment for growth. The landscape level can then destabilize the socio-technical regime, as the technologies embedded in the socio-technical regimes become obsolete because of aging. This makes time an important factor for innovations.
Chapters 2.2, 2.3 and 2.4 discussed what sociotechnical regimes are and how they change. In chapter 2.5, a framework will be introduced that explains what the existing regime should change into, to address energy and sustainability.

2.5 Sustainable innovation policy (SI)

Foxon and Pearson (2007) introduce the idea of sustainable innovation policy (SI), a policy regime that focusses on long-term sustainability goals and that embraces uncertainty, rather than using it as an excuse for lock-in and inaction. They identify five features, based on a study in The Netherlands, which can be universally applied to sustainable policy regimes. These features provide the basis for the co-evolution that is needed to develop sustainable infrastructure in renewal projects.
(1) Clear long-term sustainability goals are needed to create stability and reduce effects of uncertainty. This has a positive effect on the amount of investments made and those are needed for new technologies (Foxon & Pearson, 2007; Foxon et al, 2007).
(2) Technological diversity is needed because new successful technologies are never clear winners. Therefore, it is needed to support a wide range of technologies. This relates to supporting technological niches so that in the long-term they may develop into mainstream sustainable technology (Geels, 2002). Peeling et al (2016) provide a framework for the variety of technological categories related to tunnels and how they can benefit energy efficiency. Three of their four categories could be applied to aqueducts: energy provision, lighting and driver-based technology.
(3) Public-private partnership is based on the distinct roles that public and privatized parties play. Governments phrase societal issues and finance the solutions, whereas private parties typically have more skill, knowledge and resources to do the problem solving. Playing these complementary roles allows for specialization and increased efficiency (Foxon & Pearson, 2007).
(4) Integration of policy and technical solutions are needed, because one is unable to solve problems without the other. This heavily relates to what the LTS perspective is based on: the need for congruence between social and technical actors (Willems et al, 2016). This makes congruence in itself a measure for sustainable development.
(5)The introduction of “learning by doing”, because a transition implies that all involved parties are dealing with a new situation. Learning what works and what does not, takes time and can only be achieved by trial and error. Projects are in themselves a learning process (Foxon & Pearson, 2007).

2.6 Conceptual Model

The conceptual model **(Image 2)** has been built from all the elements previously described in this chapter. It provides the basic understanding of the actors that result in sociotechnical regime-shift: the sociotechnical landscape, the existing sociotechnical regime and technological niches drive it. The

top of the graph explains one phase in the life cycle path of the LTS perspective, with the added external effects of the MLP perspective and novel niche technology.
The bottom half explains the effect of the regime change. With sociotechnical regime-shift there is a need for new co-evolution between the technological and the social actors. The result is the new sociotechnical regime that replaces the old one.

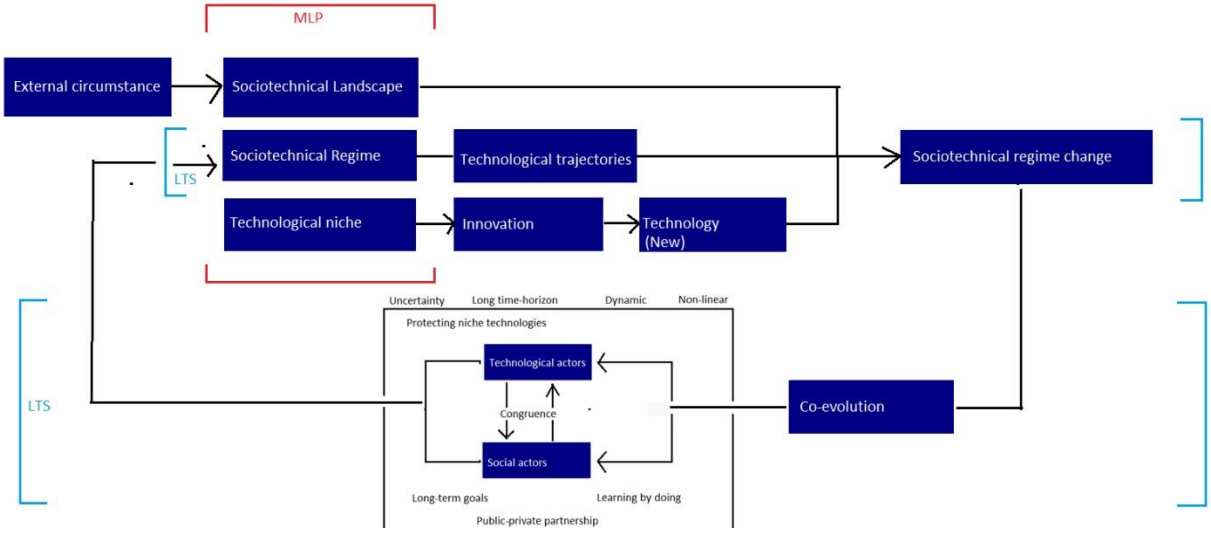

Image 2: Conceptual model for regime change.

The two models are combined to explain why regime has to change and how it needs external circumstances to change. The interaction between sociotechnical landscape, sociotechnical regime and technological niches is influenced by factors of uncertainty. Therefore, the process that leads to sociotechnical regime change is non-linear.

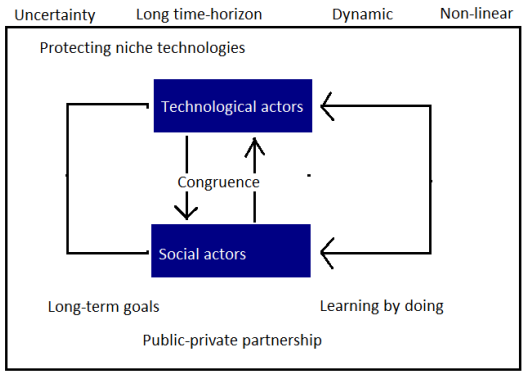

Image 3: Congruence after regime-change towards sustainability.

The result is a new sociotechnical regime **(Image 3)** that aims towards renewal and energy neutrality. This new regime develops according to the processes of system innovation and consists of the elements of the model of sustainable innovation policy. Therefore, this regime should entail clear long-term sustainability goals, enable technological diversity through experimentation, public-private partnership, congruence between policy measures and technology and finally the room to treat transitions as a process of learning.

Chapter 3 Research

3.1 Methodology

3.1.1 Research method

The research focusses on quality, understanding and in depth analysis of institutional processes in a renewal project, as well as actors, intentions and motives that led to applying measures aimed at sustainability. Qualitative measures are best suited for uncovering underlying intentions and motives. Quality, depth and understanding are also examples of strong suits of qualitative research methods (Clifford et al, 2010). Considering the subject matter and the research questions, qualitative methods will be used.

A case study has been chosen, because the focus is on uncovering general trends, relations and sociotechnical actors that relate to increasing to energy related goals in renewal projects. The strength of case studies is that they generate detailed information on relations between actors. However, there is no measurement for their generality (Rice, chp 17, 2010). In accordance, conclusions made, are about general trends and relations.

To increase the strength of results a combination of interviews and documents will be used for analysis. Such a use of multiple sources is known as triangulation (Clifford et al, 2010). The interviews are semi-structured to test the theoretical codes, while at the same time leaving room for respondents to elaborate input that they think is relevant.

Both the interviews and documents will be analyzed in chapter 4, to provide insight into institutional change, implementation of energy neutral for the Drachtsterweg and how these insights can be used for future projects. The documents will consist of policy for different levels of scale and topped-off with case specific documents. In the same manner, the respondents will represent the different involved parties.

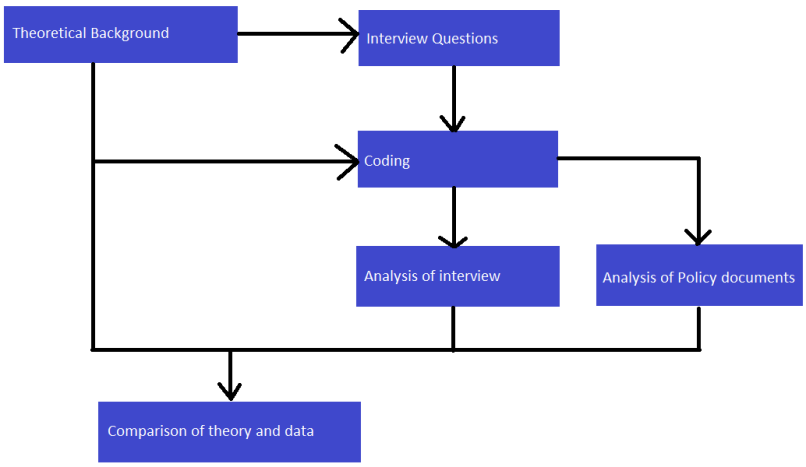

Image 4: Visual representation of the research method.

3.1.2 Interviews

The respondents **(Graph 1)** have been chosen based on their involvement with the project of the Drachtsterweg. They have all been selected based on their either their integral knowledge, or specific knowledge related to sustainability and energy. Because multiple parties were involved in the project, respondents also represent different parties and, as such, different perspectives. The identified parties in the project are Province of Friesland, Municipality of Leeuwarden,

RoyalhaskoningDKH and Heijmans.
Rijkswatertstaat, a partner in Vrij-baan, claims to have little involvement in the Drachtsterweg. Therefore, the RWS representative was not a full interview, but has been asked to comment specifically on Duurzaam GWW, a system of methods and tools applied in Drachtsterweg.

Consultant energy and sustainability RHDHV
Energycoördinator Municipality Leeuwarden
Projectmanager Drachtsterweg (Province)
Projectmanager Drachtsterweg (Municipality)
Senior Advisor Environment-Management Rijkswaterstaat Noord-Nederland

Graph 1: List of respondents

At least one representative from all parties was sought, because representative characterization matters for case studies (Rice, chp 17, 2010). Sadly, Heijmans' project manager declined an interview, which has implications for the research. One perspective is missing and although heijmans' role was discussed with other respondents, it serves to be cautious when reflecting on their role and when making conclusions.

3.1.3 Ethics

Ethical considerations have to be made for three reasons: to protect the rights of respondents, to assure respectful relations between researcher and respondent and to protect the name of the university. For interviews specifically, anonymity and confidentiality matter (Hay, chp 3, 2010).
As a researcher, I will be an outsider, as none of the respondents are likely to be people I know and I am also not a member of their organizations. Still, these are all professionals and in that sense, not many objections should arise. In terms of taken actions, it was important to ask for their informed consent (Hay, chp 3, 2010). Permission to record was asked early in the meeting and it was explained that the recording and transcripts will be used confidentially and solely within the context of this research. Their privacy is most important, so no names are mentioned, no footage will be made public and the transcripts are not added in the report. Finally, each respondent received the transcript of their interview and given the option to provide comments, or ask for changes. The final report, without transcripts, will be sent to the respondents after grading and the transcripts will be deleted.

3.1.4 Policy documents

A selection of relevant documents has been made **(Graph 2)**. This list features three policy documents on different levels of scale: municipal, national and European. Since these scales relate to each other, the combination of these documents forms an integrated whole of goals and ambitions related to sustainability and energy, that position the case in the proper context.
The two remaining documents are about the case itself. These serve to explain the development of the case itself, particularly related to energy. An Environmental Impact Assessment (EIA) would have been included, only no such report was conducted for this case. This way, also for the policy documents representative characterization was sought (Rice, chp 17, 2010)

Klimaatbrief 2050 *Uitdagingen voor Nederland bij het streven naar een concurrerend, klimaatneutraal Europa.*
Structuurvisie Infrastructuur en Ruimte *Nederland concurrerend, bereikbaar, leefbaar en veilig* (SVIR)
Visiedocument Duurzaam Leeuwarden, de sterke stad (2010).
Toelichting Bestemmingsplan "Leeuwarden - Drachtsterweg e.o. (incl. nieuw Aquaduct)"(2012).
Advies Duurzame Drachtsterweg: *Maatregelen om de Drachtsterweg te verduurzamen* Projectgroep Verdiepte Ligging Drachtsterweg- 26 april 2012 Definitief rapport.

Graph 2: Analyzed policy documents

Klimaatbrief 2050 places sustainability and energy in an international context. It discusses long-term goals, uncertainties, technological diversity and forms of (public-private) partnership.
SVIR is a policy document on a national level that relates infrastructure to spatial development. It covers sustainability and energy topics, but more importantly, it provides guidelines for the regional policy and planning documents mentioned below.
Duurzaam Leeuwarden is a vision document on a municipal level. It mentions energy as an important challenge for Leeuwarden in the coming years. It relates these challenges to (concrete) goals.
Bestemmingsplan features the spatial implementation of the project and connects sustainability goals from other policy documents to the project.
Advies Duurzame Drachtsterweg is written by RoyalHaskoningDHV. It explores all possible measures that could increase sustainability for the Drachtsterweg and their feasibility. Viable measures from this document were included in the tender.

3.1.5 Analysis

Analysis of interviews and documents will be done based on codes. Codes for the analysis were drafted from the theory, because this enables testing of the existing theory with the results, also known as deductive research (Clifford et al, 2010)
The results yielded an interesting insight, namely that considering the regional context may be a valuable concept to include in sustainable innovations regimes. Regional context has therefore been added as a code, to provide a basis for an inductive argument for the possibly inconclusive SI-theory. Inductive research adds to theory from the data (Clifford et al, 2010).
After analysis, the results will be compared to the data to present the findings.
A list of the used codes can be found in **Appendix 2**.

3.2 Casestudy: Drachtsterweg

The renewal of the Drachtsterweg is one of the projects in Leeuwarden-Vrijbaan designed to keep the city accessible. The case was chosen, because increase of sustainability become a key point over the course of the project. Many aspects within this theme are related to energy: the decrease of energy usage with energy efficient technology and the production of energy with solar panels. The location of the project site, aqueduct and solar park have been visualized in **image 5**.

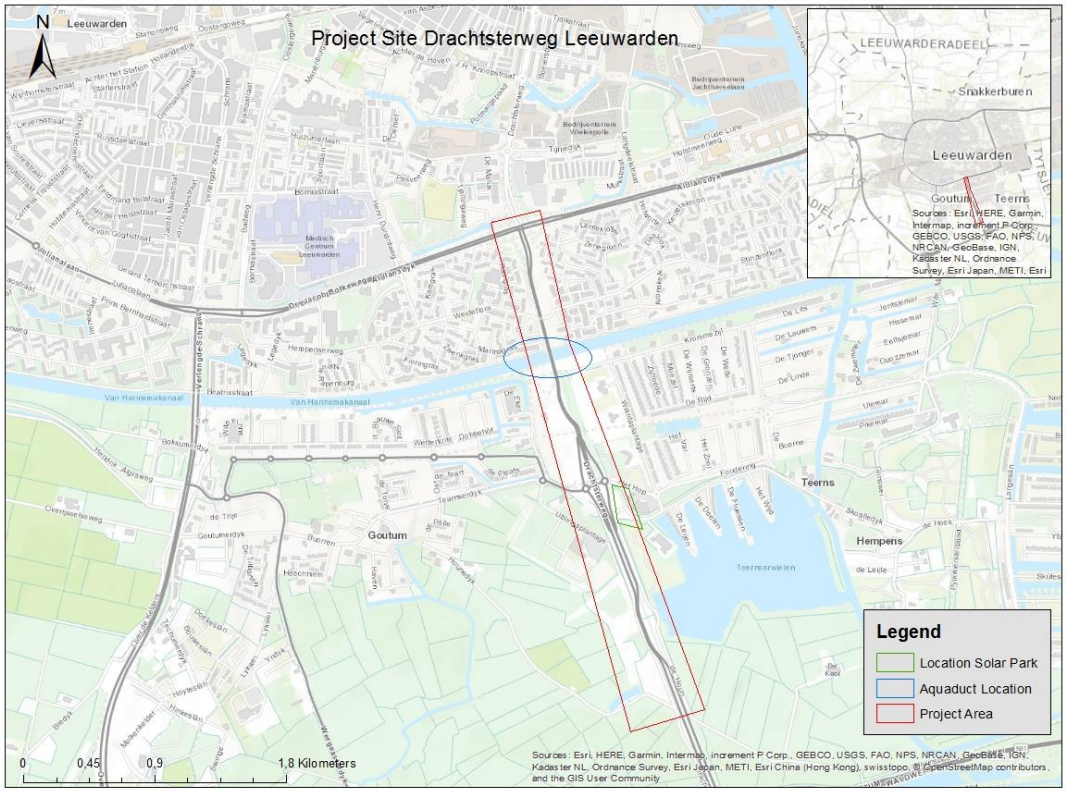

Image 5: Project site

The case was chosen, because increase of sustainability become a key point over the course of the project. Many aspects within this theme are related to energy: the decrease of energy usage with energy efficient technology and the production of energy with solar panels.
Aqueducts are considered energy consuming assets in road infrastructure. Excavation and materials for construction are energy intensive. Operating, lighting and draining consumes energy (Peeling et al, 2016).
In “Structuurvisie Infrastructuur en Ruimte” (SVIR) the increasing energy demand is posed as a challenge for the upcoming decades (Rijksoverheid, 2012). Increased demand necessitates expansion of production, when scarcity is increasing. All of the municipality’s goals are focused on their vision written in 2010. They wish to stimulate sustainable technology and decrease dependence on fossil fuels. A transition to other sources is needed, but that has spatial implications while having limited room. Decreasing consumption as much as possible, is also needed.In the case of Drachtsterweg, both these elements were used. Sustainable materials were used, maintenance was made more efficient and make use of energy efficient lighting. Based on the projectpage (Vrijbaan, 2016) the project contains many techniques, related to energy: led lighting, solar panels, energy efficient draining systems and re-use of materials such as ground from the tunnel and old asphalt.
Drachtsterweg features renewal an institutional change towards making the project energy neutral, even though aqueducts consume high amounts of energy. The combination of these aspects make “de Drachtserweg” a relevant case study for these research questions. Chapter 2 provided a theoretical understanding of the theory surrounding renewal in infrastructure and the adoption of energy efficiency.

Chapter 4 Results

4.1 Introduction

In chapter 4 the outcome of the interviews and policy documents is analyzed. In order to make sense of how the responses relate to renewal, the consequential need for institutional changes and how this helps stimulate energy neutral infrastructure, they will be linked to the themes and keywords that were discussed in the theoretical framework of chapter 2.

4.2 System changes

Chapter 2 discussed, from the LTS perspective, infrastructure as a whole of sociotechnical actors, in which the needed congruence between the actors depends on planning challenges related to a phase in a lifecycle. The required regime changes were argued as being dynamic and difficult due to effects of momentum. The MLP perspective was used as a means to explain system changes.

It was argued that making changes to the sociotechnical regime is a difficult and dynamic process, but nonetheless a necessary one. Based on multiple respondents, this can only be confirmed. Beforehand the realization of sustainability and energy goals are met with reluctance: many practitioners are set in their ways. Based on the results, regime change occurs mostly to the institutional side of the story, rather than the technical aspects.

“Op dat sociale vlak zie je dat je een team bij elkaar hebt van mensen die in eerste instantie wel wat terughoudend zijn, maar die toch warmgemaakt worden en zien: het kan dus eigenlijk wel. Dan gaat het ook lukken.” (Consultant energy and sustainablity RoyalHaskoningDHV)

Literature yielded that changes to the momentum of the sociotechnical regime could be influenced by two factors: external influences, known as sociotechnical landscape, and niche technologies.
In terms of externalities, there is the awareness that current energy sources are limited and that in order to become sustainable; energy usage has to decrease and energy to come from different sources. This has led to environmental goals and ambitions for many government agencies. However, this is not the same as working to achieve these goals. External circumstances led to goals, but according to the respondents, changes to daily practice in the sociotechnical regime require another step. All agreed that the translation to practice was made in the Drachtsterweg-project.

”Die kan je wel hebben, maar als je niet nadenkt wat voor consequenties dat heeft voor jouw dagelijks werk, voor jouw financiën en voor jouw projecten, dan wordt het sowieso niks.” (Consultant energy and sustainability RHDHV)

It was also argued that niche technologies can influence regime changes. Although innovative techniques are still developed every day, results indicate they are not the most important to consider. One respondent argued that, in principle, the technique needed for energy neutral structures already exists. Another respondent indicated that a pilot with innovative techniques was originally planned, but risk perception ultimately led to cancellation. All respondents considered the social changes to be more important than technical changes.

“Ik ben zelf van mening, dat als je kijkt wat technisch mogelijk is(…) dan zijn er technisch gezien zoveel mogelijkheden om energie op te wekken waarmee je naar energie neutraal kan werken. Ook heel veel technische oplossingen om de energievraag te verkleinen en als je die allebei hebt is daar een oplossing in te vinden.” (Consultant energy and sustainablity RoyalHaskoningDHV)

"Uiteindelijk is dat[Rozengaarde: pilot met alternatieve verlichting] niet gelukt vanwege allerlei uiterst onzekere technische en levensduur vragen." (projectmanager Municipality)

Social actors include perceptions of practitioners. According to one respondent perception is shaped by a lack of insight in what is possible, a lack of intrinsic motivation for sustainability and the expectation that every measure related to sustainability costs money and resources. These perceptions in itself create technical and financial difficulty.
Two respondents argued changing perception marks the importance of intrinsically motivated practitioners in all involved parties. On top of the importance of the entire institution, actions of the individual workers in the organization matter. What changed the importance of sustainability is the involvement of practitioners that are intrinsically motivated to tackle the problems related to sustainability. This is an important link between having ambitions and taking action that lead to energy neutral infrastructure.

"Dan denken ze vaak dat aan de voorkant het zoveel geld kost, dat dat hun eigen budget zal overschrijden, dus dat het ook om die reden niet kan. Als je dan ook nog mensen hebt die het intrinsiek niet zo interessant vinden, dan zit je zowel op het sociale, als op het financiële, als op het technische vlak in een situatie waar het gewoon niet gaat lukken. (…) Het willen met elkaar, het intrinsiek motiveren, al dat soort dingen, omdat dat zo ontzettend belangrijk is. Maar als dat lukt, dat je dan echt heel veel kunt bereiken."(Consultant energy and sustainablity RoyalHaskoningDHV)

"Dat heeft te maken met intrinsieke motivatie van het personeel eigenlijk." (Energycoördinator Municipality)

Conclusion
For the Drachtsterweg, external circumstance was not as influential in regime change as imagined. These trends led to sustainability and energy goals, but not to major changes. Actual changes occurred as a result of changes in when daily practices.
In addition, niche technology did not have a large impact on the change itself. Energy neutral can be realized with techniques that already exist.
Overcoming stability is difficult. The case study shows that changing perception and taking away reluctance is what caused institutional change. In that sense, influences from inside the sociotechnical regime were the biggest reason for regime change towards an energy neutral Drachtsterweg. An important cause for change is having people who are truly passionate about sustainability in the right place. This applies to all different involved parties.

4.3 Sustainable innovation policy

Chapter 2.5 identified five fundamentally important core concept in relation to sustainable innovation policy. These concepts provide the basis for the analysis of the degree to which sustainability was applied in the case of "de Drachtsterweg."

4.3.1 Long-term goals

Overall, there are many goals on different levels of scale, that all relate. Klimaatbrief 2050 works towards energy neutral economies on a European level for 2050. National governments (Rijksoverheid, 2018) mention the co2 neutral and energy neutral infrastructure are national goals for the years 2020 and 2030 respectively. Additionally SVIR speaks of robust energy networks for 2040. Local governments work towards these goals. Even the case specific plans mention the importance of sustainability and hint towards the importance of energy, based on municipal and national vision documents.

The respondents stated that this project originally started as a project to increase accessibility. The case for the renewal is one in a series of projects around Leeuwarden. In the early beginnings of project Leeuwarden-Vrijbaan the goals were there, but these were never translated to a course of action and got lost over time. De Drachtsterweg was the first project in which the government agencies actively acted on these goals. The municipality and province wanted to add sustainability as a theme to the project and that lead to additional support contracts with RoyalhaskoningDHV. The result was the document "advies duurzame Drachtsterweg" that feasible measures aimed towards sustainability.

"Er zijn ook wel wat doelen aan gekoppeld, maar die zijn gaandeweg eigenlijk wel uit het zicht geraakt. (…) Bij de Drachtsterweg gaan we daar vorm aan geven." (Consultant energy and sustainablity RoyalHaskoningDHV)

Goals do not necessarily lead to actions. For one, multiple respondents mentioned the importance of finances, also related to the economic crisis of 2008. Financial situations caused governments to re-evaluate how achievable goals and ambitions towards sustainability really are. This raised some general concerns that ultimately led to a decrease in acting on these ambitions. Drachtsterweg was possible due sums of money from "regiospecifiekpakket (RSP)," a compensation-fund for the Zuiderzeelijn.
In addition, a respondent mentioned that government agencies, on any level, often lack the institutional implementation of ambitions that were made higher up in the institutions' hierarchy. So, regardless of intention, strategies are needed to act on goals.

"Institutioneel is het ontzettend belangrijk, dat als je bovenaan in de organisatie, ook bij een gemeente, zegt: wij gaan iets met duurzaamheid doen. Zorg dan ook dat er geen enkel plan de deur uit gaat waar niks over duurzaamheid in staat." (Consultant energy and sustainablity RoyalHaskoningDHV)

Conclusion
All documents speak of goals about sustainability. However, goals in themselves do not lead to actions. Without thinking of implementation, perceived feasibility and the change to every day practice, goals change nothing.
The renewal of the Drachtsterweg is an example of how measures were taken to improve sustainability. Practitioners clearly said: we have these goals, but we don't act on them. This led to feasible alternatives that were added to the contracts.

4.3.2 Public private partnership

All respondents spoke of involvement of different parties and the importance of each playing to their own strengths. Governments have a role of instigator. Although Rijkswaterstaat is listed as a partner within the Leeuwarden-Vrijbaan program, their involvement was limited. Most importantly, they influence the goals that have previously been discussed. Local governments decided on a course of action. There is a need for "governance", a party that steers social, technical and financial actors towards sustainability goals and that controls the market to protect people where necessary.
In terms of the involvement between the levels of government, respondents mentioned that from day one there was an integral project group consisting of all the involved actively involved parties. A feature that was described as unique, is that the leading role shifted from municipality to province when the project went from planning and decision-making to realization. This shift had to do with difference in knowledge, skills and interests. The province had previous experience with the construction of aqueducts, relating to technical and contract management, and the municipality has responsibilities towards people in the direct surroundings, related to stakeholder management.

"Daardoor is er vanaf het begin, zowel op bestuurlijk als op hoog ambtelijk niveau, een hele goede samenwerking tot stand gekomen. Die is denk ik wel voorwaardelijk geweest voor het kunnen realiseren van zo'n groot programma." (projectmanager Municipality)
"Door hun regionale kennis en onderlinge samenwerkingsverbanden zijn gemeenten en provincies in staat om de opgaven integraal, doeltreffend en met kwaliteit aan te pakken." (SVIR)

Advising on tender and creating sustainability measures is where engineering firm RoyalHaskoningDHV got involved. Engineering firms offer complementary knowledge and skill related to innovation. One respondent even mentioned that governments should not even want the role innovator, since innovation and design should be left to the market.
Sustainability was not a part of the original plans for Drachtsterweg. When the decision was made to add sustainability, RHDHV was consulted on how to best add measures. That process led to a 70-page document consisting of sustainability measures. After the plans were finished a tender offer was made, which was ultimately won by Heijmans.
With the transition to a tender, according to all the respondents, a choice had to be made: a more traditional contract, meaning that the tender is based on price, or a tender based on EMVI, more of a price: quality-ratio. It was argued that in a traditional tender offer, the contractor is legally obligated to build all sustainability measures for a certain amount of money. Otherwise, a contractor could tender on the lowest price, by leaving out measures. Contract strategy is an important consideration: opting for a fixed contract that reduces risk, also reduces the space for initiative from the market. In order to look for a middle ground, a clause was added: initiatives merit a grant for the contractor.
The contractor is an important role to consider in the tender-process, but they were not available for comment.
The strategy that was ultimately chosen, was relatively traditional, but offered some room for the contractor to innovate.

"We hebben wel een maakbaar referentieontwerp gemaakt, maakbare kaders bepaald met elkaar, en die vervolgens als spelregels en als randvoorwaarden richting de markt meegegeven." (Projectmanager Province)

Conclusion
Four parties were actively involved in Project Drachtsterweg. Governments had an active role in steering the process and market parties towards envisioned goals. Governments control and oversee how and which sustainability goals are met. Partnership with the engineer is mostly advisory, aimed at planning and tender strategy. This led to a well-functioning integral project group, with clear complementary roles.
Partnership towards the contractor relates mostly to tender strategy. For Drachtsterweg a traditional contract was made, to ensure measurements that led to a high minimum sustainability-standard were added.

4.3.3 Learning process

The type of contract relates to the learning process and the role that the government should play. A contract form that has many design features boxed in, leaves little room for innovation and learning. Finding the right balance between leniency and control is a skill in itself and governments are still learning.

"Waar houden we grip op en waar geven we bepaalde vrijheden?" (Projectmanager Province)

Looking at the features of public-private partnership as mentioned in previous chapter, the tender-strategy, tackling new challenges and working with other parties, are all new processes. Public-private partnership is a learning process in itself.

"Je kunt nooit sneller leren, dan bij dit soort dingen.(…) Zo is het een soort snelkookpan van leerprocessen. (…) Ik denk dat dat ook een enorm leerproces is."(Energycoördinator Municipality)

The project managers flagged an important argument related to innovation. Maintenance-groups favor standardization and certainty to be efficient, which is in contrast to the project groups desire to innovate. Innovation often costs additional investment, the return on that investment over the 100 year-lifespan of the project is uncertain and new techniques may have hidden additional costs. Space for learning is related to uncertainty, due to the long time scale.
This debate about the contrast between daring to innovate and risk, demands clear decision-making high up in the government organization's hierarchy.

"In zekere zin zit daar natuurlijk wat in, dat je dat met allemaal maatregelen doet die nieuw zijn en natuurlijk geen idee hebt hoe zich dat over een jaar of vijf, een jaar of tien en laat staan een jaar of 25 of 50 manifesteert.(…) Daar heb je echt wel het hogere niveau voor nodig, om die keuzes te maken" (Projectmanager Municipality)
"Het lifecycle-denken en niet alleen de initiële investeringskosten, daar zie je wel langzaam dat dat opkomt, maar zo zijn deze projecten niet tot stand gekomen." (Projectmanager Province)

Conclusion
Governments have a responsibility to deliver functioning projects on the one hand, while at the same time there is a wish to innovate. There is a struggle between being lenient and keeping control. Leniency can result in learning and innovating, at the cost of running a higher risk, but with a potential for reward.
Daring to innovate and to learn, a switch to life-cycle thinking, is a choice that governments have to be make.

4.3.4 Stimulating technological diversity

One respondent made it clear that innovation does not come from governments. Also, governments have a high reluctance to create open tenders, but there is a change noticeable. Technological diversity relates to the amount of trust governments have in market parties. Asking the market to come up with solutions opens up possibility for new techniques that increase sustainability.

"Ik denk dat de overheid, met name provincie en Rijkswaterstaat en ook wetterskip Fryslan, steeds meer durven te vragen: kom met de beste oplossing. Dat is in de duurzaamheid een enorm interessante ontwikkeling eigenlijk, omdat de kennis en de innovatie, die zitten niet bij de overheid." (Energycoordinator Municipality)

Still, multiple respondents agreed that in this project the tender was relatively traditional, because majority of measures were put in contract. In order to stimulate initiative from the contractor a grant for additional, unconventional measures was added to the contract. It is deemed important to stimulate discussion on content, rather than cost. One respondent mentioned the example of composites. Composite was used over the course of the project, due to the grant provided.

"Ja, we hebben iets afgesproken met elkaar, dat is het uitgangspunt, maar zorg nou dat je gaandeweg het traject ruimte houdt om het met elkaar te kunnen hebben over nieuwe dingen, over innovaties." (Consultant energy and sustainablity RoyalHaskoningDHV)

Conclusion

Governments often are reluctant ask the market for solutions, but the market is best suited for innovation. That process is largely influenced by contract. Even though Drachtsterweg had a relatively traditional contract, a grant offered the room for formal and informal contact that lead to the use of unconventional, new technology.

4.3.5 Congruence between technical and social solutions

In order to act on goals, tools have to be implemented. According to the energy consultant of RHDHV, all tools used for Drachtsterweg are based on "Duurzaam Spoor-Grond-Weg-en Waterbouw" (GWW)." GWW is a method developed by multiple parties related to infrastructure that is currently used during the tender-phase. The next step is to develop the method to make sustainability an integral part of all phases.

"Dit is vooral aanbesteding technisch goed verankerd in de projecten. De volgende interne stap die we daarin maken is om de stappen die in Duurzaam GWW staan opgenomen een integraal onderdeel te laten zijn van de projecten en vervangingsopgaven die RWS heeft." (Senior Advisor Environment-Management Rijkswaterstaat Noord-Nederland)

Creating consistent methods relates to what two respondents discussed: It is difficult to define what "increasing sustainability" is, how, for what cost and where in the project contributions to sustainability can be made and how to phrase that in a contract.
One respondent mentioned the importance of perception and that the perception often is that increasing sustainability costs money, particularly for governments. Many changes to processes can be made without additional costs. According to two respondents

"Dat je dan met zijn drieën moet bepalen: wat is dat dan eigenlijk? Wat gaan wij dan doen?" (Energycoordinator Municipality)

Congruence is also about the previously discussed decision-making within organizations: are extra investmentments in the project worth reduced costs for maintenance? The respondents argue that there is a need for integral vision, for example between maintenance and project groups. This opts for a transition from initial investment cost to life-cycle thinking.
At the same time decision-making between organizations matters: one integral project group consisting of all parties was made, regardless of which agency had the lead.

"Dat soort hokjes zijn er gewoon nog steeds en het is ontzettend moeilijk om doorheen te prikken. Als je het dan hebt over institutionele wijzigingen, dan is dat dus echt iets dat moet gebeuren: veel meer die integraliteit opzoeken en eigenlijk ook heel erg naar personen kijken." (Consultant energy and sustainablity RoyalHaskoningDHV)

Conclusion

Without consistency and integral processes it is nearly impossible understand what the problems of sustainability are. It is often perceived that increasing sustainability leads to additional costs, which is not always the case.
Standardizing processes in such a way that they increase sustainability is important, because it largely shapes perception. It is a focal point of national agencies, shaped by the GWW. Between province and municipality an integral project group was created. Interestingly the leading organization changed during the project, based on interests and skills.
All processes such as project and maintenance have to be incorporated. Although life-cycle thinking was not applied to the case, it was made clear that this way of thinking should be applied.

4.4 Regional context

An interesting point that was discussed by two respondents was the effect that a project can have on the regional context for infrastructure: governments lead by example. Working on energy neutral infrastructure is important, because they heavily influence infrastructure. At the same time, Drachtsterweg is a big project, which allows for visibility of energy transition. It was mentioned that visibility could have a positive effect on stakeholders. Infrastructure can be considered a show-case. According to a respondent, it is, for one, important to consider the effects during construction and the impact on the direct environment. Not feeding curiosity can lead to distrust from residents. Secondly, the effects of the final design attribute to social sustainability. An environmental-manager was appointed and measures during construction were taken.

"Het is sowieso heel belangrijk, omdat het in mijn optiek een van de dingen is waar juist overheden vaak aan het roer staan om het aan te leggen en waar ze dus heel veel invloed op hebben. Als je het hebt over de voorbeeldfunctie van de overheden, dan moet dat dus ook daar beginnen, vind ik." (Energy consultant RHDHV)

"*Het is belangrijk dat de gemeente initiatief neemt door een aansprekend voorbeeld te zijn, oftewel: practice what you preach! Dit betekent dat de gemeente in al haar doelen, taken en ook in de uitvoering 'duurzaamheid' als fundamenteel argument zal meewegen bij het voorbereiden van keuzes en het nemen van beslissingen." (Duurzaam Leeuwarden: de sterke stad)*

"Dat zie je dan overal verschijnen en zichtbaarheid is niet altijd belangrijk, maar in veel gevallen ook wel, om mensen te betrekken." (Energycoordinator Municipality)

Infrastructure takes more space than just the road itself. This space often remains unused, while it could be used for the production of energy. The solar park in the Drachtsterweg is an example.

Locations close to neighbourhoods, roads also offer options themselves and Leeuwarden profiles itself strongly towards energy. Options can be context specific.

"Ook daar kan heel veel mee in infrastructuur, maar een weg wordt nooit aangelegd tot de rand van het asfalt, want je hebt er altijd nog een stuk naast, dus je hebt altijd ruimte om in die bermen of overhoeken, of zelfs in de infrastructuur zelf mogelijkheden om energie op te wekken." (Energy consultant RHDHV)

"Vanuit een stevig maatschappelijk fundament richten wij ons op de thema's waar Leeuwarden sterk in is en waar het resultaat van onze inspanning er daadwerkelijk toe doet: Water en Energie." (Duurzaam Leeuwarden: de sterke stad)

Conclusion

Governments have a responsibility, so they should lead by example. Positive associations of sustainability can lead to residents becoming more involved with sustainability, while negative associations can cause the direct opposite. Measures were taken for the Drachtsterweg. Measures taken in the project are based on factors such as amount of space, focal points for that municipality, location and nearby functions. Regional context is not included in the SI, but an argument could be made that it is an important concept to include in sustainable innovation.

Chapter 5 Conclusions and reflection

Chapter 4 discussed the results from the literature and documents. An overview of the important findings can be found in **Graph 3.** Chapter 5 will discuss the results in relation to the main themes from the theory. First the secondary questions will be answered, then the main question and finally the processes will be reflected on.

System change	- Internal changes more predominant than external circumstance and niche technology. -Importance of changing perception and intrinsic motivation
Long-term goals	-Energy Transition Goals on all levels of scale. -Sustainability included in project. -Changing daily practice also important
Public private partnership	-Complementary roles; Government steers and sets agenda, private parties innovate. -Use of an Integral project group. -Decided largely by tender and contract.
Learning Process	-Tender/contract creates the space for learning. -The integral project group was a learning process. -Project groups want to innovate, but maintenance groups prefer standardization and certainty.
Technological diversity	-Tender/contract deciding factor in the room for innovation. -Grant to add some initiative in a relatively traditional tender.
Congruence	-Tools and methods needed to make energy neutral/sustainability an integral part of projects. -Perception: Increasing sustainability costs money. (Often not the case). -Life-cycle thinking, instead of initial investment cost.
Regional context	-Governments lead by example and create public perception. -Possible sustainability measures partly depend on the context.

Graph 3: Overview of findings. Ordered by key concept.

Due to aging, infrastructure faces challenges of renewal (Rijksoverheid, 2018; Willems et al., 2016). Renewal marks a phase transition and congruence between sociotechnical actors needs to change accordingly (Willems et al, 2016). Regimes are forced to change to prevent mismatch. To change these regimes, external circumstances can create a window of opportunity (Tongur &Engwall, 2017; Kingdon &Thurber 1984). In turn, the window of opportunity can lead to a regime change (Geels, 2007; Geels, 2002). In addition, niche technology can contribute to the window of opportunity (Geels, 2002; Geels, 2007). Based on the case, external circumstance was not as predominant in

regime change for this case study as imagined. These trends led to sustainability and energy goals, but not to regime changes in itself. Actual changes were caused by changes in daily practices made by intrinsically motivated people. Niche technology did not have a large impact within this case. Technology overall was considered less important than technical changes. Energy neutral could be realized with techniques that already exist. Overall, a change from inside the regime does not fully conflict the theory, but it is a paradox.

Regimes have to co-evolve (Willems et, al 2016) and the principles behind these changes have been explained. The second research question sought to answer how regimes should change internally to improve energy neutrality. Energy in infrastructure is one of the main problems to consider the upcoming decades (Van Wee & Annema, 2013; Rijksoverheid, 2012). A framework of five core concepts was built from theory: Long-term goals, technological diversity, public private partnership, integration of technical and social solutions, and learning process (Foxon & Pearson, 2007).
Policy documents on different levels emphasize the importance of energy neutrality in the form goals up to 2050. Long-term goals should lead to investment in technology and processes (Foxon & pearson, 2007). However, goals have not led to changes in themselves. It is the change in daily practice that was most important. There often still is a mismatch between goals and daily practice. Changes to daily practice related to the four other concepts.
Firstly, the relation between the parties was discussed as a characteristic of public private partnership, the complementary relations between public and private actors (Foxon & Pearson, 2007). Province and municipality phrased the sustainability-agenda and developed a list of measures with RHDHV. Together they formed an integral project group. Heijmans then won the tender to build Drachtsterweg. Public-private partnership is shaped by how strict the tender is. For the Drachtsterweg a tender was chosen that was relatively strict, but offered some leniency in the form of a grant. Many of the measures that led to an energy neutral piece of infrastructure were developed on the front-end. The grant led to an additional measure.
Tender and contracts are a deciding factor in the room for technological diversity and learning. Since it is impossible to predict successful technologies, it is important support niches and to innovate (Foxon & Pearson, 2007). Time will tell which techniques will be successful (Geels, 2002). A learning process is important, because governments are still figuring out how to balance goals and markets, while markets need to try alternative techniques and processes (Foxon & Pearson, 2007). Without an interview with Heijmans, a conclusion about the room for innovation in this case cannot really be given. What is apparent, is that tender strategy, the balance between goals and what to entrust to the market (Foxon & Pearson, 2007), is important for renewal projects.
Franzeskaki & Loorbach (2010); Foxon & Pearson (2007) characterized sociotechnical innovation as a complex process filled with uncertainty. It is that uncertainty that warrants experimentation and innovation. Not addressing these uncertainties, could lead to carbon lock-in (Foxon & Pearson, 2007; Geels, 2007). For governments there is a debate about acceptable additional investment, with the potential for lower cost in maintenance. It was argued that clearer decision-making was necessary to be innovative. This lifecycle-thinking was not applied to the case, particularly in the planning phase, but has generally become a more predominant way of thinking.
Congruence was introduced as the matches and mismatches between sociotechnical actors (Willems et al, 2016). Interestingly enough, measures that address environmental externalities are unlikely to be singular, but almost always consist of combinations (Foxon & Pearson, 2007). Congruence is important to consider. Institutionally there is a need for consistent and integral processes in order to

understand problems and tackle perceptions. This is shaped by a framework to add sustainability to all stages of the project, known as GWW. From there municipality and province started an integral project group, whereas often it still is a single step in the process.
One final concept is that of regional context. It was not drafted from literature and not related to the concepts of SI. An inductive argument (Clifford et al, 2010) will be made why it could be a sixth characteristic. Governments lead by example and protect the interests of citizens. Infrastructure is where governments are in the lead and have a huge opportunity for a show-case. Working on visibility and a positive image of sustainability in infrastructure can have a positive ripple-effect that transcends the initial infrastructure. It could also be argued that options for measures that are added to a project depend on space available, policy focal points for that municipality, location and nearby functions.

What was learned is that energy neutral has to become an important goal. Governments have a leading role, but it takes people from multiple organizations to agree and then act on set goals. This change was largely caused by intrinsically motivated people. Perceptions, of for example finances, are important to consider, but without an initial will to change, all is likely stay the same. Having the right combination of people and organizations, often has the abilities to overcome any preconceived barrier leading to carbon lock-in.
Working towards energy neutral infrastructure is a process of learning and innovating. For success it is important to have an integral project group and decision-making. The phrasing of the tender has impact on learning and innovation, because these processes happen largely on the market. Governments have to control certain aspects of the market, but should not be afraid to ask the market for solutions. Innovating and learning has risks and uncertainties attached to it and governments often opt for certainty. Actively changing these processes to sensibly experiment with uncertainty is important to prevent carbon lock-in.
Finally governments have a leading role in infrastructure. This makes their work visible and enables them to lead by example. The regional context is important to consider, because it may have an impact on a broader transition to sustainability, that of society.

Using the elements from the secondary questions the main research question *"How can the need for renewal in infrastructure help stimulate energy neutral transport systems?"* will now be answered. Drachtsterweg featured a case of renewal. Willem et al. (2016) described that with a phase change, institutions have to co-evolve in order to prevent mismatches. Thus, a need renewal destabilizes the regime. This research explained how these regimes changed and which characteristics a new regime needs to address energy neutral infrastructure.
Renewal offers the opportunity to rebuild a structure from the ground up and to use new technology, goals and policies. The result for Drachtsterweg is an aqueduct that is energy neutral in operation. Based on the results of this case study, the aging of infrastructure can be used to realize energy neutral infrastructure, so long as governments make energy neutral an integral part of renewal projects, learn to work with uncertainty and market parties get the room to innovate.

Reflecting on myself and this process, I feel I have underestimated the effort it takes to find respondents. Ideally, I would at least like to have spoken to Heijmans and to an additional representative of the province with extra time.
The situation with heijmans in itself is important and interesting to reflect on. I think this had to do

with a number of reasons: the limited involvement of Heijmans institutionally, based on their correspondence, and that the project was somewhat sensitive due to delays in construction. In one of the interviews, the argument was also made that those involved with the decision-making that led to the build, might no longer work on the project. Even limited involvement, considering the debate on tendering, would have been enough reason alone to interview someone from Heijmans. The implications for the research itself, are that conclusions about heijmans' role and the process of tendering have to be made cautiously, since their own perspective is missing. Conclusions about innovation were made more generalized.
Rijkswaterstaat is a partner in Vrij-baan. When I contacted them, they explained they had no active involvement in project Drachtsterweg. Still, respondents occasionally mentioned RWS. This led to two specific questions asked via E-mail. One response, about their tools for sustainability, was added. Since RWS has not been spoken to in a full-interview, no strong conclusions have been made regarding their involvement.
All in all, it feels like this research fits within a frame of a larger research problem. This could be the limitation of having one case and this could warrant a study into multiple cases that feature goals related to sustainability in renewal challenges. For a follow-up it might also be interesting to further test the importance of regional context related to sustainability, or how governments deal with uncertainties.

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Appendix

Appendix 1 Interview Guide

Dit onderdeel is in tegenstelling tot de rest van de scriptie in het Nederlands. Dat heeft te maken met het feit dat de interviews worden afgenomen met mensen die Nederlands spreken. Dit onderdeel bevat het gebruikte draaiboek. Afhankelijk van welke thema's respondent aansnijdt, wordt de volgorde van de vragen semi-structureel aangehouden. De dikgedrukte onderdelen dienen daarbij ter ondersteuning, omdat ze overzichtelijk maken welke codes nog bevraagd dienen te worden.

Inleiding

-Bedanken voor medewerking aan het interview

-Voorstellen:
+ Student Technische planologie
+ Scriptie

-Introduceren thema en onderwerp
+ Vervanging en renovatie, duurzaamheid/energie neutraal gekoppeld aan institutionele verandering, casus Drachtsterweg, vertalen naar aanbevelingen voor andere projecten

-Herhalen verzoek voor opnemen van het interview
+ Vertrouwelijk, alleen voor deze scriptie
+ Geïnterviewde mag terugkomen op uitspraken en ze nuanceren
+ Interview wordt uitgeschreven voor analyse

-Omschrijven van de opzet/structuur van het interview
+drie thema's uit de onderzoeksvragen:
1 Verandering van sociaal technische systemen.
2 De toepassing van energie neutraliteit bij de Drachtsterweg(en/of andere aspecten van duurzaamheid).
3 De vertaling van de bevindingen naar energie neutraal/duurzaamheid naar andere vervangingsopgaven.

Algemeen

1) Kunt u zichzelf kort introduceren?

2) Hoe bent u betrokken geraakt bij de vernieuwing van de Drachtsterweg?

-Wat is uw rol bij de vernieuwing van de Drachtsterweg?

-Wat zijn uw verantwoordelijkheden?

-Wat was de aanleiding/aanleidingen voor de start van dit project?

Noodzaak voor vernieuwing en trends op groot schaalniveau

Deelvraag 1: How are sociotechnical regime changes made in large transport systems?

Waarom is het van belang om ook infrastructuur mee te nemen in de energietransitie?

Volgens de Rijksoverheid moet het Nederlandse hoofdwegen netwerk en waternetwerk in 2030 volledig energieneutraal zijn. Wat denkt u dat er, zowel institutioneel als technisch, moet veranderen om die doelstelling te halen? (**Lange termijn doelen, technische diversiteit, publiek private samenwerking, leerproces)**

-Wat is er voor nodig om die veranderingen door te voeren?**(momentum; Carbon lock-in)** (**externe factoren:** milieuschade, energiebronnen die opraken, klimaatverandering; **nieuwe technieken).**

-Hoe maak je de energietransitie echt een prioriteit? **(lange termijn doelen)**

Hoe belangrijk zijn vervangings-en-vernieuwings-opgaven (zoals de Drachtsterweg) om duurzaamheidsdoelstellingen voor infrastructuur, zoals energie neutraal, te verwezenlijken? (dus bijv: waarom kan dat niet met bijv beheer en onderhoud?) **window of opportunity**

Casus Drachtsterweg

Deelvraag 2: How did government agencies and private parties, from the LTS and Multilevel perspectives, improve energy neutrality on "de Drachtsterweg"?

-Hoe draagt dit project bij aan de energietransitie/energie neutraal?

-Op welke tijdsschaal is het ontwerp gemaakt en waarom deze?

-Welke doelstellingen (programma van eisen) zijn daarbij van belang geweest in de overweging? **Lange-termijn doelen**

-Hoe bepalen jullie welke technieken jullie meenemen in het ontwerp? **Technische diversiteit**

-Waarom is er gekozen voor een aquaduct?

-Hoe verloopt de samenwerking met andere partijen zoals RHDHV/Heijmans/RWS, provincie, gemeente/belangenverenigingen en hoe draagt dit bij aan het energievraagstuk?

-Wat ging goed en wat had beter gekund? **Publiek private samenwerking**

-Hoe draagt deze infrastructurele ingreep bij aan de ontwikkeling van de omgeving? **Regionale context**

-Hoeveel ruimte is er in dit project om te experimenteren?

-Hoeveel is daar gebruik van gemaakt? **Learning by doing; Uncertainty**

Geleerd

Deelvraag 3: How can these insights be used to improve energy neutrality in future renewal projects?

-Hoe denkt u dat het project van de Drachtsterweg valt binnen de doelstelling om energie neutrale infrastructuur te hebben in 2030?

-Wat hebt u geleerd van dit project en hoe gaat u die kennis gebruiken in vergelijkbare projecten (vervanging in infra) in de toekomst?

-Wat zou u mij nog mee willen geven?

-Zijn er dingen die u eerder benoemde die u evt nog aan wilt vullen, of nuanceren?

Afsluiten

-Aangeven dat het einde is van het interview.
-Respondent de gelegenheid geven vragen te stellen.
-Aangeven dat de respondent anders voor vragen, opmerkingen etc altijd mag mailen
-Afspraken maken over: opsturen transcripten en eindversie van de scriptie.

-Bedanken voor het interview

Appendix 2 Codes

LTS	Sociotechnical regime	(Nelson & winter, 1982; Rip &Kemp; Geels, 2004)
	Congruence	(Willems et al, 2016)
	Co-evolution	(Willems et al, 2016)
	Phases (maturity to renewal)	(Willems; 2017)
	Momentum/stabilizing	(Willems et al, 2016; Geels,2007)
	Mature	(Willems et al, 2016; Geels, 2007)
	Technological trajectory	(Geels, 2007)

Sociotechnical innovation	Complex	(Franzeskaki & Loorbach, 2010)
	Long time-horizon	(Franzeskaki & Loorbach, 2010)
	Non-linear	(Franzeskaki & Loorbach, 2010)
	uncertainty	(Foxon & Pearson, 2007; Franzeskaki & Loorbach, 2010)
	Carbon lock-in	(Foxon, 2007; Geels, 2007)

Multilevel-perspective	Innovation	(Hoogma et al, 2002; Geels, 2002; Franzeskaki &Loorbach, 2010)
	System innovation theory	(Van Wee & Annema, 2013)
	Technological niche	(Van de Poel, 2000; Geels, 2002)
	sociotechnical landscape	(Geels, 2002)
	Sociotechnical regime change	(Van De Poel, 2000; Bolton & Foxon; Geels, 2002)
	Window of opportunity	(Tongur & Engwall, 2017; Kingdon & Thurber, 1984)

Sustainable innovation	Long term goals	(Foxon & Pearson, 2007; Foxon et al 2007)
	Technological diversity	(Foxon & Pearson, 2007; Geels, 2002)
	Public private partnership	(Foxon & Pearson, 2007)
	Integration technical and social solutions; congruence	(Foxon & Pearson, 2007; Willems et al, 2016)
	Learning by doing	(Foxon & Pearson, 2007)
	(Regional context)	(Willems et al, 2016)

Appendix 3 table of abbreviations

Duurzaam GWW	GWW
Environmental Impact Assessment	EIA
Large Transport Systems Perspective	LTS
Multilevel Perspective	MLP
RoyalHaskoningDHV	RHDHV
Sustainable Innovation Policy	SI